CNS

Doctor 2021

Physiology

Modified (6)

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Neurophysiology

Vision 1

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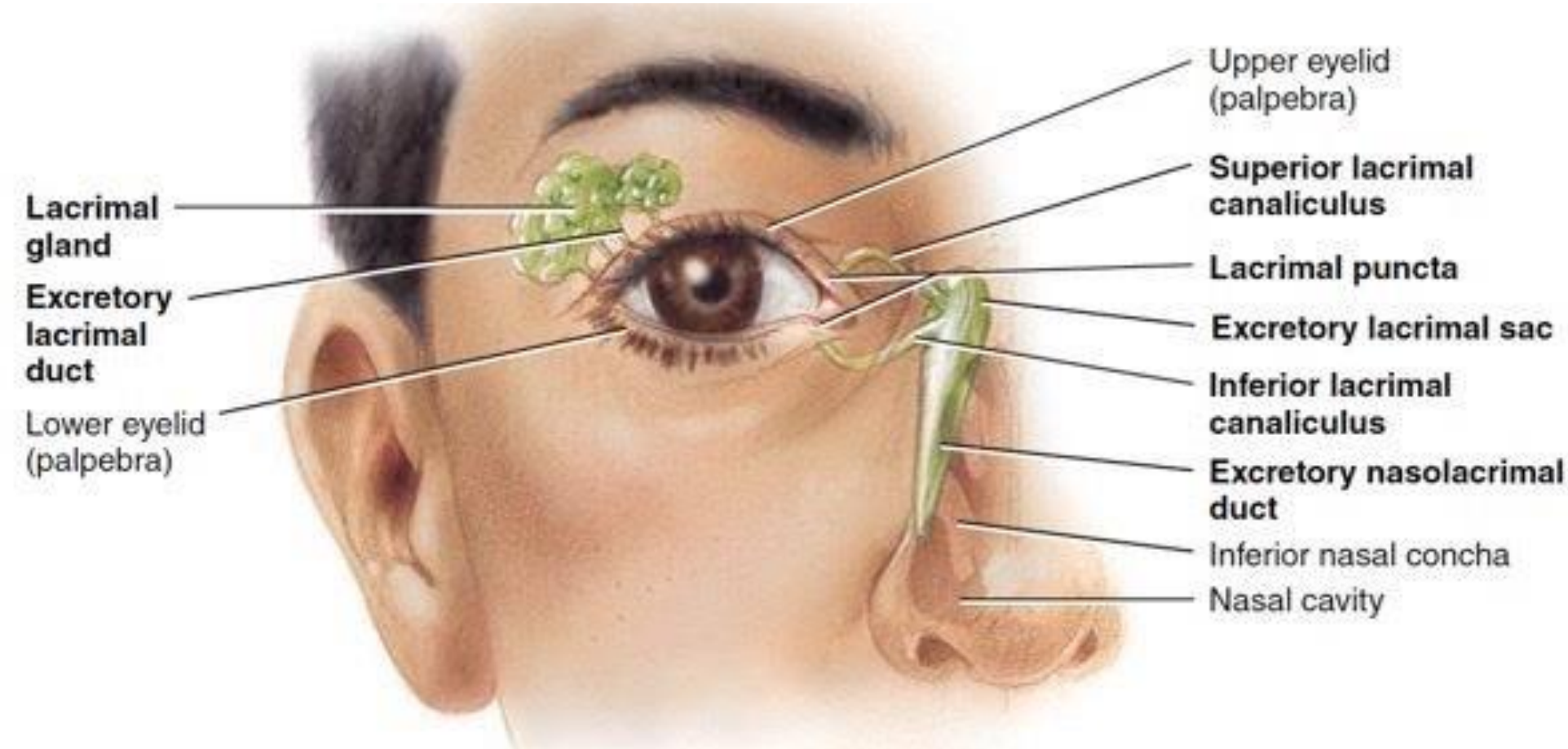
Protective mechanisms in the eye

- Several mechanisms help protect the eyes from injury:
- Except for its anterior portion, the eyeball is sheltered by the bony socket in which it is positioned.
- The eyelids act like shutters to protect the exposed part of the eye from environmental insults. They close reflexly to cover the eye under threatening circumstances
- Eyelashes trap fine, airborne debris such as dust before it can fall into the eye.


Lacrimal gland
Excretory lacrimal duct
Lower eyelid (palpebra)
Upper eyelid (palpebra)
Superior lacrimal canaliculus
Lacrimal puncta
Excretory lacrimal sac
Inferior lacrimal canaliculus
Excretory nasolacrimal duct
Inferior nasal concha
Nasal cavity

Tears

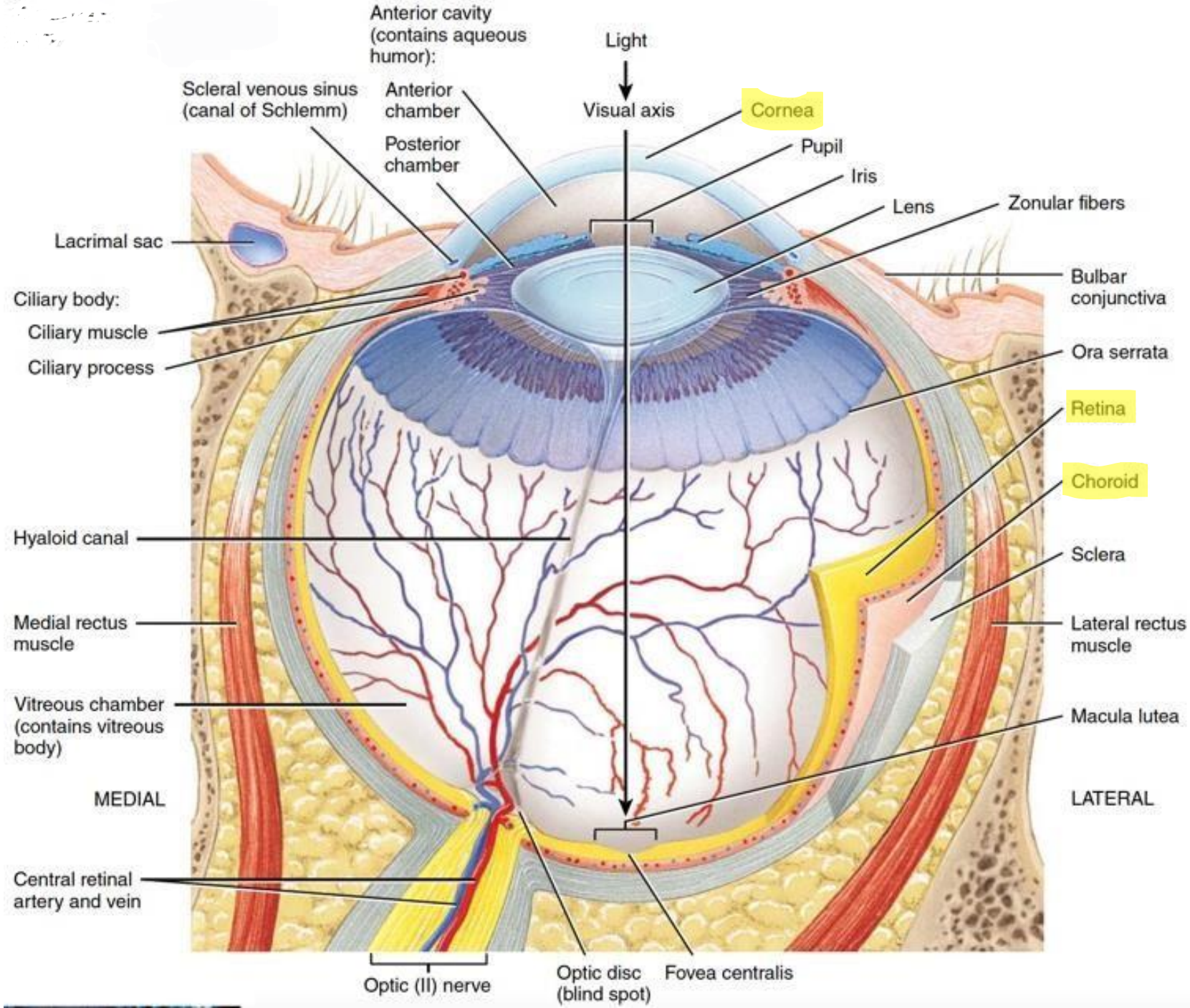
What are the functions of tears ?

- Frequent spontaneous blinking of the eyelids helps disperse the lubricating, cleansing, bactericidal tears.
- Tears are produced continuously by the lacrimal gland in the upper lateral corner under the eyelid.
- This eye-washing fluid flows across the anterior surface of the eye and drains into tiny canals in the medial corner of each eye, eventually emptying into the back of the nasal passageway.
- This drainage system cannot handle the profuse tear production during crying, so the tears overflow from the eyes.

Layers

Eye is a spherical, fluid-filled structure enclosed by three layers (From outermost to innermost):

- (1) the sclera/cornea. **The first & outermost layer.**
- (2) the choroid/ciliary body/iris.
- (3) the retina.

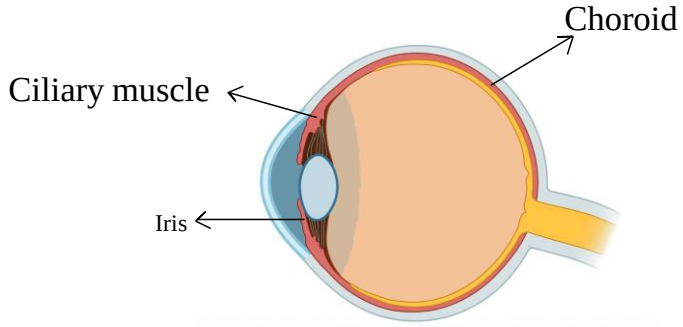

Anterior cavity (contains aqueous humor):
Light
Scleral venous sinus (canal of Schlemm)
Anterior chamber
Visual axis
Cornea
Posterior chamber
Pupil
Iris
Lens
Zonular fibers
Lacrimal sac
Bulbar conjunctiva
Ciliary body:
Ciliary muscle
Ciliary process
Ora serrata
Retina
Choroid
Hyaloid canal
Sclera
Medial rectus muscle
Lateral rectus muscle
Vitreous chamber (contains vitreous body)
Macula lutea
MEDIAL
LATERAL
Central retinal artery and vein
Optic (II) nerve
Optic disc (blind spot)
Fovea centralis

Sclera and cornea

- Most of the eyeball is covered by a tough outer layer of connective tissue, the sclera, which forms the visible white part of the eye.

