

Neurophysiology

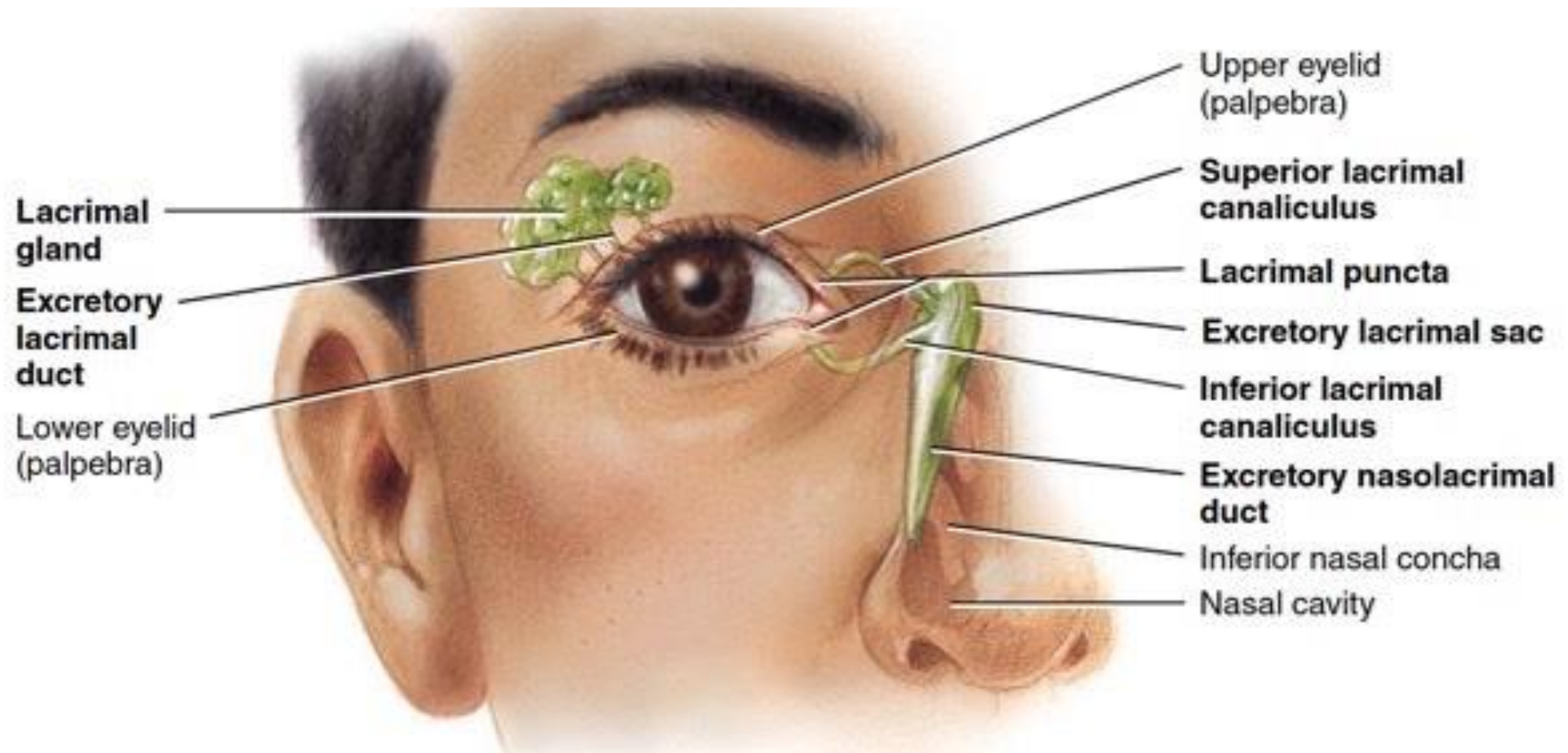
Vision 1

Fatima Ryalat, MD, PhD

Assistant Professor, Department of Physiology and Biochemistry
School of Medicine, University of Jordan

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.



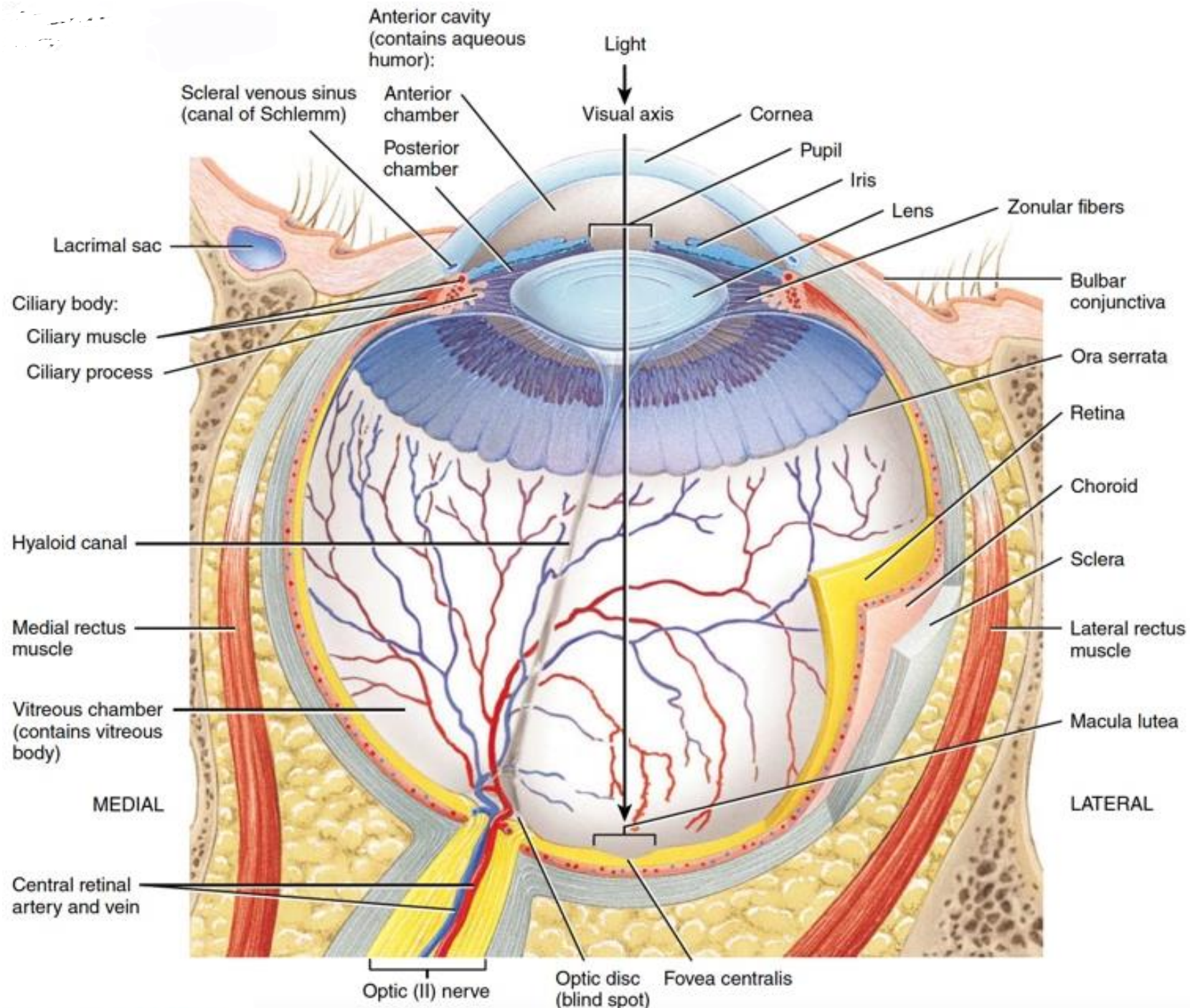
Tears

- 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.
- (2) the choroid/ciliary body/iris.
- (3) the retina.



