2 The Eyeball: Some Basic Concepts

Keywords
Concentrically arranged layers · Cornea · Sclera · Uveal tract · Iris · Ciliary body · Choroid · Posterior scleral foramen · Lamina cribrosa · Anterior chamber · Posterior chamber · Vitreous chamber · Ciliary processes · Secretion · Ultrafiltration · Circulation of aqueous · Intraocular pressure · Microscopic outlet channels of aqueous · Inflow of aqueous · Outflow of aqueous

The eyeball consists of three concentrically arranged layers. The frontal one-sixth of the outer wall is formed by a transparent dome called the cornea. The back five-sixths of the outer wall of the eye is formed by a fibrous layer protective in function called the sclera. The sclera is quite thin at its front where the rectus muscles are inserted, and quite thick at its back, which explains why traumatic rupture of the eyeball is common there. It is richly supplied by sensory nerves (ophthalmic division of the trigeminal nerve); therefore its inflammation, or scleritis, is quite painful. The outer surface of the anterior sclera is covered by a thin layer of elastic tissue, called the episclera; this contains numerous blood vessels that nourish it. The brown pigment layer on its inner surface is called the lamina fusca, which forms the outer layer of the suprachoroidal space. At its back, the sclera has a large opening called the posterior scleral foramen, bridged by the lamina cribrosa; the latter has microscopic holes, through which axons of ganglion cells of the retina leave the eyeball as the optic nerve. Around the optic nerve the sclera is penetrated by long and short posterior ciliary arteries and long and short ciliary nerves. The four vertex veins which drain the choroid exit through the sclera.

The middle coat of the eyeball is called the uveal tract. It consists of the iris on the front, the ciliary body in the middle, and the choroid at its back. The iris is like a circular diaphragm placed in a coronal plane in front of the lens with a central circular hole called the pupil. In addition to controlling the amount of light entering the eye, the pupil also acts as a communication between the anterior and posterior chambers for circulation of the aqueous. The iris has two unstriated involuntary muscles: (1) the sphincter pupillae at the pupillary margin that constricts the pupil, and (2) the dilator pupillae, which dilates the pupil in an emergency. Because the iris is rich in sensory supply, iritis, inflammation of the iris, is painful. The periphery of the iris is attached to the middle part of the ciliary body by a thin root that gets torn in severe contusions of eye, deforming the normal circular pupil.

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The space between the back of the cornea and the front of the iris is the anterior chamber (AC). The space between the back of the iris and the front of the suspensory ligament is called the posterior chamber (PC). The space between the back of the lens and the front of the retina is called the vitreous chamber (VC). The AC and PC normally both have a transparent liquid called the aqueous humor, which gives nutrition to the cornea and lens. The vitreous chamber has an avascular gelatinous body called the vitreous, which fills the space between the lens, the retina, and the optic disc.

The ciliary body is triangular in shape and located in the horizontal section of the eye; the base of triangle is in front and the apex is at the back. Its anterior 2 mm has 70 fingerlike processes in a circular fashion with a zonule on the medial side. This part of the ciliary body is called the pars plicata, which is continuous behind with a 6 mm long part with a plane surface called the pars plana. The ciliary processes and pars plana of the ciliary body are lined by a two-layered epithelium. The epithelium covering the ciliary processes is the site of an active process called "secretion" in which the aqueous is mainly secreted in the PC. From there it goes to the AC via the pupil, and then to the periphery of the AC, called the angle of the anterior chamber, which has microscopic outlet channels of aqueous called the trabecular meshwork, the canal of Schlemm, 30 collecting trunks, and 12 aqueous veins. These channels ultimately drain the aqueous to the episcleral venous plexus. This circulation of the aqueous creates a pressure inside the eyeball called intraocular pressure (IOP), which maintains the shape of the eyeball essential for refraction at the cornea. A balance between inflow and outflow of aqueous normally maintains the IOP between 12 and 20 mm Hg. For maintenance of a normal IOP, the angle of the AC must have an optimum width so that the aqueous has adequate access to its microscopic outlet channels. The width of the angle of the AC depends upon how deep the AC is, and its depth depends upon the contour of the iris. A convex forward iris will create a narrow angle as in the swelling of a hypermature cataract, or anterior traumatic dislocation of the lens. In addition, a small hypermetropic eye may have a shallow AC.

2.1 Basic Concepts

The eyeball resembles a ping-pong (table tennis) ball with a transparent dome in front called the cornea. When a patient looks at a distant object with both eyes open (the so-called primary position of the eyeball), you can see the cornea as a shiny dome in the center surrounded by the white of the eye on its two sides, called the sclera, which is normally covered by a moist mucus membrane called the conjunctiva because it connects the sclera to the inside of the lids. This part of conjunctiva is called the bulbar conjunctiva because it covers the front of the eyeball. If you trace this bulbar conjunctiva superiorly and inferiorly, you will find that it jumps to the inside of upper and lower lids in the form of a horizontal loop called the fornix. There is superior and an inferior fornix nearby, in which the accessory lacrimal glands of Krause and Wolfring are found. The circular periphery of the cornea, which constitutes the anterior one-sixth of the eyeball, is continuous behind with the sclera. The junction is called the limbus, which has a circular outline. The sclera, the outermost layer of the eyeball, is fibrous in structure and protective in function. It constitutes the posterior five-sixths of the eyeball. It has a rich sensory supply and therefore its inflammation, called scleritis, is painful. In the primary position of the eyeball the lower margin of the upper lid just touches the upper limbus (Fig. 2.1). The gaps between the two lid margins, the palpebral fissures, are normally equal on the two sides. In cases of high myopia or thyrotoxicosis, a scleral rim may be seen just below the upper lid margin or above the lower lid margin (Fig. 2.2a). In another situation, one eyeball may be pushed down and out by a mucocele of the frontal or ethmoid sinus, again creating a narrow palpebral fissure in the primary position (Fig. 2.2b). Mechanical pushing of the eyeball from the orbit can occur in space-occupying lesions of the orbit, such as thyroid orbitopathy, glioma of the optic nerve, or a gross traumatic retrobulbar

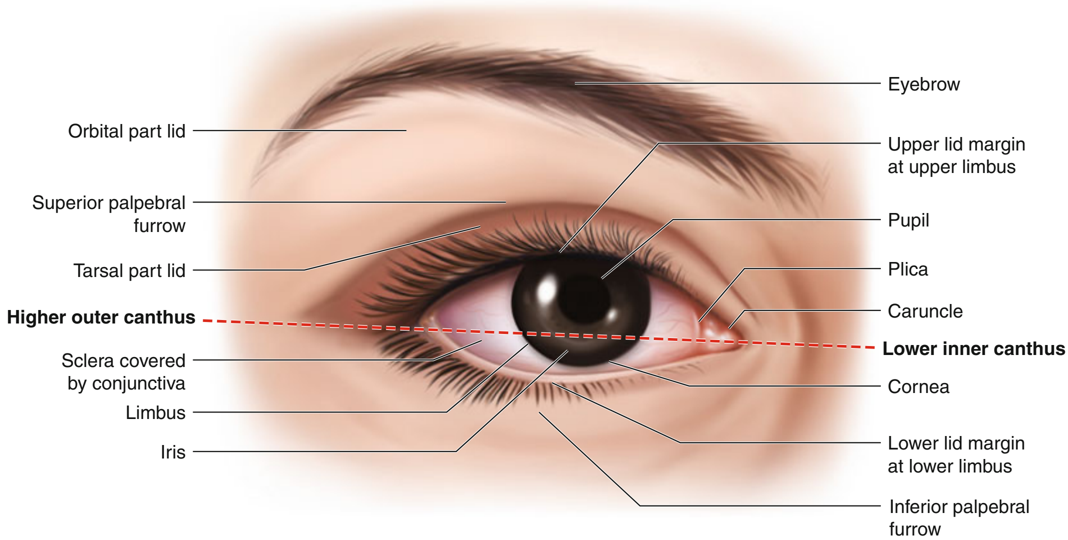
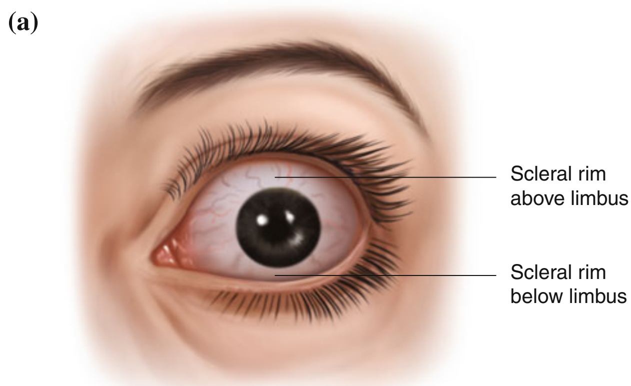
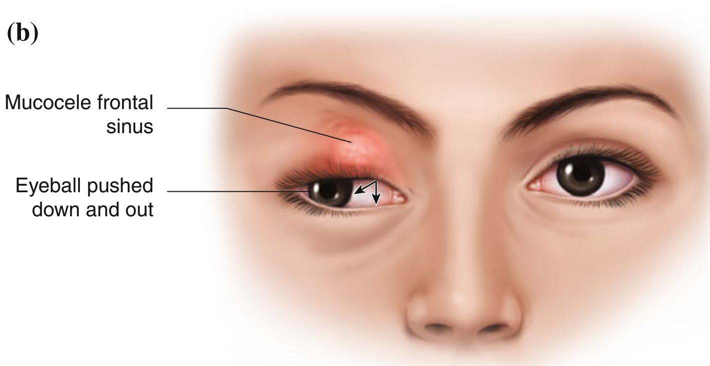


