

Clinical Atlas of Glaucoma

E. Michael Van Buskirk

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E. Michael Van Buskirk, M.D.

Professor of Ophthalmology, Director of Glaucoma Service
Oregon Health Sciences University, Portland, Oregon

Editorial Assistant

LYDIA M. HARRIS, M.A.

Glaucoma Coordinator, Department of Ophthalmology
Oregon Health Sciences University, Portland, Oregon

Photographs

PAT WALLACE, B.S. and MARK EVANS, B.S.

Ophthalmic Photographers, Department of Ophthalmology
Oregon Health Sciences University, Portland, Oregon

Illustrations

JOEL ITO, M.S.

Medical Illustrator, Oregon Regional Primate Research Center
Oregon Health Sciences University, Portland, Oregon

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Contributing Authors

SCOTT MacRAE, M.D.

Assistant Professor of Ophthalmology
Oregon Health Sciences University, Portland, Oregon

JOHN C. MORRISON, M.D.

Instructor in Ophthalmology
Oregon Health Sciences University, Portland, Oregon

EARL A. PALMER, M.D.

Associate Professor of Ophthalmology and Pediatrics
Oregon Health Sciences University, Portland, Oregon

JOHN R. SAMPLES, M.D.

Assistant Professor of Ophthalmology
Oregon Health Sciences University, Portland, Oregon

RICHARD G. WELEBER, M.D.

Associate Professor of Ophthalmology and Medical Genetics
Oregon Health Sciences University, Portland, Oregon

To
Edmund Linford Van Buskirk

Physician
Ophthalmologist
Teacher
Colleague
Friend
Father

PREFACE

The eye is a beautiful organ. Ironically, ophthalmologists must rely upon their own eyes to perceive the subtleties and intricacies of ocular structure in health and disease. This special privilege to observe directly (without probes, x-rays, or endoscopes) physiologic and pathologic processes within the eye carries an obligation to recognize and differentiate the spectrum of normal and disordered ocular appearances.

Although many of the glaucoma syndromes illustrated in this book are unusual, all come within the purview of practicing ophthalmologists. Despite the contemporary array of technical advancements for diagnosis and therapy, glaucoma remains a chronic, progressive, lifelong disorder for most patients. Thus, it calls upon the basic clinical and humanistic skills of the physician for early and specific diagnosis to precede and guide successful long-term management.

This book emphasizes the clinical appearance of the normal and the glaucomatous eye. As a book of visual images, it should supplement, not supplant, standard didactic textbooks. A single facing page of text supports and guides the reader through the illustrations of each entity and each procedure. The surgical section employs both photographs and drawings to demonstrate the approaches favored by the author. New techniques constantly replace and supplement the old, rendering today's latest method obsolete tomorrow, but the basic principles of good surgical technique will likely apply even to the newest methodologies. The varied appearances of filtration blebs receive special attention, emphasizing the diversity of the functioning bleb and guiding diagnosis and management of the troublesome one.

The eye in health and disease perceives and manifests images of the beautiful and the grotesque. Its structural simplicity and delicacy belie the variety and complexity of its internal mechanisms. This book presents visual images through photographs and drawings in the hope that it will cement the reader's own visual conceptualization of the varieties of glaucoma and celebrate the esthetics of the eye.

E. MICHAEL VAN BUSKIRK

ACKNOWLEDGMENTS

A book depicting the appearance of things derives primarily from the artists who create the illustrations. This book would not have been possible without my association with two exceptional photographers, Pat Wallace and Mark Evans. As true professionals, their personal pride in their work and their refusal to accept less than the best underlie the quality of the photographs. By the same token, I am indebted to Joel Ito, medical illustrator, not only for his drawings in this and other projects, but especially for his patience with my requests for revisions, often to correct some small, previously overlooked detail.

We are all the product of our mentors and predecessors. I am truly and unusually fortunate to have had teachers of superb skill, patience, and humanity. In particular, Ephriam Friedman, Simmons Lessell, Morton Grant, and Thomas Hutchinson molded many of my thoughts and approaches.

I thank my colleagues at the Oregon Health Sciences University for their advice, their help, and their contributions to this book. John Morrison's intensive proofreading and critique of the entire typescript were invaluable. I thank my friend and colleague Bruce Shields for his support and for reviewing this project.