- Anteriorly, the outer layer consists of the transparent cornea, through which light rays pass into the interior of the eye. **Till they reach photoreceptors on retina**

Choroid

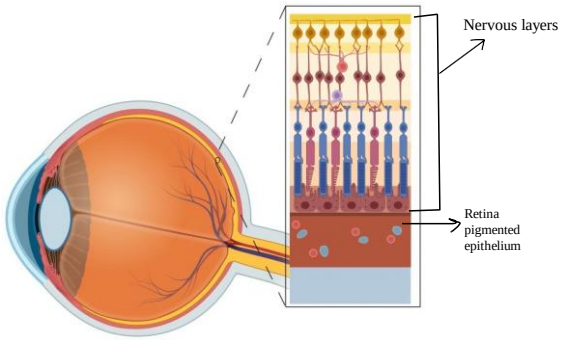


- The middle layer underneath the sclera is the highly pigmented choroid, which contains many blood vessels that nourish the retina.

- The choroid layer becomes specialized anteriorly to form the ciliary body and iris. **Ciliary body consists of : ciliary muscle, ciliary processes**

  Iris : pigmented muscular structure (smooth muscles)

- the pigment in the choroid and retina absorbs light after it strikes the retina to prevent reflection or scattering of light within the eye.



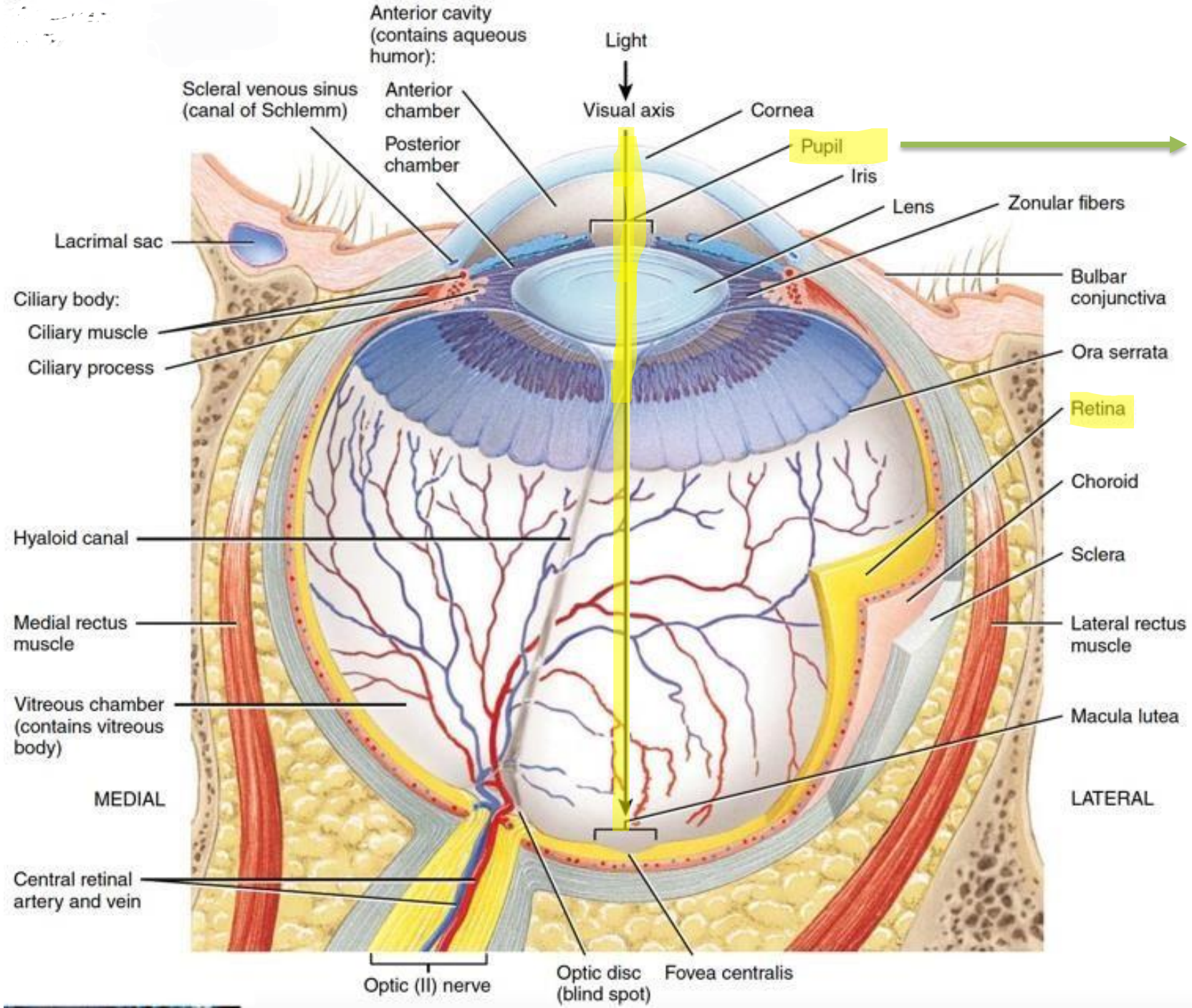
Retina

1. Pigmented layer.

2. Nervous layer (contains photoreceptors).

- The innermost coat under the choroid is the retina, which consists of an outer pigmented layer **(to prevent scattering of light)**and an inner nervous-tissue layer.

- The nervous layer contains the rods and cones, the photoreceptors that convert light energy into nerve impulses.



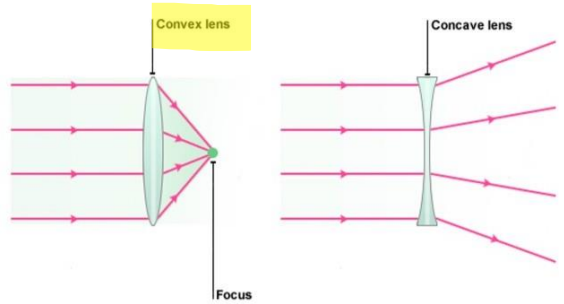
The light enters from cornea(transparent structure) to the pupil to be refracted towards retina, however some light come from pigmented area like iris will be reflected or absorbed.

Lens

- The interior of the eye consists of two fluid-filled cavities, separated by a lens, all of which are transparent to permit light to pass through the eye from the cornea to the retina.

Types of lenses

- A convex surface curves outward (like the outer surface of a ball), whereas a concave surface curves inward (like a cave).
- Convex surfaces converge light rays, bringing them closer together. Because convergence is essential for bringing an image to a focal point, refractive surfaces of the eye are convex.
- Concave surfaces diverge light rays (spread them farther apart). A concave lens is useful for correcting certain refractive errors of the eye. **Like in myopia (Nearsightedness)**

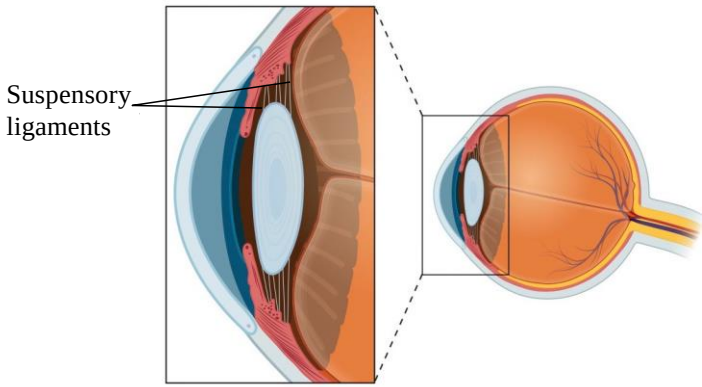


Cataract

- “Cataracts” are an especially common eye abnormality that occurs mainly in older people.
- A cataract is a cloudy or opaque area (or areas) in the lens.
- In the early stage of cataract formation, the proteins in some of the lens fibers become denatured.
- Later, these same proteins coagulate to form opaque areas in place of the normal transparent protein fibers.

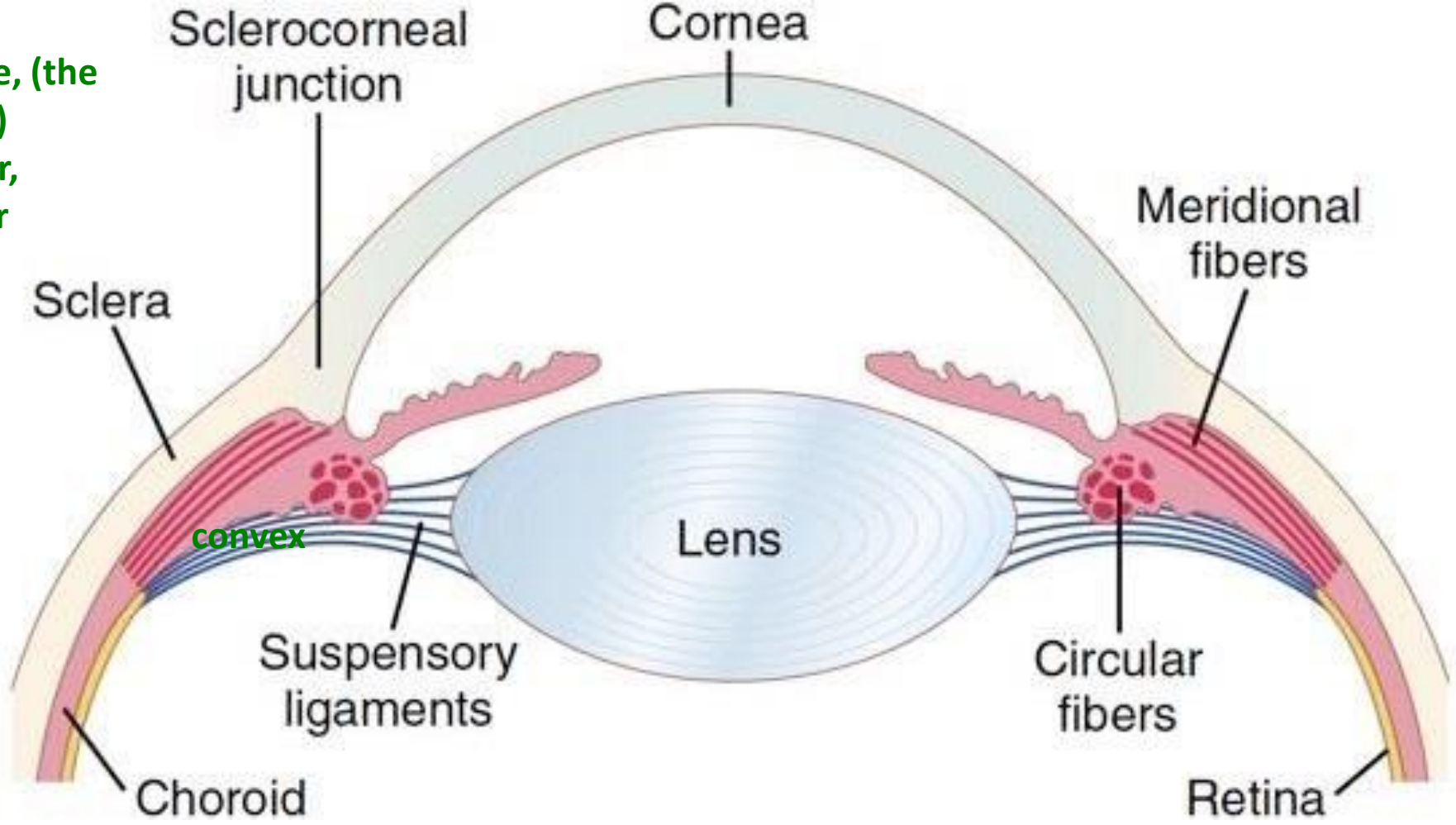
The suspensory ligaments are thin, transparent fibers that attach the ciliary body to the lens capsule. The ciliary body is a ring-shaped structure located behind the iris (the colored part of the eye) and is responsible for producing the aqueous humor, which fills the front part of the eye.
Suspensory ligaments play a crucial role in the accommodation mechanism by exerting tension on the lens.

