

# Retinal and Vitreoretinal Diseases and Surgery

Samuel Boyd, MD • Rafael Cortez, MD • Nelson Sabates, MD



**JAYPEE - HIGHLIGHTS**  
MEDICAL PUBLISHERS, INC.

# Retinal and Vitreoretinal Diseases and Surgery

Samuel Boyd, MD  
Rafael Cortez, MD  
Nelson Sabates, MD



www.jaypeehighlights.com



An Editorial Branch of Jaypee Brothers Medical Publishers (P) Ltd.

#### PRODUCTION

**Production Director:** Kayra Mejia  
**Chief, Digital Composition:** Laura Duran  
**Art Director:** Eduardo Chandeck  
**International Communications:** Joyce Ortega

#### MARKETING

**Customer Service:** Miroslava Bonilla  
**Sales Manager:** Tomas Martinez

© Copyright, English Edition, 2010 for Jaypee - Highlights Medical Publishers, Inc.

All rights reserved and protected by Copyright. No part of this publication may be reproduced, stored in retrieval system or transmitted in any form by any means, photocopying, mechanical, recording or otherwise, nor the illustrations copied, modified or utilized for projection without the prior, written permission of the copyright owner.

Due to the fact that this book will reach ophthalmologists from different countries with different training, cultures and backgrounds, the procedures and practices described in this book should be implemented in a manner consistent with the professional standards set for the circumstances that apply in each specific situation. Every effort has been made to confirm the accuracy of the information presented and to correctly relate generally accepted practices. The authors, editors, and publisher cannot accept responsibility for errors or exclusions or for the outcome of the application of the material presented herein. There is no expressed or implied warranty for this book or information imparted by it.

Any review or mention of specific companies or products is not intended as an endorsement by the authors or the publisher.

Boyd, Samuel, MD; Cortez, Rafael, MD.; Sabates, Nelson, MD.

**Retinal and Vitreoretinal Diseases and Surgery**

ISBN: 978-9962-678-23-6

Published for: Jaypee - Highlights Medical Publishers, Inc.  
City of Knowledge  
International Technopark, Bldg. 237  
Gaillard Highway, Clayton  
Panama Rep. of Panama

Phone: (507) 301-0496 / 97 - Fax: (507) 301-0499

E-mail: [cservice@jphmedical.com](mailto:cservice@jphmedical.com)

Worldwide Web: [www.jphmedical.com](http://www.jphmedical.com)

www.jaypee.com



## **EDITORS**

### **SAMUEL BOYD, MD**

Director, Laser Section, and Associate Director, Retina and Vitreous  
Department, Clinica Boyd-  
Ophthalmology Center  
Panama

### **RAFAEL CORTEZ, MD**

Medical Director and Founder  
Centro de Cirugía Oftalmológica  
(CECOF),  
Caracas, Venezuela

### **NELSON SABATES, MD**

Professor and Chairman,  
Department of Ophthalmology,  
University of Missouri  
Eye Foundation of Kansas City  
Kansas City, Missouri, USA



## ACKNOWLEDGEMENTS

After having devoted great efforts and hard work to this major project, we wish to express our profound recognition and gratitude to the people that have had a positive impact in our personal and professional life.

We are, of course, very much indebted with our dear *Prof. Benjamin F. Boyd, MD*, for his strong support and valuable advice, who encouraged us to overcome problems with courage and to seek major goals with excellent results.

To our wives, *Maruchi, Dinorah and Rachel*, for their unconditional patience, love and understanding.

We are very much indebted to the Contributing Authors. Without their combined efforts and valuable collaboration, this publication would have been impossible.

We also wish to thank our very special staff at **JAYPEE HIGHLIGHTS**, especially *Kayra Mejia, Eduardo Chandeck, Laura Duran* and *Joyce Ortega* for their dedication and enthusiasm in the creation of all our publications. To *Javier Montero, MD* from Spain, whose participation as Editor and Translator of the Spanish version of this Volume has also been vital to the success of this project.

To all the readers of **JAYPEE HIGHLIGHTS MEDICAL PUBLISHERS**, whose support and interest for what we write is the main stimulus for the major commitment we have made to continuously serve ophthalmologist all over the world.

To *Mr. Jitendar P. Vij* for his perseverance and support.

www.jaypee.com



## PREFACE

It is a pleasure to introduce *Retinal and Vitreoretinal Diseases and Surgery* by Samuel Boyd, MD, Rafael Cortez, MD and Nelson Sabates, MD. This volume contains chapters written by global leaders in the field, and has both breadth and depth in covering clinically relevant and important topics. In forty-one chapters the editors have selected authors with particular areas of expertise, and areas of interest not only to vitreoretinal surgeons, but also to medical retina specialists, comprehensivists and trainees.

With 718 pages of content and 1000 color images and illustrations this book provides not only the fundamentals but the focus needed for the clinician to care for patients with both straightforward and complex retinal disease.

