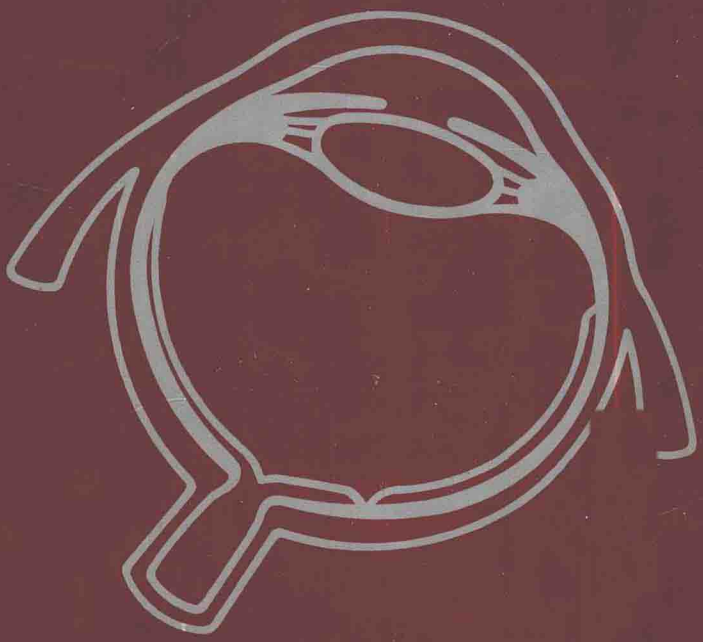
The Eye and its Disorders

SECOND EDITION

PD Trevor-Roper/PV Curran



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The Eye and its Disorders

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THE EYE AND ITS DISORDERS

Preface to the First Edition

In 1964 a conflagration at the warehouse destroyed all the remaining copies of the second edition of *Ophthalmology: A textbook for diploma students*, which I had first published with Lloyd-Luke in 1955. Now it re-emerges, like a modest Phoenix from those flames, after rather a long gestation. Its title and its publishers have changed, but it retains the form and much of the basic substance of its predecessor, although infused with all the new knowledge and perspectives that a crowded eleven years have brought.

Textbooks of ophthalmology abound, each with their individual approach, their differing patterns, frontiers and attitudes; and nearly all of them admit the hope that they will suit the needs, not only of every grade of ophthalmologist, but students, nurses, G.P.s, opticians and so on. The predecessor of this book apparently had enough appeal to justify its re-appearance; and for those postgraduates, to whom it was originally dedicated, and for any others who seek to understand our specialty, I trust that this re-appraisal will still enhance their knowledge without ever forfeiting their interest.

P.D. Trevor-Roper
1974

Preface to the Second Edition

As the pattern of ophthalmology changes apace, the attitudes of a single ageing author can easily congeal, unless fortified by a younger associate. Hence this new joint appraisal.

The last decades have witnessed the emergence of ophthalmology from its established framework, so that, by now, a multitude of sub-specialties have evolved. No single book can hope to cover this panorama in as much detail as it deserves, but the authors hope that they have produced a comprehensive outline of the subject and stimulated the reader to look deeper into the specialist literature.

The basic chapters have changed little, except in their emphasis and detail, but the illustrations have largely been amended. Much has been added to the clinical text, but much has been discarded, so as to leave, we trust, a not too indigestible account of the principles and practice of ophthalmology today.

P.D. Trevor-Roper
P.V. Curran
1984

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Acknowledgements

Our thanks, as in the previous edition, are due to our many friends and colleagues at Moorfields and the Institute of Ophthalmology, upon whose kindness we have presumed, and upon whose expertise we have drawn.

For the illustrations we are principally indebted to Mr R. Leng, Chief Medical Photographer at Queen Mary's Hospital, and for others we are indebted to Sir Stewart Duke-Elder's *Textbook* or *System of Ophthalmology* (H. Kimpton), E. Wolff's *Anatomy of the Eye* (H.K. Lewis), J.R.O. Collin's *Manual of Systematic Eyelid Surgery* (Churchill Livingstone), M. Parks' *Atlas of Strabismus Surgery* (Harper and Row), G. Van Noorden from *Maumenee's Atlas of Strabismus* and F. Newell's *Ophthalmology. Principles and Concepts* (both from C.V. Mosby, St Louis). The line drawings of this edition are nearly all original, although in many cases based on illustrations culled from standard textbooks. In any instance in which we have made too faithful a copy and omitted mention of its source, it is hoped that the author will accept this blanket acknowledgement and our gratitude.