Lens



- 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.

There are two types of fluids in the eye, (the lens serves as a marker within the eye)
anterior to the lens ⇒ Aqueous humor,
posterior to the lens ⇒ vitreous humor



- The lens is composed of connective tissue, a-nuclear cells, proteins, water, elastin.
- It's Avascular; since the primary function of the lens is to focus light onto the retina to get clear image, so to achieve this, the lens needs to be transparent. Blood vessels contain red blood cells that can scatter or absorb light, which would interfere with the lens's transparency, so the lens nourish by diffusion from aqueous humor . Cornea is also an avascular structure , It receives oxygen directly from the air and nutrients from the tears, aqueous humor, and limbal vessels.

Intraocular fluid

- The aqueous humor is a freely flowing fluid, whereas the vitreous humor, sometimes called the vitreous body, is a gelatinous mass held together by a fine fibrillar network composed primarily of greatly elongated proteoglycan molecules.
- Aqueous humor is continually being formed and reabsorbed.
- Aqueous humor is formed almost entirely as an active secretion by the epithelium of the ciliary processes.
- The balance between formation and reabsorption of aqueous humor regulates the total volume and pressure of the intraocular fluid.

Aqueous humor

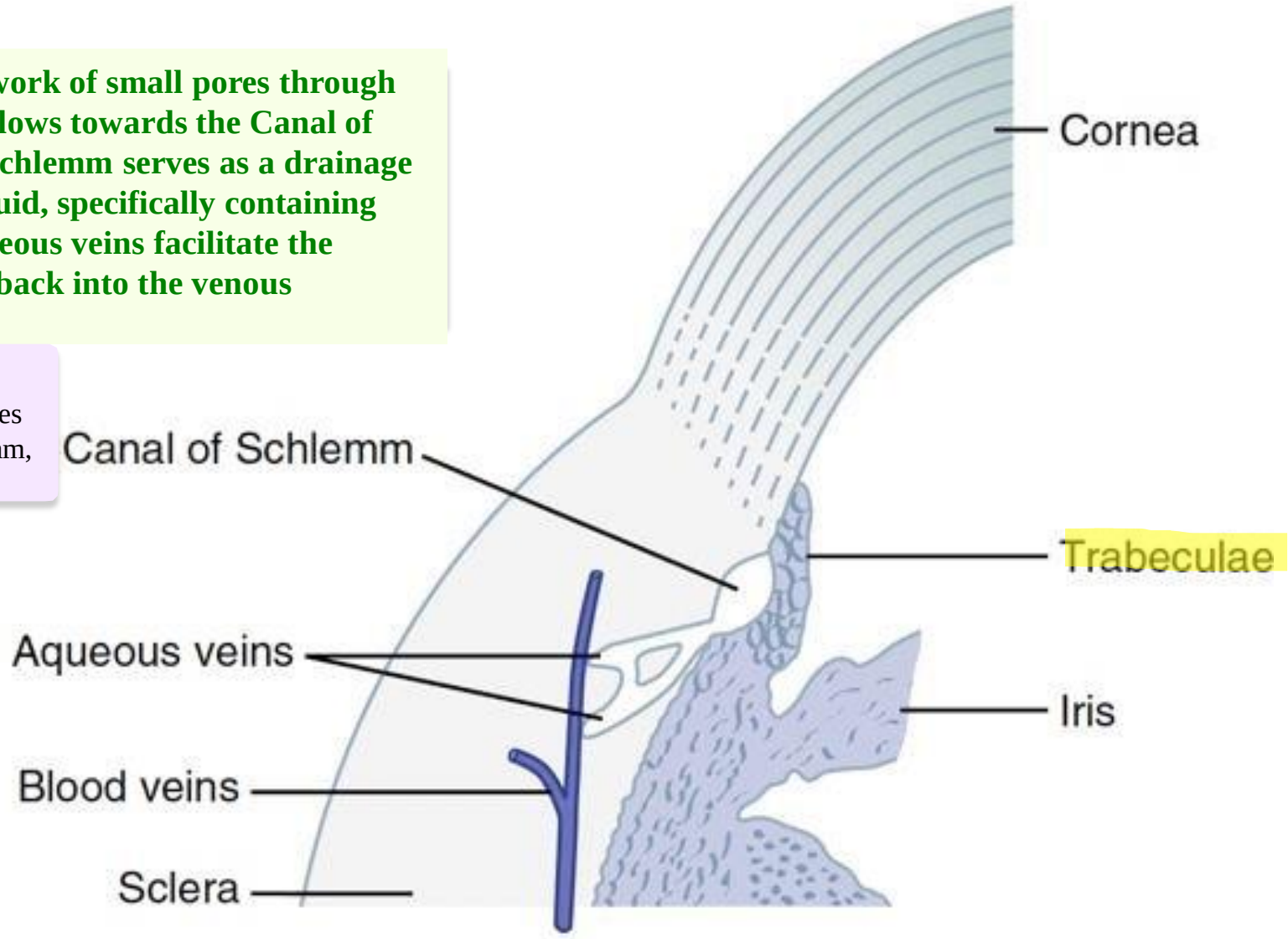
- The anterior cavity between the cornea and the lens contains a clear, watery fluid, the aqueous humor.

- The aqueous humor carries nutrients for the cornea and lens, both of which lack a blood supply. Blood vessels in these structures would impede the passage of light to the photoreceptors.

The trabeculae are a network of small pores through which the aqueous fluid flows towards the Canal of Schlemm. The Canal of Schlemm serves as a drainage system for the aqueous fluid, specifically containing aqueous veins. These aqueous veins facilitate the reabsorption of the fluid back into the venous circulation.

Life cycle of aqueous humor

- Production : By ciliary processes
- Reabsorption : canal of Schlemm, through the trabeculae.



Aqueous humor

- The aqueous humor is produced at a rate of about 5 mL/day by a capillary network within the ciliary body.

- This fluid drains into a canal at the edge of the cornea and eventually enters the blood. **Canal of schlemm**

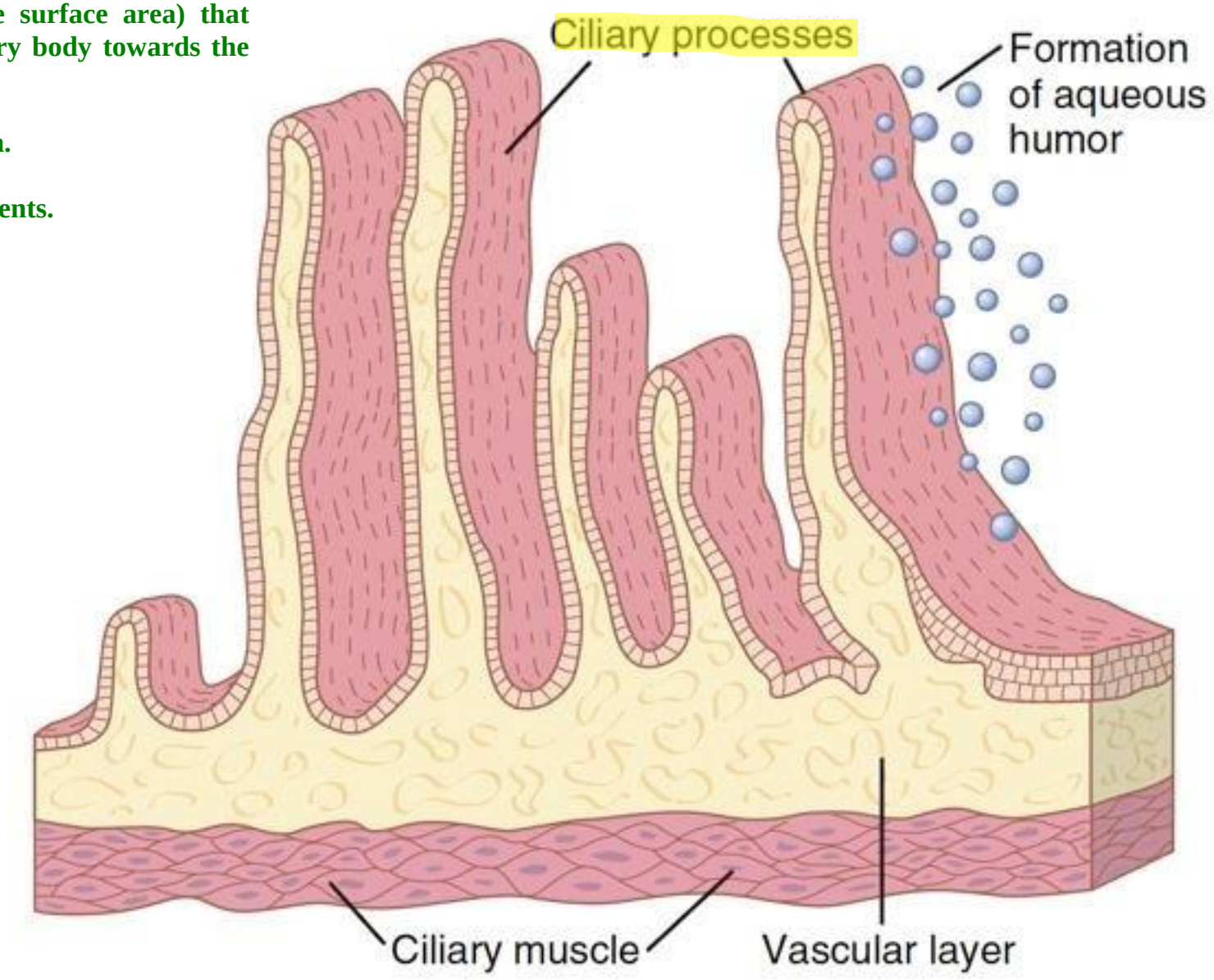
- If the aqueous humor is not drained as rapidly as it forms, the excess accumulates in the anterior cavity, causing the pressure to rise within the eye. This condition is known as glaucoma.

Glaucoma should be treated promptly because elevated intra-ocular pressure will cause kind of displacement in the lens as a result will increase the pressure in vitreous humor finally that will cause compression on optic nerve ⇒ leading to blindness

The ciliary processes are small, finger-like projections (to increase the surface area) that extend inward from the ciliary body towards the lens.

Function :

1. **Aqueous humor production.**
2. **Nutrient Supply.**
3. **Attach to suspensory ligaments.**



Aqueous humor

- When large amounts of debris are present in the aqueous humor, as occurs after hemorrhage into the eye or during intraocular infection, the debris is likely to accumulate in the trabecular spaces leading from the anterior chamber to the canal of Schlemm.