Fig. 2.1 The eye in a primary position. Note the *upper* and *lower* limbi along the lid margins

Fig. 2.2 **a** and **b** Mucocele of the right frontal sinus. The right eyeball is pushed down and out-proptosed obliquely





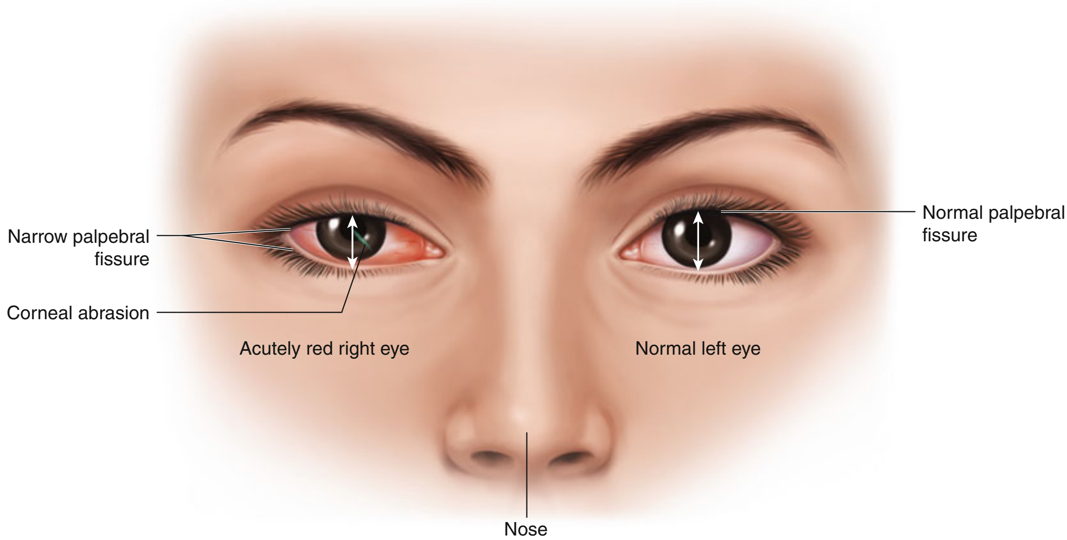


Fig. 2.3 Narrow palpebral fissure in a red eye

hemorrhage behind the eyeball because the orbit is a closed space and has limited capacity. In cases of inflammation of the anterior segment of the eye (e.g., conjunctivitis, keratitis, scleritis, and anterior uveitis), the palpebral fissure on that side becomes narrow because of a reflex spasm of the palpebral part of orbicularis oculi (Fig. 2.3). The most exposed part of the globe is just below the center of the cornea. When we close both lids, the eyeball moves up. Even when the lids are shut, the part below the center of the cornea remains uncovered. That explains why it is a common site of degenerative changes, which may result from exposure. In injuries caused by burns or caustics this part is most likely to be affected because the eyeball goes up in a threatening reflex motion when a dangerous object is in front of the eye.

2.2 Surface Anatomy of the Eye

The upper eyelid extends above to the eyebrow, which separates it from the forehead; the lower eyelid passes into the skin of the cheek, usually without a line of demarcation. The upper lid is more mobile than the lower. The upper lid has an elevator muscle called the levator palpebrae superioris. The lid margins meet laterally to form the outer canthus and medially to form the inner canthus. When the eyes are open widely the outer canthus measures about 60° and is about 5–7 mm from the orbital margin. It is at a slightly higher level than the medial canthus.

The inner canthus encloses a small area of a skinlike structure called a caruncle. Touching the lateral edge of the caruncle is a semilunar fold of conjunctiva called the plica semilunaris. The caruncle is normally covered by a microscopic layer of tears called the lacrimal lake. The lateral canthus is directly placed on the globe. The portions of the eye normally visible in the palpebral opening are the shiny cornea in the center, behind which is the colored iris surrounded by a triangle of white sclera on the lateral side and by crescentie sclera medially. When the eye is open, the upper lid shows a sulcus along the upper border of the upper tarsus called the superior palpebral furrow, produced by the pull of the tendon of the levator palpebrae superioris. It disappears when the lids are closed. The corresponding furrow in the lower lid is illmarked. The eyeball is made of three concentric layers; the outermost layers are the cornea in the front and the sclera in the back. The transparent dome of the cornea forms the front one-sixth of the outer wall, and the posterior

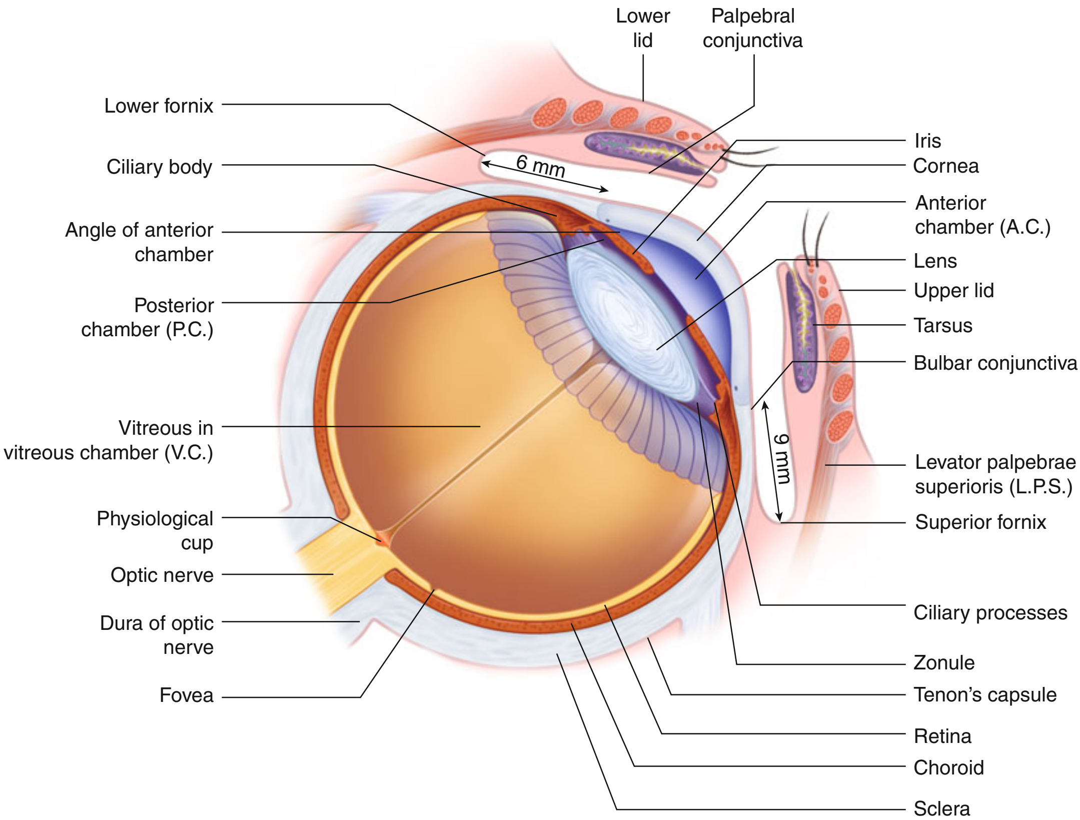


Fig. 2.4 Horizontal section of the eyeball. Note that the superior fornix is higher than the inferior fornix. Note also the three chambers: the *AC*, *PC*, and *VC*. There are three layers of the eyeball and the superior and inferior fornices are visible. See the continuity of the sclera with the dura of the optic nerve

five-sixths of the outer wall is formed by the sclera (Fig. 2.4). The middle coat is the uveal tract, which is vascular in structure and nutritive in function. It has three parts: the iris in the front and the ciliary body in the middle, which is continuous with the choroid in the back. The innermost nervous layer is called the retina. The iris and ciliary body are also called the anterior uvea by virtue of their position, and the choroid is often called the posterior uvea. Their description follows, starting with the sclera.