We must also thank our tireless secretarial assistants, Miss Janet Browne, Mrs Sally Stone and Miss Linda Batterham. And finally a word of thanks to our publishers—to Mr Per Saugman, for his guidance over a quarter of a century, and to Mr Jony Russell, who has so leavened the production of this edition.

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PART I
ANATOMY

Chapter 1
The Eyeball

Ophthalmic anatomy is conventionally divided into a study of the eyeball itself, of its adjacent structures, and of those more distant parts that are functionally related to the eye. The latter aspects diffuse into the world of general medical knowledge, but the globe itself, the citadel of ophthalmology, demands a more thorough consideration, albeit made less arduous by its easy accessibility and by the details of its structure that can readily be revealed by the slit-lamp and the ophthalmoscope.

The eyeball, nearly an inch in diameter, lies suspended in the fat that largely fills the orbit, so that the slightest pull of one of the muscles that insert into it will rotate it about its own centre. Separated by a few millimetres from the four converging bony walls of the orbit, it is unprotected only on its anterior surface, where the convex corneal window lies.

The eyeball consists essentially of three separate concentric layers that are modified anteriorly to admit and regulate the passage of light; within these lies a transparent jelly, the vitreous body. The outermost of these layers, the sclera, is purely protective; the innermost, the retina, is a light-sensitive recorder of images; and the intervening uveal layer consists principally of the choroid, a nutrient vascular bed for the retina; but the anterior rim of this uveal layer is continued forwards to contain the intra-ocular muscles that govern the accommodative and pupillary movements, thus forming the ciliary body and the iris (Fig. 1.1).

Measurements

The cornea is more convex than the rest of the globe (7·8 mm radius of convexity as opposed to 12 mm), forming an anterior prominence to the eye. The antero-posterior length thus averages 24 mm, while the vertical diameter is 23 mm and the horizontal is 23·5 mm. The globe is shorter in hypermetropes and longer in myopes.

THE SCLERA

The sclera or sclerotic is the tough fibrous envelope of the eye, often reinforced with bone in lower vertebrates; it is white (rather bluish in children and yellowing in old age), and relatively avascular. It covers five-sixths of the surface of the eye, the remaining one-sixth comprising the corneal window and the small fenestrated exit for

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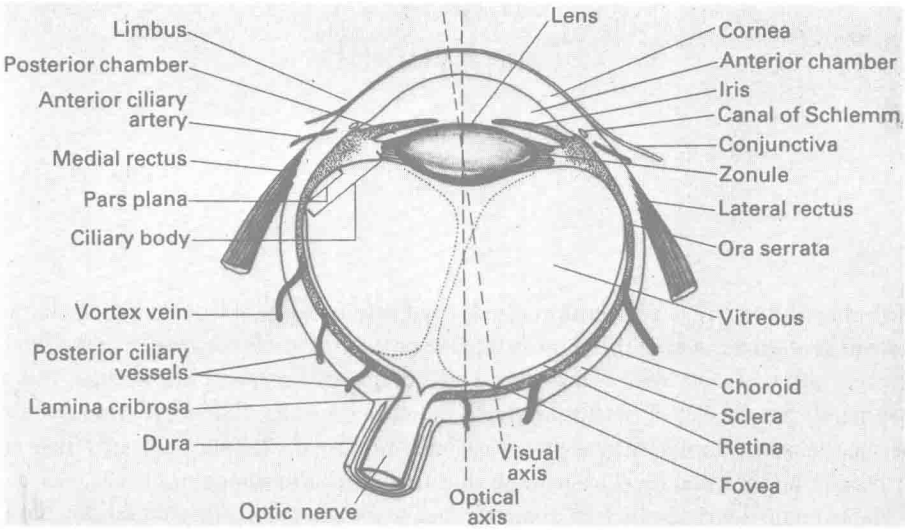

