

OPHTHALMOLOGY

Lecture Notes



Bruce James
Anthony Bron
Manoj V. Parulekar

12th Edition



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Ophthalmology

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Ophthalmology

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Twelfth Edition

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Preface to twelfth edition

Welcome to the twelfth edition of *Ophthalmology Lecture Notes*! As in the past, our aim has been to make the diagnosis and management of eye disease a palatable process and once again we stress the value of a good history and careful clinical examination of the eye.

The eye is remarkably accessible. Optical and digital techniques continue to develop giving increasingly detailed access to the structures of the eye at cellular level. Specular microscopy can image the corneal endothelial cells which regulate corneal hydration and transparency; optical coherence tomography allows the layers of the retina to be dissected and recently allows the retinal vasculature to be imaged without the need for injection of fluorescein. Confocal microscopy provides a three-dimensional view of the optic nerve head. The shape of the cornea can be plotted digitally and, outside the globe, orbital structures and the visual pathway can be viewed by neuroimaging.

Therapeutically, lasers are used to relieve acute, angle closure glaucoma, to lower ocular pressure in chronic glaucoma, to open up an opaque lens capsule following cataract surgery and to seal retinal holes. They have an established role in reshaping the cornea to treat refractive errors of the eye and their role is now extending to use in cataract surgery itself. Sight-threatening diabetic retinopathy can be treated effectively by retinal photocoagulation, to remove the angiogenic stimulus to vasoproliferation. More recently, it has become possible to inhibit new vessel formation in diabetic retinopathy, macular degeneration and other retinal vascular disorders by intravitreal injections of antiangiogenic drugs. Roles for these drugs in treating oedema of the retina, see for example in diabetes, are also becoming established.

These techniques are matched by technological innovations in microsurgery, responsible for dramatic advances in cataract and vitreoretinal surgery. Optical function in cataract surgery is restored by insertion of a lens which unfolds within the eye. These are becoming increasingly complex allowing for the treatment of

astigmatism and restoring near and distance vision in some patients without the need for glasses. Vitreoretinal surgery employs inert gases and silicone oil to flatten the detached retina and endoscopic probes which allow manipulations in the vitreous space and the dissection of microscopic membranes from the retinal surface. Glaucoma surgery is developing tiny drainage implants to reduce intraocular pressure.

Despite these advances, most ophthalmic diagnoses can still be made from a good history and clinical examination of the eye. This book aims to teach skills which will be useful to anyone engaged in medical practice. Many systemic disorders have ocular features which are critical in diagnosis. This book covers the ophthalmic features of systemic hypertension, diabetes, sarcoidosis, endocarditis, demyelinating disease and space-occupying lesions of the brain. It also explains how to recognize iritis, distinguish various forms of retinopathy and understand the difference between papilloedema and papillitis.

As in the eleventh edition, each chapter provides a set of learning objectives and a summary of key points, as well as bullet lists for emphasis. You can test your understanding with the questions and picture quizzes at the end of each chapter. In this edition, we have updated all the chapters and added to the extended matching questions (EMQs) and multiple choice questions to bring this small volume up to date.

Chapter 20 offers classical case histories, which will let you test your diagnostic skills. The final section of the book provides a list of further reading and the details of attractive websites which offer an expanded view of the speciality. Try some of these out.

We hope that you will have as much fun reading these Lecture Notes as we did putting them together.

*Bruce James
Anthony Bron
Manoj V. Parulekar*

Preface to first edition

This little guide does not presume to tell the medical student all that he needs to know about ophthalmology, for there are many larger books that do. But the medical curriculum becomes yearly more congested, while ophthalmology, still the 'Cinderella' of medicine, is generally left until the last, and only too readily goes by default. So it is to these harassed final-year students that the book is principally offered, in the sincere hope that they will find it useful; for nearly all eye diseases are recognized quite simply by their appearance, and a guide to ophthalmology need be little more than a gallery of pictures, linked by lecture notes.

My second excuse for publishing these lecture notes is a desire I have always had to escape from the traditional textbook presentation of ophthalmology as a string of small isolated diseases, with long unfamiliar names, and a host of eponyms. To the nineteenth-century empiricist, it seemed proper to

classify a long succession of ocular structures, all of which emerged as isolated brackets for yet another sub-catalogue of small and equally isolated diseases. Surely it is time now to try and harness these miscellaneous ailments, not in terms of their diverse morphology, but in simpler clinical patterns; not as the microscopist lists them, but in the different ways that eye diseases present. For this, after all, is how the student will soon be meeting them.

I am well aware of the many inadequacies and omissions in this form of presentation, but if the belaboured student finds these lecture notes at least more readable, and therefore more memorable, than the prolix and time-honoured pattern, perhaps I will be justified.