2.3 The Sclera

The fibrous outermost layer of the sclera of the eyeball is thinner in front at the insertions of the rectus muscles and thicker at the back. That explains why rupture of the eyeball occurs mostly in that area in severe contusion injuries. At the back of the sclera is a large gap called the posterior scleral foramen; this is bridged by layers of connective tissue called lamina cribrosa containing microscopic holes through which axons of the ganglion cells of the retina leave the eyeball as the optic nerve. Figure 2.5 gives all the details of the scleral shell, which has to be pierced by arteries, veins, and nerves supplying the eyeball. The two superior and two inferior vertex veins pierce it 4 mm behind the equator of the eye. The long and short posterior ciliary arteries and nerves have to pierce it to supply the eyeball. From the limbus to the fornix, the sclera is covered by bulbar conjunctiva, which is kept moist by a film of tears. The outer surface of the limbus to the optic nerve is covered by a part of

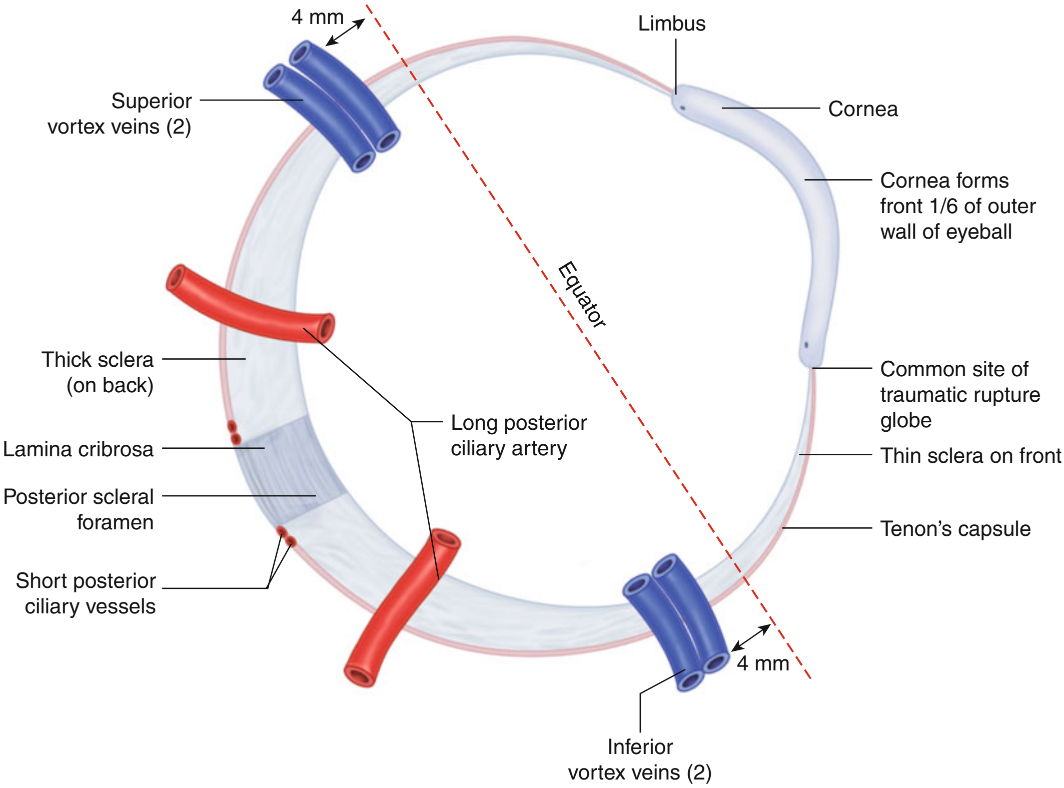


Fig. 2.5 The scleral shell. Note the blood vessels and nerves piercing it. The posterior five-sixths of the outer layer of the eyeball is formed by the sclera, which is very thin at insertions of the rectus muscles; therefore traumatic rupture mostly occurs there. The optic nerve passes through its back hole, which is called the posterior scleral foramen. Note the Tenon capsule covering it. Because it is rich in sensory supply, scleritis is very painful

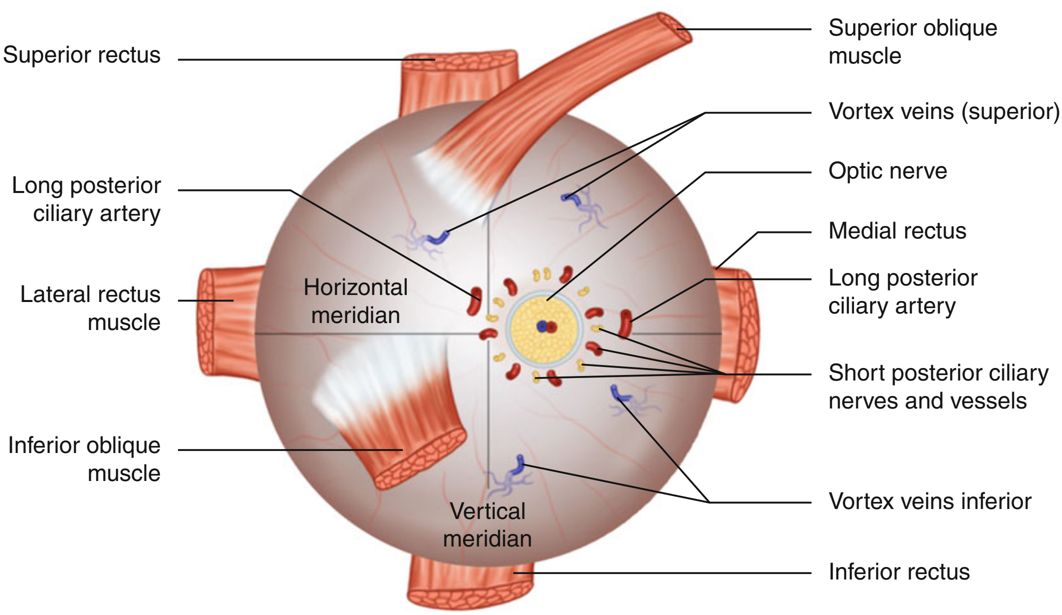


Fig. 2.6 The left eyeball from behind

the orbital fascia called the Tenon capsule, which is continuous at its back with the dura of the optic nerve. The sclera is richly supplied by sensory nerves; therefore its inflammation, called scleritis, is painful. The four rectus muscles—the superior rectus (SR), the inferior rectus (IR), the medial rectus (MR), and the lateral rectus (LR)—are inserted on the front of the sclera at variable distances from the limbus in front of the equator of the eye. The superior oblique (SO) and inferior oblique (IO) muscles are inserted at the back behind the equator of the eye (Fig. 2.6).

2.4 Uveal Tract: Iris, Ciliary Body, Choroid (Figs. 2.7 and 2.8)

The iris is a circular diaphragm placed in a coronal plane in front of the lens forming the posterior boundary of the space between the back of the cornea and the front of the iris called the anterior chamber (AC). It has a central circular hole called the pupil, which controls the amount of light entering the eye and also acts as a communication between the anterior and posterior chambers for the aqueous. It has a peripheral ciliary border and a central pupillary border. The ciliar border houses the major arterial circle of the iris formed by the joining of two long posterior ciliary arteries, which send radial branches to supply the iris and also to the fenestrated capillaries of the ciliary processes. The attachment of the periphery of the iris to the ciliary body is called the root of iris, which is thinner than the rest of the iris. This explains why a traumatic tear of the iris may occur at its root, which creates a deformed pupil. The potential space between the back of iris and the front of the zonule is called the posterior chamber (PC). The anterior and posterior chambers both have a fluid called the aqueous humor, which is secreted chiefly in the posterior chamber by fenestrated capillaries of the ciliary processes. The iris is lined by two-layered epithelia that are a continuation of the two-layered epithelia lining the ciliary body.