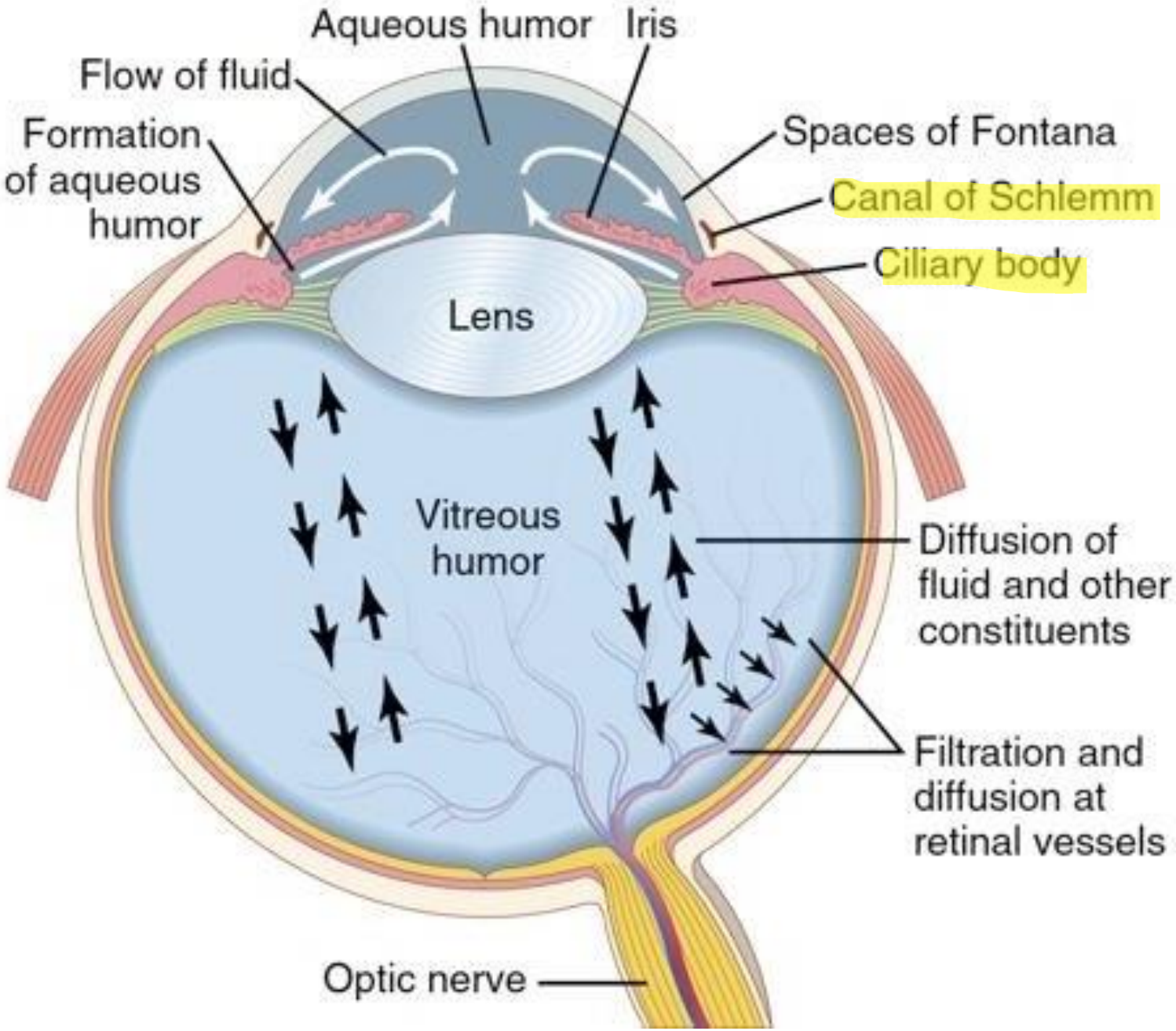
- this debris can prevent adequate reabsorption of fluid from the anterior chamber, sometimes causing “glaucoma,”.

- However, on the surfaces of the trabecular plates are large numbers of phagocytic cells **But in pathological conditions (like infection or hemorrhage of eye) with a large quantity of debris, the phagocytes are unable to overcome it ,and the pores will close as a result the aqueous humor will over increase (increasing the intraocular pressure).**

Intraocular pressure

- The average normal intraocular pressure is about 15 mm Hg, with a range from 12 to 20 mm Hg.

- Measured by tonometry. **Non- invasive procedure used to measure intra-ocular pressure(before use it , we put local anesthesia, so we have pain receptors on the cornea)**


Aqueous humor
Iris
Flow of fluid
Formation of aqueous humor
Spaces of Fontana
Canal of Schlemm
Ciliary body
Lens
Vitreous humor
Diffusion of fluid and other constituents
Filtration and diffusion at retinal vessels
Optic nerve

Vitreous humor

- The larger posterior cavity between the lens and the retina contains a clear, jellylike substance, the vitreous humor.

Function:

- The vitreous humor helps maintain the spherical shape of the eyeball.

Iris

- Not all light passing through the cornea reaches the light sensitive photoreceptors because of the presence of the iris, a thin, pigmented smooth muscle that forms a visible ringlike structure within the aqueous humor. **The iris reflect & absorb light.**
- The pigment in the iris is responsible for eye color.

Pupil

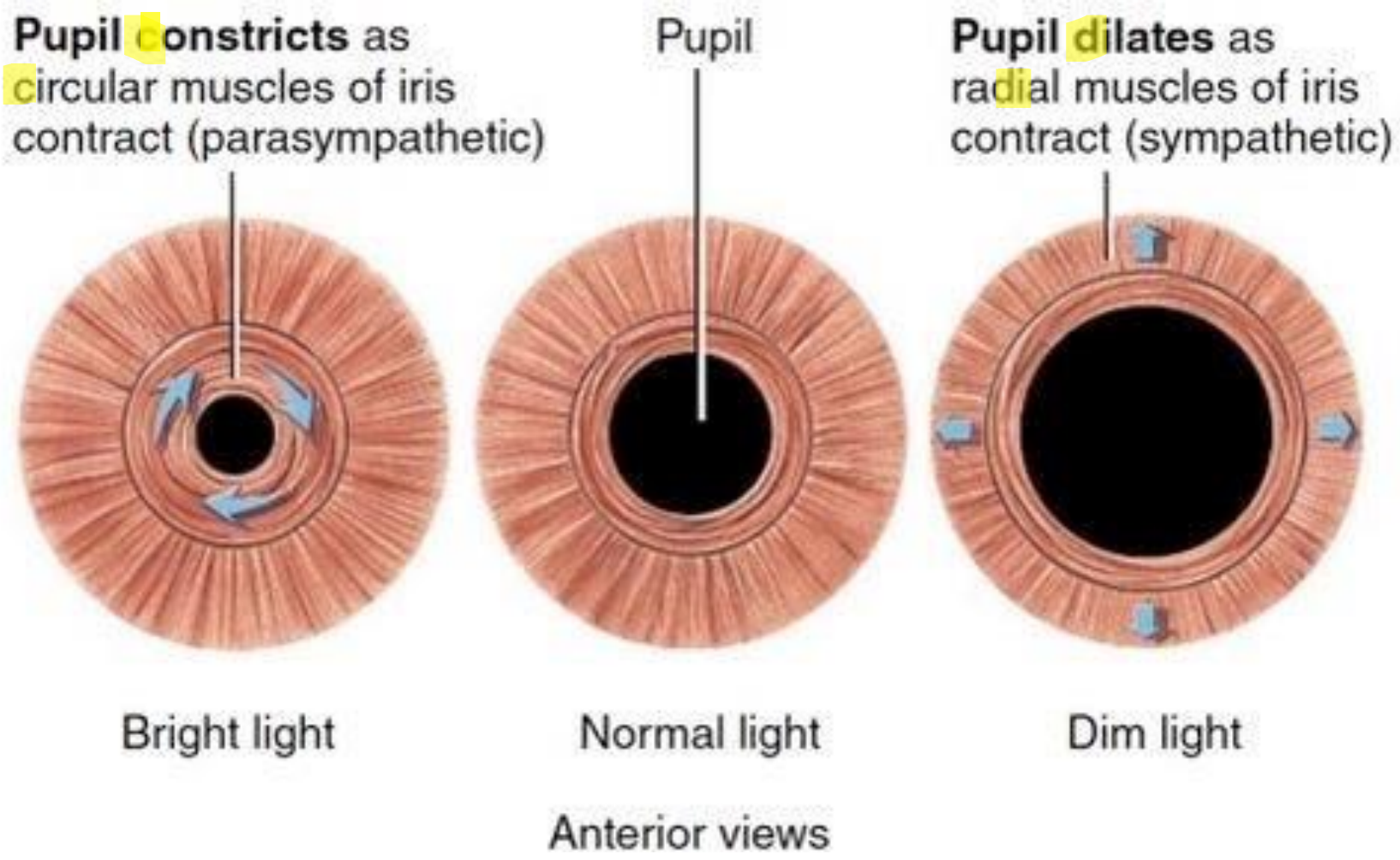
- The round opening in the center of the iris through which light enters the interior portions of the eye is the pupil.
- The size of this opening can be adjusted by variable contraction of the iris smooth muscles to admit more or less light as needed.

Iris

- The iris contains two sets of smooth muscle networks, one circular and the other radial.
- Because muscle fibers shorten when they contract, the pupil gets smaller when the circular (or constrictor) muscle contracts and forms a smaller ring.
- This reflex pupillary constriction occurs in bright light to decrease the amount of light entering the eye.

The iris is formed by smooth muscles which will be contracted and relaxed , and that will affect the pupil size .

Iris have 2 types of muscles :
1-circular muscles (inner ones)
2-radial muscles
Because they are smooth muscles ,the autonomic nervous system will stimulate them , parasympathetic for circular muscles , As well as sympathetic for radial muscles which makes sense because in fight and flight reflex (threating condition), we need to dilate the pupil for clear vision



Iris

- When the radial (or dilator) muscle shortens, the size of the pupil increases.
- Such pupillary dilation occurs in dim light to allow the entrance of more light.
- Iris muscles are controlled by the autonomic nervous system. Parasympathetic nerve fibers innervate the circular muscle (causing pupillary constriction), and sympathetic fibers supply the radial muscle (causing pupillary dilation).