Patrick Trevor-Roper

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Numerous colleagues have provided valuable advice in their specialist areas, for which we are most grateful. The authors wish to thank Tom Meagher and Ramona Khooshabeh for providing additional pictures for the twelfth edition. Tom Butler provided substantial input to the chapter on clinical optics. We are particularly grateful to Professor Allen Foster at the London School of Hygiene and Tropical Medicine, who kindly provided the illustrations for the chapter on tropical ophthalmology. Richard James, Chris King and Ajay Mohite worked on the questions and assessments.

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*Bruce James
Anthony Bron
Manoj V Parulekar*

Abbreviations

AIDS	acquired immunodeficiency syndrome	LASEK	laser-assisted subepithelial keratomileusis
AION	anterior ischaemic optic neuropathy	LASIK	laser-assisted <i>in situ</i> keratomileusis
AMD	age-related macular degeneration	LGB	lateral geniculate body
ARM	age-related maculopathy	MLF	medial longitudinal fasciculus
CCTV	closed circuit television	MRA	magnetic resonance angiogram
CMV	cytomegalovirus	MRI	magnetic resonance imaging
CNS	central nervous system	NSAID	non-steroidal anti-inflammatory drug
CRVO	central retinal vein occlusion	OCT	optical coherence tomogram
CSF	cerebrospinal fluid	PAS	peripheral anterior synechiae
CT	computed tomography	PEE	punctate epithelial erosions
DCR	dacryocystorhinostomy	PHMB	polyhexamethylene biguanide
ENT	ear, nose and throat	PMN	polymorphonuclear leucocyte
ERG	electroretinogram	PPRF	parapontine reticular formation
ESR	erythrocyte sedimentation rate	PRK	photorefractive keratectomy
GCA	giant cell arteritis	PS	posterior synechiae
GI	gastrointestinal	PVR	proliferative vitreoretinopathy
GPC	giant papillary conjunctivitis	RAPD	relative afferent pupil defect
HAART	highly active anti-retroviral therapy	RPE	retinal pigment epithelium
HIV	human immunodeficiency virus	TB	tuberculosis
HLA	human leucocyte antigen	TNF	tumour necrosis factor
HSV	herpes simplex	UV	ultraviolet
ICG	indocyanine green angiography	VA	visual acuity
INR	international normalized ratio	VEGF	vascular endothelial growth factor
IOL	intraocular lens	VKH	Vogt-Koyanagi-Harada disease
KP	keratic precipitate		

About the companion website

Don't forget to visit the companion website for this book:

www.lecturenoteseries.com/ophthalmology



There you will find valuable material designed to enhance your learning, including:

- Interactive MCQs
- Interactive EMQs
- Figures from the book

Scan this QR code to visit the companion website.



Anatomy

Learning objective

- ✓ To learn the anatomy of the eye, the orbit and the third, fourth and sixth cranial nerves, as a background to the medical conditions affecting them.

Introduction

Knowledge of ocular anatomy and function is important to the understanding of eye diseases. A brief outline is given below.

Surface anatomy of the face

The eyes are disposed symmetrically about the face and their forward-looking arrangement permits a large overlap in visual fields, the basis of stereopsis. Lying within the bony orbits, they are protected from trauma by the orbital walls and rims and by the eyelids, by blinking and eye closure. With the eyes open and looking straight ahead, all but the upper and lower corneal margins are exposed in the *palpebral aperture*, together with two small white triangles of bulbar conjunctiva, overlying the sclera. The medial and lateral ends of the fissure are known as the medial and lateral *canthi* (Figure 1.1).

The lids and the upper and lower orbital rims are overlain by the orbicularis muscle which sweeps over these structures in an ellipse, from a region

just medial to the medial orbital rim. It acts as the palpebral sphincter (Figure 1.2). Like all other muscles of the face, it is supplied by the seventh cranial nerve. Contraction of its orbital part results in protective, forced eye closure, while contraction of its palpebral part is employed in the downstroke of the upper lid during a blink. The levator palpebrae muscle, the elevator of the upper lid (see below), is concerned with the upstroke of the blink (third cranial nerve). These synchronized contractions are completed within just 300 ms. The contents of the orbit are separated from those of the lid by a connective tissue sheet, or orbital septum, which extends from the orbital rim to the tarsal plate, deep to orbicularis.

Sensory innervation of the face: the fifth cranial nerve

The sensory innervation of each half of the face is provided by the trigeminal nerve (Figure 1.3). The eye, upper lid, eyebrow, forehead and nose are supplied by its ophthalmic division (V1), via its lacrimal, frontal and nasociliary branches, which enter the orbit through the superior orbital fissure. The maxillary division (V2), lying inferolaterally to V1 in the cavernous sinus, exits the cranial cavity via the foramen rotundum and, at the inferior orbital fissure, gives rise to the infraorbital and zygomatic nerves. These supply, chiefly, the lower lid and the