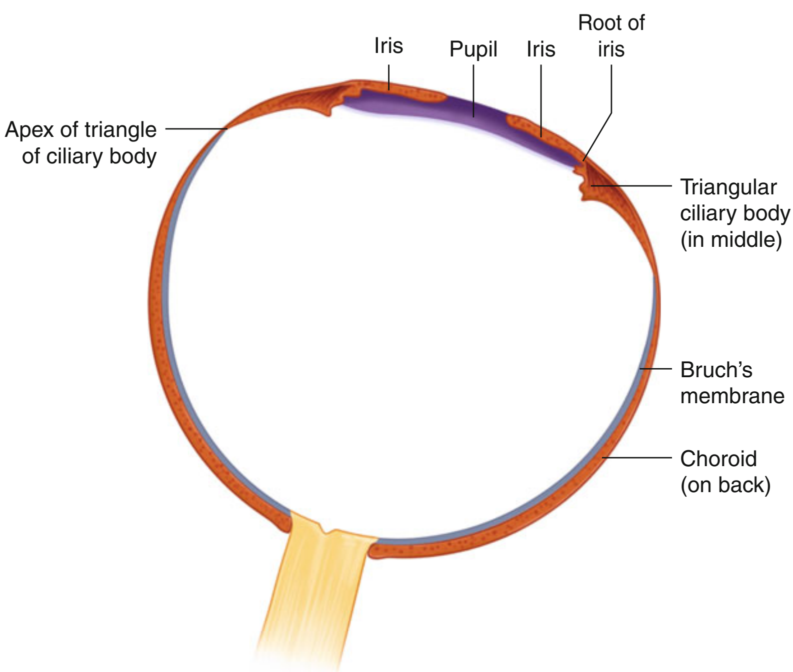


Fig. 2.7 The middle coat of the eyeball: (1) the uvea; (2) the iris (*front*); (3) the ciliary body (*middle*); (4) the choroid (*back*). It is vascular in structure and nutritive in function. The suprachoroidal space is between the choroid and the sclera. It is partly used for aqueous drainage

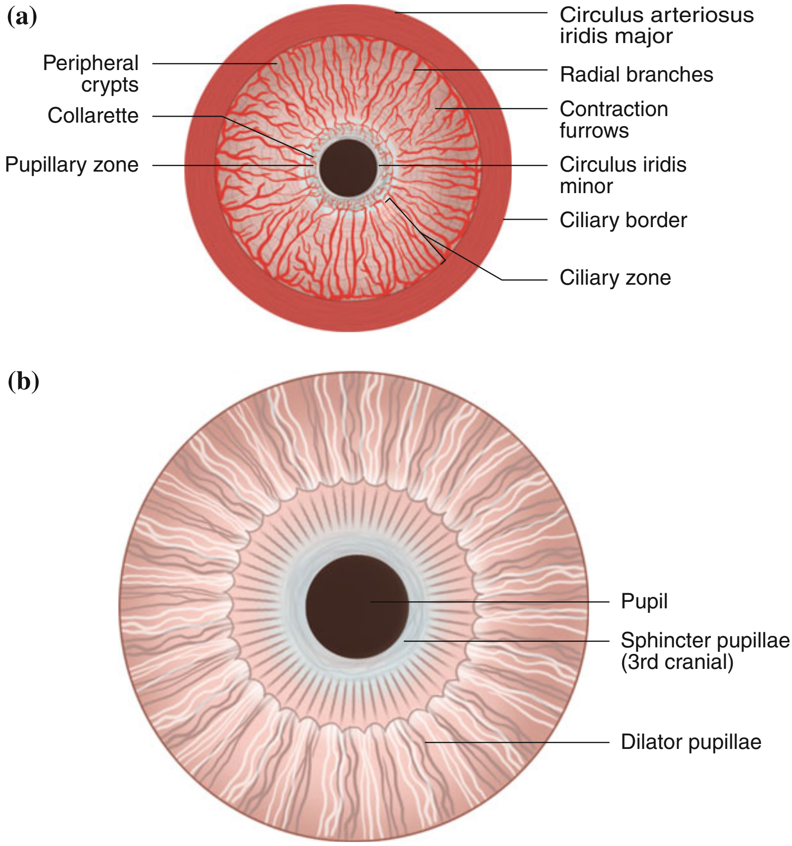


Fig. 2.8 **a** Iris blood vessels (anterior surface). **b** Involuntary muscles of the iris

The pupillary margin of the iris has a circularly arranged unstriated involuntary muscle called the sphincter pupillae that constricts the pupil. It is supplied by a third cranial nerve (parasympathetic). Another involuntary muscle in the iris is radially arranged. It is called the dilator pupillae and is supplied by the cervical sympathetic nerves, which dilate the pupil in emergencies. Pupillary size is principally determined by a balance between the constrictor and dilator pupillae. The iris is richly supplied by the sensory nerves and therefore iritis is painful.

2.5 Anatomy of the Angle of the Anterior Chamber

The periphery of the AC is called its angle. It lies at the junction of the peripheral cornea and the root of the iris. In it are situated the microscopic outlet channels of the aqueous, i.e., the trabecular meshwork, the canal of Schlemm, and collecting trunks and aqueous veins that ultimately drain the aqueous to the episcleral venous plexus (Fig. 2.9).

We know that the aqueous is chiefly secreted in the PC from the fenestrated capillaries of the ciliary processes. From the PC it goes to the AC via the pupil; it then reaches the periphery of the AC (called the angle of the anterior chamber) to reach the microscopic outlet channels of the aqueous. It is clear that the angle of the AC must have an optimum size for adequate access of the aqueous to the outlet channels there. Naturally, the width of the angle of the AC depends on the depth of the AC. A shallow AC has a narrow angle. The size of the angle cannot be directly assessed on slit-lamp examination because of total internal reflection. Therefore, it can be assessed only using an instrument called a gonioscope, which removes total internal reflection. This is done under surface anesthesia with a gonioscope by an

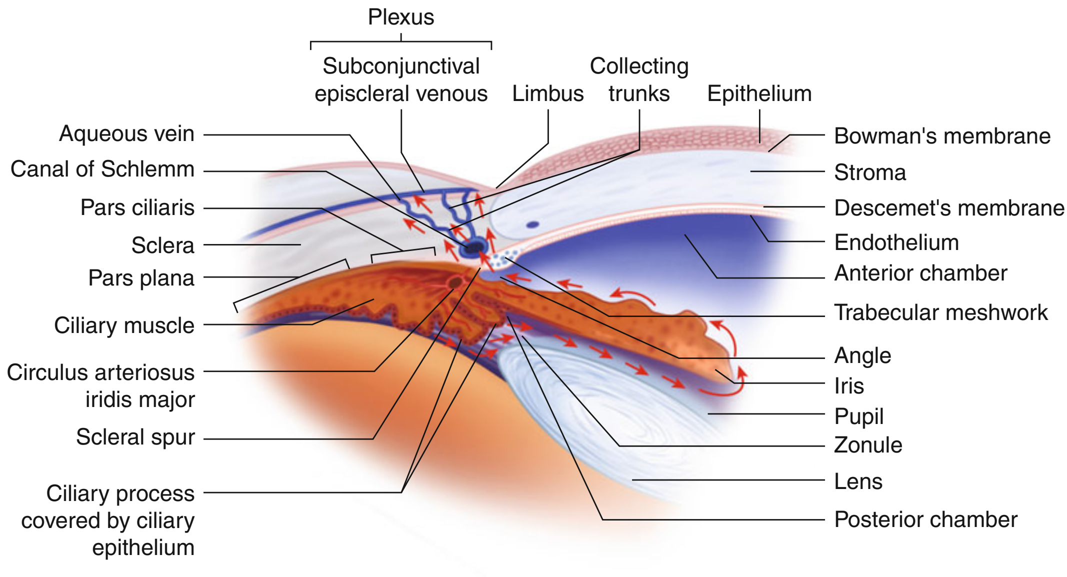


Fig. 2.9 The microscopic outlet channels: (1) trabecular meshwork; (2) canal of Schlemm; (3) aqueous veins (there are 12); (4) collecting trunks (there are 30)

ophthalmologist on a slit lamp. Any condition that makes the AC shallow, such as a small hypermetropic eye, anterior dislocation of the lens by injury, or a hypermature swollen senile cataract may cause acute congestive glaucoma (ACG), in which intraocular pressure suddenly rises to almost 60 mm Hg or above, causing stretching of the corneal nerves, severe pain, and vomiting; this is an ophthalmic emergency. Dilatation of the pupil in an eye of a shallow AC also can cause crowding of the iris tissue in the angle and Acute Congestive Glaucoma. Therefore before dilating the pupil in any eye, it must be checked that the AC is not shallow. This can be clinically assessed by throwing torchlight from the lateral side into the eye. If the iris is convex at the front (shallow AC), you will see a crescentic shadow called the iris shadow at the pupillary margin. This is the iris shadow test (Fig. 2.10).