Sclera and cornea

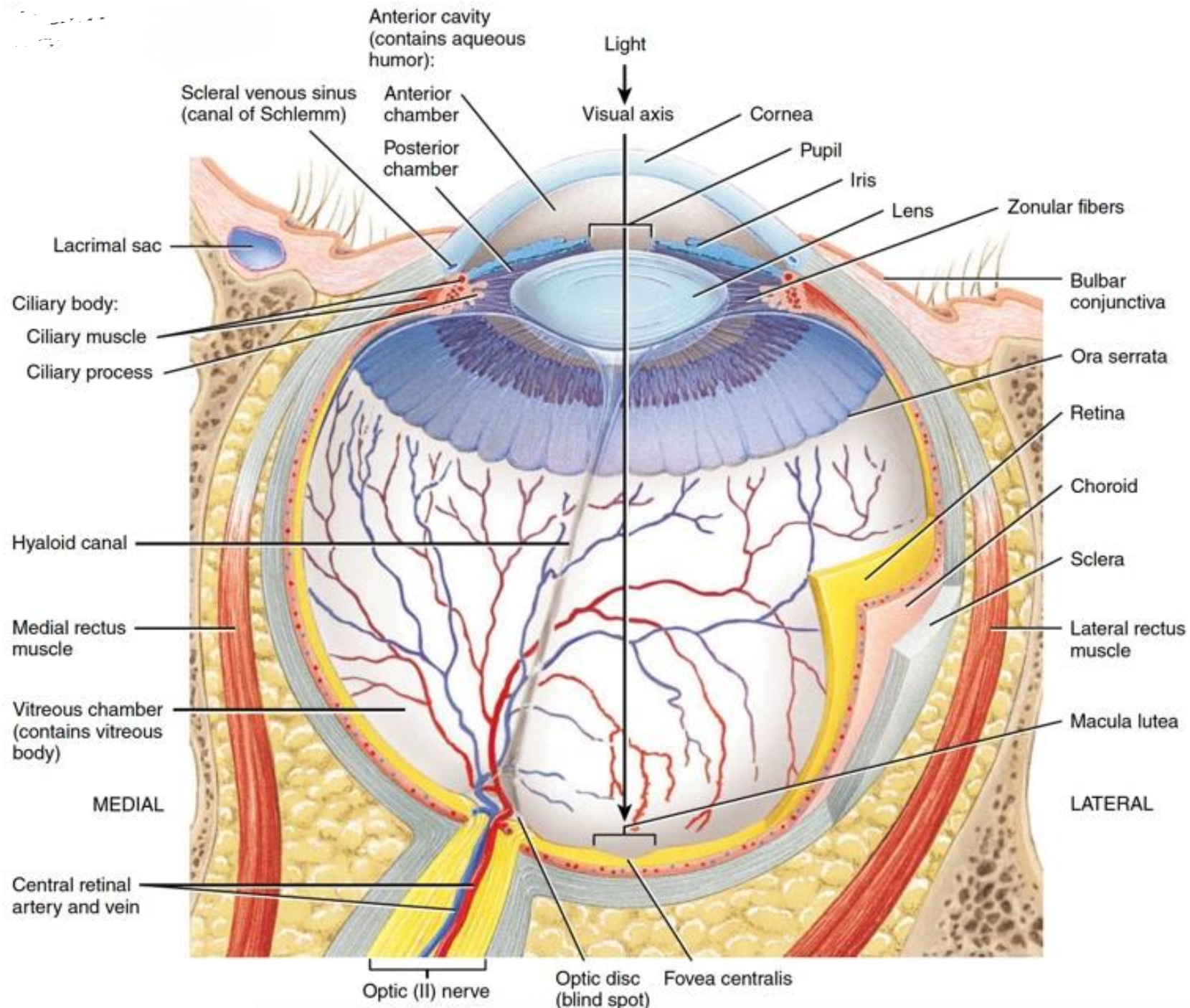
- Most of the eyeball is covered by a tough outer layer of connective tissue, the sclera, which forms the visible white part of the eye.
- Anteriorly, the outer layer consists of the transparent cornea, through which light rays pass into the interior of the eye.

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.
- 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

- The innermost coat under the choroid is the retina, which consists of an outer pigmented layer and an inner nervous-tissue layer.
- The nervous layer contains the rods and cones, the photoreceptors that convert light energy into nerve impulses.



Lens

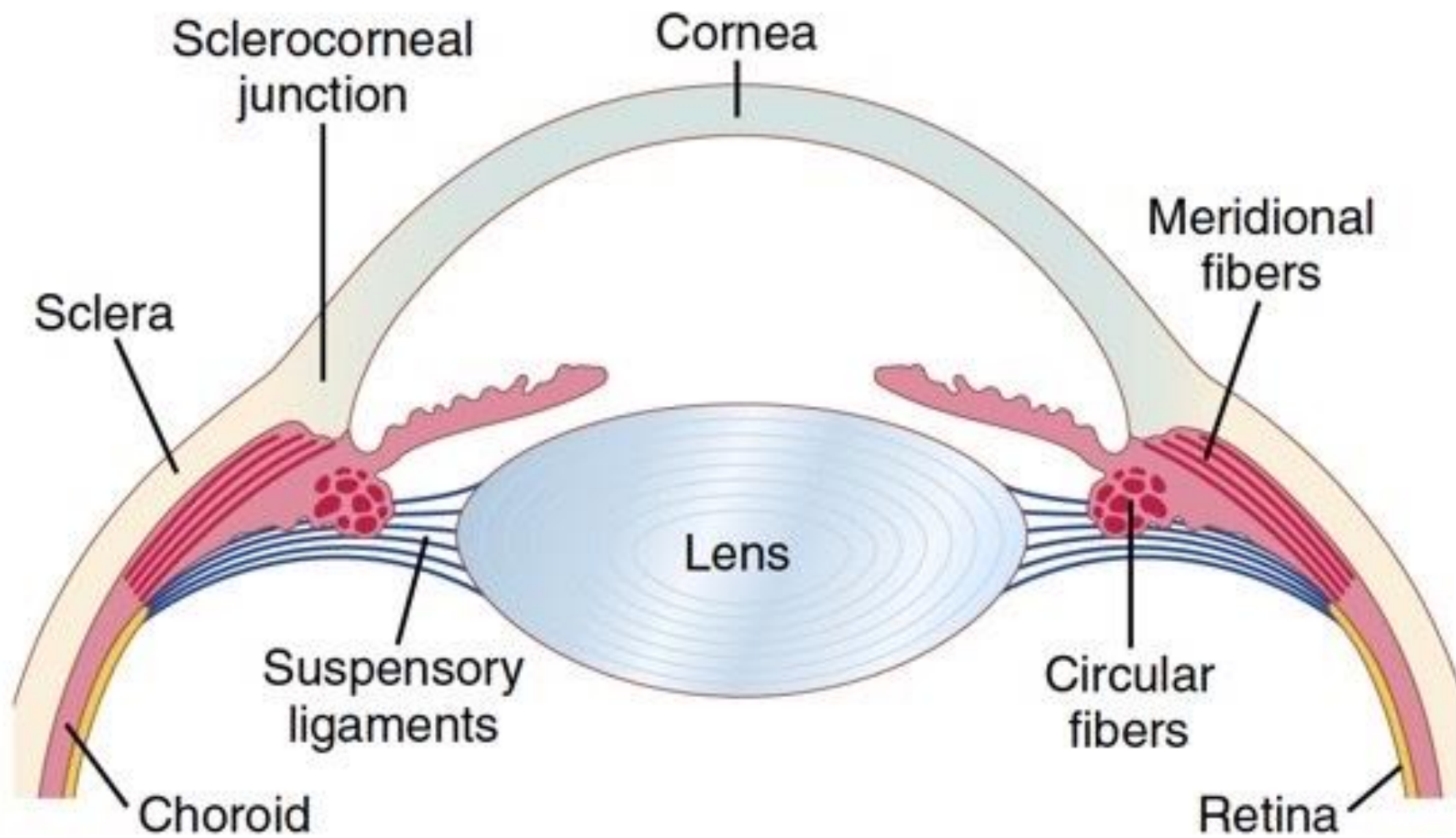
- The interior of the eye consists of two fluid-filled cavities, separated by a lens, all of which are transparent to permit light to pass through the eye from the cornea to the retina.

