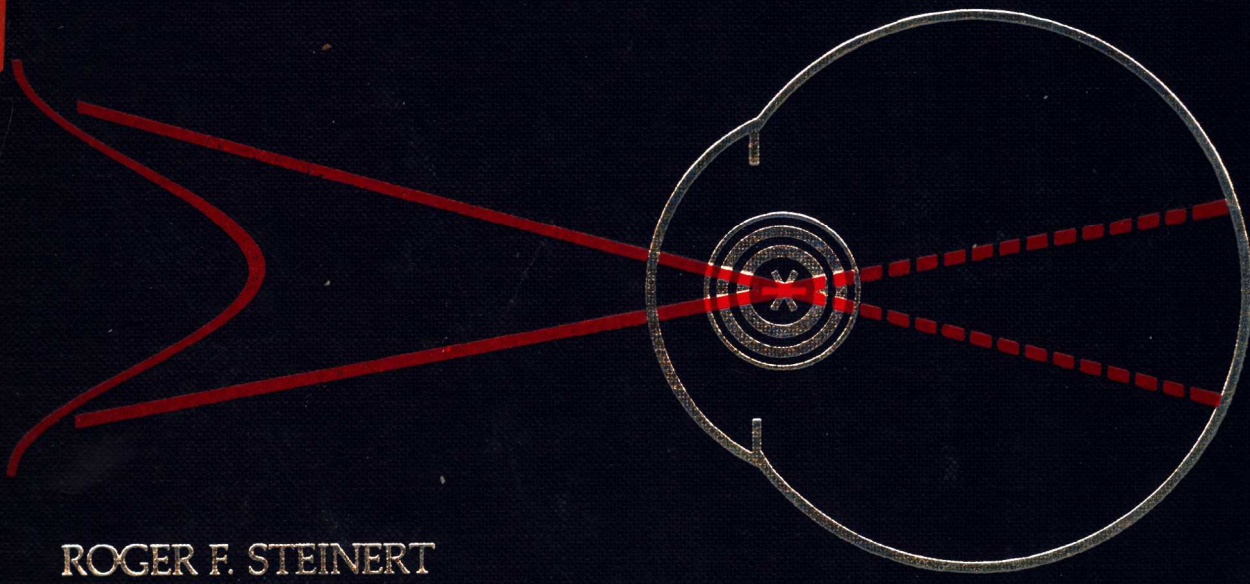
The Nd-YAG Laser in Ophthalmology

Principles and Clinical Applications of Photodisruption



ROGER F. STEINERT

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ROGER F. STEINERT, M.D.

CARMEN A. PULIAFITO, M.D.

Department of Ophthalmology, Massachusetts Eye and Ear Infirmary, Harvard Medical School, Boston, Massachusetts; Regional Laser Center, George R. Harrison Spectroscopy Laboratory, Massachusetts Institute of Technology, Cambridge, Massachusetts

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Sao Cristovao Caixa Postal 21176
Rio de Janeiro, Brazil

9 Waltham Street
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Dedicated to
our families

ACKNOWLEDGMENTS

The pioneer work of Drs. Danielle Aron-Rosa and Franz Fankhauser and their colleagues brought photodisruption with the Nd-YAG laser into safe and effective clinical therapeutics. For this all ophthalmologists are in their debt. Dr. Aron-Rosa has welcomed and encouraged our work from the outset, and we thank her for her support.

This book would not have been possible without the help of many individuals. We owe a particular debt of gratitude to many members of the scientific communities at the Massachusetts Institute of Technology and Harvard University, who welcomed us into their laboratories and generously made available their time and resources. Our first experimental studies in short-pulsed laser research were performed at the Regional Laser Center and the George R. Harrison Laboratory of Spectroscopy at MIT. Special thanks must go to Dr. Michael S. Feld, Director of the Regional Laser Center, and Drs. Carter Kittrell and Ramachandra Dasari. Drs. James G. Fujimoto and Erich P. Ippen of the MIT Department of Electrical Engineering provided early technical support as well as ideas and have become valued collaborators. Dr. Kevin Peters of the Harvard Chemistry Department provided ready access to his scientific mode-locked laser system.