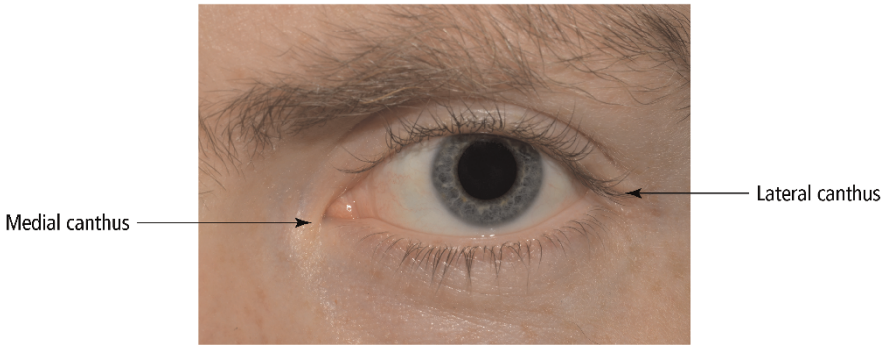
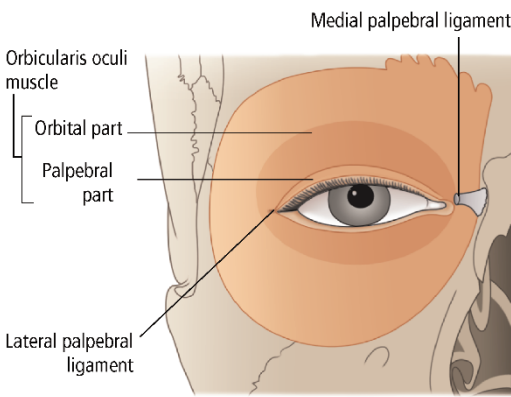


Figure 1.1 The eye, looking straight ahead.



upper lip and cheek. The mandibular division (V3), exiting the skull via the foramen ovale, supplies the lower lip, chin and jaw and the preauricular skin and temporal region. It is also motor to the muscles of mastication.

The neurons of the three divisions of the trigeminal nerve converge upon the trigeminal ganglion, whose sensory roots enter the pons to be distributed to the trigeminal nuclei in the brainstem. The mesencephalic nucleus is concerned with proprioception, the main sensory nucleus with touch and the medullary nucleus of the spinal tract with pain and temperature sensibility. Fibres from the ophthalmic division go to the lowest part of this nucleus, those from the mandibular division to its highest part.

Figure 1.2 Disposition of the orbicularis is muscle.

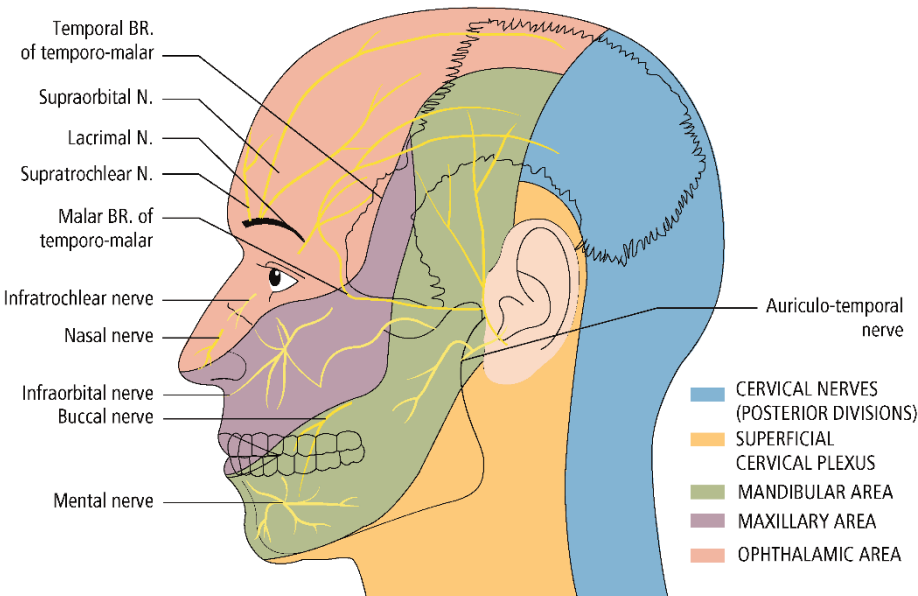


Figure 1.3 Sensory innervation of the face by the trigeminal nerve.

