

**PHYSIOLOGY OF  
THE EYE  
CLINICAL  
APPLICATION**

# **PHYSIOLOGY OF THE EYE**

## **Clinical Application**



# PHYSIOLOGY OF THE EYE

## CLINICAL APPLICATION

by

**FRANCIS HEED ADLER, M.A., M.D., F.A.C.S.**

William F. Norris and George E. de Schweinitz Professor of  
Ophthalmology, School of Medicine, University of  
Pennsylvania, and Consulting Surgeon,  
Wills Hospital, Philadelphia.

*With 329 Illustrations  
Including 3 in Colour*

LONDON  
HENRY KIMPTON  
1953

**COPYRIGHT 1950, 1953, BY THE C. V. MOSBY COMPANY**

*(All rights reserved)*

**Printed in the  
United States of America**

This book is dedicated to the three men  
who inspired in me an enduring  
interest in Physiology

MERKEL H. JACOBS

Who introduced me to General Physiology

H. CUTHBERT BAZETT

Who gave me the opportunity to work in his laboratory

ALFRED NEWTON RICHARDS

Who taught me to be critical of my own work



## **PREFACE TO SECOND EDITION**

---

The main plan and purpose of the book continues to be the same, namely, to provide a book "which offers to the student and the practicing ophthalmologist the recent findings of the physiology of the eye gleaned from the experimental laboratory," and to relate these facts wherever possible with clinical concepts.

A considerable amount of new material has been added, particularly in the sections on the cornea, aqueous humor, and vitreous. The chapter on visual acuity has been considerably enlarged, and in many places rewritten to include some practical features, such as physiological factors of importance in refraction, the Stiles-Crawford effect and the part it plays in accommodation. The section on muscles has been enlarged in the light of recent concepts developed as the result of the Symposium on Strabismus given at the Academy of Ophthalmology and Otolaryngology last fall. The recent work of Wald on the visual purple cycle has been included in the chapter on Photochemistry.

FRANCIS HEED ADLER

Philadelphia





## PREFACE TO FIRST EDITION

---

Since the publication of the "Clinical Physiology of the Eye" twenty years ago the knowledge of this subject has so increased that an entirely new book, rather than a revision, is demanded. This is clearly indicated by the progress made in subjects such as the dynamics of aqueous humor formation, the photochemistry of the retina, and the application of electrophysiologic technics to retinal function. From the point of view of basic physiology the material to be covered requires fresh treatment.

The application of physiology to the study of disease has been richly rewarded in many fields of medicine and surgery. The time has come when knowledge of the function of the various parts of the eye can be likewise applied to ocular disorders. The ophthalmologist should know how the various portions of the eye normally function before he can adequately treat their diseases. The treatment of glaucoma, to be rational, should be based on an understanding of the formation and elimination of the aqueous humor, the permeability characteristics of the cornea, and the hemodynamics of the ocular circulation. The medical and surgical approach to strabismus should be through a comprehension of the neuromuscular mechanisms which normally maintain the two eyes in alignment.

A book is needed, therefore, which offers to the student and the practicing ophthalmologist the recent findings of the physiology of the eye gleaned from the experimental laboratory, and which applies these facts clinically. Such an undertaking has many pitfalls and obstacles. Many parts of ocular physiology are still unexplored, many are still controversial, and some facts have been determined in lower animals that have not yet been confirmed in the human subject. In many phases of ocular physiology the application to disease is still remote, and it will be some time before their application to the practical problems of therapy can be made.

For a comprehensive knowledge of each of the basic subjects the original literature should be consulted. The bibliography given at the end of each chapter contains those books and papers which I have found helpful; this list is by no means complete. Wherever possible the material has been correlated with clinical experience. It is hoped that the reader will discover other correlations, and may be encouraged to make his own investigations in what are still fertile fields for research.

It would have been impossible for me to have written the chapters on the aqueous humor, the lens, and portions of the chapter on the cornea without the help of Dr. V. Everett Kinsey, who has contributed much to our present

knowledge of these fields. I spent many pleasant weekends in Boston utilizing his time and energy in an endeavor to portray correctly the dynamics of the aqueous humor as he conceives it.

The skill and ingenuity of my artist, Miss Marie Wilson, have been of inestimable value in the preparation of the illustrations, which I consider to be of equal value with the text in any book. There are others, too numerous to mention, whose advice and suggestions I have followed with advantage. My particular thanks go to all those authors whose published articles and illustrations have been used.