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Kratz, John Hunkeler, Paul Woodward, Thomas Richardson, and David Epstein kindly made available case material and photographs for this book. Laurel Cook skillfully prepared the line drawings and interpreted clinical concepts in her beautiful artwork. Linda Mikula artfully drafted the charts. Alan Ball provided excellent administrative and secretarial support, without which the book would not have been possible.

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To the patients who participated in the clinical studies reported in this book we owe a special debt. In many ways, these patients were co-investigators whose enthusiasm and hope has helped us to carry forward our inquiries.

Finally, we acknowledge our parents, who provided the foundation, our wives, Dr. Marilyn Steinert and Dr. Janet Pine, who gave daily encouragement, advice, and support, and our children, who inspire us with curiosity and enthusiasm.

ROGER F. STEINERT, M.D.

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PREFACE

Photodisruption is the mechanical alteration of an object by an extremely powerful ionizing electromagnetic field associated with radiation in the portion of the electromagnetic spectrum defined as "light" (ultraviolet, visible, and infrared). In ophthalmology, the Q-switched and mode-locked neodymium-yttrium-aluminum-garnet (Nd-YAG) lasers are clinical photodisruptors. By emitting light pulses lasting billionths to trillionths of a second, focused to a spot the size of a white blood cell, these lasers create such a strong electromagnetic field that electrons are torn from their atoms, and a strong localized pressure wave results. This process is known as optical breakdown.

This book is intended for the ophthalmologist who wishes to understand photodisruption and apply it therapeutically to the eye. No prior knowledge of lasers, physics, or photobiology is assumed.

Section I explores the principles of photobiology and lasers in general and of photodisruption in particular. After the history of phototherapy of ocular disease and the development of photodisruption are reviewed, the special properties of laser light are introduced. Physics and mathematics are restricted to pertinent major concepts. Optical breakdown, plasma formation, and photodisruption are explained, and a detailed discussion of laser-tissue interaction follows. These chapters are intended as a foundation for understanding not only current laser technology but future developments as well. Section I concludes with a chapter on Nd-YAG lasers and ophthalmic delivery systems, both to explain engineering goals and constraints and to serve as a buyer's and user's guide to current and future commercial lasers.

Section II is devoted to clinical applications of Q-switched and mode-locked ophthalmic Nd-YAG lasers. Section II may be used independently of Section I. Section II begins with a review of the important principles of optical breakdown in clinical applications. Liberal reference is made to the relevant areas in Section I that support and explain the principles of critical focus. Each chapter on applications then reviews the current literature in that area, presents illustrative cases with discussion of indications and complications, and concludes with a summary of patient preparation, operative technique, and postoperative care.

This book should serve as a coherent teaching text and as a reference source. While we have attempted to be comprehensive and objective in our treatment of the subject, this work must also reflect our personal experiences and viewpoints. We apologize for any inaccuracies that result. Your comments, criticisms, and suggestions are encouraged.

ROGER F. STEINERT, M.D.

CARMEN A. PULIAFITO, M.D.

PLATE I

A Four millimeter posterior capsulotomy behind a posterior chamber intraocular lens.

B Coreoplasty to restore the optical axis to the central cornea. The pupil was drawn upward to the left after wound leak following intracapsular cataract extraction and was covered by the eyelid in its normal position. Arrowheads indicate the pupillary border before sphincterotomy.

C Aphakic malignant glaucoma with apposition of inferior iris to edematous cornea.

D Depth is restored to the anterior chamber immediately after Nd-YAG laser pulses have opened the anterior hyaloid face. Arrows show separation of iris and cornea, in comparison with IC.