Fig. 1.1 Diagrammatic horizontal section of the eye.

the passage of the optic nerve fibres. The sclera is pierced by four vortex veins (4 mm behind the equator between the rectus muscles), the long and short ciliary nerves and vessels posteriorly, and the anterior ciliary nerves and vessels just behind the corneo-scleral junction. The sclera is thickest posteriorly (1 mm), but this becomes reduced to a third on passing forwards to the equator; thereafter it receives the insertion of the rectus muscles and their sheaths (another third), with the result that it is 0·66 mm thick when it reaches the cornea, at the corneo-scleral margin or 'limbus'.

Histology (Fig. 1.9)

Three ill-defined layers of fibres are described.

The episclera is an external layer of loose fibrous tissue, having fine strands that connect it with the investing fascia of the eyeball (Tenon's capsule), and containing numerous fine capillaries.

The sclera proper is composed of a dense network of collagen fibres lying in bundles that are disposed concentrically at the anterior and posterior poles but tend otherwise to lie meridionally or with backwardly directed loops. They are continuous with the lamellae of the cornea and with the incoming tendons of the extra-ocular muscles, whose fibres differ from those of the sclera in being parallel and not interlacing, and in being of uniform diameter. The plan of the scleral fibres is determined by the intra-ocular pressure and the pull of the muscles.

The lamina fusca is the inner layer, in which the fibre bundles are smaller and an increasing number of pigment cells and elastic fibres are found. The former are

chromatophore immigrants from the subjacent choroid and ciliary body, and may even reach the outer scleral surface along the anterior ciliary vessels to become noticeable as pigment spots beneath the conjunctiva.

THE CORNEA

Measurements

The cornea forms the transparent anterior pole of the eyeball; it is 11·6 mm in diameter except where the vertical diameter is encroached upon by the sclera on its anterior surface, reducing it there by 1 mm, so that it appears as a transverse oval when viewed from in front but circular when viewed from behind. The cornea is nearly 1 mm thick peripherally, but the greater concavity of its posterior surface (6·6 mm radius compared to an anterior curvature of 7·8 mm) makes its central or 'axial' area only 0·5 mm thick; the periphery of the cornea is slightly less curved than the centre, approximating to the curve of the adjacent sclera, from which it is demarcated by the scleral furrow. These measurements vary slightly and the refraction of the eye is influenced accordingly.

Histology (Fig. 1.2)

As in the sclera there are three cell layers, but these are quite distinct both in appearance and origin, being separated in each case by important lamellae that appear structureless under the optical microscope.

The epithelium is a regular layer 5–6 cells deep, and is continuous with the conjunctival epithelium that overlies the adjacent sclera. As in the stratified epithelium of the skin or

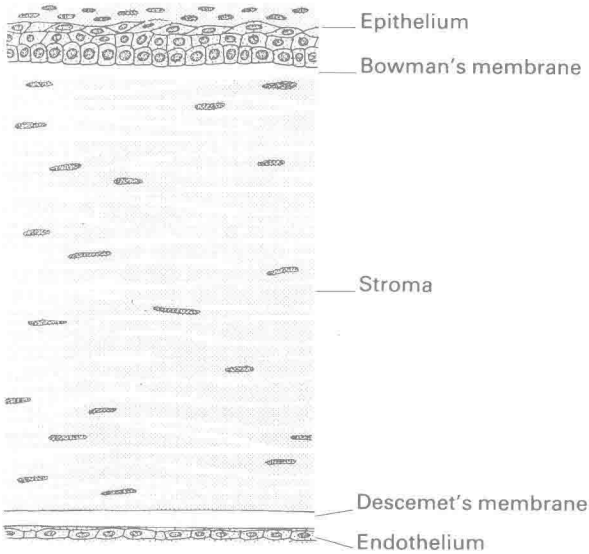

Fig. 1.2 Transverse section of the cornea.