I am deeply indebted to Lydia Harris for her professional approach to editing and management of the multiple details involved with the project. Her persistent adherence to self-imposed deadlines allowed timely completion of the typescript.

I thank Fred Thompson for providing a beautiful environment conducive to the completion of the typescript.

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E. MICHAEL VAN BUSKIRK

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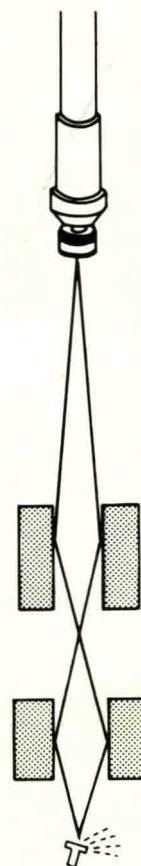
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ANATOMY AND CLINICAL EXAMINATION

Part A THE AQUEOUS HUMOR COMPARTMENTS

JOHN C. MORRISON, MD



I

CILIARY PROCESSES AND AQUEOUS HUMOR PRODUCTION

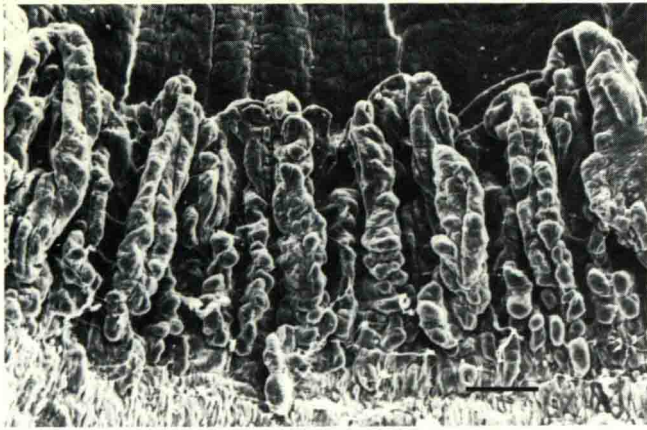
Aqueous humor formation occurs in the pars plicata of the ciliary body. This consists of a series of approximately 70 radially arrayed tissue leaflets (ciliary processes) alternating with an equal number of smaller minor processes. They are most easily seen behind the iris in the enucleated eye after removal of the lens and zonules (Fig. 1-1). The ciliary processes lie internal to the anterior half of the ciliary muscle (CM) and project into the posterior chamber (Fig. 1-2), with their anterior borders joining the iris at its root to create the ciliary sulcus (Fig. 1-3).

High magnification of a ciliary process cross section shows its three major components (Fig. 1-4): a vascular core, an intermediate stroma (S), and an epithelial surface (E). The vascular anatomy of the ciliary process is best viewed in profile by scanning electron microscopy of methylmethacrylate microvascular castings (Fig. 1-5*). Major ciliary processes are supplied with blood by two types of arterioles that radiate from the major arterial circle (MAC). The characteristically attenuated anterior arterioles supply capillaries occupying the anterior and marginal aspects of the process. Their anterior constrictions may reflect the effects of precapillary "sphincters" controlling ciliary process perfusion. Less attenuated posterior arterioles supply capillaries confined primarily to the base of the process. The concentrically arranged capillaries demonstrate irregular caliber and conduct blood through the process in an anterior-to-posterior direction, ultimately draining into the choroidal veins (CV). The fenestrated capillary walls allow plasma to escape into the loose stroma, which envelops the vascular core and consists of a ground substance containing scattered collagen fibrils and connective tissue cells.

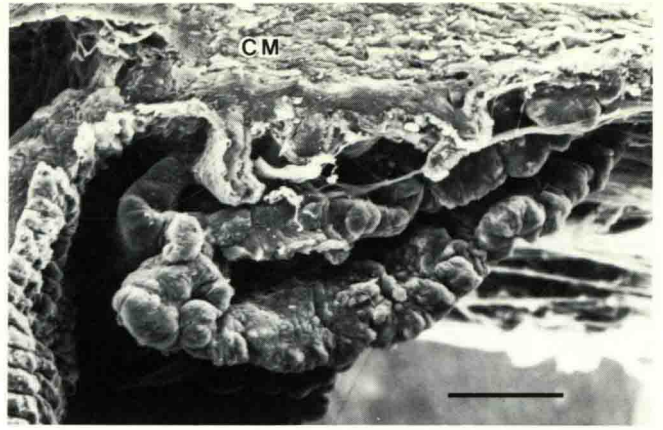
The epithelium is formed by an inner non-pigmented and outer pigmented layer lying apex-to-apex (Fig. 1-4). Non-pigmented epithelial cells line the posterior chamber and are closely applied to each other with tight junctions, which prevent the passage of larger molecules into the posterior chamber, thus constituting the blood aqueous barrier. They are considered "leaky" because they allow the diffusion of water and small ions. Increased numbers of mitochondria and rough endoplasmic reticulum have been found within these cells, along with evidence of membrane-bound enzymes (carbonic anhydrase and sodium- and potassium-dependent ATP-ase).