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.

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.



Intraocular fluid

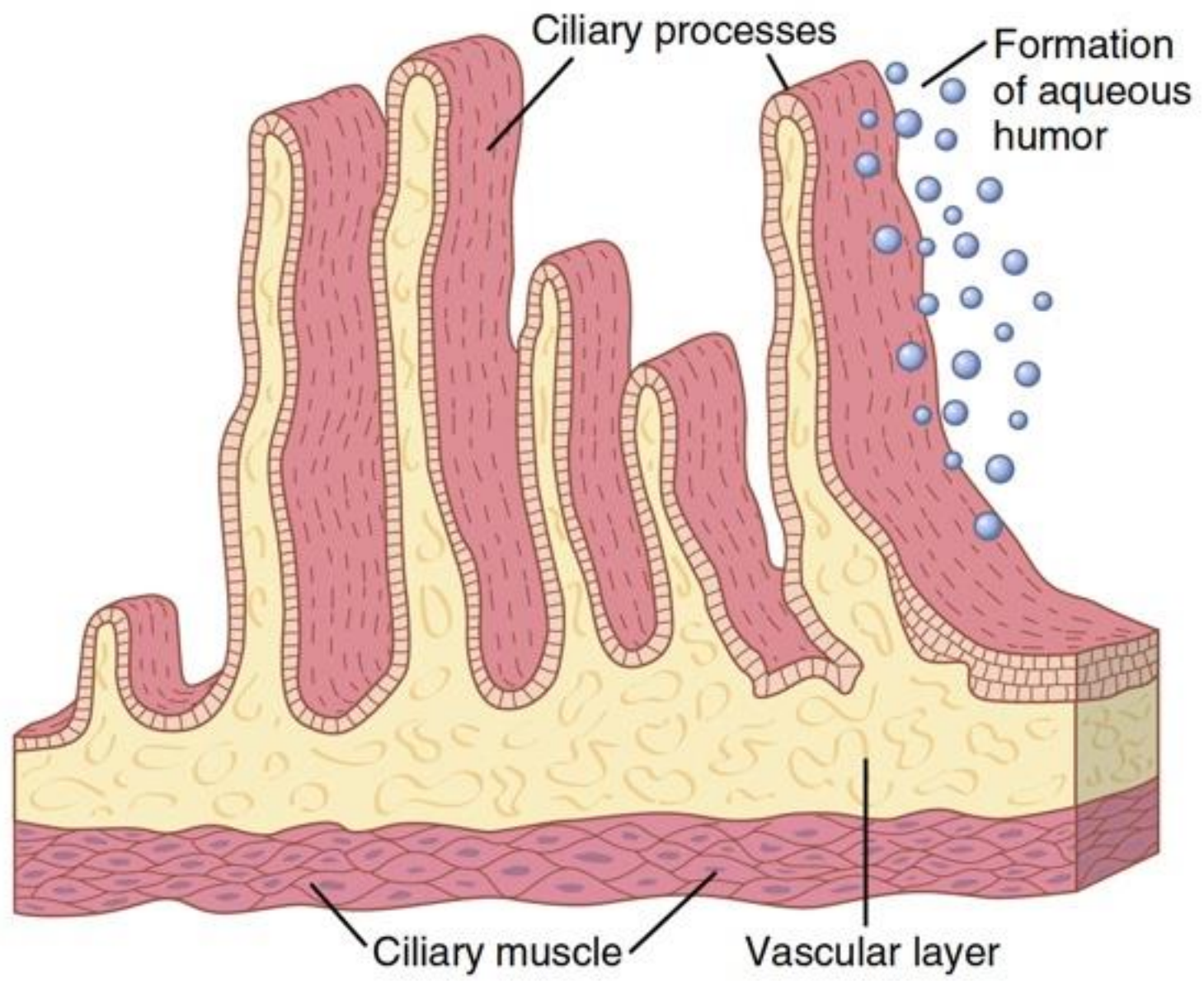
- The aqueous humor is a freely flowing fluid, whereas the vitreous humor, sometimes called the vitreous body, is a gelatinous mass held together by a fine fibrillar network composed primarily of greatly elongated proteoglycan molecules.
- Aqueous humor is continually being formed and reabsorbed.
- Aqueous 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.

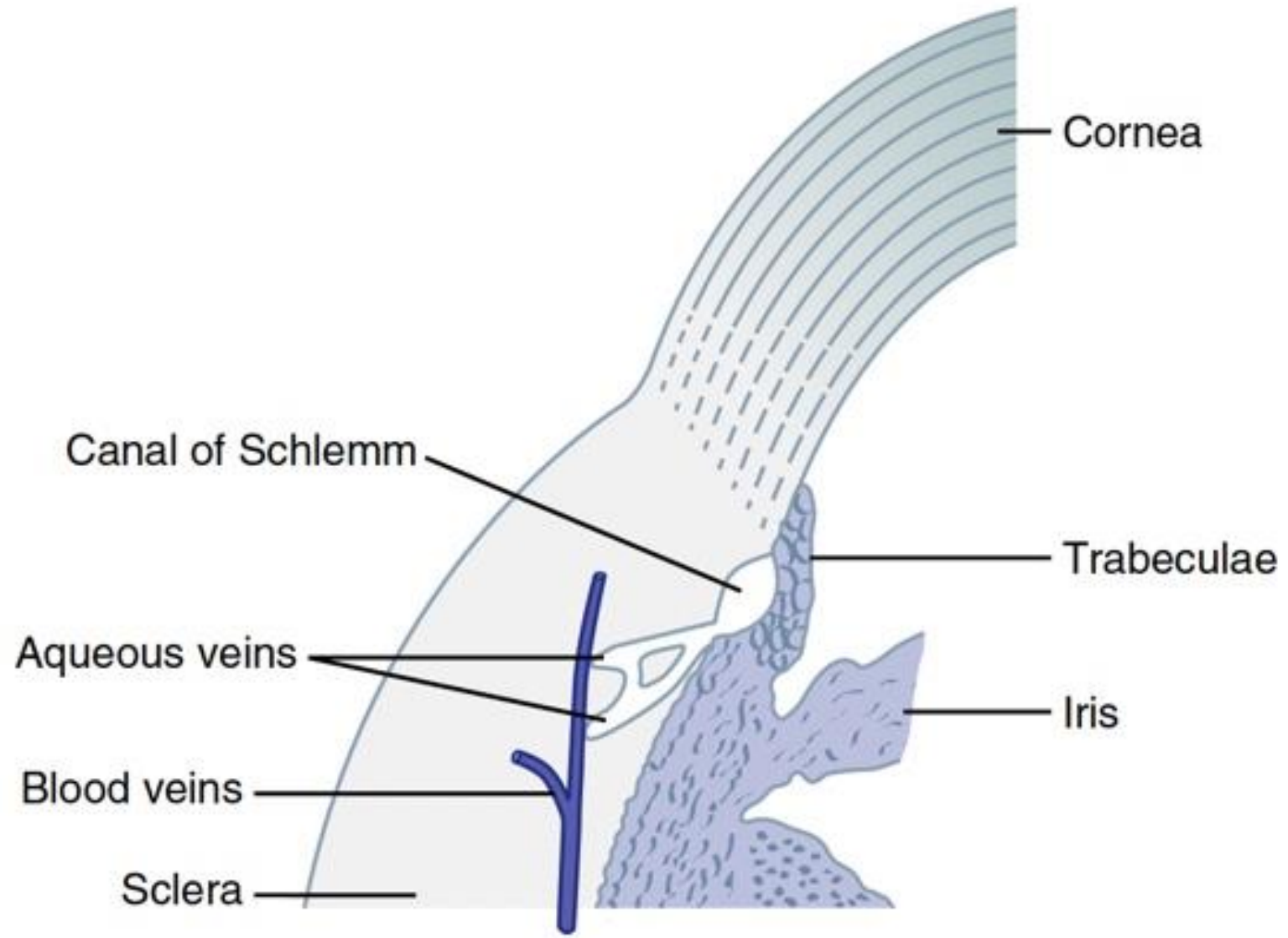
Aqueous humor

- 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.
- 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.