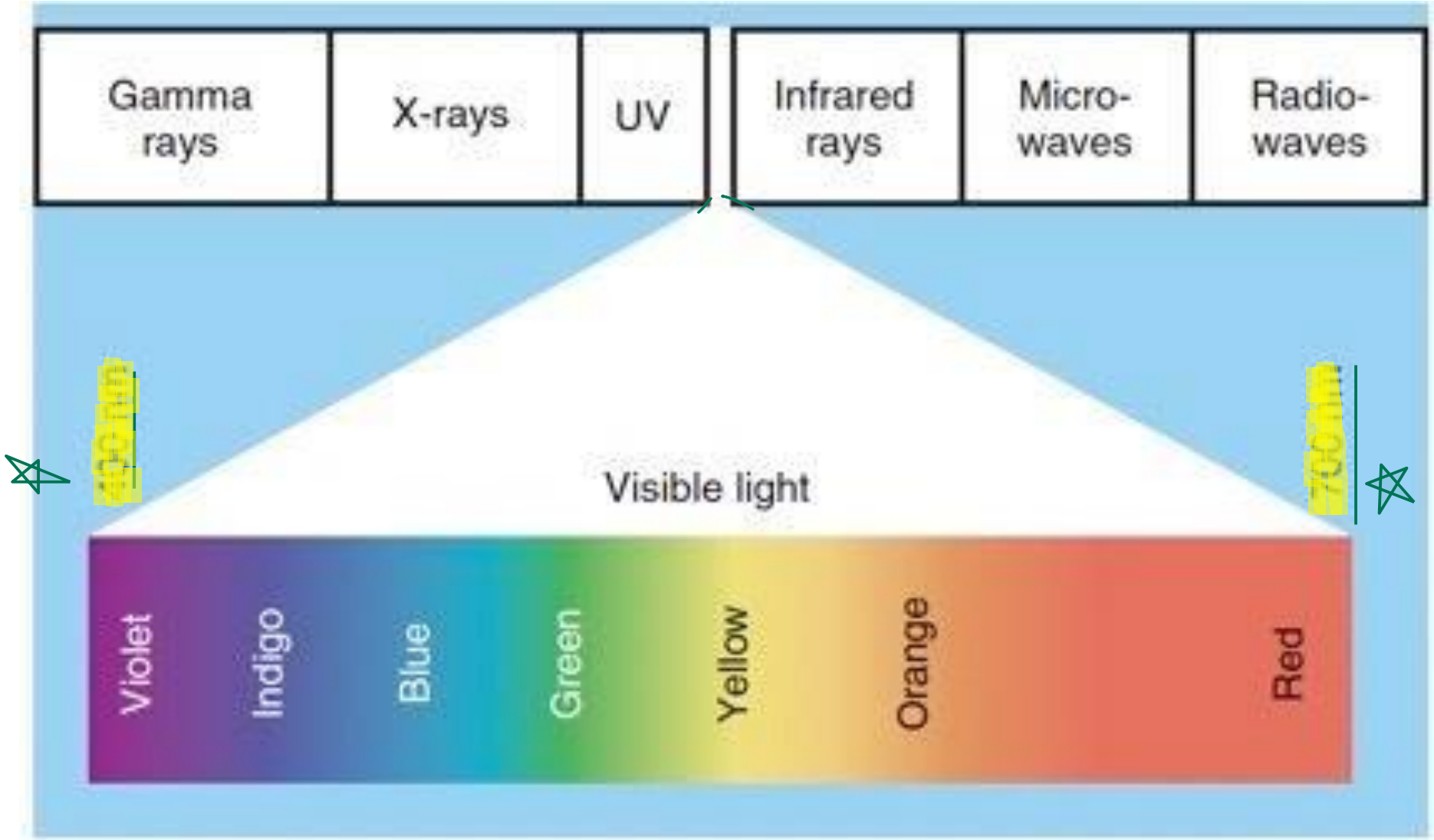
Light wave can be described by several parameters :

1. Wavelength.
2. Amplitude. There are other parameters that haven't been mentioned by the doctor^ ^

Light

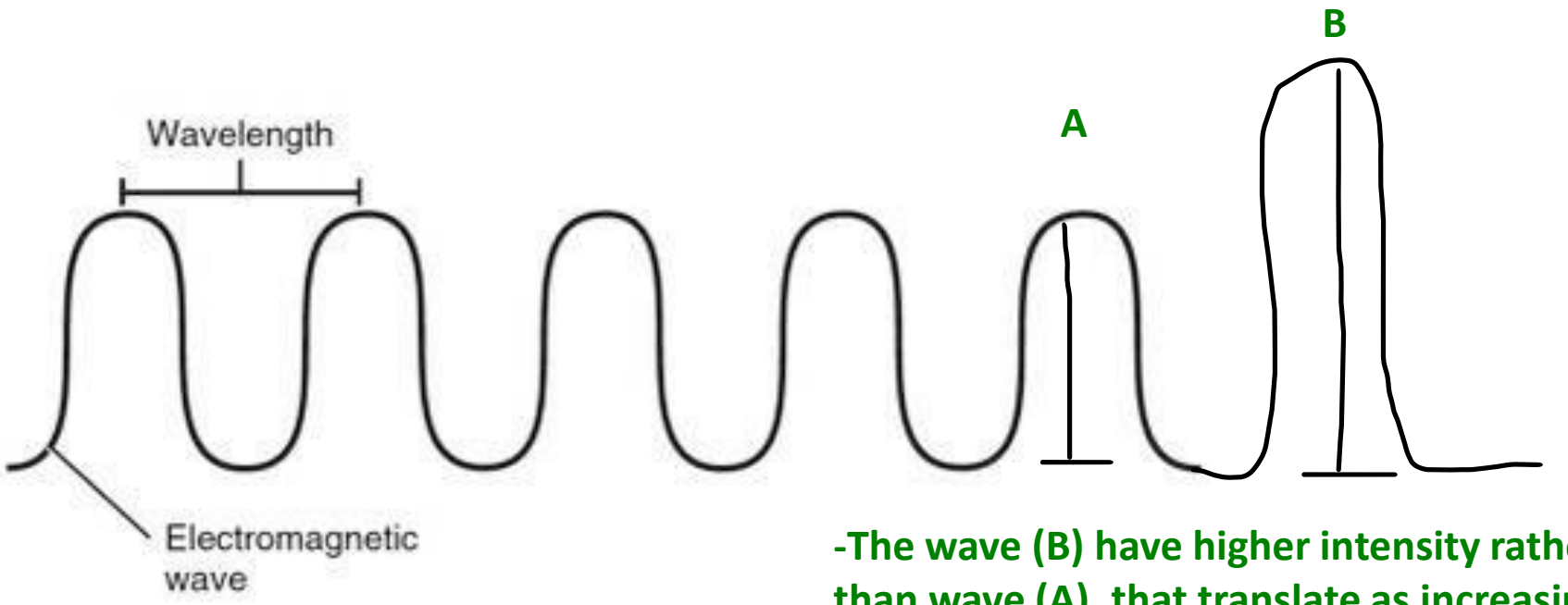
- Light is a form of electromagnetic radiation. The distance between two wave peaks is known as the wavelength.
- The photoreceptors in the eye are sensitive only to wavelengths between 400 and 700 nanometers.
- Light of different wavelengths in this visible band is perceived as different color sensations.

  Violet has the shortest wavelength
  Red has the longest wavelength


Gamma rays
X-rays
UV
Infrared rays
Micro-waves
Radio-waves
Visible light
Violet
Indigo
Blue
Green
Yellow
Orange
Red

Light waves

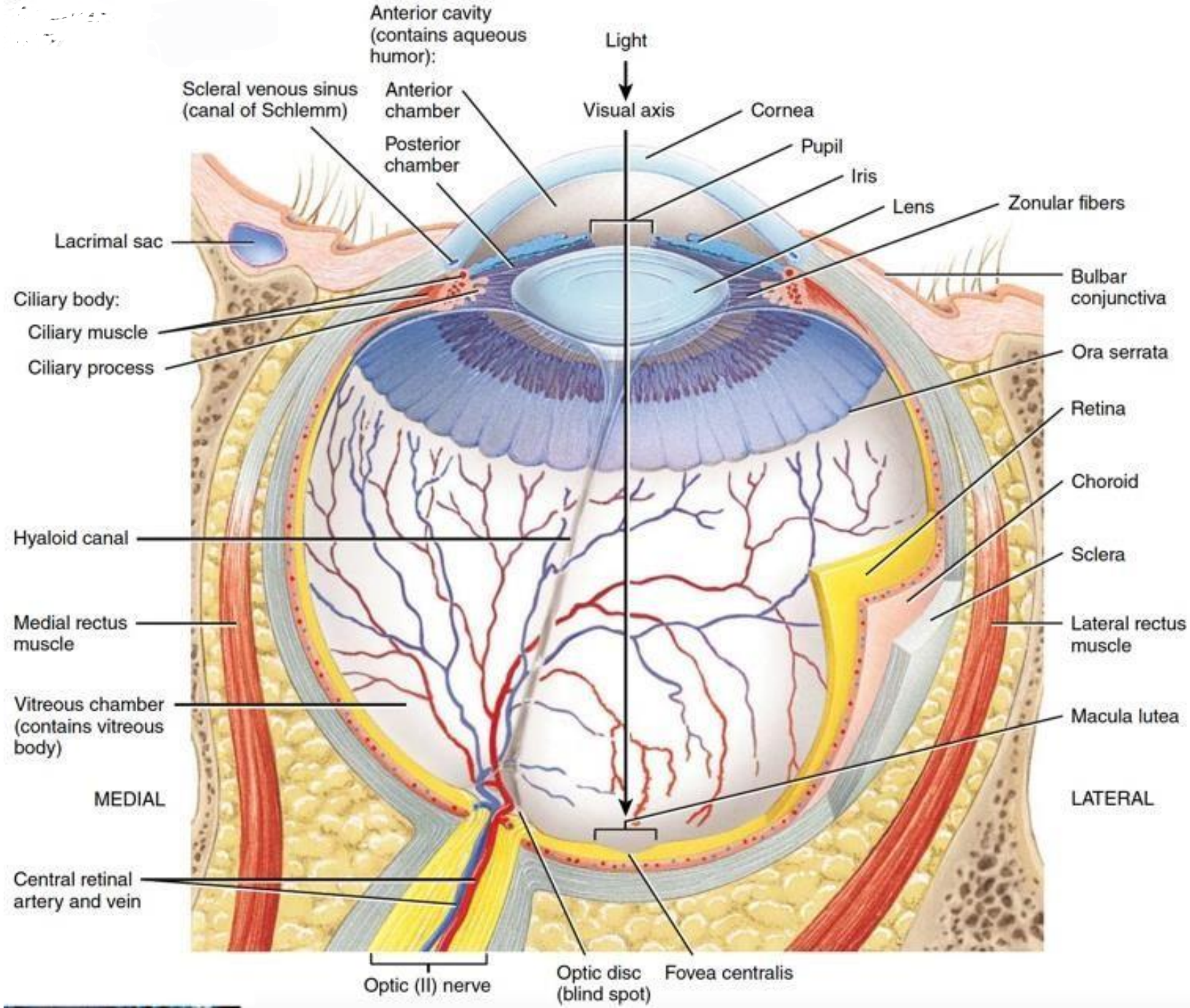
- In addition to having variable wavelengths, light energy varies in intensity—that is, the amplitude of the wave (intensity or brightness).