Gross anatomy of the eye

The eye comprises (Figure 1.4):

- A tough, collagenous outer coat which is transparent anteriorly (the *cornea*) and opaque posteriorly (the *sclera*). The junction between them is called the *limbus*. The extraocular muscles attach to the outer sclera, while the optic nerve leaves the globe posteriorly.
 - A rich vascular coat (the uvea) forms the choroid posteriorly and the ciliary body and iris anteriorly. Internal to the choroid lies the retina, to which it is firmly attached and whose outer two-thirds it nourishes.
 - The ciliary body contains the smooth *ciliary muscle*, whose contraction controls focusing by altering lens shape. The *lens* lies behind the iris, supported by the *zonules*, whose fine fibres run from the lens equator to the ciliary body. When the eye is focused for distance, tension in the zonule maintains a flattened profile of the lens. When the ciliary body contracts, tension is relaxed, the lens takes up a more curved shape and focusing for near objects is achieved.
 - The ciliary body also provides attachment for the *iris*, which forms the pupillary diaphragm. The *ciliary epithelium* secretes *aqueous humour* and maintains the ocular pressure.
- The space between the cornea anteriorly and the iris and central lens posteriorly, filled with aqueous humour, is the anterior chamber, whose periphery is the iridocorneal angle or drainage angle. The angle gives access to a meshwork of cells and collagen beams called the trabecular meshwork, through which aqueous drains into Schlemm's canal and thence into the venous system via the aqueous veins. This is the basis of aqueous drainage.
 - Between the iris, lens and ciliary body lies the *posterior chamber*, a narrow space distinct from the *vitreous body* behind. Both the anterior and posterior chambers are filled with aqueous humour. Between the lens and the retina lies the vitreous body, occupying most of the posterior segment of the eye. The posterior segment refers to the posterior two-thirds of the eye, lying behind the anterior vitreous face. The anterior segment comprises all those structure lying *anterior* to the vitreous.

Anteriorly, the *bulbar conjunctiva* of the globe passes from the limbus into the fornices of the conjunctival sac and thence onto the posterior surface of the lids, where it becomes the *tarsal conjunctiva*. A connective tissue layer (*Tenon's capsule*) separates the conjunctiva from the sclera and is prolonged backwards as a sheath around the rectus muscles.

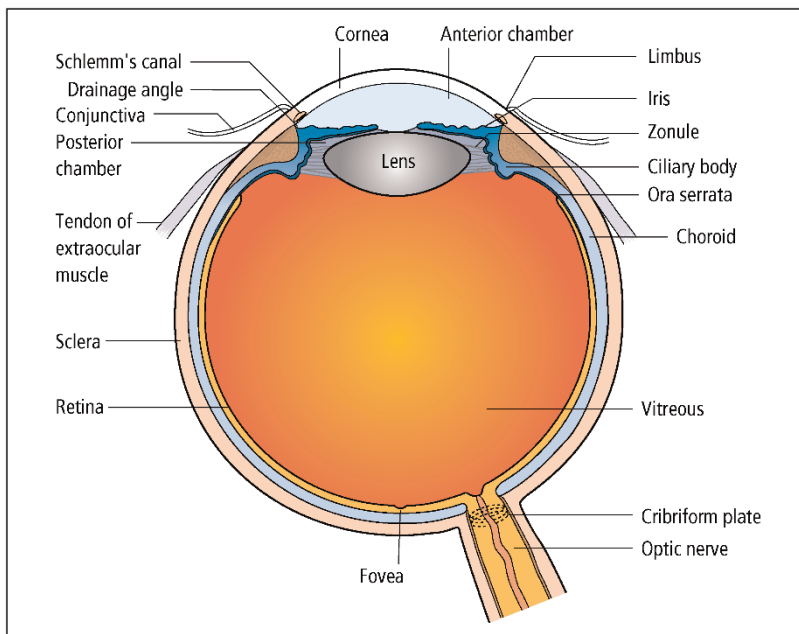


Figure 1.4 The basic anatomy of the eye.

The orbit

The eye, or globe, lies within the bony orbit, which has the shape of a four-sided pyramid (Figure 1.5). At its posterior apex is the *optic canal*, which transmits the optic nerve to the chiasm, tract and lateral geniculate body. The *superior and inferior orbital fissures* transmit the blood vessels and cranial nerves that supply the orbital structures. The *lacrimal gland* lies anteriorly in the superolateral aspect of the orbit. On the anterior part of the medial wall lies the fossa for the *lacrimal sac*.

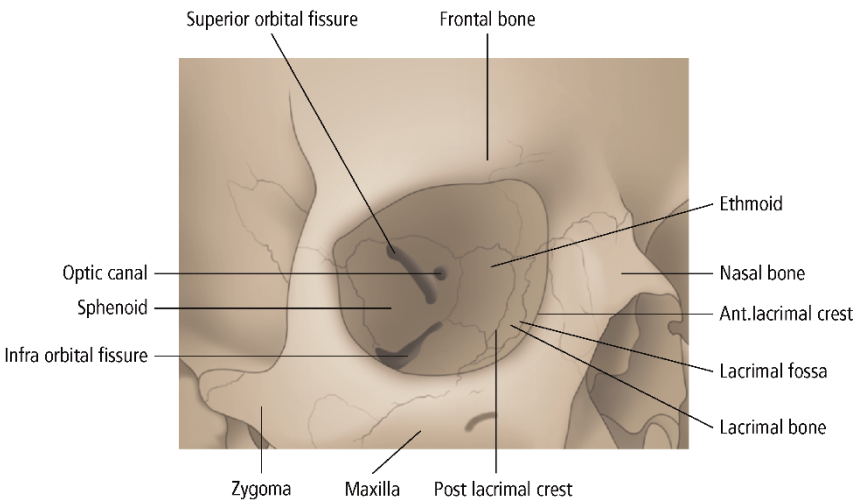


Figure 1.5 The anatomy of the orbit.