*Joel S. Schuman, MD.*  
*Professor and Chairman,*  
*Department of Ophthalmology*  
*University of Pittsburgh School of Medicine.*  
*Director, UPMC Eye Center Professor of Bioengineering*  
*Pittsburgh, PA*



## CONTRIBUTING AUTHORS

***Carlos A. Abdala, MD***

Retina Specialist,  
Ophthalmology Center  
Unidad Laser del Atlantico  
Barranquilla, Colombia

***Pedro Amat-Peral, MD***

Alicante Institute of Ophthalmology,  
VISSUM, Retina Unit,  
Alicante, Spain

***J. Fernando Arevalo, MD, FACS***

Director,  
Clinica Oftalmologica Centro Caracas  
The Arevalo-Coutinho Foundation for  
Research in Ophthalmology  
Caracas, Venezuela

***Enrique Ariza Camacho, MD***

Unidad Oftalmológica del Valle  
Mexico D.F., Mexico

***George K. Asdourian, MD***

Professor of Ophthalmology  
University of Massachusetts,  
School of Medicine  
Worcester, Massachusetts

***Maria H. Berrocal, MD***

Berrocal and Associates  
Assistant Professor  
University of Puerto Rico  
San Juan, Puerto Rico

***Samuel Boyd, MD***

Director, Laser Section, and Associate  
Director, Retina and Vitreous  
Department, Clinica Boyd-  
Ophthalmology Center  
Panama

***Rosario Brancato, MD***

Professor and Chairman  
Department of Ophthalmology and  
Visual Sciences  
University Hospital San Raffaele  
Milano, Italy

***Dhiren Bujarborua, MD***

Director, Pragjyoti Eye Care and  
Research Centre,  
Guwahati, India

***Jorge I. Calzada, MD***

Vitreo-Retinal Surgery,  
Chief of Retinopathy of Prematurity  
Service, Charles Retina Institute.  
Assistant Clinical Professor  
Hamilton Eye Institute  
University of Tennessee  
Memphis, TN, USA

***Stanley Chang, MD***

Columbia University of  
Physicians and Surgeons  
Department Ophthalmology  
New York, NY, USA

**Steve Charles, MD**

Director,  
Charles Retina Institute  
Memphis, Tennessee, USA

**Borja Corcóstegui, MD.**

Professor of Ophthalmology.  
Instituto de Microcirugía Ocular (IMO).  
Barcelona, Spain

**Rafael T. Cortez, MD**

Medical Director and Founder  
Centro de Cirugía Oftalmológica  
(CECOF),  
Caracas, Venezuela

**Emanuele Di Bartolo, MD**

Ospedale Santa Chiara di Pisa  
Italy

**Francesco Faraldi, MD**

Ospedale Oftalmico di Torino  
Italy

**Marta Fernández-Muñoz, MD, PhD**

Pío del Río Hortega University  
Hospital, Ophthalmology Unit,  
Valladolid, Spain

**Anibal Martin Folgar, MD**

Laboratory of Investigations in  
Ophthalmology and Visual Sciences  
LIOCIV  
Department of Pathology  
University of Buenos Aires  
Buenos Aires, Argentina

**Gerardo García-Aguirre, MD**

Retina Service  
Hospital "Dr. Luis Sánchez Bulnes"  
Asociación para Evitar la Ceguera  
Mexico, DF, Mexico.  
Clinical Professor of Ophthalmology  
School of Medicine - Tecnológico de  
Monterrey  
Mexico, DF, Mexico

**Justus G. Garweg, MD**

Berner Augenklinik am Lindenhofspital  
Swiss Eye Institute,  
University of Bern,  
Bern, Switzerland

**Gian Paolo Giuliari, MD.**

Princess Margaret Hospital  
Ocular Oncology Department  
Toronto, Ontario  
Canada

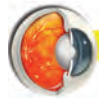
**Federico A. Graue-Wiechers, MD**

Chief, Vitreoretinal Department  
Instituto de Oftalmología Conde de  
Valenciana  
Mexico, D.F.

**Prof. Patrick C.P. Ho, MD**

Clinical Professor of Ophthalmology,  
Chinese Academy of Traditional  
Medicine and Eye Hospital  
Beijing, China  
Hong Kong's former Secretary for  
Home Affairs,  
Regional Chair Person for the  
International Association  
for the Prevention of Blindness  
Beijing, China




***Shalesh Kaushal, MD., Ph.D.***

Associate Professor and Chairman  
Department of Ophthalmology  
University of Massachusetts Memorial  
Medical Center  
Worcester, Massachusetts, USA

***Ferenc Kuhn, MD., PhD***

President, American Society of  
Ocular Trauma  
Executive Vice President, International  
Society of Ocular Trauma  
Associate Professor of Clinical  
Ophthalmology,  
University of Alabama at Birmingham.  
Associate Director of Clinical Research,  
Helen Keller Foundation for Research  
and Education  
Birmingham, Alabama, USA