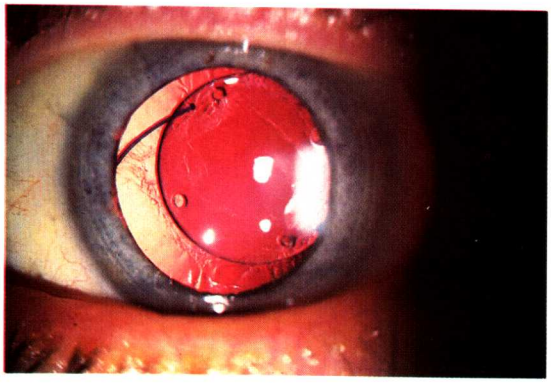
E Pupillary block glaucoma with loss of anterior chamber one day after intracapsular cataract extraction with anterior chamber intraocular lens implant. Hemorrhage covers the implant optic, and the iris is in apposition to the superior cornea, except where the edge of the optic creates a small aqueous lacuna (*arrow*).

F Postlaser photograph of patient in IE. Immediately after Nd-YAG laser iridectomy, the chamber begins to form, with aqueous space between the superior iris and the hemorrhage-covered optic (*arrows*).

G Gonioscopy shows the iris drawn upward into the angle in a tentlike formation as a result of vitreous incarceration in the wound. The arrow indicates the iris deformation and the arrowhead the adjacent peripheral iridectomy. Figure 10–4*A* shows the slit lamp appearance of this eye.

H Appearance of angle shown in IG after laser vitreolysis. The pigmented trabecular meshwork is now visible (*arrow*) adjacent to the peripheral iridectomy (*arrowhead*). Figure 10–4C shows the slit lamp appearance of the same eye at this stage of the procedure.

PLATE I



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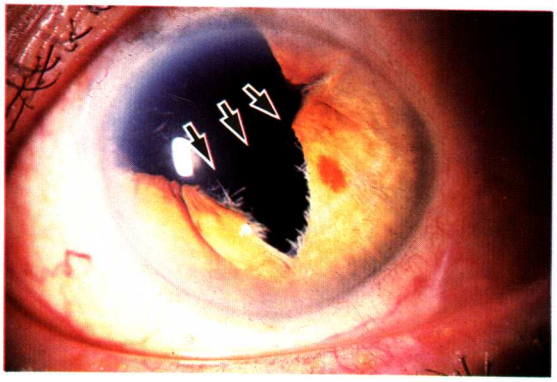

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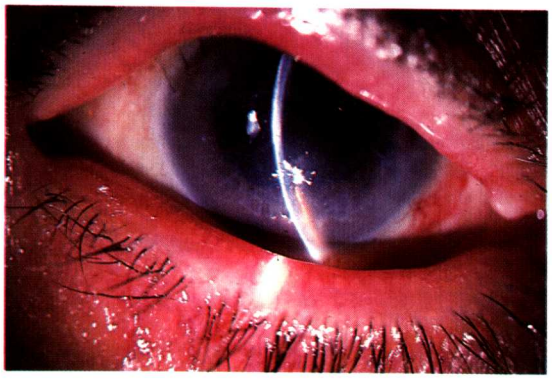

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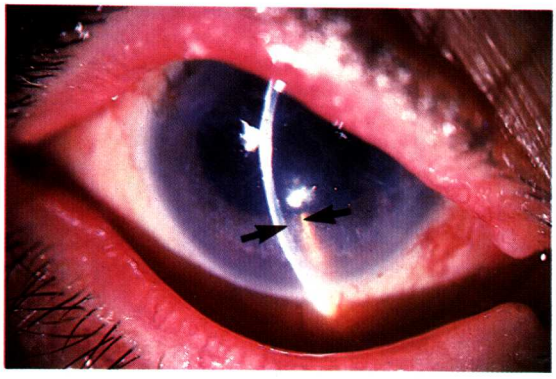