These morphologic and biochemical characteristics suggest that aqueous humor is formed in a stepwise process, beginning with intracapillary hydrostatic pressure forcing a plasma-derived ultrafiltrate into the stroma. Epithelial enzymes extract certain plasma constituents from this stromal pool (notably sodium, amino acids, and ascorbate) and actively transport them into the posterior chamber, creating an osmotic gradient. Water and other small ions then diffuse along this gradient into the posterior chamber as the final step in aqueous humor production.

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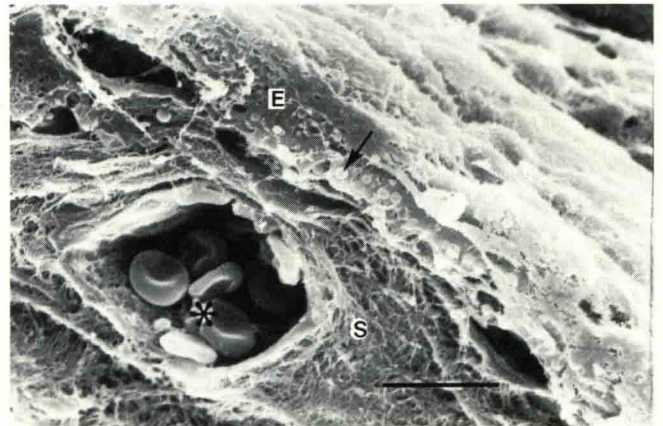
1-1 Major and minor ciliary processes. Bar = 250 μ .



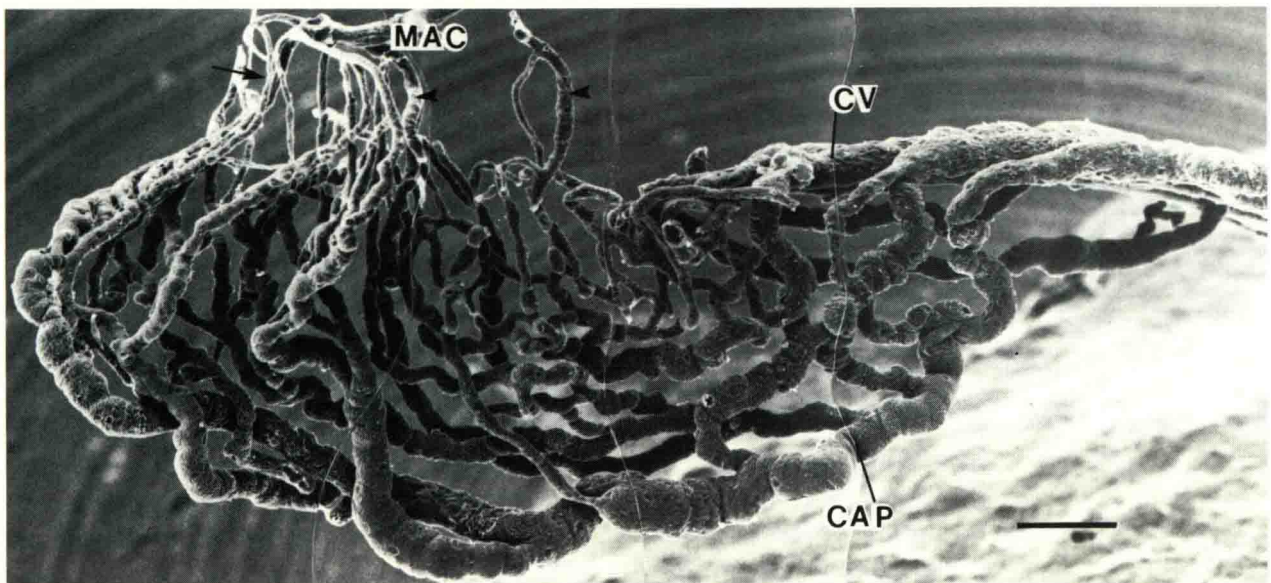
1-2 Profile of major ciliary process. Bar = 250 μ .