***Madhavi Kurli, MD***

The New York Eye and Ear Infirmary,  
New York, USA

***Ketan Laud, MD***

New York University School of  
Medicine  
New York, New York, USA

***Janice C. Law, MD***

Assistant Professor  
Vitreoretinal Surgery and Diseases  
Department of Ophthalmology  
and Visual Sciences  
Vanderbilt Eye Institute  
Nashville, Tennessee, USA

***Konstantinidis Lazaros, MD***

Hôpital Ophtalmique Jules Gonin,  
University of Lausanne,  
Switzerland

***Hilel Lewis, MD***

Department of Ophthalmology,  
Edward S. Harkness Eye Institute,  
Columbia University College of  
Physicians and Surgeons,  
New York, New York, USA

***Jeffrey K. Luttrull, MD***

Director  
Retina Diagnostic Laboratory  
Ventura County Retina Vitreous  
Medical Group  
Ventura, California

***Sachin Mehta, MD***

Department of Ophthalmology and  
Visual Sciences,  
Vanderbilt Eye Institute,  
Vanderbilt University School of  
Medicine,  
Nashville, Tennessee, USA

***Javier A. Montero, MD, PhD***

Pío del Río Hortega University  
Hospital, Ophthalmology Unit,  
Valladolid, Spain.  
Alicante Institute of Ophthalmology,  
VISSUM, Retina Unit,  
Alicante, Spain

***Virgilio Morales-Cantón, MD***

Chief, Retina Service  
Asociación para Evitar la Ceguera  
en Mexico  
Mexico DF, Mexico

**Robert Morris, MD**

President, International Society of  
Ocular Trauma  
Founder, United States Eye Injury  
Registry  
President, Helen Keller Foundation  
Associate Professor of Clinical  
Ophthalmology,  
University of Alabama at Birmingham  
Birmingham, Alabama, USA

**Darius Moshfeghi, MD**

Associate Professor of Ophthalmology  
Stanford University  
Palo Alto, California, USA

**Manish Nagpal, MD**

Retina Foundation  
Gujarat, India

**P. N. Nagpal, MD**

Director,  
RETINA FOUNDATION  
Aso-Palov Eye Hospital  
Ahmedabad, India

**Yoshihide Nakai, MD**

Tokai Eye Clinic  
Tokai University School of Medicine  
Hadokoro-cho Tsu Mie, Japan

**Shunsuke Osawa, MD**

Okanami General Hospital,  
Iga, Japan

**Anil Patil, MD**

Vitreo Retinal Consultant,  
Retina Foundation  
Ahmedabad, India

**David E. Pelayes, MD., PhD.**

Professor of Ophthalmology,  
University of Buenos Aires.  
Coordinator,  
Laboratory of Investigations in  
Ophthalmology and Visual Sciences  
LIOCIV  
University of Buenos Aires  
Buenos Aires, Argentina

**Ana T. Peralta, MD**

Ophthalmologist,  
Ophthalmology Center  
Unidad Laser del Atlantico  
Barranquilla, Colombia

**George B. Peters III, MD., M.B.A.**

Assistant Professor of Ophthalmology  
University of Massachusetts, School of  
Medicine  
Worcester, Massachusetts, USA

**Gholam Peyman, MD**

Professor of Ophthalmology  
Co-Director of Vitreo-Retinal Surgery  
Tulane University Health Sciences  
Center, School of Medicine  
Department of Ophthalmology  
New Orleans, Louisiana, USA

**L. Pierro, MD**

Department of Ophthalmology  
and Visual Sciences  
University Hospital San Raffaele  
Milano, Italy



**Hugo Quiroz-Mercado, MD**  
Chief, Retina Service  
Asociacion Para Evitar la Ceguera in  
Mexico, (APEC),  
Chief, Experimental Surgery Laboratory,  
APEC,  
Professor of Ophthalmology  
Universidad Nacional de Autonoma  
de Mexico (UNAM)  
Mexico, DF., Mexico

**Maria Maddalena Rabbione, MD**  
Ospedale Oftalmico di Torino  
Italy

**Franco M. Recchia, MD**  
Department of Ophthalmology and Vi-  
sual Sciences, Vanderbilt Eye Institute,  
Vanderbilt University School of  
Medicine,  
Nashville, Tennessee, USA

**Carl D. Regillo, MD, FACS**  
Director, Clinical Retina Research  
Wills Eye Institute  
Professor of Ophthalmology  
Thomas Jefferson University  
Philadelphia, PA, USA

**Stanislao Rizzo, MD**  
Chair U.O.Chirurgia Oftalmica  
Azienda Ospedaliero Universitaria  
Pisana  
Pisa, Italy

**Elena Rodríguez-Neila MD**  
Instituto de Microcirugía Ocular (IMO).  
Barcelona, Spain

**Richard B. Rosen, MD, FACS, FASRS.,  
CRA.**  
Vice Chair and Surgeon Director  
Director of Ophthalmology Research  
New York Eye and Ear Infirmary  
Professor of Ophthalmology  
New York Medical College  
New York, New York, USA