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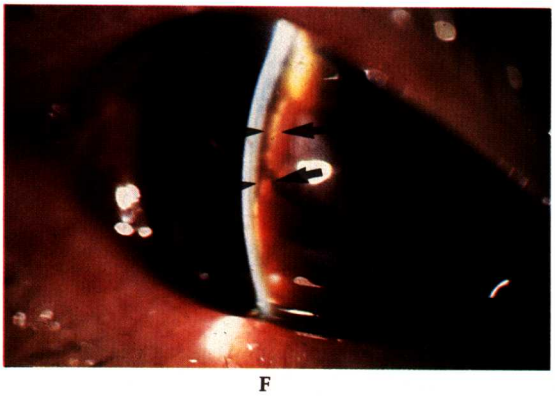

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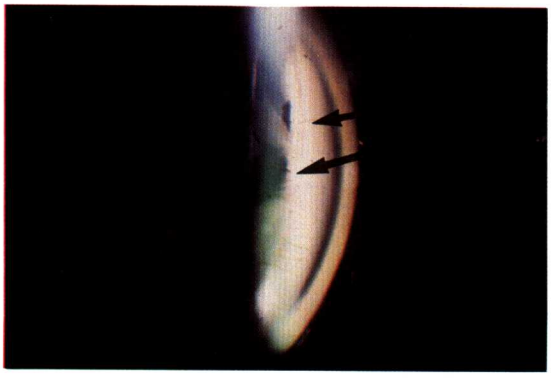

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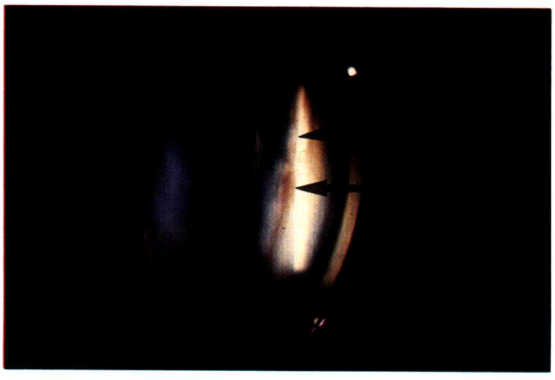

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PLATE II

A A strand of vitreous humor to the wound is present in association with cystoid macular edema. A fine wisp of vitreous passes from the pupil (*arrowhead*) across the peripheral iridectomy to the wound (*arrow*). Figure 10–5*A* shows the slit lamp appearance of this pupil.

B After laser vitreolysis, the strand seen in II*A* is gone. A fine hemorrhage can be seen at the edge of the peripheral iridectomy (*arrow*) and is caused by the pressure wave emanating from the zone of optical breakdown anterior to the iridectomy.

C A retained fragment of anterior capsule after extracapsular cataract extraction is in contact with the corneal endothelium. Localized stromal thickening can be seen in the slit beam (*arrow*).

D After laser disruption of the capsule shown in IIC, the corneal edema has resolved. A small fragment of capsule remains adherent to the endothelium (*arrow*).

E Preoperative laser anterior capsulotomy. Vacuoles have been created centrally by laser shots in the anterior cortex behind the anterior capsule. A series of closely spaced shots has formed a nearly complete circular anterior capsulotomy in the mid-periphery. (Courtesy of Paul M. Woodward.)

F Appearance of the lens in II*E* the next day, 18 hours after anterior capsulotomy. The cortex has become opaque owing to hydration through the anterior capsule defects. (Courtesy of Paul M. Woodward.)

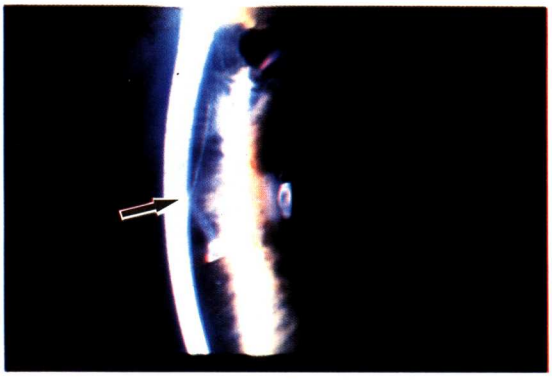
G Preoperative photograph of the fundus. This patient had a history of long-term uveitis in this eye, with opacification of the posterior hyaloid membrane and a nasal traction detachment. (Courtesy of Thomas A. Hanscom.)