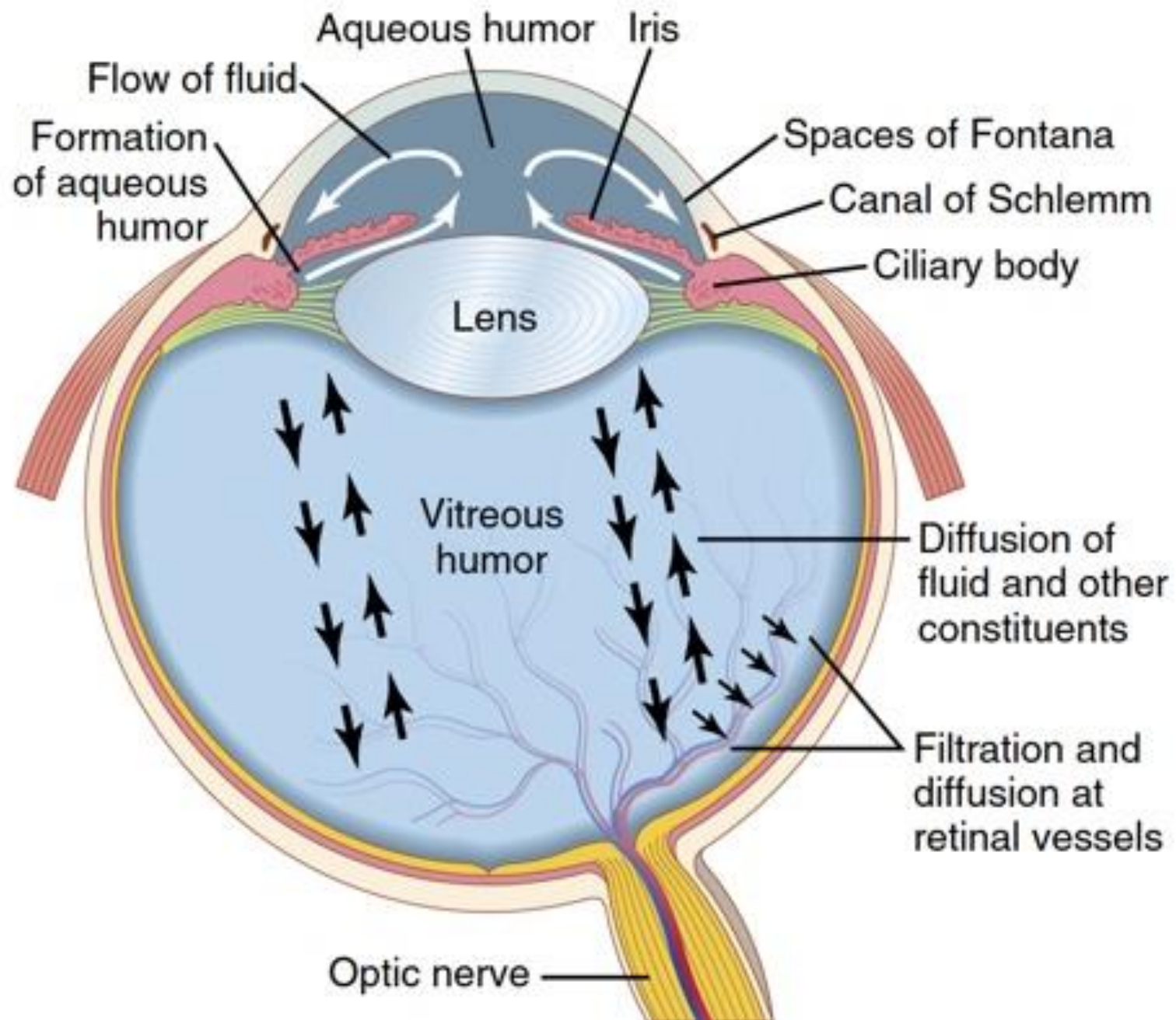
Aqueous humor

- 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



Intraocular pressure

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



Vitreous humor

- The larger posterior cavity between the lens and the retina contains a clear, jellylike substance, the vitreous humor.
- 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 pigment in the iris is responsible for eye color.

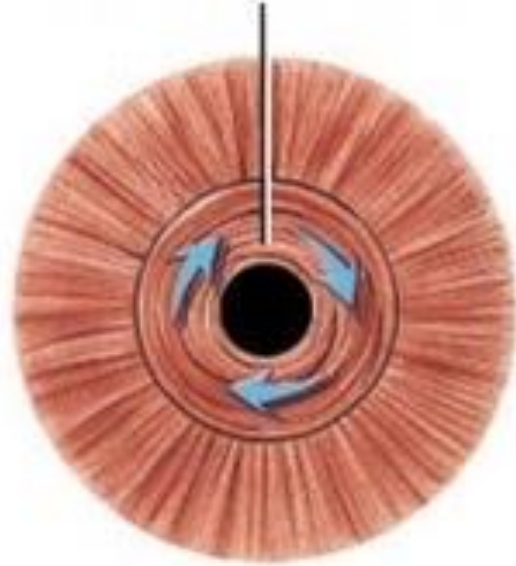
Pupil

- 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

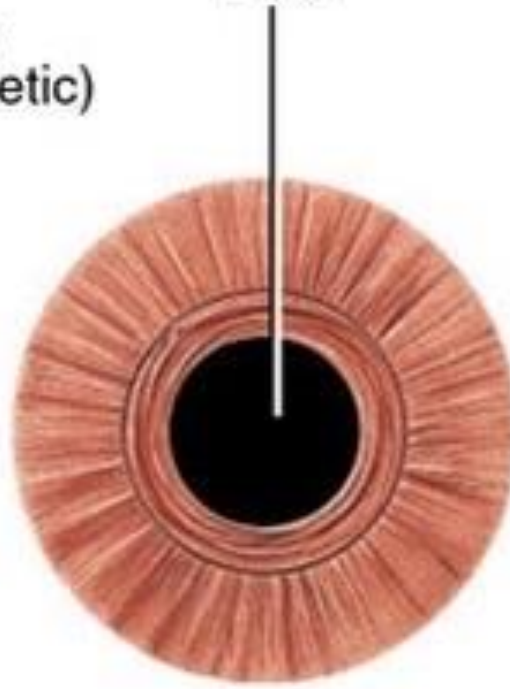
- The iris contains two sets of smooth muscle networks, one circular and the other radial.
- Because muscle fibers shorten when they contract, the pupil gets smaller when the circular (or constrictor) muscle contracts and forms a smaller ring.
- This reflex pupillary constriction occurs in bright light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

Pupil constricts as circular muscles of iris contract (parasympathetic)



Bright light

Pupil



Normal light

Pupil dilates as radial muscles of iris contract (sympathetic)