2.6 Ciliary Body

The middle part of the uveal tract is continuous in front with the iris and at the back with the choroid. It is triangular in cross section. Its front part (about 2 mm) has about 70 fingerlike processes called ciliary processes that have fenestrated capillaries from the circulus iridis major in the root of the iris. It has a zonule (the suspensory ligament of lens) on its medial side. These ciliary processes are in a circle and are attached to the zonular fibers around the lens. To have a three-dimensional concept, imagine yourself standing inside the vitreous behind the lens looking in front, where you will see five concentric circles (Fig. 2.11). Innermost is the edge of the lens; next is the zonule, connecting the lens to the zonule; third is the pars plicata, part of the ciliary body with ciliary processes; fourth is the pars plana, the third part of the ciliary body that is plain; and fifth is the margin ora serrata, where the retina ends.

The ciliary body has an unstriated involuntary muscle called the ciliary muscle with a combination of circular, radial, and longitudinal fibers. The circular fibers on contraction relax the zonule of the lens, which in turn relaxes the capsule of the lens. This produces an increased curvature of the anterior pole of the lens because of moldable lens matter in people below 40 years of age in whom the lens matter is soft. This increased curvature of the anterior pole of the

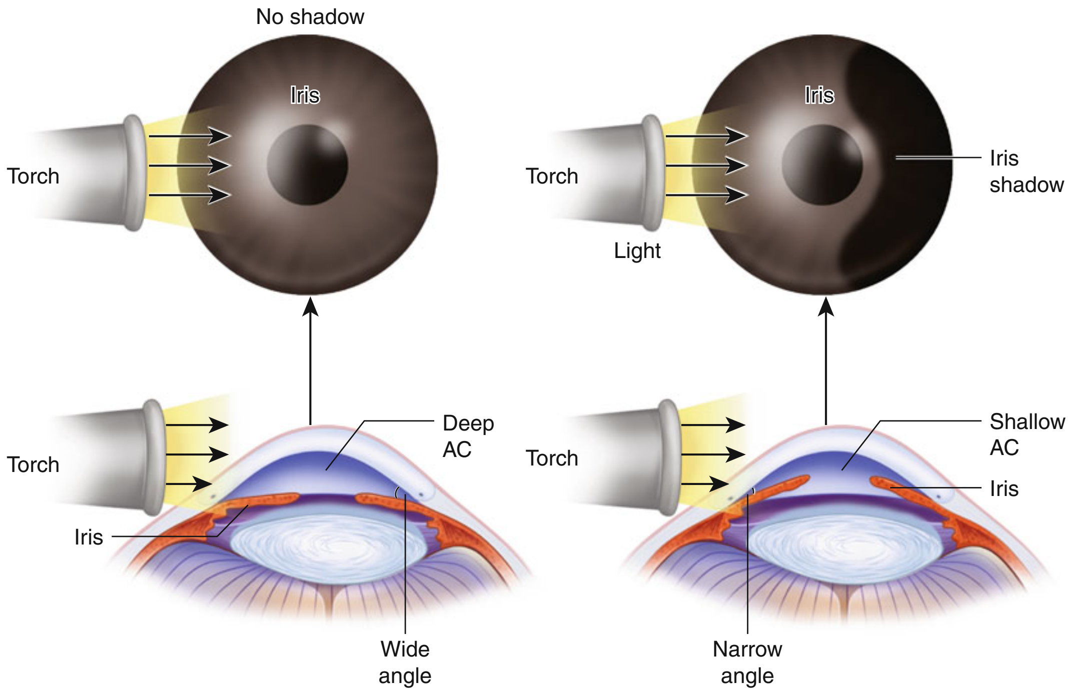
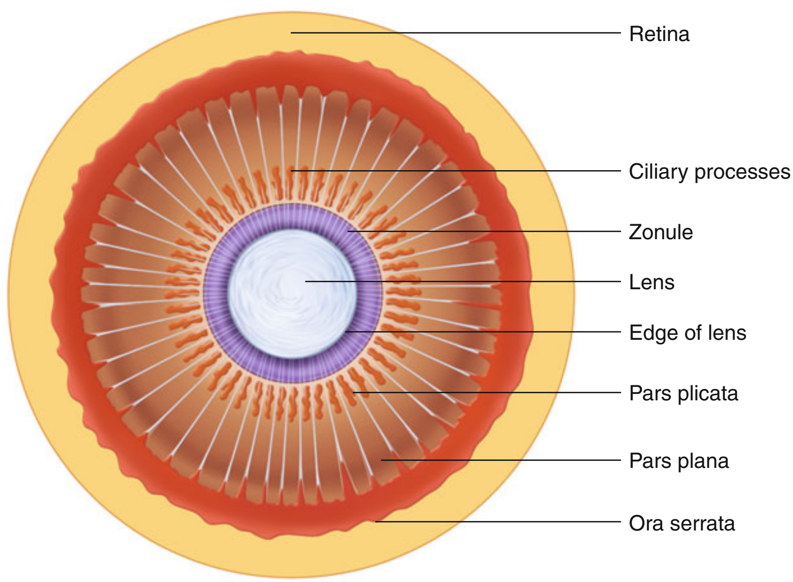


Fig. 2.10 Iris shadow test for narrow angle of the anterior chamber

Fig. 2.11 Imaginary posterior view of the ciliary body, zonule, lens, and ora serrata while sitting in vitreous



lens helps to focus on a near object from which the incoming rays of light are divergent and need to be converged by increased curvature of the anterior pole of lens. This device in young people is called accommodation, which becomes weak in old people; if they want to read small letters they have to use reading glasses because their accommodation is poor.

The longitudinal fibers of ciliary muscle are inserted into the trabecular meshwork. They

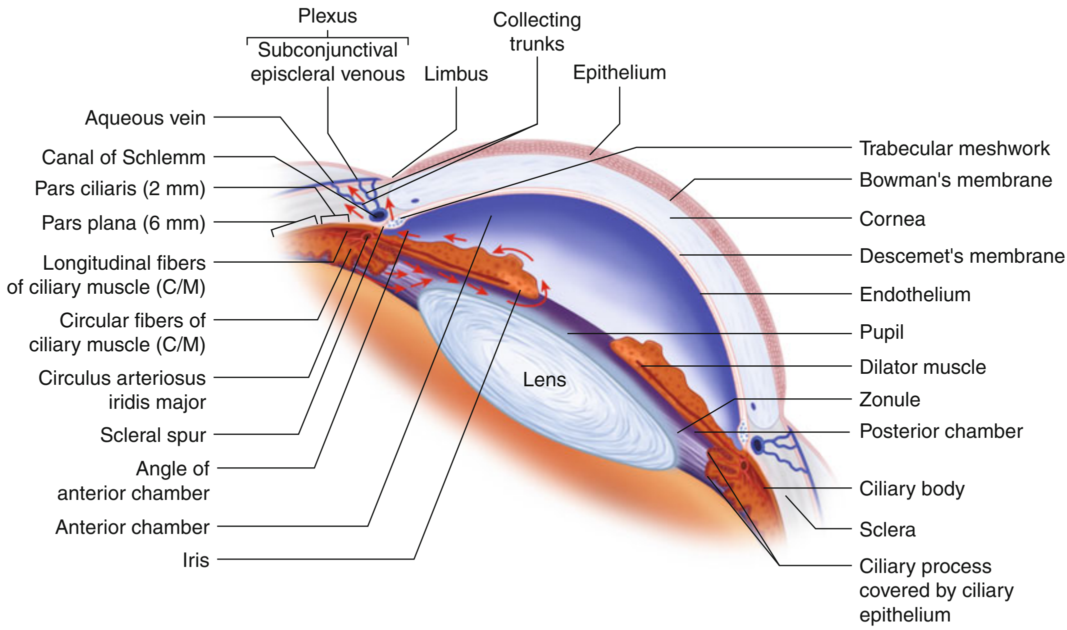


Fig. 2.12 Ciliary body, ciliary processes, and circulation of the aqueous (*red arrows*)

dilate the trabecular spaces to improve the aqueous outflow, thus keeping intraocular pressure within normal limits. The inward extension of the sclera between the ciliary body and the Schlemm canal is called the scleral spur, to which the iris and the ciliary body are attached (Fig. 2.12). The ciliary body is richly supplied by sensory nerves; therefore cyclitis, its inflammation, is quite painful.