1-3 Anterior view of ciliary sulcus. I = iris. Bar = 250 μ .



1-4 Ciliary process cross-section. * = Erythrocyte. Arrow = epithelium pigment granule. Bar = 10 μ .



1-5 Primate ciliary process. Arrow = anterior arteriole. Arrowhead = posterior arteriole.

Aqueous humor occupies the anterior segment of the eye, which is divided by the iris into the anterior and posterior chambers. The boundaries and contents of these two chambers significantly alter the composition of aqueous humor as it travels from the ciliary processes to its exit from the eye at the anterior chamber angle.

The anterior face of the vitreous body, the ciliary body, and the iris form the posterior, lateral, and anterior boundaries of the posterior chamber, respectively. The vitreous face is composed of loosely organized collagen filaments lying in ground substance that is comprised mostly of hyaluronic acid. After processing for scanning electron microscopy, the anterior vitreous condenses over the pars plana near its firm attachment to the ora serrata, demonstrating the posterior chamber lateral recess (Fig. 2-1).

The ciliary muscle, a triangular structure composed of circular, tangential, and longitudinal fibers, forms the outer aspect of the ciliary body. Outer longitudinal fibers attach to the scleral spur at the base of this triangle. The inner border of the ciliary body exists as two zones (Fig. 2-2). Anteriorly, the ciliary processes make up the pars plicata, measuring approximately 2 mm in length. The pars plana overlies the posterior portion (4 mm to 5 mm) of the ciliary muscle, ending at the ora serrata. As with the ciliary processes, it is covered by an outer pigmented and an inner non-pigmented layer of epithelium. However, these cells lack the secretory characteristics that distinguish those of the ciliary processes.

Bundles and packets of tubular fibrils form the suspensory ligaments (zonules) of the crystalline lens (Fig. 2-3). They originate in the intercellular spaces of the non-pigmented epithelium of the pars plana and interprocess valleys of the pars plicata, traverse the posterior chamber, and fuse with the lens capsule near its equator.

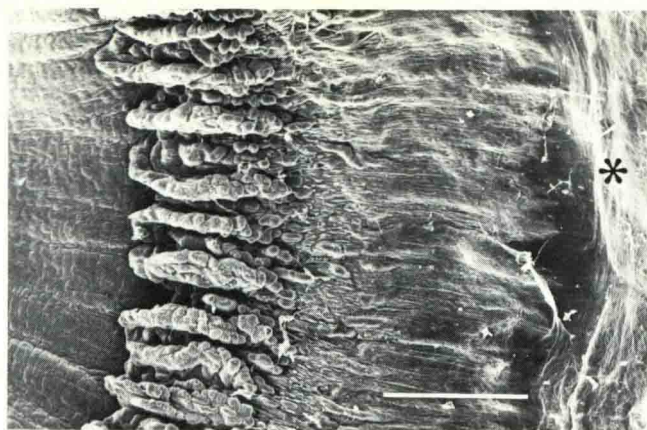
Aqueous humor flows anteriorly through the zonules, around the lens, and through the pupil of the iris to enter the anterior chamber. A layer of pigmented epithelial cells with incompletely formed desmosomes forms the posterior surface of the iris (Fig. 2-4). The iris pigment epithelium extends through the pupil and ends as the clinically visible pupillary ruff (Fig. 2-5).

Pigmented and non-pigmented cells loosely embedded in ground substance and collagen fibrils constitute the iris stroma. The sphincter muscle (SM) lies just within the pupillary border, measuring approximately 1 mm in width (Fig. 2-5). Loosely arranged stromal cells and collagen fibrils form the anterior border layer of the iris (Fig. 2-6). This creates the posterior boundary of the anterior chamber, its numerous crypts allowing free access of aqueous humor to the iris stroma.