H Postoperative photograph of the fundus. After two treatments employing 650 pulses with energies up to 8 mJ, the membrane was successfully cut (*arrows*). (Courtesy of Thomas A. Hanscom.)

PLATE II

A

B



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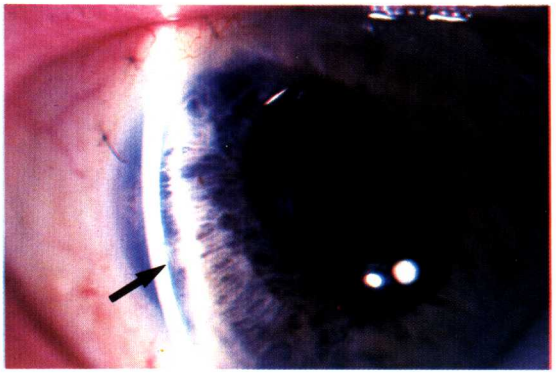

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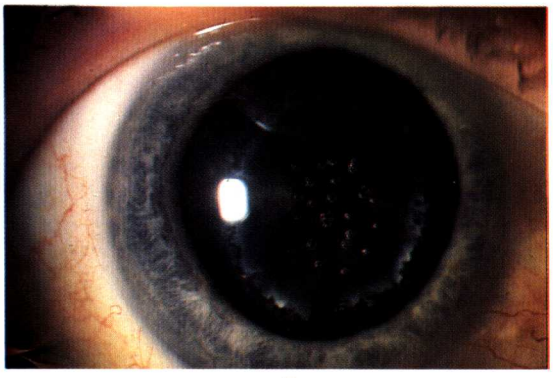

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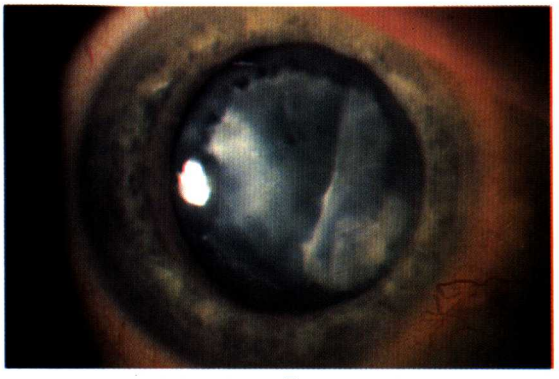

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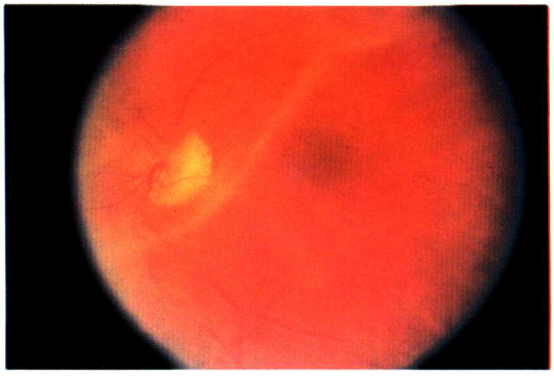

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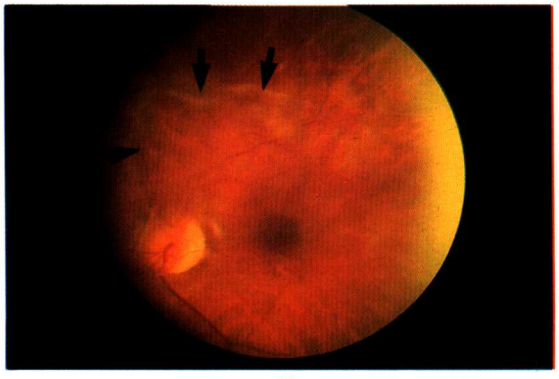