**Kamolika Roy, MD**  
Department of Ophthalmology,  
University of Massachusetts Medical  
School, Department of Ophthalmology,  
Worcester, MA, USA

**Jose M. Ruiz-Moreno, MD, PhD**  
Alicante Institute of Ophthalmology,  
VISSUM, Retina Unit,  
Alicante, Spain  
Albacete Medical School,  
Castilla La Mancha University,  
Spain

**Felix Sabates, MD**  
Professor,  
Department of Ophthalmology,  
University of Missouri  
Eye Foundation of Kansas City  
Kansas City, Missouri, USA

**Nelson Sabates, MD**  
Professor and Chairman,  
Department of Ophthalmology,  
University of Missouri  
Eye Foundation of Kansas City  
Kansas City, Missouri, USA

www.elsevier.com/locate/jcr



**Natalia Saldaña-Verduzco, MD**  
Autonomous University of Mexico  
Vitreous Retinal Department,  
Institute of Ophthalmology  
Fundación Conde de Valenciana  
Mexico, D.F.

**Jason S. Slakter, MD**  
Clinical Professor of Ophthalmology  
New York University School of  
Medicine;  
Surgeon Director,  
Manhattan Eye, Ear & Throat Hospital  
New York, New York, USA

**Marc Sporn, MD**  
Instructor of Ophthalmology  
Wills Eye Institute  
Thomas Jefferson University  
Philadelphia, PA, USA

**Linda Stein, MS**  
Science Writer  
Department of Ophthalmology  
University of Massachusetts,  
School of Medicine  
Worcester, Massachusetts, USA

**Paul Sternberg, Jr., MD**  
Professor and Chairman  
Department of Ophthalmology  
and Visual Sciences,  
Vanderbilt Eye Institute, Vanderbilt  
University School of Medicine,  
Nashville, Tennessee, USA

**Savak Teymoorian, MD., MBA**  
Resident Physician,  
Department of Ophthalmology,  
University of Missouri  
Eye Foundation of Kansas City  
Kansas City, Missouri, USA

**Juan Verdaguer T., MD**  
Professor of Ophthalmology,  
University of Chile and  
University of Los Andes.  
Academic Director,  
Fundación Oftalmológica Los Andes  
Santiago, Chile

**Juan Ignacio Verdaguer D., MD**  
Associate Professor of Ophthalmology,  
University of Los Andes  
Santiago, Chile

**C. Douglas Witherspoon, MD., FACS.**  
Professor of Ophthalmology,  
University of Alabama  
Birmingham, Alabama, USA

**Lihteh Wu, MD**  
Instituto de Cirugía Ocular  
San José, Costa Rica

**Jiong Yan, MD**  
Assistant Professor  
Vitreous-Retina Division  
Emory Eye Center  
Atlanta, Georgia, USA

**Jorge O. Zarate, MD., PhD.**  
Professor of Pathology  
University of Buenos Aires  
Director of the Laboratory of  
Investigations in Ophthalmology  
and Visual Sciences LIOCiV  
Department of Pathology  
University of Buenos Aires  
Buenos Aires, Argentina

**Leonidas Zografos, MD**  
Hôpital Ophtalmique Jules Gonin,  
University of Lausanne,  
Switzerland



## CONTENTS

### SECTION 1: DIAGNOSTIC SYSTEMS IN RETINA

<b>Chapter 1: The Normal Retina</b> .....	3
<i>Samuel Boyd, MD</i>	
<b>Chapter 2: Fluorescein Angiography</b> .....	11
<i>Samuel Boyd, MD</i>	
<b>Chapter 3: Introduction to Optical Coherence Tomography</b> .....	27
<i>Rosario Brancato, MD</i>	
<i>L. Pierro, MD</i>	
<b>Chapter 4: Optical Systems for Ocular Diagnosis and Vitreoretinal Surgery</b> .....	39
<i>Samuel Boyd, MD</i>	
<b>Chapter 5: Wide Angle Viewing Systems for Vitreoretinal Surgery</b> .....	53
<i>Shunsuke Osawa, MD</i>	
<i>Yoshihide Nakai, MD</i>	

### SECTION 2: LASER PHOTOCOAGULATION

<b>Chapter 6: Practical Aspects of Laser Photocoagulation</b> .....	69
<i>Nelson Sabates, MD</i>	
<i>Savak Teymoorian, MD, MBA,</i>	
<i>Felix Sabates, MD</i>	
<b>Chapter 7: Subthreshold Retinal Photocoagulation for Diabetic Retinopathy</b> .....	85
<i>Jeffrey K. Luttrull, MD</i>	



<b>Chapter 8: Laser Treatment for Retinal Holes, Tears and Peripheral Degenerations.....</b>	<b>111</b>
<i>Federico A. Graue-Wiechers, MD</i>	
<i>Natalia Saldaña-Verduzco, MD</i>	