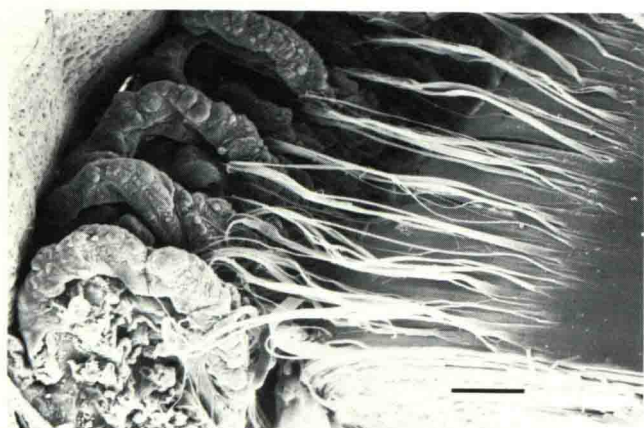
A single layer of corneal endothelial cells lines the dome of the anterior chamber. These hexagonal cells possess tight junctions and numerous pump sites that actively transport sodium and water into the anterior chamber to maintain corneal clarity (Chapter 8).



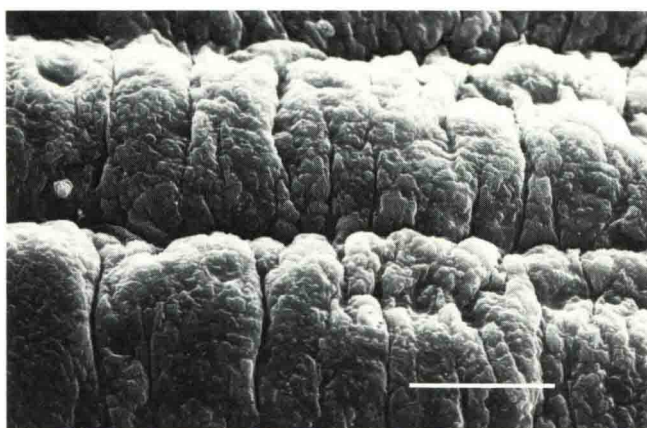
2-1 Zonules and condensed anterior vitreous face. Bar = 100 μ .



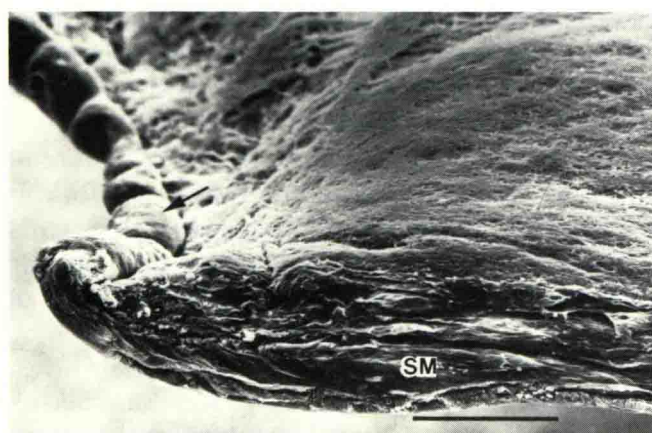
2-2 The ciliary body. * = vitreous base. Bar = 1 mm



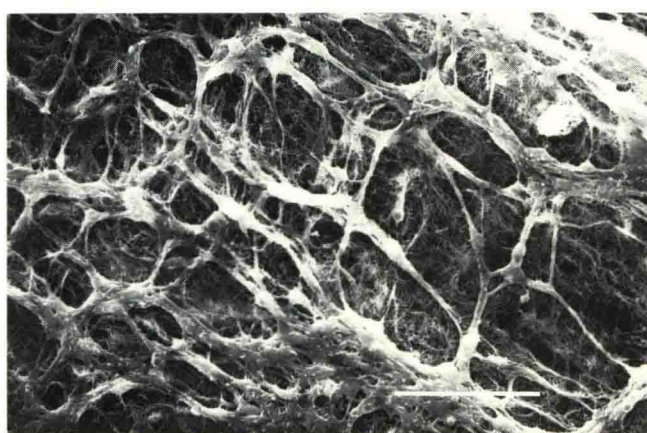
2-3 Zonule attachments to pars plicata and lens. Bar = 250 μ .



2-4 Iris pigment epithelium. Bar = 50 μ .



2-5 Iris cross section. Arrow = pupillary ruff. Bar = 250 μ .



2-6 Iris anterior border layer. Bar = 50 μ .