2.7 Circulation of the Aqueous and the Shape of the Eyeball

We have already stated that a sterile fluid called the aqueous humor is chiefly secreted by fenestrated capillaries of the ciliary processes into the PC. These ciliary processes are covered on their inner surfaces by two layers of epithelium called the ciliary epithelium. Two processes are at work in the formation of the aqueous: one is an ultrafiltration of plasma in the stroma of the ciliary processes (20 %); the other is an active process of secretion (80 %) conducted by the metabolic activity of the cells of the ciliary epithelium and resulting in secretion of sodium and ascorbic acid. Secretion is an active process that needs energy. Aqueous is a transparent clear liquid that fills the ACs and PCs of the eye. Its volume is about 250 μL and its rate of production, subject to diurnal variation, is about 2.5 μL/min. Its osmotic pressure is slightly higher than that of plasma. The composition of the aqueous is similar to that of plasma except for much higher concentrations of ascorbate, pyruvate, and lactate and lower concentrations of protein, urea, and glucose.

Entering the posterior chamber, the aqueous passes through the pupil into the AC and then to the trabecular meshwork in the angle. During this period, there is some differential exchange of components of blood in the iris.

The trabecular meshwork is composed of collagen and elastic tissue that form a filter with a decreasing pore size as the canal of Shlemm is reached. Trabecular spaces in the trabecular meshwork open into the canal of Schlemm. Passage of the aqueous into the canal of Schlemm depends upon cyclic formation of transcellular channels in the endothelial lining of the cornea. There are efferent channels from the canal of Schlemm (about 30 collector channels and 12 aqueous veins) that conduct the fluid directly into the venous system. In brief, aqueous comes from blood veins (INFLOW) and goes to the blood (OUTFLOW). A balance between inflow and outflow maintains a pressure inside the eye called IOP that maintains the shape of the eyeball. Otherwise, the eye would be indented by atmospheric pressure. This support of the shape of the eyeball is necessary for refraction at the cornea. The walls of the eyeball have to be kept tight by this intraocular pressure for proper refraction at the cornea. Some aqueous passes (20 %) between the bundles of the ciliary muscle into the suprachoroidal space and then to the venous system of the ciliary body, the choroid, and the sclera (uveoscleral flow).

2.8 Choroid

Between the retina and the sclera is the choroid, the posterior segment of the uveal tract, composed of three layers of blood vessels—large, medium, and small. The innermost layer is known as choriocapillaries, which supply nutrition to the outer third of the retina by diffusion. Between the sclera and the choroid is the suprachoroidal space, through which 20 % of the aqueous is drained. The rest of the 80 % of the aqueous is drained to the episcleral venous plexus. Posteriorly, the choroid is attached to the margins of the optic nerve, where it ends. On the inner side the choroid is covered by a membrane called the membrane of Bruch. The choroid is supplied with sensory nerve fibers from the trigeminal as well as the autonomic nerves.

2.9 The Retina

The retina is a thin, semitransparent multilayered sheet of neural tissue that lines the choroid. It extends from the optic disc posteriorly up to the end of the ciliary body anteriorly. The anterior end has a ragged edge called the ora serrata. The outer surface is opposed to the retinal pigment epithelium. There is a subretinal space between the pigment epithelium and the sensory retina, but at the optic disc and the ora serrata both are united, thus limiting the spread of subretinal fluid in a retinal detachment. A retinal detachment occurs at the level of the subretinal space. The retina is thinnest at the ora serrata anteriorly and at the fovea on the posterior pole. This explains the common site of traumatic retinal holes in retinal detachment. Embryologically, the retina is continued forward beyond the ora serrata as a two-layered epithelium that lines the ciliary body and the iris up to the pupil.

Most externally, in contact with the pigment epithelium is a neural epithelium with rods and cones, the end organs of vision. Following this, moving inward, are the outer nuclear layer (nuclei of rods and cones), the outer plexiform layer (having synapses), the inner nuclear layer (nuclei of bipolar cells), the inner plexiform layer (having synapses), the ganglion cell layer, and finally innermost the nerve fiber layer composed of axons of ganglion cells coming out of the lamina cribrosa as the optic nerve. All these are bound together by neuroglia formed by special vertical cells called the fibers of Müller. All this is completed by two limiting membranes, the outer perorated by rods and cones and the inner separating the retina from the vitreous. At the posterior pole of the eye, about 3 mm on the temporal side to the optic disc, a specially differentiated spot is called the fovea centralis, which is the avascular and most sensitive part of the retina containing only cones and no other cells. It has a maximum visual acuity of 20/20 because of the one-to-one relationship of its cones to the ganglion cells. There are no rods here. Cones are responsible for color vision; they have three types of pigments for red, blue, and green. The fovea centralis receives its nutrition from neighboring choriocapillaries in the choroid, which is seen as a red spot in the occlusion of the central retinal artery by an embolus. The fovea is surrounded by a small area called the macula leutea or yellow spot, which is more sensitive than other parts of the retina. It is here that the nuclear layers become gradually thinned while ganglion cells are heaped up into several layers. The structural and functional development of the macula is completed by the age of 3 years to reach 20/20 acuity, for which its stimulation by a simultaneous, almost similar bifoveal image is a necessity for proper binocular vision.

The spot where the axons of the ganglion cells come out of the eye through the lamina cribrosa as the optic nerve is called the optic disc, and normally it has a small depression in the center called the physiologic cup (Fig. 2.13a) of the disc, through which central retinal vessels can be seen to emerge by a direct ophthalmoscope (Fig. 2.13b). This cupping becomes deep in a glaucomatous disc (Fig. 2.15).