### SECTION 3: ESSENTIAL ELEMENTS IN VITREORETINAL SURGERY

<b>Chapter 9: Indications of Intraocular Gases in Retinal Surgery.....</b>	<b>125</b>
<i>Gholam Peyman, MD</i>	
<i>Darius Moshfeghi, MD</i>	

<b>Chapter 10: Application of Perfluorocarbon Liquids in Vitreoretinal Surgery.....</b>	<b>141</b>
<i>Stanley Chang, MD</i>	

### SECTION 4: RETINAL VASCULAR DISEASES

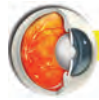
<b>Chapter 11: Classification and Management of Diabetic Retinopathy.....</b>	<b>167</b>
<i>Juan Verdaguer T., MD</i>	
<i>Juan Ignacio Verdaguer D., MD</i>	

<b>Chapter 12: Vitrectomy for Diabetic Retinopathy.....</b>	<b>193</b>
<i>Jorge I. Calzada, MD</i>	

<b>Chapter 13: Pars Plana Vitrectomy in the Management of Diabetic Macular Edema.....</b>	<b>209</b>
<i>Maria H. Berrocal, MD</i>	

<b>Chapter 14: The Vitreous in Diabetes.....</b>	<b>219</b>
<i>Prof. Patrick C. P. Ho, MD</i>	

<b>Chapter 15: Branch Retinal Vein Occlusion.....</b>	<b>227</b>
<i>Lihteh Wu, MD</i>	



- Chapter 16: Central Retinal Vein Occlusion**.....241  
*Lihteh Wu, MD*
- Chapter 17: Management of Active Retinopathy of Prematurity**.....255  
*Carlos A. Abdala, MD*  
*Ana T. Peralta, MD*

### SECTION 5: MACULAR DISEASES

- Chapter 18: Evaluation of Age-Related Macular Degeneration**.....267  
*Ketan Laud, MD*  
*Jason S. Slakter, MD*
- Chapter 19: Highlights in the Management of Age-Related Macular Degeneration**.....287  
*Stanislao Rizzo, MD*  
*Francesco Faraldi, MD*  
*Emanuele Di Bartolo, MD*  
*Maria Maddalena Rabbione, MD*
- Chapter 20: Central Serous Chorioretinopathy**.....309  
*Pran N. Nagpal, MD*  
*Dhiren Bujarborua, MD*  
*Anil Patil, MD*
- Chapter 21: Cystoid Macular Edema**.....329  
*Federico Graue Wiechers, MD*  
*Enrique Ariza Camacho, MD*
- Chapter 22: Traction Maculopathies: Vitreomacular Traction Syndrome, Cellophane Maculopathy, Macular Pucker, Macular Hole**.....345  
*Ferenc Kuhn, MD, Ph.D.*  
*Robert Morris, MD*  
*C. Douglas Witherspoon, MD, FACS*



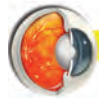
## SECTION 6: RETINAL DETACHMENT SURGERY

- Chapter 23: Evaluation and Management of Retinal Detachment**.....369  
*Rafael T. Cortez, MD*  
*Gian Paolo Giuliani, MD*
- Chapter 24: Management of Giant Retinal Tears**.....399  
*Sachin Mehta, MD*  
*Franco M. Recchia, MD*  
*Paul Sternberg, Jr., MD*
- Chapter 25: Proliferative Vitreoretinopathy  
 Clinical, Pathophysiological and Therapeutic Considerations**.....413  
*Justus G. Garweg, MD*

## SECTION 7: VITRECTOMY TECHNIQUES AND TECHNOLOGY

- Chapter 26: Anterior Vitrectomy**.....443  
*Samuel Boyd, MD*
- Chapter 27: Pars Plana Lensectomy**.....451  
*Samuel Boyd, MD*
- Chapter 28: Retinectomies and Retinotomies**.....459  
*Janice C. Law, MD*  
*Jiong Yan, MD*  
*Paul Sternberg Jr., MD*





**SECTION 8:  
MANAGEMENT OF COMPLEX CASES**

<b>Chapter 29: Dislocated IOLs and Crystalline Lens.....</b>	<b>475</b>
<i>Samuel Boyd, MD</i>	
<b>Chapter 30: Retinal Complications After Refractive Surgery.....</b>	<b>491</b>
<i>J. Fernando Arevalo, MD, FACS</i>	
<b>Chapter 31: Management of Intraocular Hemorrhage and Other Complications.....</b>	<b>507</b>
<i>George B. Peters III, MD., M.B.A.</i>	
<i>George K. Asdourian, MD.</i>	
<i>Linda Stein, MS.</i>	
<i>Shalesh Kaushal, MD., Ph.D.</i>	
<b>Chapter 32: Suprachoroidal Hemorrhage.....</b>	<b>521</b>
<i>Madhavi Kurli, MD</i>	
<i>Richard Rosen, MD</i>	
<b>Chapter 33: Management of Traumatic Subretinal and/or Suprachoroidal Hemorrhage.....</b>	<b>529</b>
<i>Gerardo García-Aguirre, MD</i>	
<i>Virgilio Morales-Cantón, MD</i>	
<i>Hugo Quiroz-Mercado, MD</i>	
<b>Chapter 34: Surgical Management of Proliferative Vitreoretinopathy.....</b>	<b>559</b>
<i>Marc J. Spirn, MD</i>	
<i>Carl Regillo, MD</i>	
<i>Hilel Lewis, MD</i>	
<b>Chapter 35: Vitreoretinal Surgery for Epiretinal Membranes.....</b>	<b>571</b>
<i>Javier A. Montero, MD, PhD.,</i>	
<i>Jose M. Ruiz-Moreno, MD, PhD.,</i>	
<i>Marta Fernández-Muñoz, MD, PhD.,</i>	
<i>Pedro Amat-Peral, MD</i>	



