

CARDIOLOGY: FUNDAMENTALS AND PRACTICE

Volume 2

CARDIOLOGY: FUNDAMENTALS AND PRACTICE

Second Edition

Emilio R. Giuliani, M.D.

Consultant, Division of Cardiovascular Diseases and
Internal Medicine,

Mayo Clinic and Mayo Foundation;

Professor of Medicine,

Mayo Medical School; Rochester, Minnesota

Valentin Fuster, M.D.

Chief, Division of Cardiology,

Professor of Medicine,

Mount Sinai Medical Center and Medical School,

New York, New York

(Formerly, Consultant, Division of Cardiovascular
Diseases and Internal Medicine, Mayo Clinic and
Mayo Foundation)

Bernard J. Gersh, M.B., Ch.B., D.Phil.

Consultant, Division of Cardiovascular Diseases and
Internal Medicine,

Mayo Clinic and Mayo Foundation;

Professor of Medicine,

Mayo Medical School; Rochester, Minnesota

Michael D. McGoon, M.D.

Consultant, Division of Cardiovascular Diseases and
Internal Medicine,

Mayo Clinic and Mayo Foundation;

Assistant Professor of Medicine,

Mayo Medical School; Rochester, Minnesota

Dwight C. McGoon, M.D.

Emeritus member, Division of Thoracic and
Cardiovascular Surgery,

Mayo Clinic and Mayo Foundation;

Emeritus Professor of Surgery,

Mayo Medical School; Rochester, Minnesota

Volume 2

M Mosby
Year Book

St. Louis Baltimore Boston Chicago London Philadelphia Sydney Toronto



Dedicated to Publishing Excellence

Sponsoring Editor: Nancy Megley
Assistant Director, Manuscript Services: Frances M. Perveiler
Production Project Coordinator: Karen E. Halm

Copyright © 1987, 1991 Mayo Foundation

Mosby-Year Book, Inc.
11830 Westline Industrial Drive
St. Louis, MO 63146

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without prior written permission from the Mayo Foundation.

Printed in the United States of America.

Permission to photocopy or reproduce solely for internal or personal use is permitted for libraries or other users registered with the Copyright Clearance Center, provided that the base fee of \$4.00 per chapter plus \$.10 per page is paid directly to the Copyright Clearance Center, 21 Congress Street, Salem, MA 01970. This consent does not extend to other kinds of copying, such as copying for general distribution, for advertising or promotional purposes, for creating new collected works, or for resale.

1 2 3 4 5 6 7 8 9 0 CL SL MY 95 94 93 92 91

Library of Congress Cataloging-in-Publication Data

Cardiology: fundamentals and practice.—2nd ed./Emilio R.

Giuliani . . . [et al.]

p. cm.

Includes bibliographical references.

Includes index.

ISBN 0-8016-2006-6

1. Heart—Diseases. 2. Cardiology. I. Giuliani, Emilio R.
(Emilio Romolo), 1927—

[DNLM: 1. Heart Diseases. WG 200 C2656]

RC681.C1791991

616.1'2—dc20

DNLM/DLC

for Library of Congress

91-13681

CIP

Dedication

Dedicated to our families

Contributing Editors

David L. Hayes, M.D.

Consultant, Division of Cardiovascular Diseases
and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Associate Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Rick A. Nishimura, M.D.

Consultant, Division of Cardiovascular Diseases
and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Associate Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Hartzell V. Schaff, M.D.

Consultant, Section of Cardiovascular Surgery,
Mayo Clinic and Mayo Foundation;
Associate Professor of Surgery,
Mayo Medical School; Rochester, Minnesota

Contributors

Charles F. Abboud, M.D.

Consultant, Division of Endocrinology and Metabolism,
Mayo Clinic and Mayo Foundation;
Associate Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Martin D. Abel, M.D.

Consultant, Department of Anesthesiology,
Mayo Clinic and Mayo Foundation;
Assistant Professor of Anesthesiology,
Mayo Medical School; Rochester, Minnesota

Thomas G. Allison, Ph.D.