The eyelids (the tarsus)

The eyelids (Figure 1.6):

- offer mechanical protection to the globe;
- spread the tears over the conjunctiva and cornea with each blink.

The levator muscle is the main elevator of the upper lid. It passes forwards from an attachment on the sphenoid bone, above the optic foramen, to an aponeurosis which inserts into the tarsal plate. It is innervated by the third cranial nerve. Damage

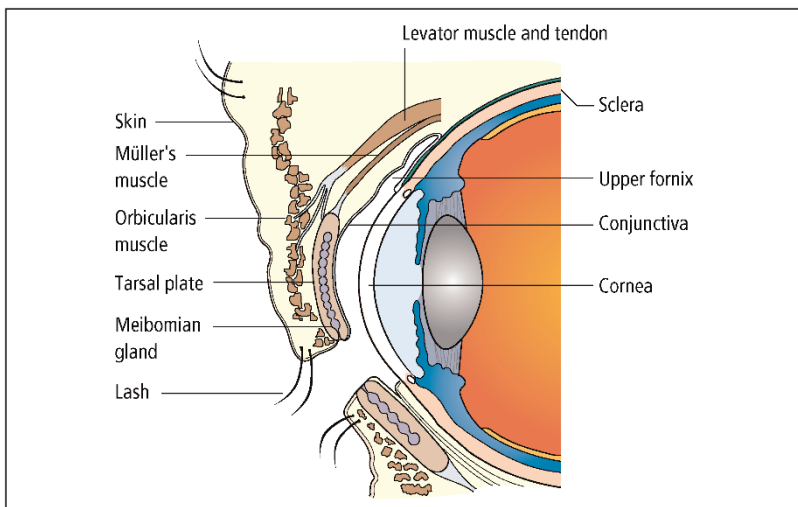


Figure 1.6 The anatomy of the eyelids.

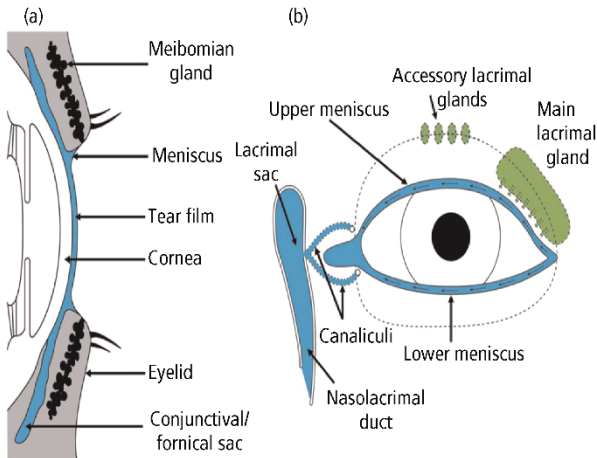


Figure 1.7 Drawing of the eye: (a) in cross section, (b) in frontal view to illustrate the distribution of the tears. (Source: Gaffney EA et al. *Progress in Retinal and Eye Research* 2010; **29**(1):59–78. Reproduced with permission of Elsevier.)

to the nerve or weakening of the aponeurosis in old age results in drooping of the upper eyelid (ptosis). A flat, smooth muscle, (the superior tarsal, or Müller's muscle) innervated by the sympathetic nervous system, arises from the deep surface of the levator and inserts into the tarsal plate. Müller's muscle also contributes to a lesser extent to elevation of the lid, and if the sympathetic supply is damaged, a slight ptosis results as part of Horner's syndrome.

Each eyelid comprises:

- an anterior layer of skin;
- the palpebral part of the *orbicularis muscle*;
- a tough collagenous layer (the *tarsal plate*) which houses the meibomian oil glands;
- an epithelial lining, the *tarsal conjunctiva*;
- the lash-bearing, lid margins.

The tarsal conjunctiva is reflected, via the fornices, onto the anterior surface of the globe, where it becomes the bulbar conjunctiva. When the eyes are closed, this lining forms the conjunctival sac, which contains the tears. When the eyes open, a tear film is formed which covers and protects the exposed cornea and conjunctiva. At the lid margins, the tear film is bordered by the tear menisci (Figure 1.7).

The lid margins exhibit a narrow, posterior conjunctival zone, continuous with the tarsal conjunctiva and a cutaneous zone anteriorly, which bears the lashes. These zones are separated by the mucocutaneous junction which forms the anterior boundary of each tear meniscus (Figure 1.8). At the medial ends of each lid margin, dipping into a lake of tears at the nasal canthus, are the lacrimal puncta, through which tears drain from the tear menisci into the lacrimal drainage system.