Dim light

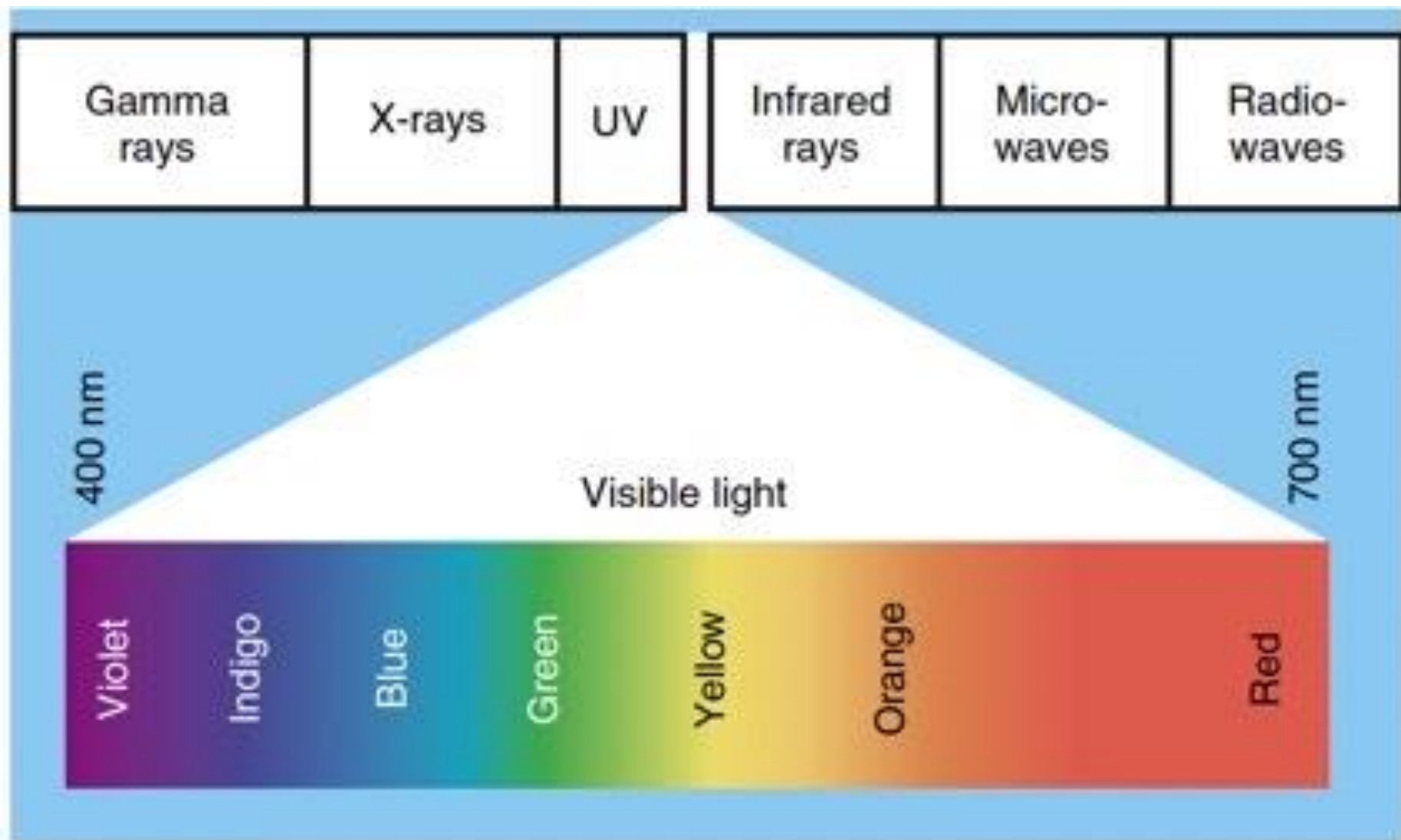
Anterior views

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).

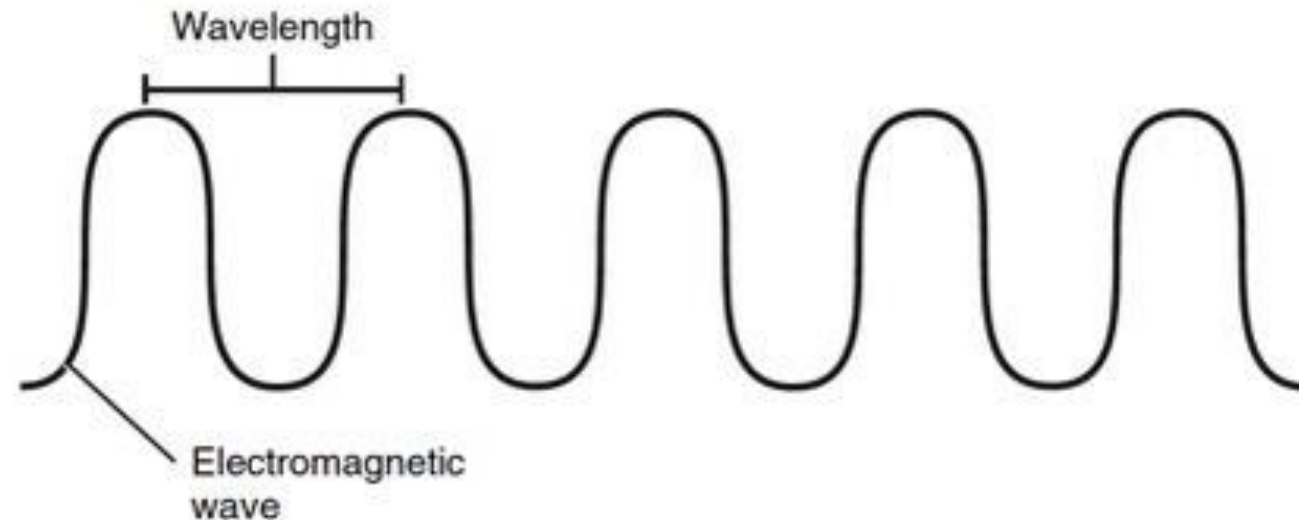
Light

- 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.