conjunctiva, the cells proliferate from a columnar basal layer, becoming progressively flatter as they approach the surface. The basal cells are tall with oval nuclei, the intermediate layers (2 or 3 deep) of polyhedral 'wing cells' have horizontally flattened nuclei, and the surface layers (about 2) of very flat cells resemble the surface cells of skin but are not keratinized and retain their nuclei. Cytoplasmic organelles gradually disappear as the cells migrate to the surface, indicating a progressive decrease in metabolic activity. All the epithelial cells are joined by desmosomes and those on the surface have fused adjacent cell membranes (zonula occludens), which accounts for the relative impermeability of the epithelium to water; microvilli on the surface epithelial cells help to retain the inner mucus layer of the tear film. The corneal epithelium rests on a basement membrane secreted by the basal cells; firm attachments connect the membrane to the overlying epithelium and underlying Bowman's layer. The 'turnover time' for the corneal epithelium is about seven days.

The substantia propria or stroma, comprising 90% of the corneal thickness, is composed of about 60 layers of collagen fibrils of uniform diameter arranged in sets of bundles or lamellae lying parallel to the surface. The fibres of alternate layers are arranged at right-angles to one another, forming a crystalline-like lattice in a ground substance of glycoprotein and mucopolysaccharide (the sclera sacrifices its transparency by having an irregular arrangement of fibres in at least three planes). Scattered between the lamellae are the corneal corpuscles, branching syncytial connective-tissue cells that are flattened (possibly by the pressure of the lamellae), and a few wandering leucocytes. Unlike the sclera, it normally lacks any vessels or pigment.

The endothelium is a single layer of flattened granular polygonal cells with central nuclei

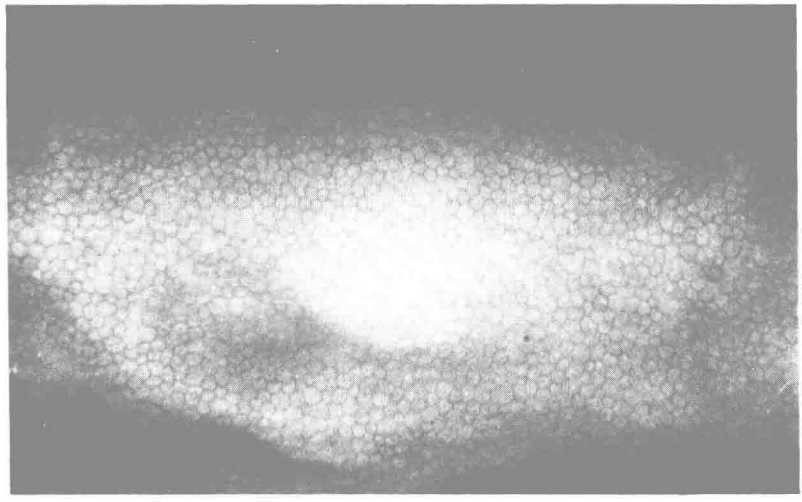

Fig. 1.3 Specular micrograph showing 1 mm^2 of normal human endothelium. The cells are of regular size and arrangement, with a density of 2862 cells/mm^2.

(Fig. 1.3), which is continuous with the endothelium over the anterior surface of the iris. Each cell is joined on its inner aspect to its neighbours by a continuous 'zona occludens' which closes the inter-cellular space from the anterior chamber. With age, effete cells are not replaced and in the older eye the cells are flatter and tend to be irregular in shape.

Bowman's membrane (the anterior elastic lamina) is essentially an anterior condensation of the substantia propria and presents a smooth surface towards the epithelium which is, in consequence, very easily stripped from it by injury, disease or death. Electron micrographic pictures reveal that, unlike the rest of the stroma, the collagen fibrils are arranged in a completely random fashion. It offers a fair resistance to infection but, once eroded, it cannot be replaced and an opaque scar will result. Thickest in the centre, it ends just before reaching the corneal margin.