The meibomian oil glands, embedded in the tarsal plates (Figure 1.8), deliver their oil to the skin of the lid

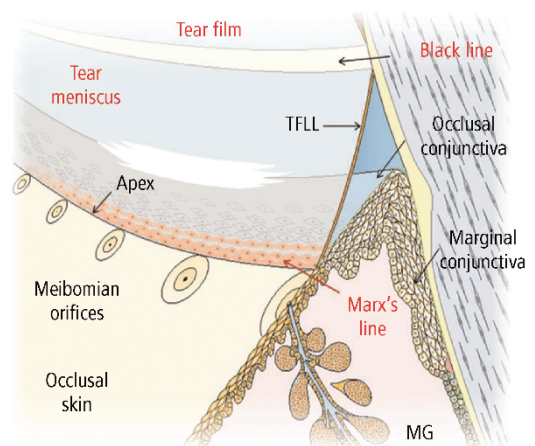


Figure 1.8 Diagram of lid margin to show meibomian orifices, meniscus and tear film lipid layer (TFLL). (Source: Bron et al. *Ocul Surf* 2011; **9**(2):70–91. Reproduced with permission of Elsevier.)

margin, just anterior to the *mucocutaneous junction*. This oil spreads onto the anterior surface of the tear film with each blink, to form a lipid layer, which retards evaporation and stabilizes the tear film.

The lacrimal drainage system

Tears drain into the upper and lower *puncta* and then into the *lacrimal sac* via the upper and lower *canaliculi* (Figure 1.9). They form a common canaliculus before entering the lacrimal sac. The *nasolacrimal duct* passes from the sac to the nasal cavity which enters at the *inferior meatus*. Failure of the distal part of the

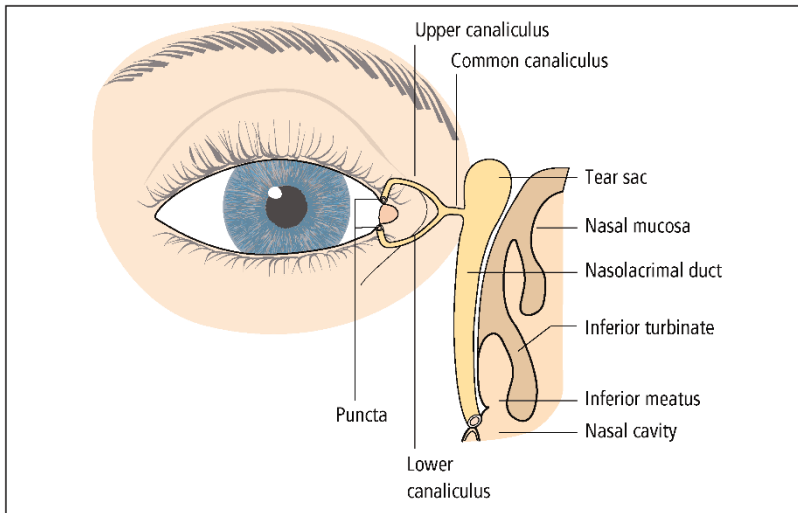


Figure 1.9 The major components of the lacrimal drainage system.

nasolacrimal duct to fully canalize at birth is the usual cause of a watering, sticky eye in an infant. Tear drainage is an active process. Each blink helps to pump tears through the system.

Detailed functional anatomy

The tear film

The eye is bathed constantly by the tears, secreted by the lacrimal gland into the upper fornix of the conjunctival sac. There is a small contribution from the conjunctiva. Tears are lost from the surface in part by evaporation and in part by drainage via the nasolacrimal system. Lacrimal secretion is under parasympathetic control through a feedback loop from the cornea, via the trigeminal nerve, to the superior salivatory nucleus and thence to the lacrimal gland. This ensures that tear production is regulated reflexly in response to signals from the ocular surface.

The most superficial epithelial cells of the ocular surface express a *mucin-rich glycocalyx* which renders the surface wettable. When the eyes are open, the exposed ocular surface is covered by a tear film, 3 μm thick. This has two layers:

- A *mucoaqueous layer* containing gel mucin from the conjunctival goblet cells and *aqueous tear fluid* from the lacrimal gland, directly in contact with the ocular surface.
- A thin surface *oil layer* (100 nm) produced by the meibomian glands and delivered to the tear film from the lid margins.

Functions of the tear film

- It moistens the eye, preventing dehydration of its surface.
- It provides a smooth, air/tear, optical interface for distortion-free refraction of light at the cornea.
- It transmits oxygen to the avascular cornea.
- It removes debris and foreign particles from the ocular surface through the flow and drainage of the tears and the action of the blink.
- It has antibacterial properties by means of lysozyme, lactoferrin, defensins and the immunoglobulins, particularly secretory IgA.

The tear film is replenished with each blink.