-The wave (B) have higher intensity rather than wave (A), that translate as increasing of brightness for the same color

Light rays

- Light waves diverge (radiate outward) in all directions from every point of a light source.
- The forward movement of a light wave in a particular direction is known as a light ray.
- Divergent light rays reaching the eye must be bent inward to be focused back into a point (the focal point) on the light sensitive retina **(where the photoreceptors get activated)** and provide an accurate image of the light source.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Zonular fibers
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Ciliary body:
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Ciliary process
Ora serrata
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Sclera
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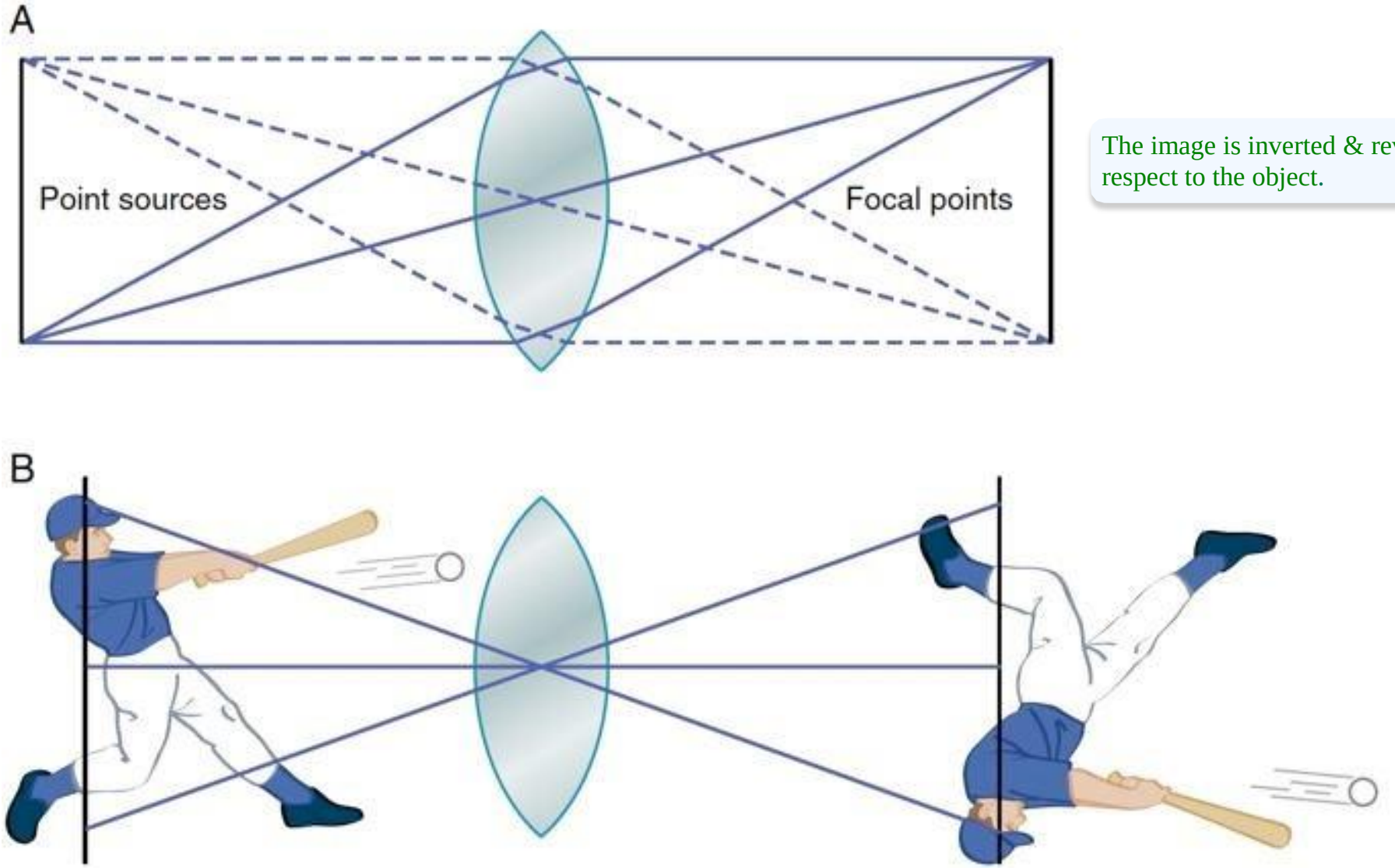
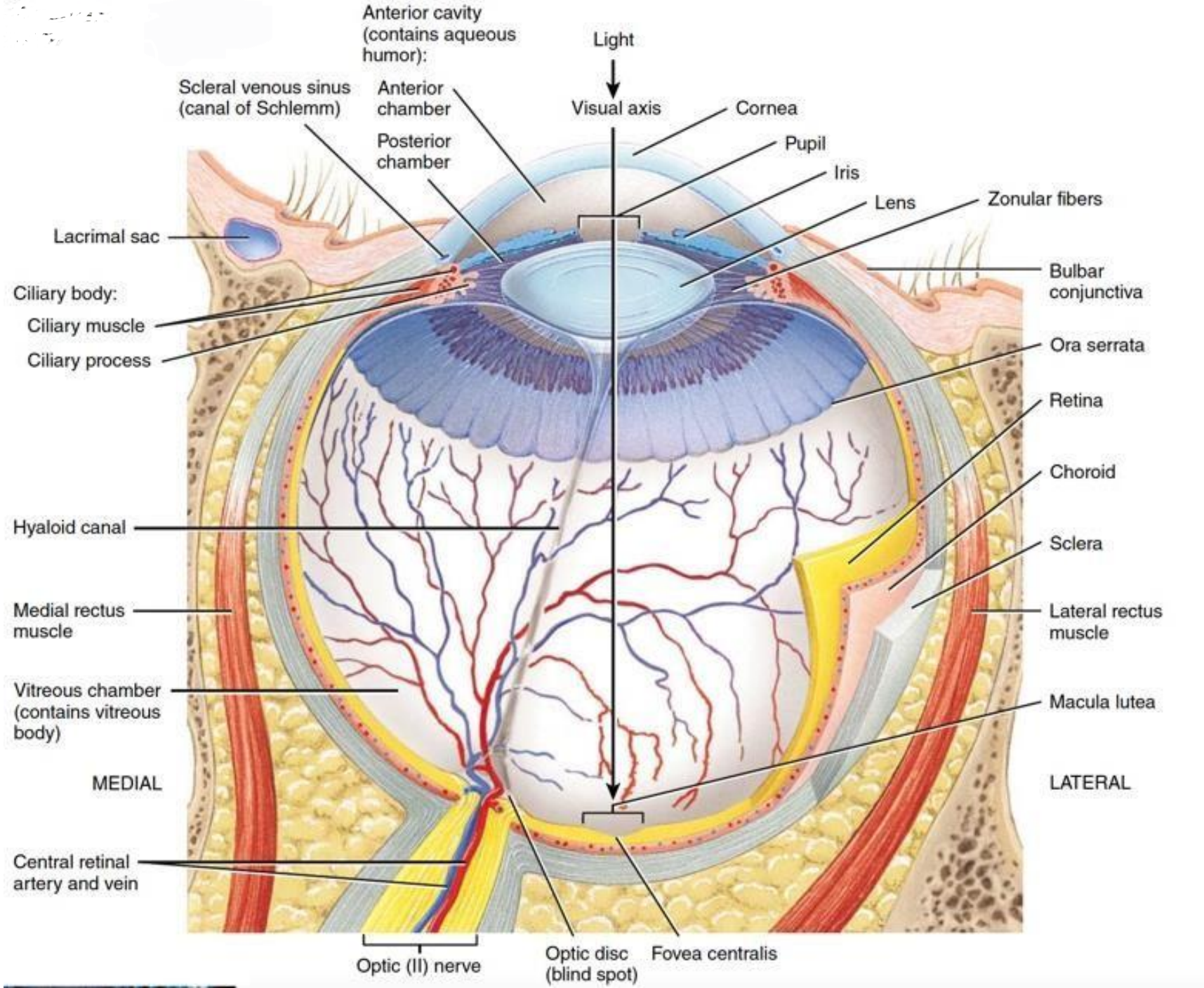
Lateral rectus muscle
Vitreous chamber (contains vitreous body)
Macula lutea
MEDIAL
LATERAL
Central retinal artery and vein
Optic (II) nerve
Optic disc (blind spot)
Fovea centralis

Convex lens



The image is inverted & reversed with respect to the object.

- The lens system of the eye can focus an image on the retina.
- The image is inverted and reversed with respect to the object.
- However, the mind perceives objects in the upright position despite the upside-down orientation on the retina because the brain is trained to consider an inverted image as normal.



Refraction

When light rays traveling through a transparent substance pass into a second transparent substance with a different density, they bend at the junction between the two substances (refraction).

Refraction differs between the different refraction interfaces.

Refraction

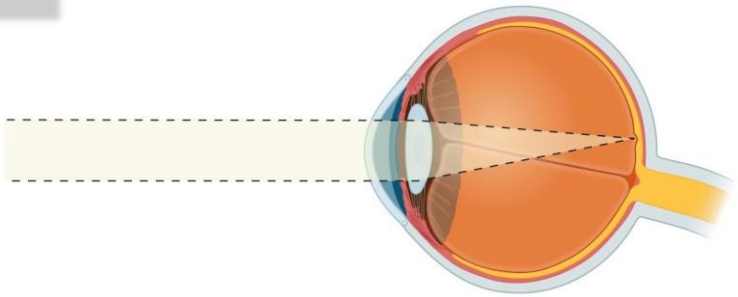
- The lens system of the eye is composed of four refractive interfaces:

- (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.

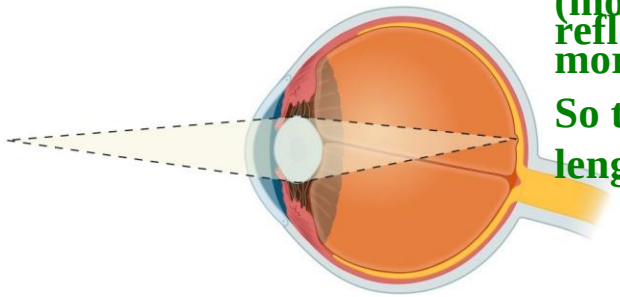
Refractive index

- The refractive index of a transparent substance is the ratio of the velocity of light in air to the velocity in the substance.
- The refractive index of air is 1.00.
  - **Different materials have different refractive indices due to variations in their densities.**
- The distance beyond a convex lens at which parallel rays converge to a common focal point is called the focal length of the lens.