<b>Chapter 36: Fine Needle Aspiration Biopsy in Intraocular Tumors.....</b>	<b>589</b>
<i>David E. Pelayes, MD, PhD</i>	
<i>Anibal Martin Folgar, MD</i>	
<i>Jorge O. Zarate, MD, PhD</i>	

<b>Chapter 37: Management of Intraocular Foreign Bodies.....</b>	<b>599</b>
<i>Elena Rodríguez-Neila, MD</i>	
<i>Borja Corcóstegui, MD</i>	

<b>Chapter 38: Endophthalmitis.....</b>	<b>609</b>
<i>Manish Nagpal, MD</i>	
<i>Anil Patil, MD</i>	

#### SECTION 9: LEADING ACHIEVEMENTS IN RETINA

<b>Chapter 39: Nutrition in Retinal Diseases.....</b>	<b>629</b>
<i>Konstantinidis Lazaros, MD.,</i>	
<i>Leonidas Zografos, MD</i>	

<b>Chapter 40: Advances in Vitreoretinal Surgery.....</b>	<b>655</b>
<i>Steve Charles, MD</i>	

<b>Chapter 41: Ocular Gene Therapy: An Evaluation of rAAV-mediated Gene Therapy Interventions for the Treatment of Ocular Disease.....</b>	<b>663</b>
<i>Kamolika Roy, MD</i>	
<i>Linda Stein, MD</i>	
<i>Shalesh Kaushal, MD</i>	

<b>Index.....</b>	<b>691</b>
-------------------	------------



# Section 1

## Diagnostic Systems in Retina

www.munich.de



# 1

## *The Normal Retina*

SAMUEL BOYD, MD

In vertebrate embryonic development, the retina and the optic nerve originate as outgrowths of the developing brain, so the retina is considered part of the central nervous system (CNS). It is the only part of the CNS that can be imaged directly.

The retina ranges in thickness from about 100-500  $\mu\text{m}$ . It is a composite of numerous cellular and synaptic layers which can be grossly split into an outer epithelial layer (referred to as the retinal epithelium or retinal pigment epithelium) and an inner sensory layer (referred to as the sensory retina or neuroretina). The retina is one of the most metabolically active tissues in the body. Its major function is to convert light energy into chemical and electrical energy so that vision can occur (if a functional brain is present).

The retina is a complex, layered structure with several layers of neurons intercon-

nected by synapses. The only neurons that are directly sensitive to light are the photoreceptor cells. These are mainly of two types: the rods and cones. Rods function mainly in dim light, while cones support daytime vision. A third, much rarer type of photoreceptor, the photosensitive ganglion cell, is important for reflexive responses to bright daylight.

Neural signals from the rods and cones undergo complex processing by other neurons of the retina. The output takes the form of action potentials in retinal ganglion cells whose axons form the optic nerve. Several important features of visual perception can be traced to the retinal encoding and processing of light.

### **Functional Anatomy**

The vital structures of the retina are conveniently arranged for us in distinct

www.boydmd.com



layers. These are clearly shown in Figure 1. The order of retinal layers starting from outer to inner layers (that is, from choroid to vitreous) is as follows: Retinal pigment epithelium, Photoreceptor outer segments, Photoreceptor inner segments, Outer or external limiting membrane, Outer or external nuclear layer, Outer or external plexiform layer, Inner nuclear layer, Inner plexiform layer, Ganglion cell layer, Nerve fiber layer, Internal limiting membrane.