Light waves

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

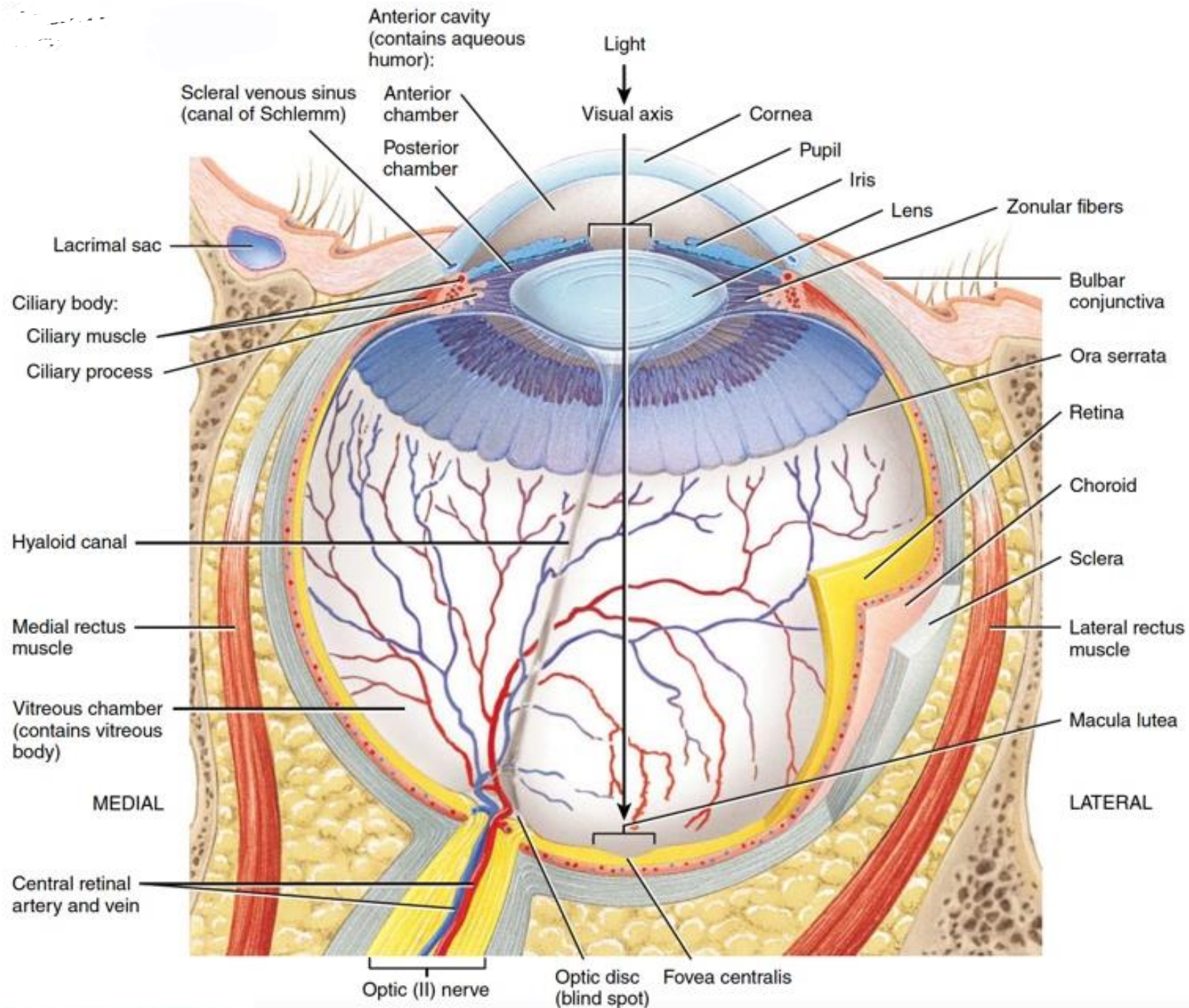


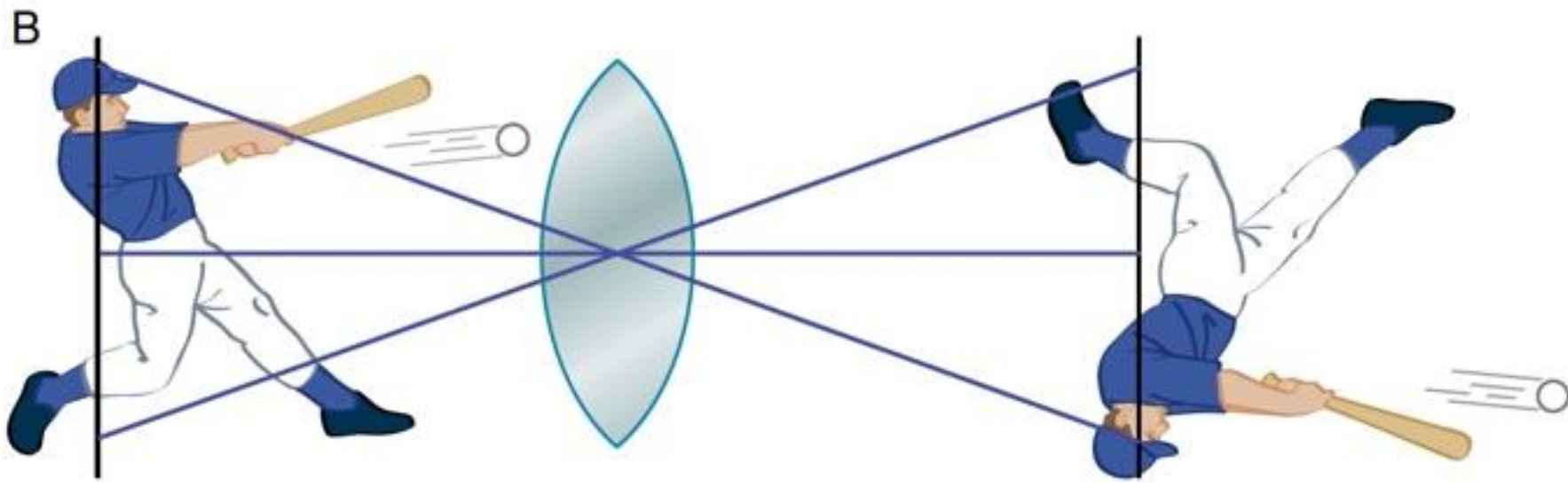
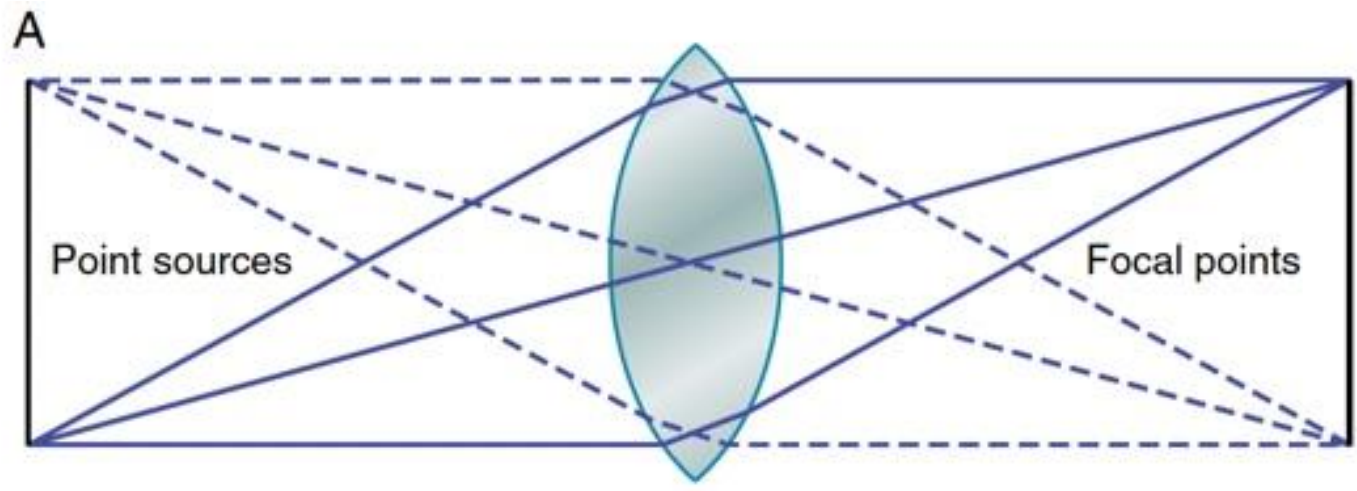
Light rays

- 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 and provide an accurate image of the light source.

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.