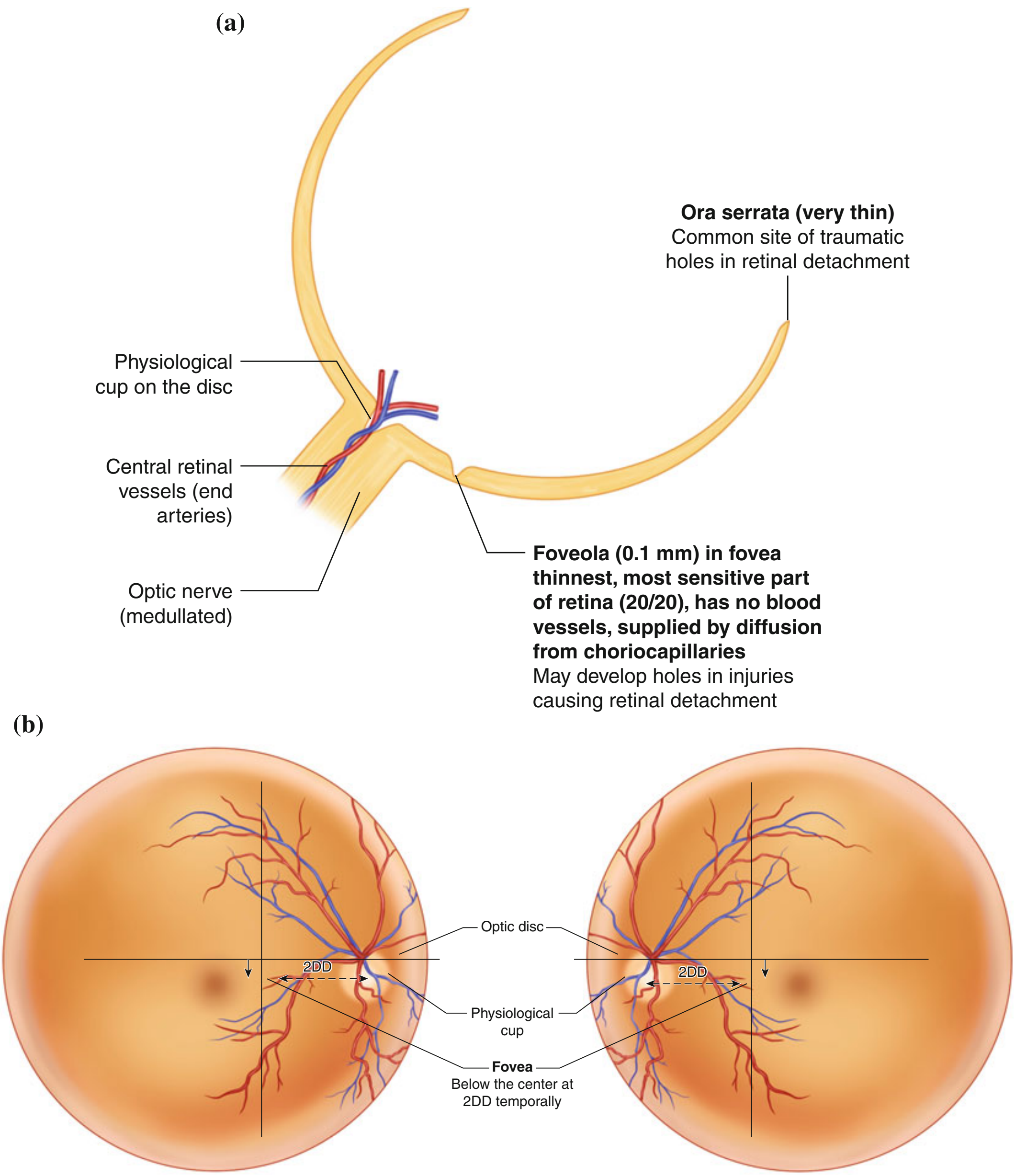


Fig. 2.13 **a** Innermost layer of the eyeball. The retina is thinnest at the ora serrata and the fovea; therefore traumatic holes in the retina mostly occur there. **b** The fundus by direct ophthalmoscope. Note that the fovea is slightly below the center and at two-disc diameter (2DD) away on the temporal side. **c** Layers of the retina

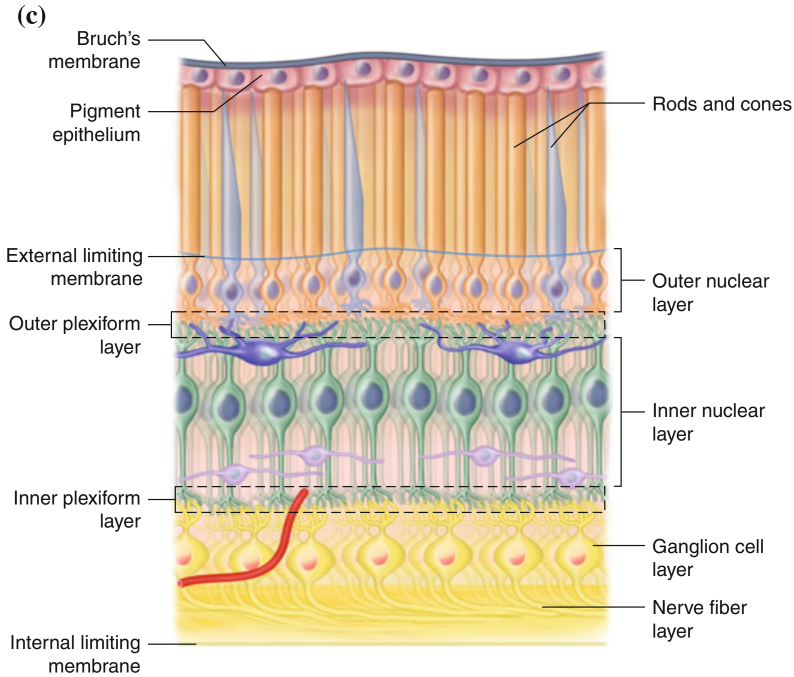


Fig. 2.13 (continued)

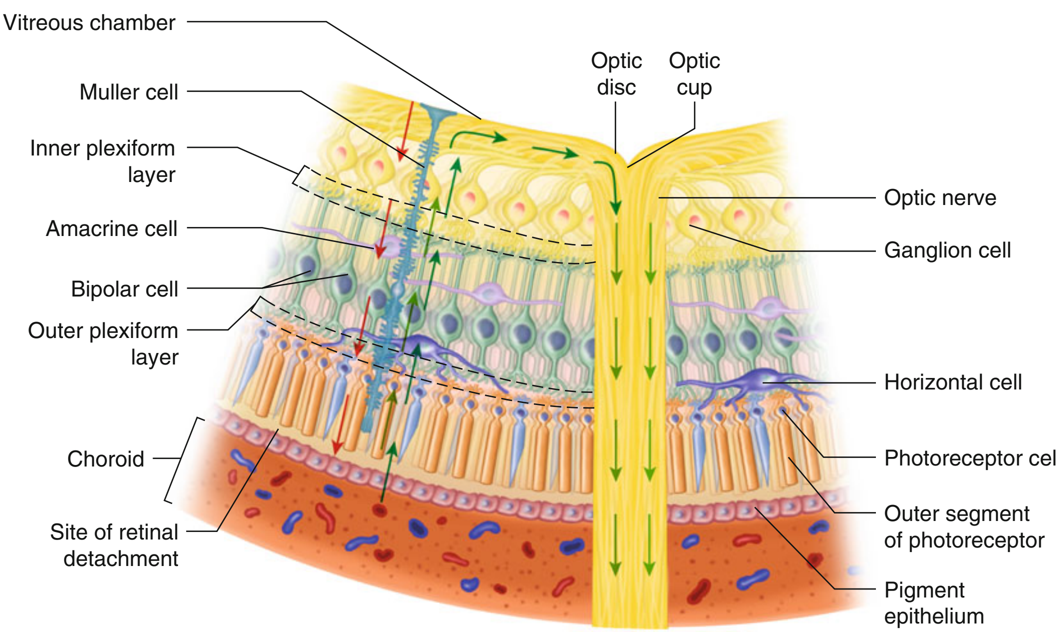


Fig. 2.14 Layers of the retina (*schematic*). *Red arrows* show incident light rays; *green arrows* show the path of the return nerve impulse, which travels back along the visual pathway to the visual center in the occipital lobe

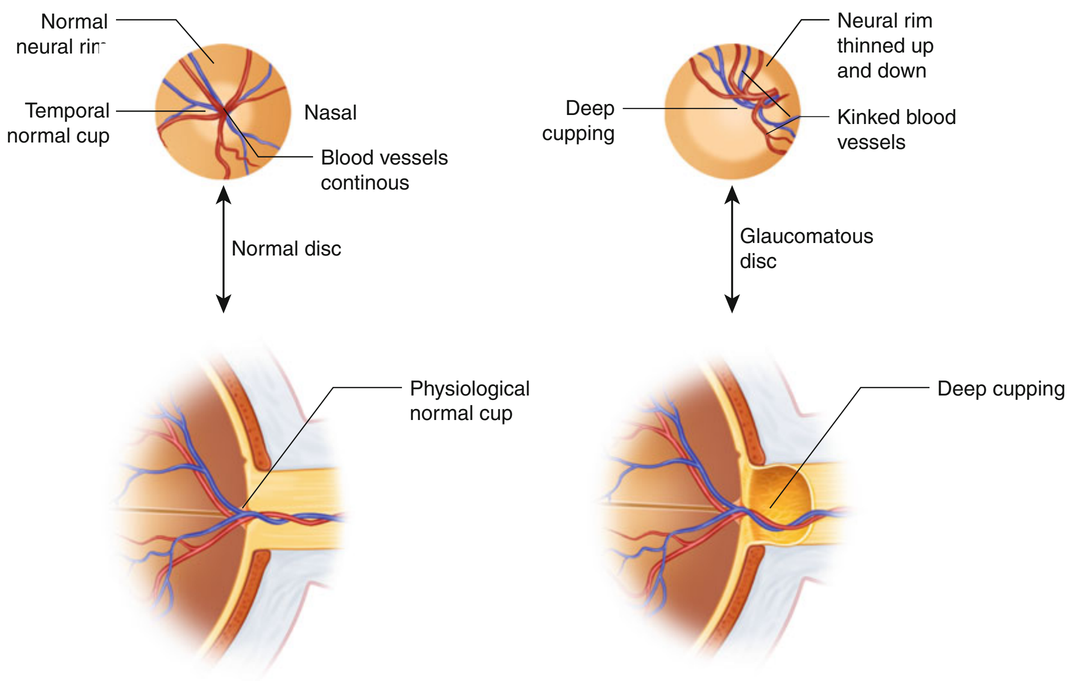


Fig. 2.15 Normal and glaucomatous optic disc

To excite the rods and cones, incident light has to cross the whole retina to reach them. Before striking the photoreceptors, light passes through the entire thickness (*red arrows*) of the retina (Fig. 2.14). The photoreceptor cells initiate a chain of neuronal impulses from the photoreceptor to the bipolar cells and from there to the ganglion cells (*green arrows*, Fig. 2.15), whose axons become the optic nerve when they come out of the eye. This nerve then extends to the brain as a visual pathway.