The cornea

The cornea is 0.5 mm thick and comprises (Figure 1.10):

- The epithelium, an anterior, non-keratinised squamous layer, five cells thick, thickened peripherally at the limbus where it is continuous with the conjunctiva. The limbus houses the germinative *stem cells* which maintain the corneal epithelium. The basal cells of the epithelium are firmly attached to an underlying basal lamina by hemidesmosomes and by anchoring fibrils which extend into Bowman's layer.
- An underlying *stroma* which accounts for over 90% of the corneal thickness. On its most anterior aspect is a tough, *anterior limiting layer* (Bowman's layer), 20 μm thick, which is free of cells and composed of fine, short, tightly interwoven collagen fibrils. The main body of the stroma consists of type I collagen fibrils arranged in

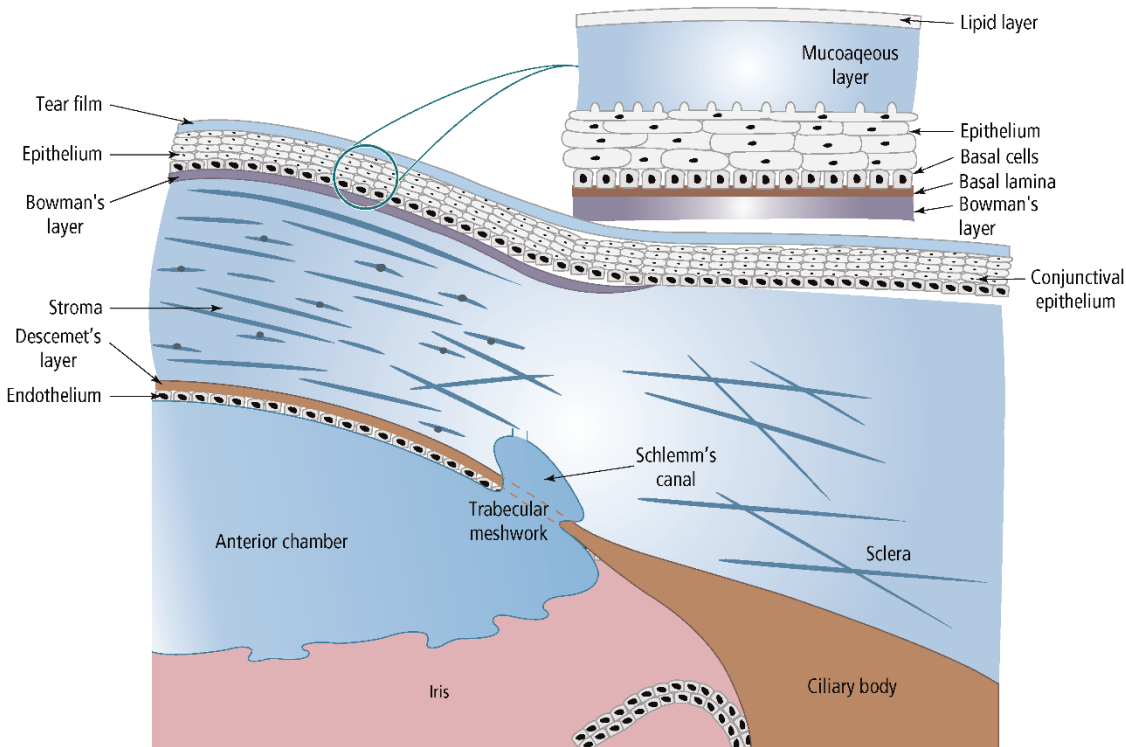


Figure 1.10 The structure of the cornea and precorneal tear film (schematic, not to scale—the stroma accounts for 95% of the corneal thickness).

parallel within lamellae, each fibril surrounded by a ground substance rich in proteoglycans. Between the lamellae are scattered keratocytes which, like fibroblasts, engage in stromal maintenance and repair. The anterior lamellae lie in the plane of the cornea, while posteriorly they have a more woven arrangement. The regular packing of the collagen fibrils, their small diameter and narrow separation (in the region of 200 nm) accounts for corneal transparency. Backscattered light, towards the source, is obliterated by destructive interference and over 90% of the light is transmitted. This orderly architecture is maintained by regulating stromal hydration. The stroma is bounded behind by the *posterior limiting layer* (Descemet's layer), the basal lamina of the corneal endothelium. It is chiefly composed of type IV collagen.

- The *endothelium*, a monolayer of hexagonal, non-regenerating cells (Figure 1.11) which actively pump ions from the stroma into the anterior chamber carrying water with them. This controls corneal hydration and thickness and hence transparency.