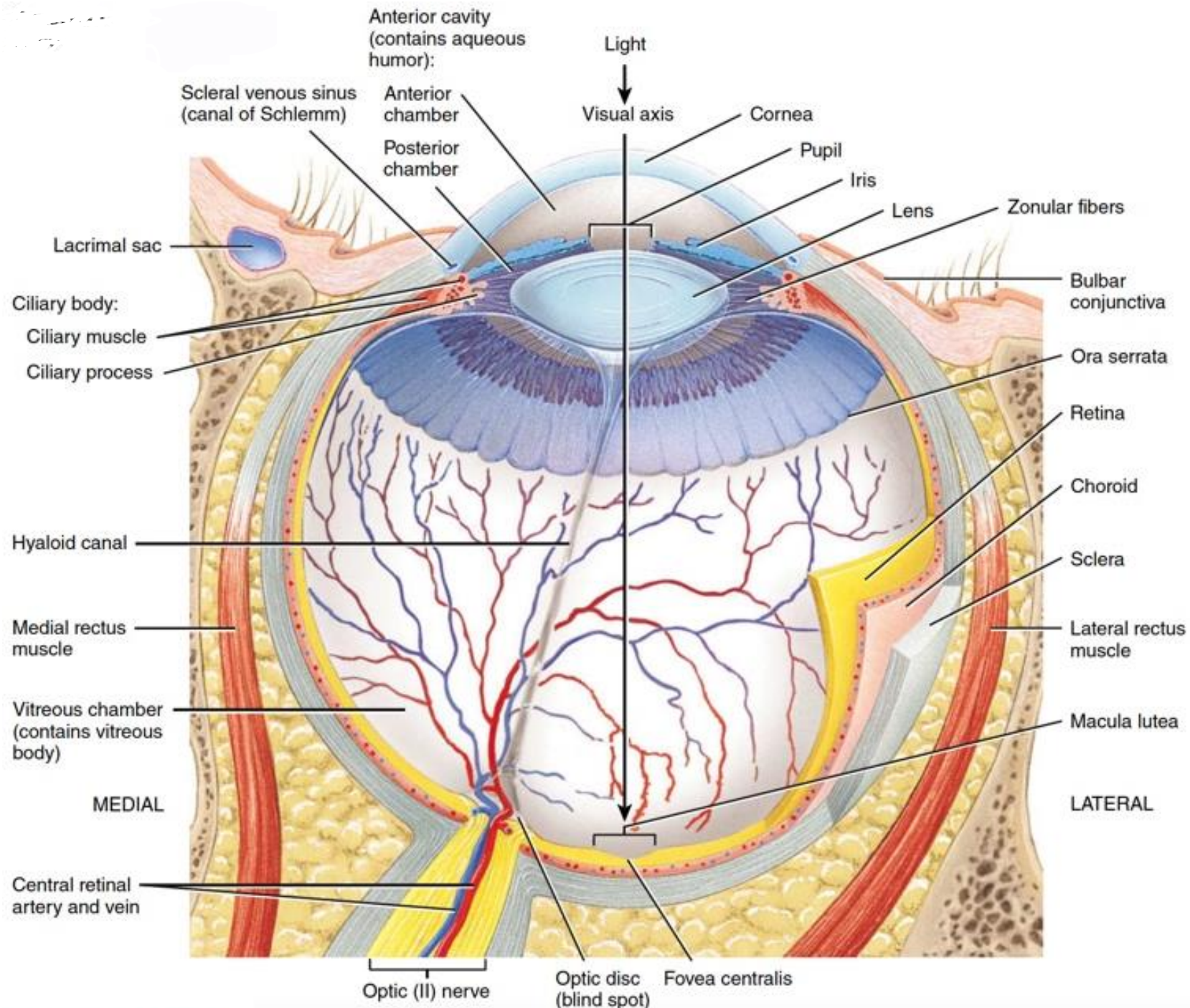




- The lens system of the eye can focus an image on the retina.
- The image is inverted and reversed with respect to the object.
- However, the mind perceives objects in the upright position despite the upside-down orientation on the retina because the brain is trained to consider an inverted image as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

Refraction

- 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.

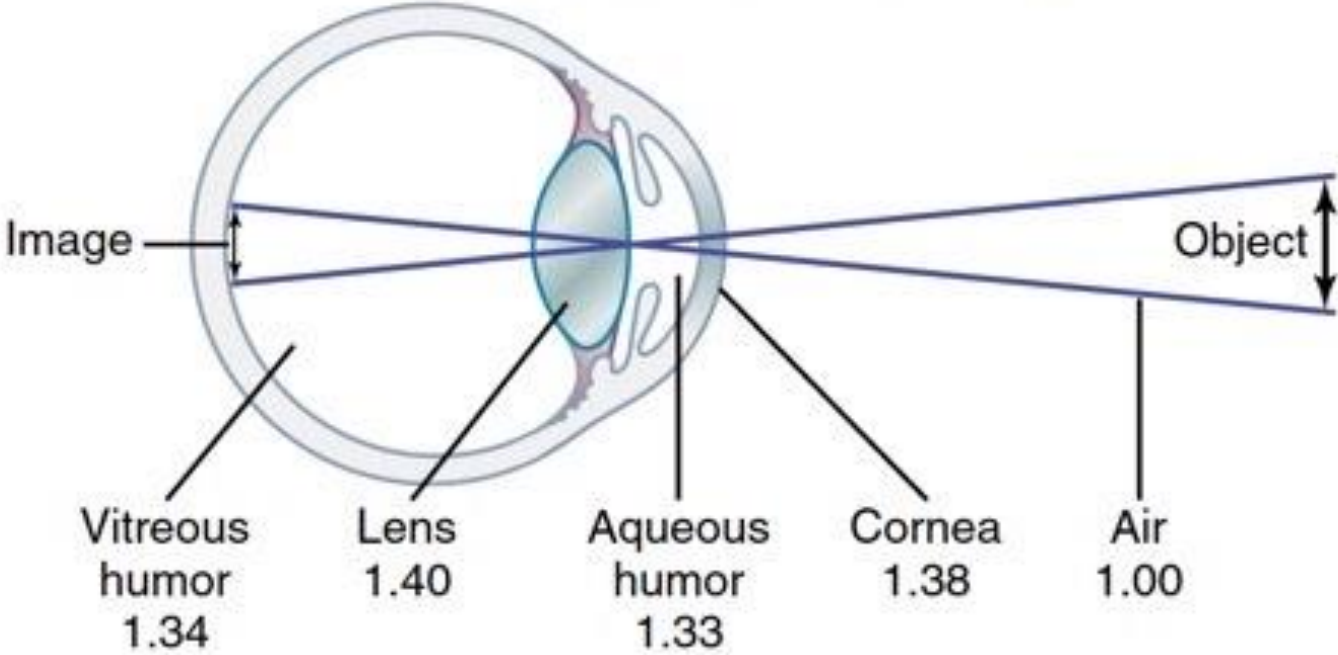


When light rays traveling through a transparent substance pass into a second transparent substance with a different density, they bend at the junction between the two substances (**refraction**).

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.
- The distance beyond a convex lens at which parallel rays converge to a common focal point is called the focal length of the lens.

Total refractive power = 59 diopters



Refractive power

- 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.

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

Refraction

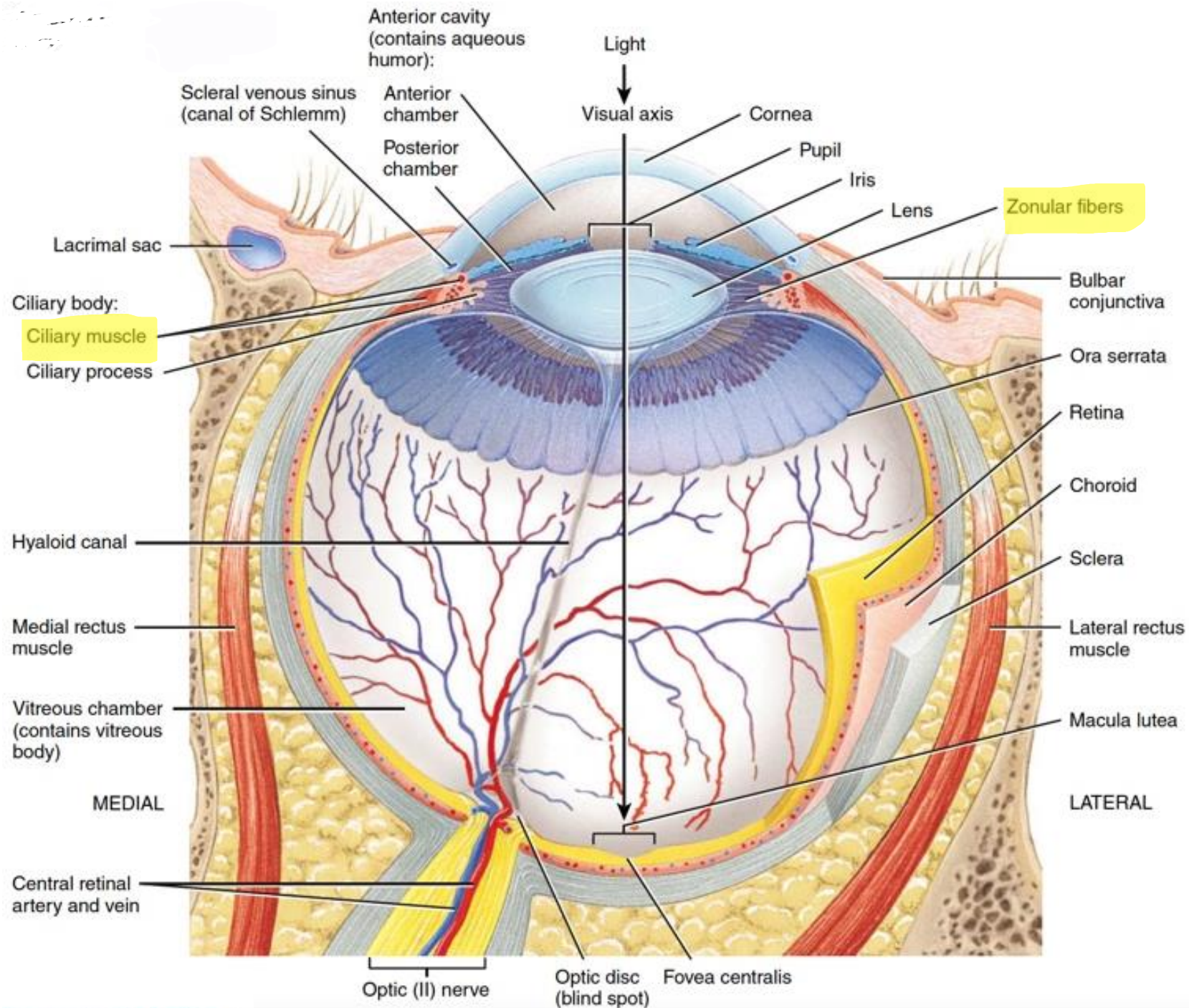
- However, the importance of the internal lens is that in response to nervous signals from the brain, its curvature can be increased markedly to provide “accommodation,”
- The ability to adjust the strength of the lens is known as accommodation.