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CONTENTS

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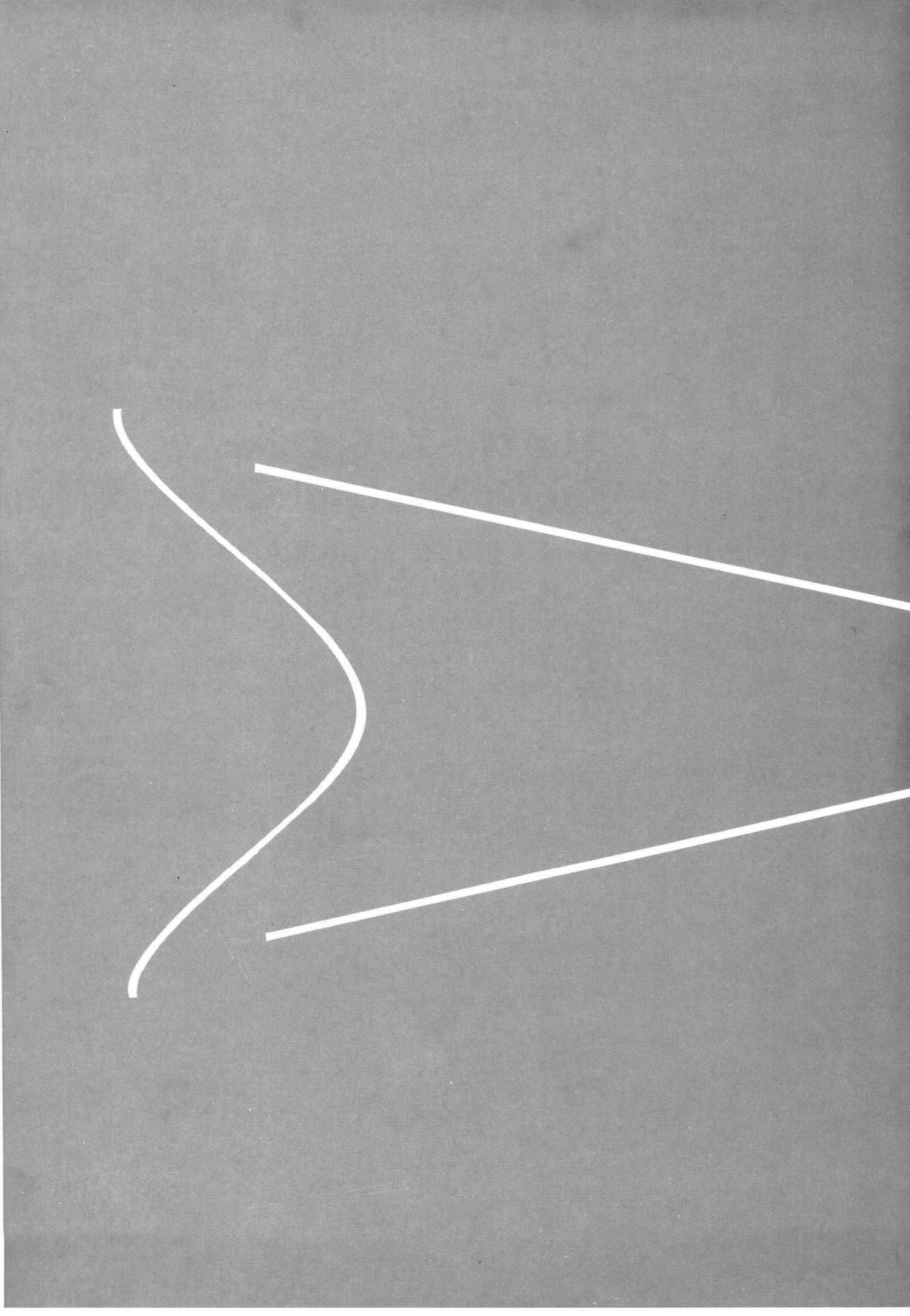

SECTION I

PRINCIPLES