Descemet's membrane (the posterior elastic membrane) is a strong independent sheet separating the substantia propria from the endothelium; it is equally resistant to infection but (unlike Bowman's membrane) it readily regenerates after injury and is elastic (although it contains no elastin), curling it up if torn or ballooning forwards under the intra-ocular pressure if the anterior layers of the cornea are eroded. Descemet's membrane is continued peripherally beneath the sclera as a meshwork known as the pectinate ligament, from which strands may pass onwards to insert into the ciliary muscle and the sclera which lies most posteriorly. It is secreted by endothelial cells and is essentially their basement membrane. At birth it is about the same thickness as the endothelial cell layer (3–4 μm), but continues to grow to reach about 10 μm in adult life. In old age it may bear some warty elevations called Hassall–Henle bodies at its periphery.

The limbus is the transitional zone between cornea and sclera, where the epithelium becomes thickened with basal papillae as in skin, and the palisade cells become smaller and darker, as its five layers give place to the 10–12 layers of conjunctiva. At the same point, the corneal lamellae become less regular, as they merge with the circular and oblique fibres of the sclera. Capillary loops, from the anterior ciliary vessels, invade the corneal periphery for about 1 mm.

The corneal nerves

The corneal nerves, deriving from the long and short ciliary nerves, enter the inner surface of the sclera just outside the limbus, anastomosing there with the conjunctival nerves (forming the pericorneal plexus), and then pass on into the cornea as 60–70 trunks. These lose their myelin sheaths after a millimetre or two and separate into an anterior group (which ramify under Bowman's membrane and, after piercing this, under and among the epithelial cells), and a posterior group which wander among the deeper layers of the stroma, but do not reach the central portion.

Canal of Schlemm

The canal of Schlemm is a circular sinus, irregularly oval in section and sometimes plexiform, which lies among the deeper fibres of the sclera at the limbus (Figs. 1.4, 1.5). It has a firm wall lined by endothelium on a fenestrated basement membrane, and is separated from the anterior chamber only by the trabecular meshwork, which includes the pectinate ligament. Those endothelial cells adjoining the trabeculum are more loosely arranged and vacuolated and, since the aqueous drains into the canal of Schlemm through the trabeculum, these vacuoles are probably a manifestation of pinocytosis. Aqueous leaves the canal by about 25 outlet channels to the veins of the superficial and deep scleral plexus; such outlet channels may course through the episclera before joining the episcleral veins and can be observed in life as 'aqueous veins' (p. 96). During life, the canal and structure of the angle of the anterior chamber may be examined through a modified contact lens or 'gonioscope' (p. 471). After death, blood flows back to replace the aqueous in the canal of Schlemm.

Trabecular meshwork

The trabecular meshwork lies circumferentially between the canal of Schlemm and the