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.

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.



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.

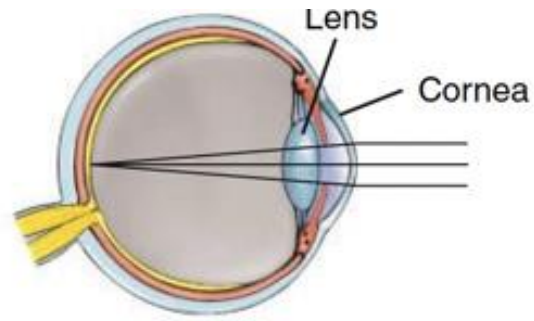
Accommodation

- 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.

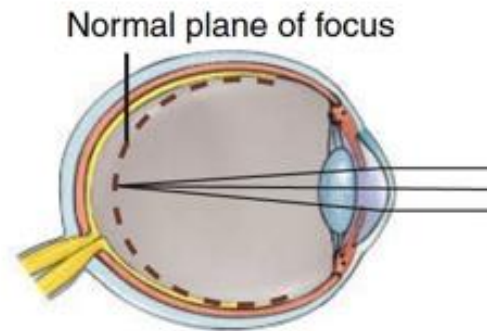
Accommodation

- 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**.

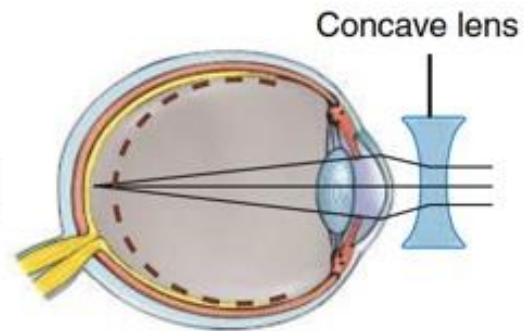
- Once a person has reached the state of presbyopia, each eye remains focused permanently at an almost constant distance; this distance depends on the physical characteristics of each person's eyes.
- The eyes can no longer accommodate for both near and far vision. To see clearly both in the distance 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).



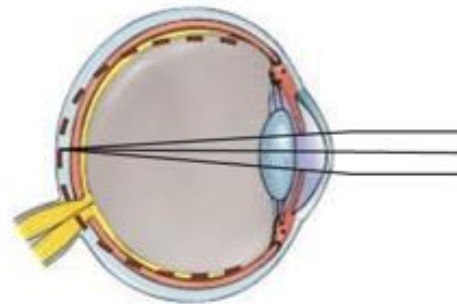
(a) Normal (emmetropic) eye



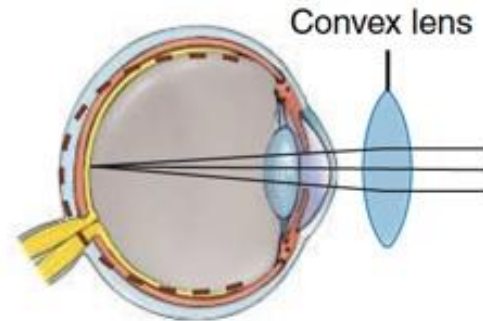
(b) Nearsighted (myopic) eye, uncorrected



(c) Nearsighted (myopic) eye, corrected

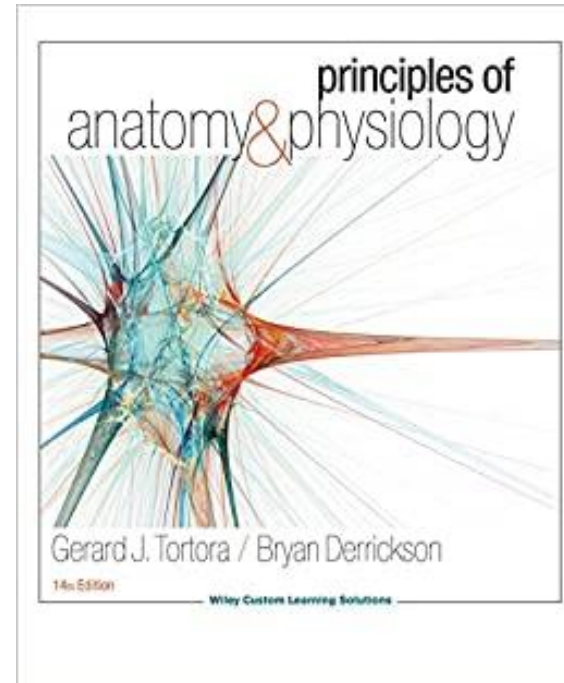
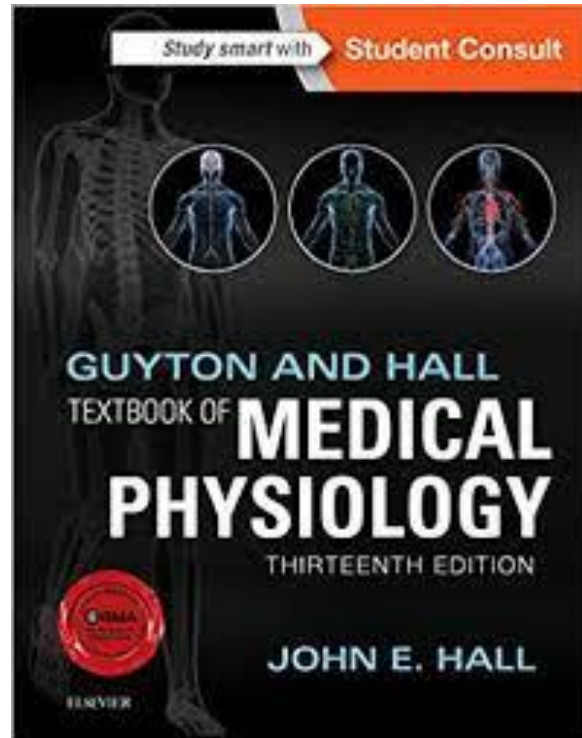
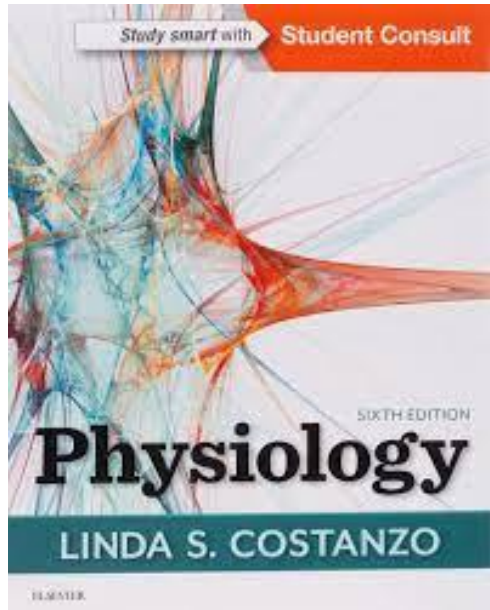


(d) Farsighted (hyperopic) eye, uncorrected



(e) Farsighted (hyperopic) eye, corrected

References



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Human Physiology From Cells to Systems

Lauralee Sherwood
Department of Physiology and Pharmacology
School of Medicine
West Virginia University

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