Focal length :



Far points



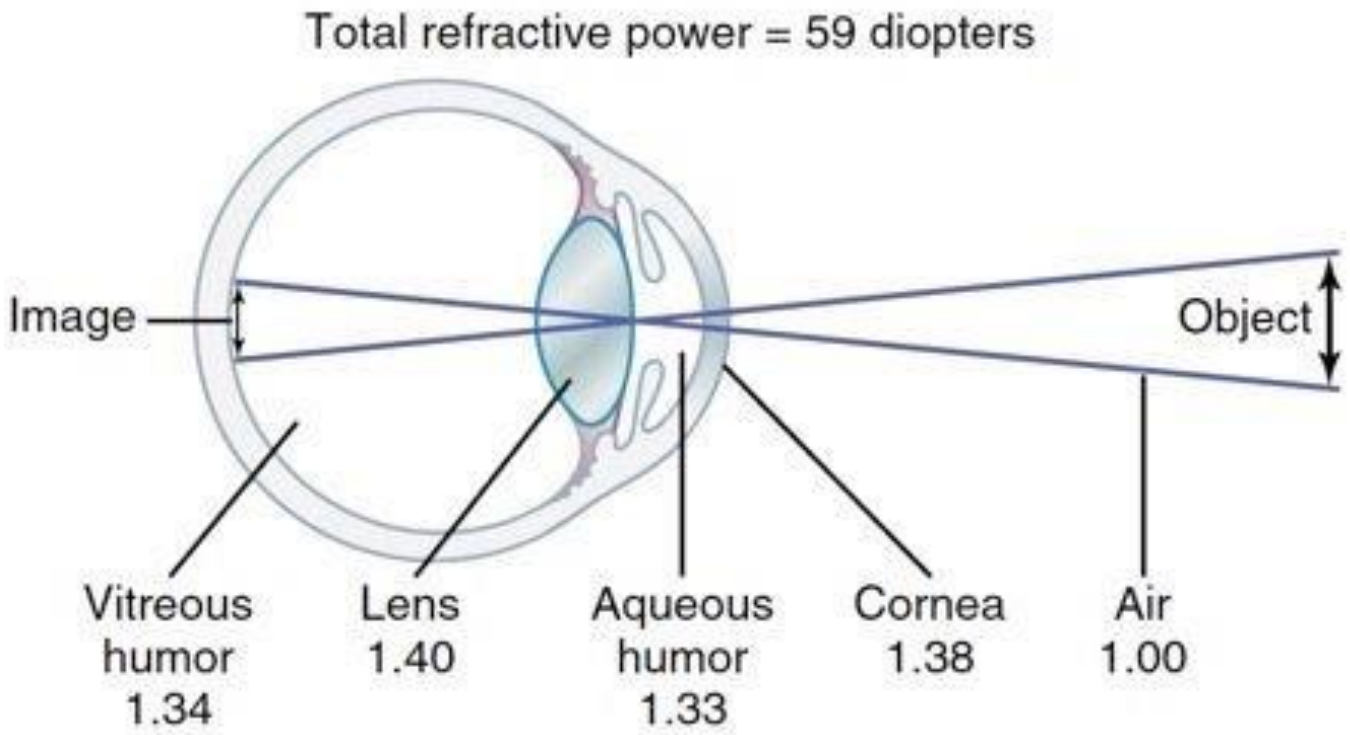
Near point

*** note the different lens shapes.**

The stronger the lens (more convex), the more reflective power, the more conversions

So the shorter the vocal length.

Refractive index in the 4 refractive interfaces



-Reduced eye : all the 4 refractive interfaces are considered as one single structure with refractive power of 59 diopters

Refractive power

The reciprocal of the focal length (1/ focal length).

- The more a lens bends light rays, the greater is its “refractive power.” This refractive power is measured in terms of diopters.

- The refractive power in diopters of a convex lens is equal to 1 meter divided by its focal length.

- Thus, a spherical lens that converges parallel light rays to a focal point 1 meter beyond the lens has a refractive power of +1 diopter.

Refractive power

• Assume that the focal length in Figure A is 0.5 diopters, and the focal length in Figure B is 1 diopter.
• Accordingly, the refractive power in figure A is 2 diopters and 1 diopter in figure B.

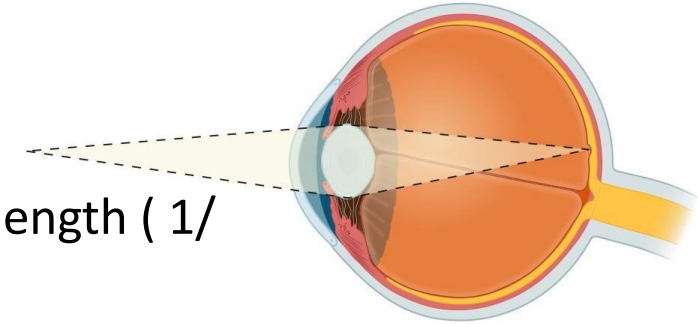


Figure A

• Remember that refractive power is the reciprocal of the focal length (1/ focal length).
• Refractive power is positive for convex lens, negative for the concave (+ → convex, − → concave).

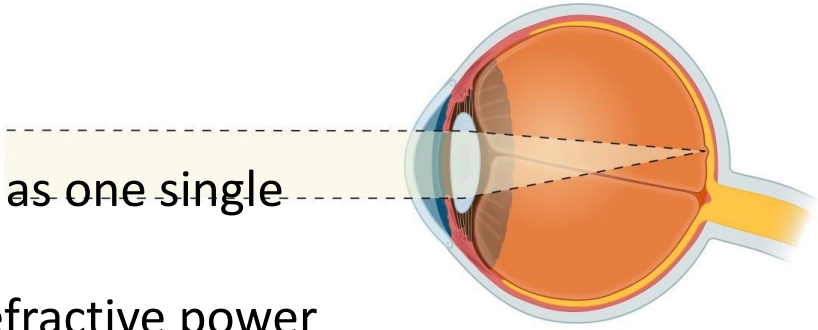


Figure B

• Reduced eye : all the 4 refractive interfaces are considered as one single structure with refractive power of 59 diopters.
• Cornea is the structure that contributes the most for the refractive power of the eye (about 2/3 of the refractive power of the eye).

Refraction

- 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 is provided by the anterior surface of the cornea (not the lens).

  - **While the lens contributes only to 1/3 of the total refractive power of the eye, it plays a crucial role in refraction due to its ability to accommodate, while the cornea is fixed structure.**

- The principal reason for this phenomenon is that the refractive index of the cornea is markedly different from that of air.

  The cornea has a higher refractive index compared to the surrounding air and fluids within the eye

Refraction

- 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.

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. **Ciliary muscles are relaxed, the ligaments are tightened As seen in figure B (next slide)**

Accomodation

- 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.

As seen in figure A

Figure A

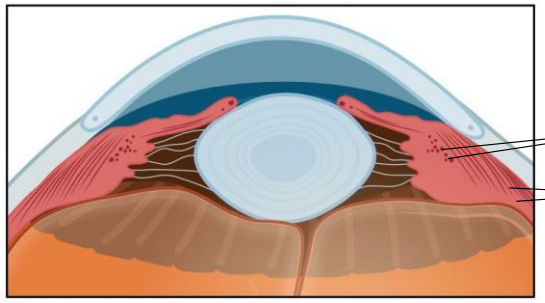
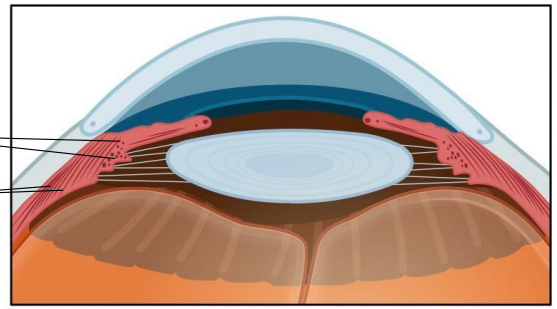
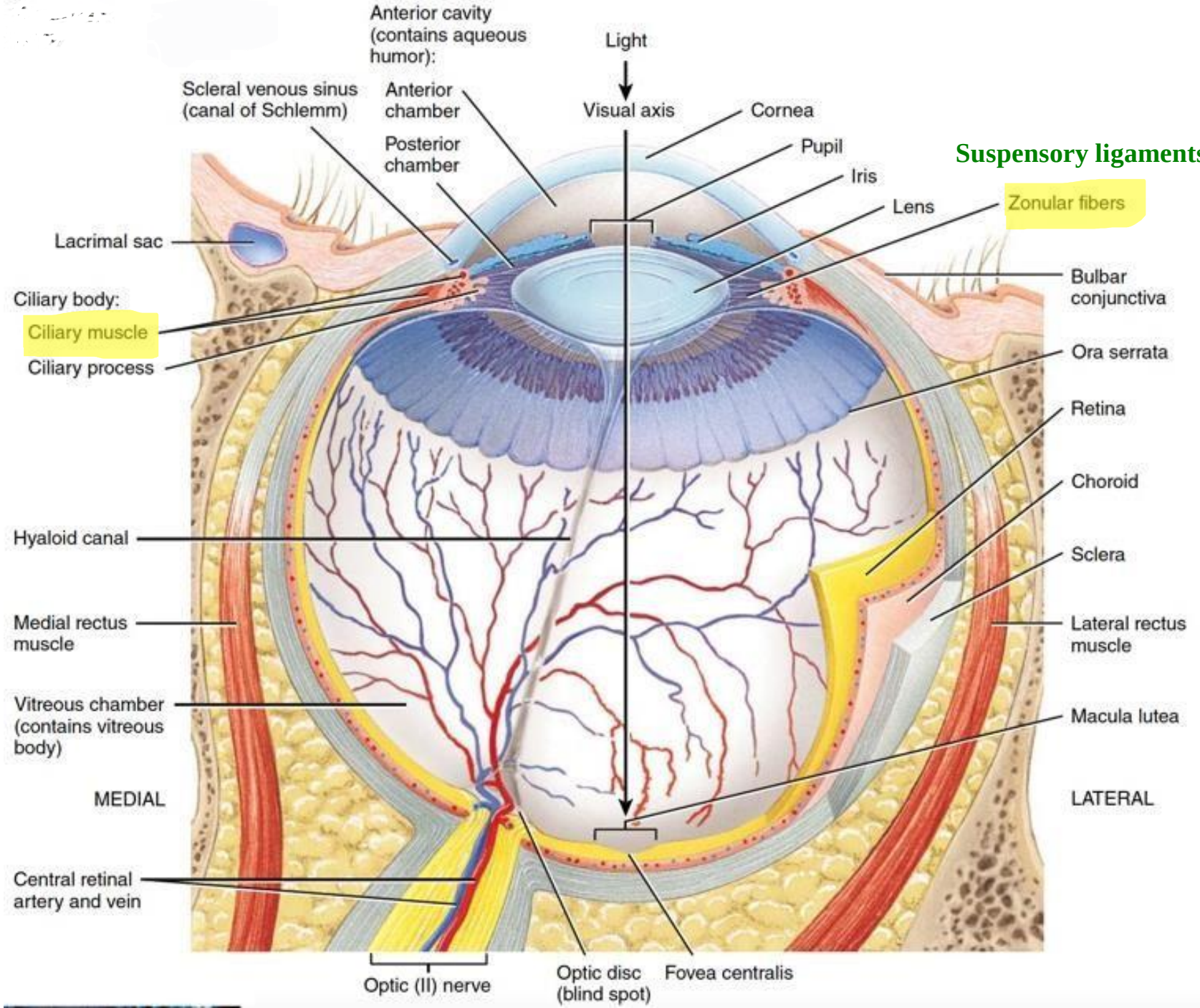


Figure B





Suspensory ligaments = Zonular fibers

✿ **When we look at objects up close (where light rays are more diverged) we have to increase lens's curvature.**

- **the ciliary muscles in the eye contract, suspensory ligaments are relaxed, which causes the lens to become more convex/rounded. This adjustment increases the refractive power of the lens, allowing it to focus light from near objects onto the retina. This process is known as accommodation.**

✿ **Conversely, when we shift our focus to objects at a distance, the ciliary muscles relax, suspensory ligaments are tightened and the lens becomes flatter and thinner. This reduces the refractive power of the lens, allowing it to focus light from distant objects onto the retina.**

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

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**. They wear bifocal glasses

- 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.