FRANCIS HEED ADLER

Philadelphia

CONTENTS

CHAPTER I		PAGE
THE EYELIDS - - - - -		17
Function of the Lids, 17; The Cilia, 17; The Eyebrows, 18; The Palpebral Fissures, 19; The Normal Lid Movements, 20; The Lids in Sleep, 26; The Centers and Pathways for Lid Movements, 26; Associated Lid Movements, 27.		
CHAPTER II		
THE LACRIMAL APPARATUS - - - - -		29
The Secretion of the Tears, 29; The Elimination of the Tears, 33; The Composition of the Tears, 35.		
CHAPTER III		
THE CORNEA - - - - -		39
The Anatomy and Physical Properties of the Cornea, 39; The Chemical Characteristics of the Cornea, 41; Metabolism of the Cornea, 43; The Permeability of the Cornea, 49; Corneal Turgescence, 58; Corneal Transparency, 61; The Corneal Sensibilities, 63; Healing of Corneal Wounds, 76; Corneal Vascularization, 79.		
CHAPTER IV		
THE AQUEOUS HUMOR - - - - -		84
The Chemical and Physical Properties of Normal Aqueous Humor, 84; Plasmoid Aqueous, 95; Changes in the Composition of Aqueous Humor With Experimental Alterations in the Constitution of the Blood, 97; The Formation of Aqueous Humor, 100; The Elimination of Aqueous Humor From the Eye, 116.		
CHAPTER V		
THE INTRAOCULAR PRESSURE - - - - -		120
The Normal Pressure, 120; Alterations in Intraocular Pressure Caused by Variations in the Fluid Contents of the Eye, 125; Physiological Principles Underlying Operations for Glaucoma, 140; Tonometry, 141.		
CHAPTER VI		
IRIS AND PUPIL - - - - -		143
The Iris Pigment, 143; The Iris Muscles, 144; The Normal Pupil, 155; Pupillary Reflexes, 158; The Reactions of the Pupil in Lesions of Various Parts of the Reflex Arc, 173; Pupillary Phenomena Associated With or Following Third Nerve Paralysis, 180; The Pharmacodynamics of the Sphincter and Dilator Muscles, 181.		

## CHAPTER VII

	PAGE
LENS AND VITREOUS - - - - -	196
The Structure of the Lens, 196; The Chemistry of the Normal Lens, 198; The Metabolism of the Lens, 210; The Permeability of the Lens Capsule, 213; The Pathologic Physiology of the Lens.—Cataract, 214; The Vitreous, 219.	

## CHAPTER VIII

ACCOMMODATION - - - - -	228
The Necessity of Changing the Dioptric Power of the Eye, 228; The Anatomy of the Parts of the Eye Concerned With Accommodation, 230; The Innervation of the Ciliary Muscle, 238; Changes in the Eye During Accommodation, 241; Theories of the Mechanism of Accommodation, 244; Presbyopia, 252.	

## CHAPTER IX

THE OCULAR CIRCULATION - - - - -	256
General Characteristics of Ocular Circulation, 256; The Arterial Pulse, 258; The Venous Pulse, 262; The Normal Pressure in the Retinal and Uveal Arteries and Veins, 263; The Capillary Pressure, 265; Blood Volume and Circulation Time, 266; The Control of the Circulation, 267; Capillary Permeability, 274; Lymph, 277; Functions of the Capillary Bed, 278; Circulation in Localized Regions, 278; The Role of the Sympathetic Nervous System in Essential Hypertension and Its Effectiveness on the Ocular Circulation, 288.	

## CHAPTER X

OCULAR MOTILITY - - - - -	297
The Articulation of the Eyeball in the Socket, 297; The Gross Anatomy and Action of Each of the Ocular Muscles, 303; The Mechanics of the Movement of Each Eye, 308; The Muscles Concerned in Monocular Movements, 315; The Characteristics of the Ocular Muscles, 320; The Nervous Centers and Pathways for Voluntary Movements, 351; The Nervous Centers and Pathways for Reflex Activity of the Eye Muscles, 373; The Nuclei of the Ocular Motor Nerves, 392; Position of Rest and the Normal Tonus of the Eyes—Orthophoria and Heterophoria, 398; Binocular Movements, 406; The Pathologic Physiology of Strabismus, 414; Physiologic Principles to be Considered in the Choice of Operations for Strabismus, 426; The Choice of Surgical Procedures in Comitant Convergent Squint, 426; The Choice of Surgical Procedures in Incomitant Convergent Squint, 428; Procedures in Paralysis of a Lateral Rectus, 430; The Choice of Procedures in Paralysis of One or More of the Vertically Acting Muscles, 432.	