Embryologically the retina, being a part of the brain, has a dual blood supply. The outer one-third of the retina receives its nutrition from choriocapillaries, and the inner two-thirds of the retina is supplied by the central retinal artery and vein. The central retinal artery is an end artery like other arteries of the brain; therefore its occlusion should result in loss of vision. Because choriocapillaries supply nutrition to the outer one-third of the retina, choroidal disease like choroiditis will affect the retina secondarily.

2.10 The Optic Nerve

We have learned that the optic nerve consists of axons of ganglion cells of the retina that travel via the optic chiasma and the optic tract to the nucleus of the lateral geniculate body, where a synapse occurs and a new neuron takes over the visual nerve impulse to proceed to the visual center of the occipital lobe as optic radiation. The optic radiation fibers end in the visual center, where fusion of two retinal images occurs. That explains why our vision is termed binocular vision. For fusion to occur two retinal images have to be simultaneous, almost similar, and bifoveal (on each fovea).

2.11 Visual Pathway

The cranial parts of each optic nerve join one another above the pituitary fossa to form a four-sided structure called the optic chiasma in which nasal fibers from one side cross to the other side. The optic tract starts from the chiasma, which has 80 % visual fibers and 20 % pupillary fibers. Thus the optic tract of the right side has all the axons of the ganglion cells of the temporal half of the right retina and axons of ganglion cells of the nasal half of the left retina. There axons end in the nucleus of the right lateral geniculate body, where axons of a new neuron start as optic radiation, which ends in the right visual center of the right occipital lobe. The pupillary fibers leave the distal part of the optic tract to reach the Edinger–Westphal nucleus of the third cranial nerve after decussation. That explains why in a lesion of the visual pathway above the level of the lateral geniculate body pupils may be perfectly normal although the patient may have what is called cerebral blindness.

Thus together the optic nerve, optic chiasma, optic tract, lateral geniculate body, optic radiation, and occipital visual center are called the visual pathway. The defects in field of vision can be easily found out if nerve fibers in various parts of the visual pathway are known.

2.12 The Vitreous

A gelatinous body, forming two-thirds of the volume and weight of the eye, is found in the vitreous chamber, the space bounded by the lens, retina, and optic disc. The outer surface of vitreous, the hyaloid membrane, is normally in contact with the posterior lens capsule, the zonular fibers, the pars plana epithelium, the retina, and the optic nerve head. Its base has a firm attachment throughout life to the pars plana epithelium and the retina, just behind the ora serrata. Its attachment to the lens capsule and the optic nerve head is firm only in early life. It is made up of 99 % water and the remaining 1 % includes two components, collagen and hyaluronan, which confer a gel-like form and consistency because of their ability to bind large volumes of water. The optic disc normally has a central depression called the physiologic cup, which becomes very deep in glaucoma (Fig. 2.15).

2.13 Arrangement of Nerve Fibers in the Retina

The innermost layer of the retina is the nerve fiber layer. These nerve fibers are actually axons of the ganglion cells of the retina. The nerve fiber layer also has centrifugal fibers, fibers of Müller cells, neuroglial cells, and retinal vessels. The nerve fibers are arranged in bundles that run parallel to the surface of the retina. The bundles interweave with each other, forming a network in whose meshes are the processes of Müller and other glial cells. All the fibers converge toward the optic disc. Those from the nasal side reach it without interruption; those from the temporal side do not pass through the macula but they have to arch over it. The fibers above the horizontal meridian pass above the macula and those below pass under it. Toward the lateral side of the macula is a sort of raphae from which the nerve fibers arise in a pennate manner (Fig. 2.16). Those just to the lateral side of the macula encircle this structure closely, while the more lateral ones arch over it above and below in ever-increasing arcs.

The fibers from the macula itself pass straight in toward the temporal side of the disc, constituting the papillomacular bundle.

The nerve fiber layer is thickest around the margins of the disc and differs in different quadrants. Directly laterally it is thinnest in the region of the papillomacular bundle. The thickest parts are the upper and lower medial quadrants. This explains why swelling of the optic disc (called papilloedema) is first visible in the thicker upper and lower medial quadrants and last in the directly lateral part. From the disc, the nerve fiber layer becomes thinner when going toward the periphery and near the ora serrata, which is the thinnest layer. At the bottom of the fovea, it

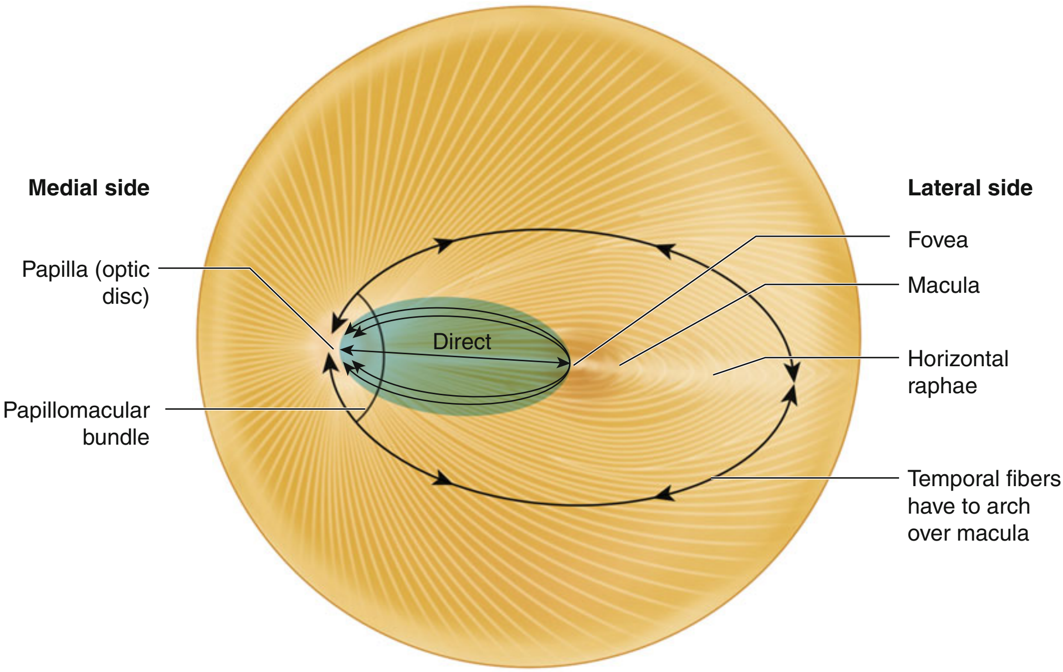


Fig. 2.16 Arrangement of retinal nerve fibers (*schematic*)

appears to disappear entirely. The nerve fibers are nonmodulated inside the eye. Individual fibers are separated by neuroglial processes.

The retinal blood vessels are found mainly in the nerve fiber layer, but they may also lie in the ganglion cell layer. They do not project on the inner surface of the retina. At the junction of the retina and vitreous is a membrane that forms both the inner limit of the retina and the outer boundary of the vitreous. There are no fibers of Müller at the optic disc, which has an important bearing on the swelling of the disc. There are no visual cells at the optic disc, which projects in the field of vision as a blind spot. It is important to remember that the retina is the only place in the human body where blood vessels of the arteriolar size can be directly seen by a direct ophthalmoscope, especially the changes in their walls. Since retinal circulation is an offshoot of cerebral circulation, the condition of the cerebral blood vessels can be guessed.

Suggested Reading

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