The difference between the regenerative capacity of the epithelium and endothelium is important. Damage to the epithelial layer, by an abrasion, for example,

is rapidly repaired by cell spreading and proliferation. Endothelial damage by disease or surgery is repaired by cell spreading alone, with a loss of cell density. When cell density falls below a critical level, a loss of

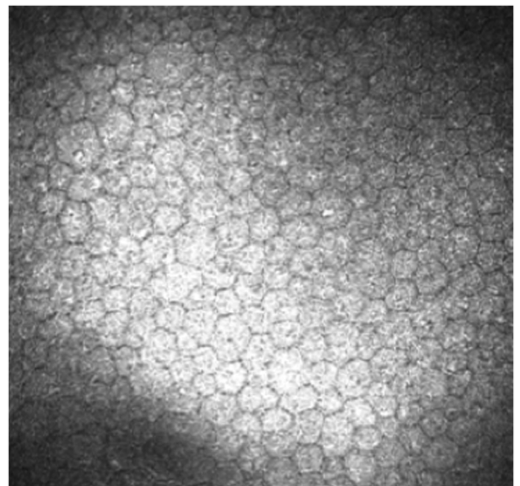


Figure 1.11 Normal corneal endothelium shown by confocal microscopy. (Courtesy of Paula Hedges.)

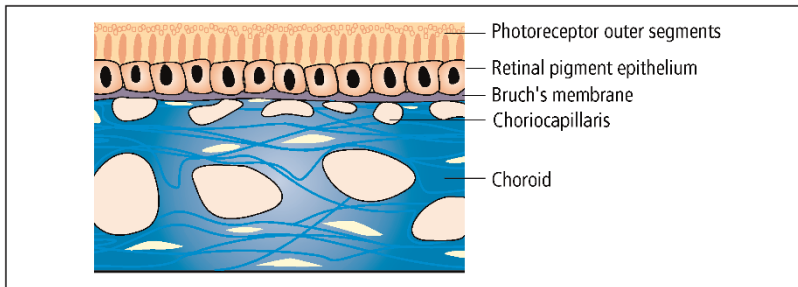


Figure 1.12 The relationship between the choroid, RPE and retina.

barrier and pumping functions leads to corneal overhydration (oedema), stromal swelling, disruption of the regular packing of the collagen fibrils and to corneal clouding. The effect on vision is compounded by an associated epithelial oedema.

The nutrition of the cornea is supplied almost entirely by the aqueous humour, which circulates through the anterior chamber and bathes the posterior surface of the cornea. The aqueous also supplies oxygen to the posterior stroma, while the anterior stroma receives its oxygen from the ambient air. The oxygen supply to the anterior cornea is reduced but still sufficient during lid closure; however, a too tightly fitting contact lens may deprive the anterior cornea of oxygen, causing epithelial oedema and visual loss.

Functions of the cornea

- It protects the internal ocular structures.
- Together with the lens, it refracts and focuses light onto the retina. The junction between the ambient air and the curved surface of the cornea, covered by the optically smooth tear film, forms a powerful refractive interface.

The sclera

- The sclera is formed from interwoven collagen fibrils lying within a ground substance and maintained by fibroblasts. Because of the coarse weave and the variation in fibril width, the sclera scatters light strongly and appears white and opaque.
- It is of variable thickness, 1 mm around the optic nerve head and 0.3 mm just posterior to the rectus muscle insertions.

The choroid

- The choroid (Figure 1.12) is a vascular layer formed of arterioles and venules and a dense, fenestrated capillary network, fused with the basal lamina of the retina.

- It is loosely attached to the sclera.
- It has a remarkably high blood flow.
- It nourishes the deep, outer two-thirds of the retina and may have a role in its temperature homeostasis.
- Its basal lamina, together with that of the retinal pigment epithelium (RPE), forms the acellular *Bruch's membrane* that acts as a diffusion barrier between the choroid and the retina which facilitates the passage of nutrients and metabolites between the retina and choroid.

The retina

The retina (Figure 1.13) is a highly complex structure derived embryologically from the primitive optic cup. Its outermost layer is the RPE while its innermost layer forms the neuroretina, consisting of the photoreceptors (rods and cones), the bipolar nerve layer (and the amacrine and horizontal nerve cells) and the ganglion cell layer, whose axons give rise to the innermost, nerve fibre layer. These nerve fibres converge to the optic nerve head, where they form the optic nerve.

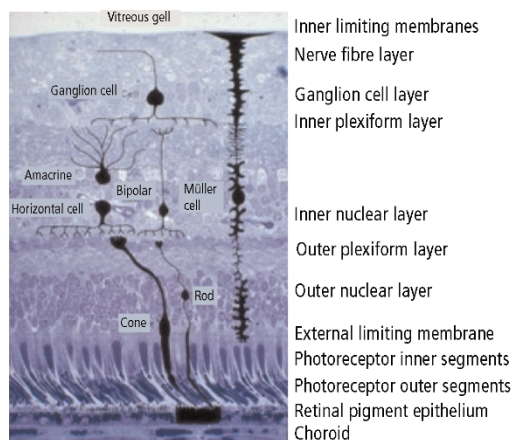


Figure 1.13 The structure of the retina. (Courtesy of Professor John Marshall.)