## CHAPTER XI

LIGHT - - - - -	443
The Nature and Origin of Light, 443; Physical Measurements of Light, 448; Lighting Standards, 450; The Transmission of Light by the Ocular Media, 451.	

## CHAPTER XII

METABOLISM OF THE RETINA - - - - -	454
Anaerobic and Aerobic Glycolysis, 454; Production of Ammonia, 455; Acetylcholine and Organic Phosphate, 455; Hydrogen-Ion Concentration, 457.	

## CHAPTER XIII

	PAGE
THE PHOTOCHEMISTRY OF VISION - - - - -	459
The Absorption of Light, 459; Visual Purple or Rhodopsin, 461; Iodopsin, 475; Other Substances in the Retina, 477; The Nature of the Photoreceptor Process, 477; Pathological Conditions in Which the Visual Purple Mechanism is Affected, 484; Photomechanical Changes in the Retina, 485.	

## CHAPTER XIV

ELECTRICAL PHENOMENA IN THE EYE - - - - -	487
Electrical Phenomena in Nerves, 487; Action Potentials From the Optic Nerve of Invertebrates, 494; Action Potentials in Vertebrate Optic Nerves, 507; The Electroretinogram, 515.	

## CHAPTER XV

THE OPTIC NERVE - - - - -	528
Comparison of Optic Nerve With True Sensory Nerves, 528; Functions of the Optic Nerve, 531; Degeneration of Fibers, 534; The Production of Cupping in the Optic Nerve, 536; The Production of Choked Disc, or Papilledema, 536.	

## CHAPTER XVI

VISUAL PATHWAYS - - - - -	538
The Retina, 540; The Optic Nerve, 555; The Chiasm, 556; Optic Tract, 561; Lateral Geniculate Body, 562; The Optic Radiation, 563; The Visual Cortex, 564; The Conscious Level of Vision, 574.	

## CHAPTER XVII

ADAPTATION - - - - -	581
Temporal Induction, 581; Spatial Summation, 601.	

## CHAPTER XVIII

SENSORY RESPONSE - - - - -	605
The Sensory Response to a Single Stimulus, 605; Intermittent Stimuli, 611.	

## CHAPTER XIX

VISUAL ACUITY - - - - -	624
Clinical Measurements of Visual Acuity, 624; The Light Sense, 626; Visibility of a Single Line on a Background, 628; Visibility of Gratings, 632; The Discrimination of a Break in a Line, 636; Factors Influencing Visual Acuity, 640.	

## CHAPTER XX

COLOR VISION - - - - -	665
The Physical Basis of Color, 665; The Effect of Lowering the Illumination on the Spectral Luminosity Curve. The Purkinje Phenomenon, 670; Color Mixtures, 671; Physiological Basis of Color Vision, 673; Color Blindness, 680.	

## CHAPTER XXI

	PAGE
ENTOPTIC AND ALLIED PHENOMENA - - - - -	682
Opacities in the Ocular Media, 682; Entoptic Phenomena Connected With the Tear Film and the Cornea, 684; Entoptic Phenomena Connected With the Lens, 685; The Retinal Blood Vessels, 685; The Capillary Circulation, 686; Choriocapillary Circulation, 688; The Blue Arcs of the Retina, 689; Self-Illumination of the Retina—Phosphenes, 690; Physiological and Pathological Haloes, 690.	

## CHAPTER XXII

BINOCULAR VISION - - - - -	692
Definition, 692; The Binocular Field of Vision, 694; Retinal Correspondence, 696; Diplopia, 701; Fusion, 704; Depth Perception, 706; The Development of Binocular Vision, 714.	

---

 COLOR PLATES

	PAGE
Fig. 25.—Kinsey's scheme showing the dynamics of the formation of aqueous humor as found in the anterior chamber - - - - -	112
Fig. 45.—Diagrammatic representation of the pupillo-motor pathways - - - - -	174
Fig. 305.—The photopic spectrum - - - - -	666

**PHYSIOLOGY OF THE EYE**  
**Clinical Application**