The outermost layers next to the choriocapillaris are Bruch's membrane and the retinal pigment epithelium (RPE). Bruch's membrane allows passage of nutrients from the choriocapillaris to the retina, while acting as a barrier to invasion of the retina by its vessels. The RPE are supporting cells for the neural portion of the retina and are important for photopigment regeneration. The RPE is dark with melanin, which decreases light scatter within the eye. The rod and cone layer contains the outer and inner segments of the rods and cones photoreceptors. The outer limiting membrane orders these from the outer nuclear layer (ONL) - the cell bodies of rods and cones. Next, we see the outer plexiform layer (OPL), with the rods and cones axons horizontal cell dendrites, and bipolar dendrites. The inner nuclear layer (INL) contains the nuclei of the horizontal and bipolar cells. The inner plexiform layer (IPL) neatly contains the axons of the bipolar cells (the amacrine), and the dendrites of the ganglion cells. The layer of ganglion cells (GCL), is covered by the layer of the optic nerve fibers - fibers from ganglion cells traversing the retina to leave the eyeball at

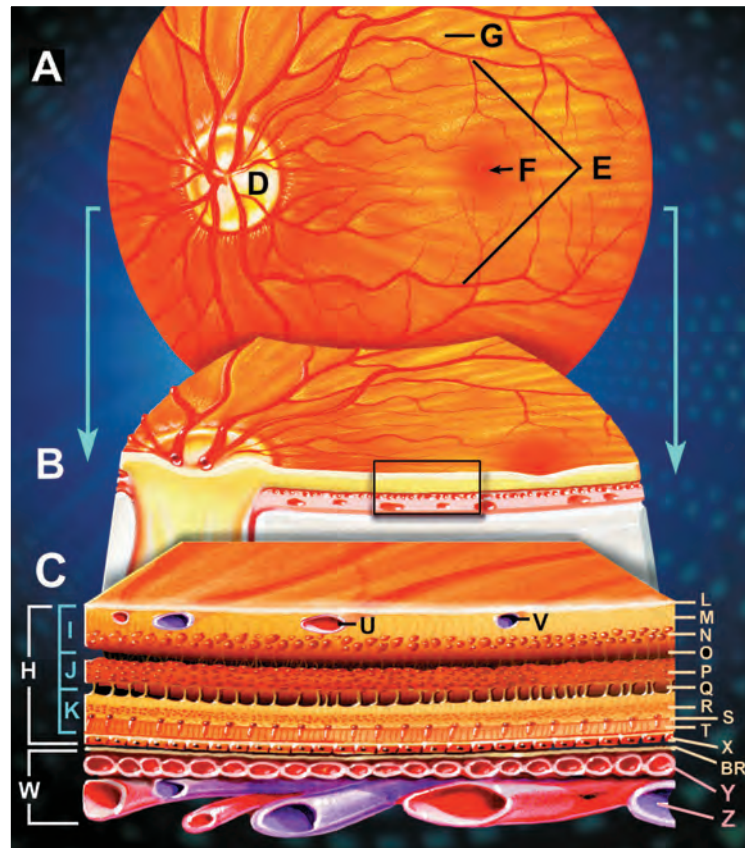
the optic disk. Finally, the internal limiting membrane forms the border between the retina and the vitreous.

There are two distinct vascular systems in the ocular fundus: retinal and choroidal. The retinal vasculature is identified in Figure 1C as (U) and (V). The choroidal vasculature is identified in Figure 1C as W. Between them lies the retinal pigment epithelium (RPE), Fig. 1-C-X, an opaque monolayer of cells anterior to the choroid that normally largely obscures its vasculature from ophthalmoscopic view. Pathologic alteration of the structure and pigmentation of the RPE affects the pattern of choroidal fluorescence perceptible during angiographic studies. Familiarity with the anatomy and interaction of these anatomic layers is the key to accurate interpretation of fluorescein angiograms, an examination which is vital to the diagnosis of retinal diseases.

The photoreceptor cells (rods and cones), Figure 1C-K and T, are supplied with nutrients from the choroid (Figure 1C-W) through the retinal pigment epithelium (Figure 1C-X).

### *Choroid*

The choroid is composed of connective tissue and vessels that nourish the RPE (Figure 1C-X) and outer retina (Figure 1C-H). The inner layer is the choriocapillaris (Figure 1C-Y). The choroidal circulation is completely independent of the retinal circulation. It is supplied by the long and short posterior and recurrent anterior ciliary arteries and is



**Figure 1:** Anatomy of the Normal Retina and Choroid. Anatomy of the normal retina and choroid is displayed. (A) The posterior fundus view shows optic nerve (D), retinal arteries and veins of the parafoveal arcade (E), fovea (F), and visible choroidal vasculature (G) beneath the normal retina. From the oblique cross section (B), an area of the retina and choroid is magnified in (C) to show the direct relationship between clinical ophthalmoscopic fundus view above and its corresponding cellular pathology. Overall layers of the retina (H) include ganglion cell layer (I), layer of intermediary neurons (J), and photoreceptor layer (K). Detailed elements of the retina include inner limiting membrane (L), nerve fiber layer (M), ganglion cells (N), inner plexiform layer (O), inner nuclear layer (P), outer plexiform layer (Q), receptor nuclear layer (R), outer limiting membrane (S), and rods and cones (T)(photoreceptor cells). Retinal arteries (U) and retinal veins (V) run through the nerve fiber layer (M) beneath the inner limiting membrane (L), supplying all cells of the neural retina, except the photoreceptor cells. The photoreceptor cells are supplied by active transport from the choroid (W) through the retinal pigment epithelium (X). The choroid consists of the choriocapillaris (Y) supplied by the larger choroidal vessels (Z). Bruch's membrane (BR) lies between the pigment epithelial cell layer (X) and the choriocapillaris (Y). (Art from Jaypee-Highlights Medical Publishers).



drained by the four mid-peripheral vortex veins (Figure 1C-W). The choroidal capillary system, the choriocapillaris, is located innermost (Figure 1C-Y), its basement membrane forming the outer layer of Bruch's membrane. It has a lobular pattern, with central arterioles feeding capillary beds drained by peripheral venules.