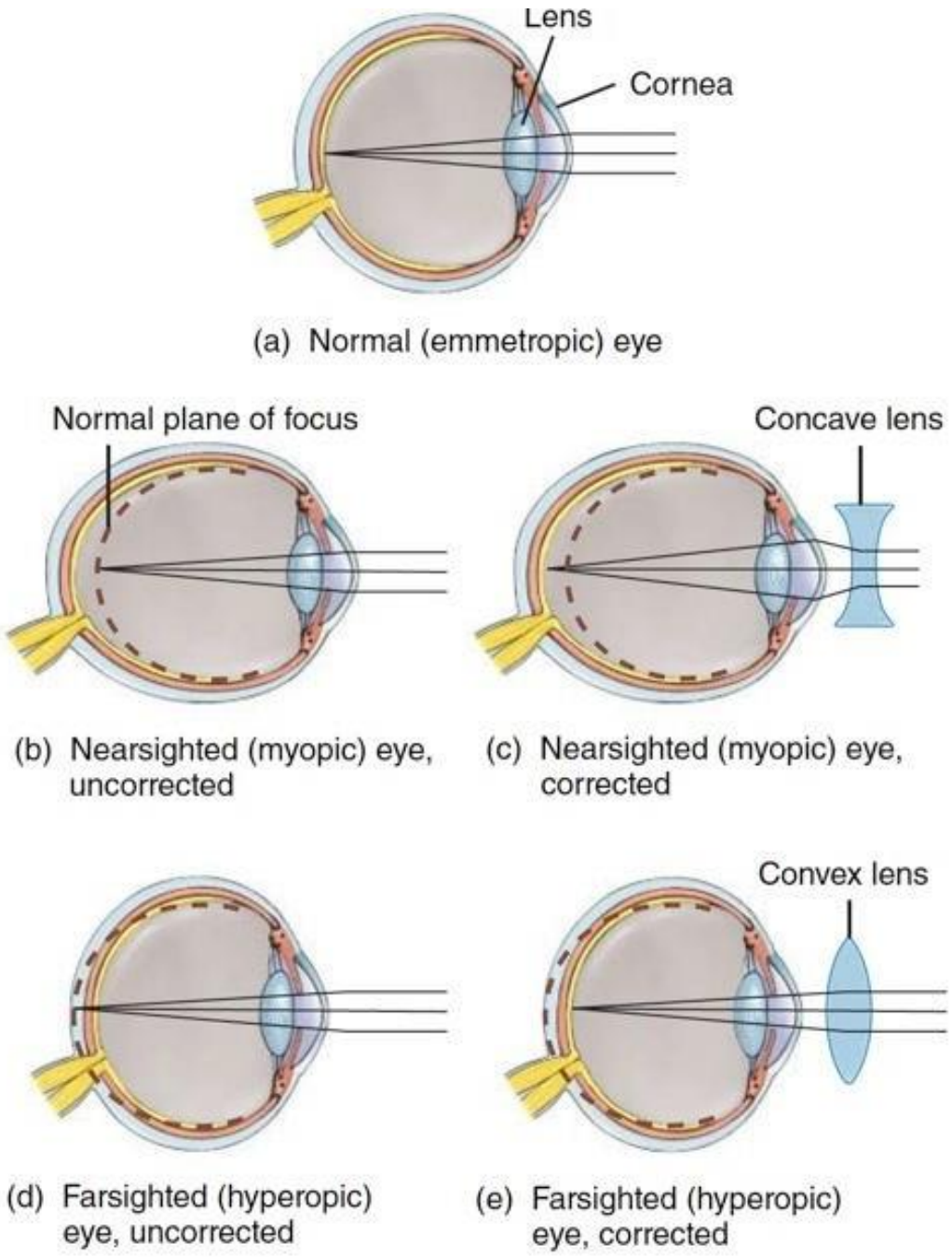
- The eyes can no longer accommodate for both near and far vision. To see clearly both in the distance and nearby, an older person must wear bifocal glasses, with the upper segment focused for far-seeing and the lower segment focused for near-seeing (e.g., for reading).

Refractive errors

Emmetropic : normal eye.

Myopia (nearsightedness) : is a common refractive error mostly genetically determined in which the eyeball is typically longer than normal, or the lens is strongly convex (has a higher than usual refractive power) . This causes light entering the eye to converge in front of the retina, resulting in blurred vision when viewing distant objects. However, near vision is typically unaffected.

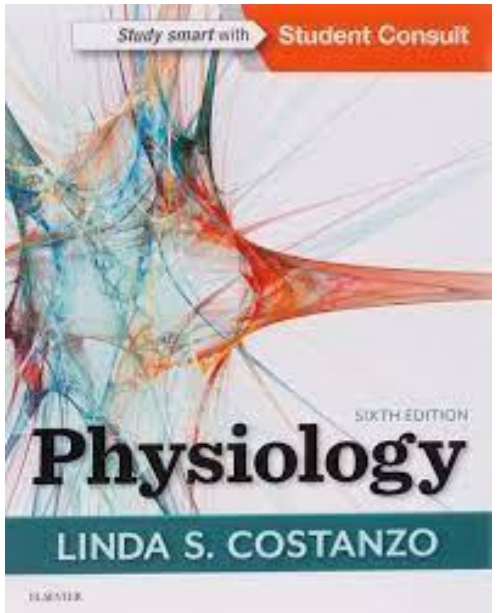
Treatment for myopia involves the use of concave lenses; these lenses are designed to increase the divergence of light rays entering the eye, compensating for the excessive convergence caused by the elongated eyeball or strong convexity of the lens.



Hyperopic (farsighted) : is a refractive error in which the eyeball is smaller than normal or the lens is weaker (loosely convex), has a lower than normal refractive power, this causes light entering the eye to converge behind the retina, resulting in blurred vision when viewing near objects.

Treatment involves the use of convex lenses; these lenses are designed to increase the conversions of light entering the eye, compensating for the reduced convergence.

References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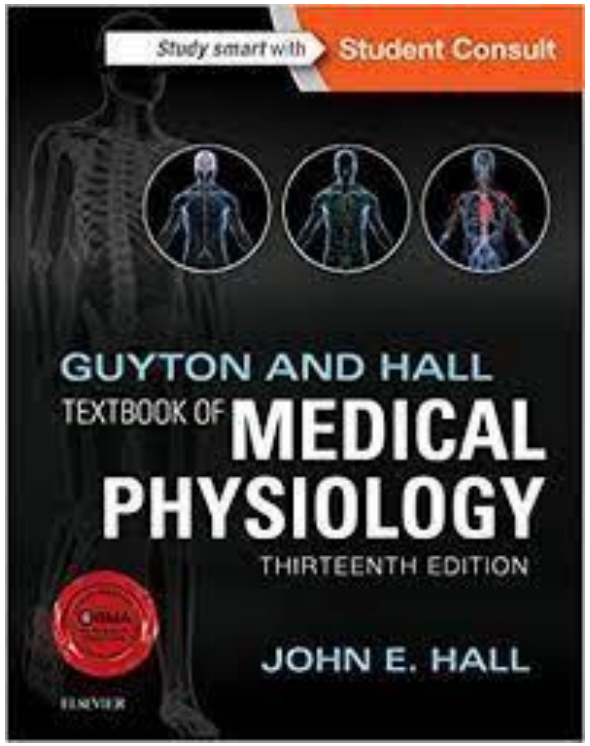
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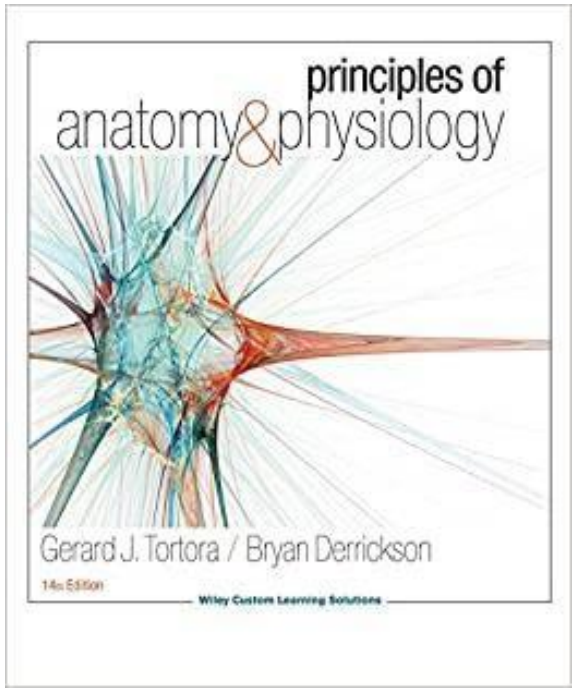
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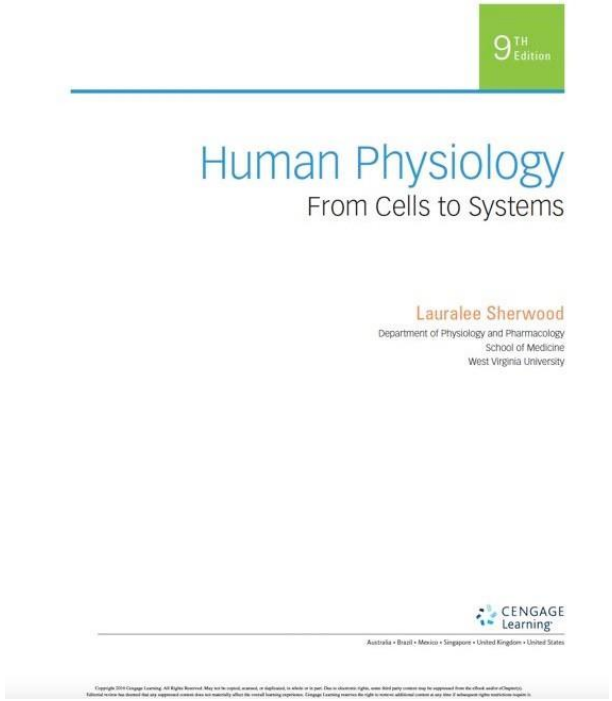
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