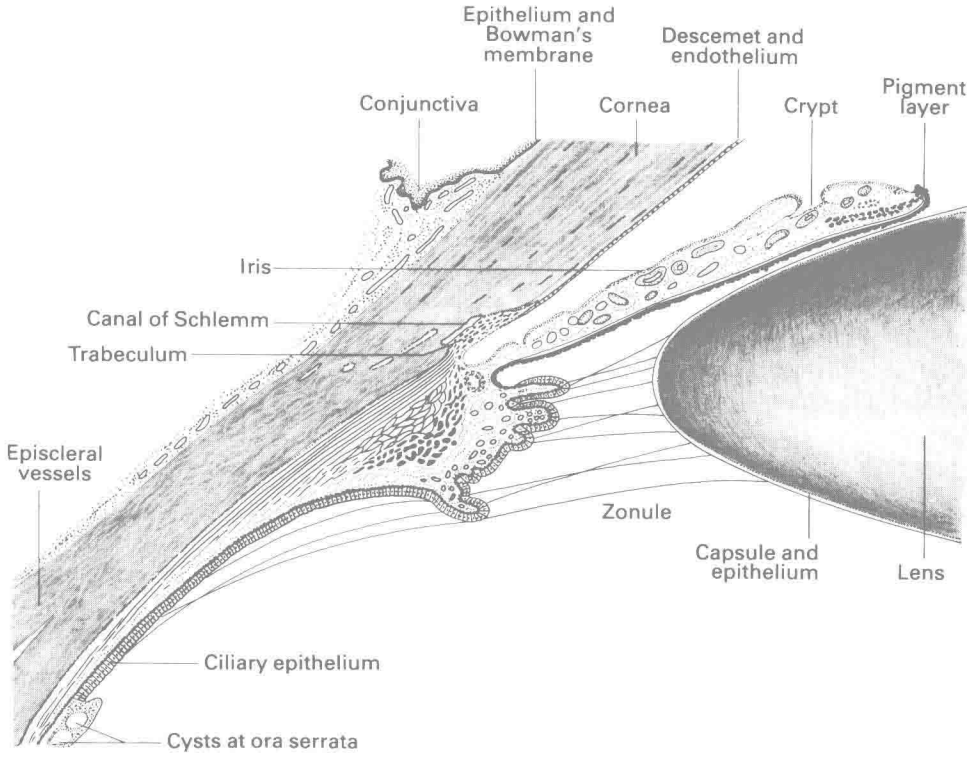

Fig. 1.4 Section through the iris and ciliary region.

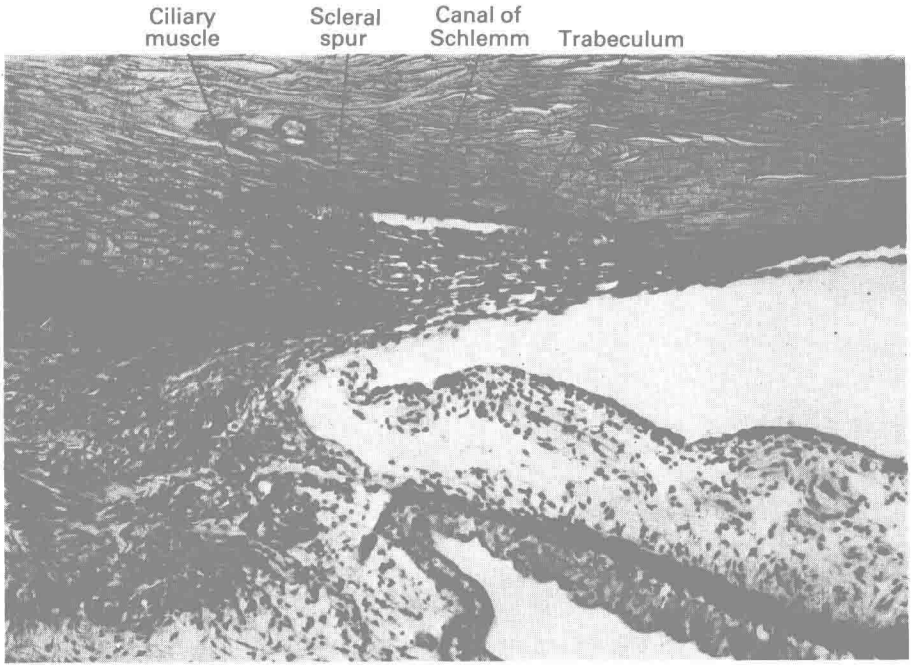

Fig. 1.5 Structures around the angle of the anterior chamber.

anterior chamber, extending forwards from the scleral spur to Schwalbe's line (the peripheral end of Descemet's membrane) and bounded by corneosclera externally and ciliary body at its base. It is formed by a porous meshwork of elastic and collagen fibrils lined by endothelium, and receives an extension of Descemet's membrane, known as the pectinate ligament.

THE IRIS

The vascular intermediate coat of the eye is known as the uvea or uveal tract, and consists of choroid, ciliary body and iris. The two former are adherent to the sclera, but the iris is separated from the cornea by a mushroom-shaped space—the anterior chamber—with the 'stalk' of the mushroom passing backwards through the pupil. The posterior chamber is the very shallow space between the iris and the subjacent lens.

The iris thus forms a disc, perforated (usually slightly towards the nasal side) by the pupil, whose size can be made to vary exceedingly in adjustment to the amount of light by contraction of its sphincter or dilator muscles, like the variable aperture of a camera. The peripheral 'root' of the iris arises from the anterior end of the ciliary body, which is attached to the sclera 2 mm behind the limbus, and the pupil lies against and is pressed slightly forwards by the anterior lens surface which it brushes gently with its restless excursions.

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