The walls of the choroidal capillaries are extremely thin, with multiple fenestrations permitting passive fluid transport from the capillary lumen to the surrounding extravascular space. During fluorescein angiography studies, the fluorescein molecule is sufficiently small to pass readily and rapidly out of the choriocapillaris, but it does not pass through the overlying retinal pigment epithelium (Figure 1C-X).

### *Retinal Pigment Epithelium*

The retinal pigment epithelium (RPE) (Figure 1C-X), is a single layer of pigmented cuboidal cells which are attached to the photoreceptors (Figure 1C-K-T) and whose basal portions lie on Bruch's membrane (Figure 1C-BR). It serves important metabolic functions for the overlying photoreceptors (Figure 1C-K-T) and forms a structural barrier between the sensory retina and choroid that, under normal circumstances, fluorescein dye will not cross.

Because of the presence of pigmented cells, the RPE serves as an optical barrier. Pigment density is not uniform across the whole retina. It is more intense in the macular region, where pigment epithelial cells are tall, columnar, and densely packed, and least in regions anterior to the equator, where these cells are flatter and have a sparsity of pigment granules.

### *Retina*

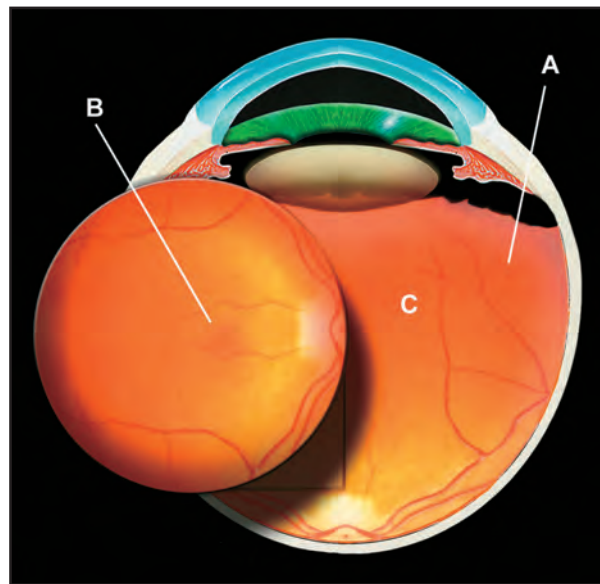
The most important characteristics of the retina are its functional architecture and its light transmission and absorption properties. The retina is a thin transparent tissue perfused by vessels from the central retinal artery and, in about 30% of eyes, by an additional cilioretinal artery. The cilioretinal artery, when present, fills at the same time as the choroid. Unlike the choroid, the retinal capillaries are not fenestrated, and there is virtually no extracellular space between the densely packed retinal cells. As a result, the retinal vasculature constitutes a "closed system" that stands out in stark optical contrast to the surrounding tissue, especially in fluorescein angiography.

The outer nuclear and plexiform retinal layers of the retina (Figure 1C-Q) have a high concentration of yellow xanthophyll pigment, particularly in the macula, which is



about two disc diameters in size surrounding (but not including) the fovea (Figure 2). The fovea centralis, which lies at 3.5 mm lateral to the optic disc, is specialized for fine visual perception. In the fovea, the cells are all cones. The axons of the receptor cells pass directly to the inner side of the outer plexiform layer, where they connect with dendrites of horizontal and bipolar cells, extending from the inner nuclear layer. Selective absorption of blue light by this pigment produces a relatively darker macular background in fluorescein angiography.

The retina receives its blood supply from two sources: the choriocapillaris and the central retinal artery. The choriocapillaris is a layer of capillaries intimately attached to the outer surface of Bruch's membrane. The choriocapillaris supplies the outer third of the retina, including the outer plexiform and outer nuclear layers, the photoreceptors, the pigment epithelium and all of the fovea. The remaining inner two thirds of the retina is supplied by branches of the central retinal artery.



**Figure 2:** Schematic Representation of the Retina and Related Structures. The retina terminates anteriorly at the ora serrata approximately 7-8 mm posterior to the corneoscleral limbus (A). The macula is clinically an area of altered light reflex which lies 3.5 mm lateral and 1 mm inferior to the edge of the optic nerve (B). The vitreous is a gel of approximately 4.3 ml and is attached anteriorly to the posterior lens capsule, posteriorly to the peripapillary zone and extends centrally to the attachment with the pars plana and anterior retina (C). (Art from Jaypee-Highlights Medical Publishers).