Senior Associate Consultant, Division of Cardiovascular
Diseases and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Instructor in Medicine,
Mayo Medical School; Rochester, Minnesota

William T. Bardsley, M.D.

Consultant, Division of Cardiovascular Diseases and
Internal Medicine,
Mayo Clinic and Mayo Foundation;
Assistant Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

James B. Bassingthwaighe, M.D., Ph.D.

Center for Bioengineering,
University of Washington,
Seattle, Washington
(Formerly, Consultant, Department of Physiology and
Biophysics, Mayo Clinic and Mayo Foundation)

Thomas Behrenbeck, M.D., Ph.D.

Senior Associate Consultant, Division of Cardiovascular
Diseases and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Assistant Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Alfred A. Bove, M.D., Ph.D.

Section of Cardiology,
Temple University Medical School,
Philadelphia, Pennsylvania
(Formerly, Consultant, Department of Physiology and
Biophysics, and Consultant, Division of Cardiovascular
Diseases and Internal Medicine, Mayo Clinic and
Mayo Foundation)

Robert O. Brandenburg, M.D.

Emeritus member, Division of Cardiovascular Diseases
and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Emeritus Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Jerome F. Breen, M.D.

Senior Associate Consultant, Department of Diagnostic
Radiology,
Mayo Clinic and Mayo Foundation;
Instructor in Radiology,
Mayo Medical School; Rochester, Minnesota

John F. Bresnahan, M.D.

Consultant, Division of Cardiovascular Diseases and
Internal Medicine,
Mayo Clinic and Mayo Foundation;
Assistant Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Mahlon K. Burbank, M.D.

Consultant, Division of Cardiovascular Diseases and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Assistant Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

John C. Burnett, Jr., M.D.

Consultant, Division of Cardiovascular Diseases and Internal Medicine, and Consultant, Department of Physiology and Biophysics,
Mayo Clinic and Mayo Foundation;
Associate Professor of Medicine and of Physiology,
Mayo Medical School; Rochester, Minnesota

John A. Callahan, M.D.

Emeritus member, Division of Cardiovascular Diseases and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Emeritus Associate Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Mark J. Callahan, M.D.

Consultant, Division of Cardiovascular Diseases and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Assistant Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

James H. Chesebro, M.D.

Consultant, Division of Cardiovascular Diseases and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Ian P. Clements, M.D.

Consultant, Division of Cardiovascular Diseases and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Assistant Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Roger L. Click, M.D., Ph.D.

Consultant, Division of Cardiovascular Diseases and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Assistant Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Gordon K. Danielson, M.D.

Chairman, Division of Thoracic and Cardiovascular Surgery,
Mayo Clinic and Mayo Foundation;
Joe M. and Ruth Roberts Professor of Surgery,
Mayo Medical School; Rochester, Minnesota

David E. Dines, M.D.

Emeritus member, Division of Thoracic Diseases and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Emeritus Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

David J. Driscoll, M.D.

Head, Section of Pediatric Cardiology,
Mayo Clinic and Mayo Foundation;
Professor of Pediatrics,
Mayo Medical School; Rochester, Minnesota

Brooks S. Edwards, M.D.

Senior Associate Consultant, Division of Cardiovascular Diseases and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Assistant Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

William D. Edwards, M.D.

Consultant, Division of Pathology,
Mayo Clinic and Mayo Foundation;
Professor of Pathology,
Mayo Medical School; Rochester, Minnesota

Richard L. Ehman, M.D.

Consultant, Department of Diagnostic Radiology,
Mayo Clinic and Mayo Foundation;
Associate Professor of Radiology,
Mayo Medical School; Rochester, Minnesota

Titus C. Evans, Jr., M.D., Ph.D.

Consultant, Division of Cardiovascular Diseases and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Associate Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

William P. Fay, M.D.

Fellow in Cardiovascular Diseases,
Mayo Graduate School of Medicine, Rochester,
Minnesota

William K. Freeman, M.D.

Senior Associate Consultant, Division of Cardiovascular Diseases and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Instructor in Medicine,
Mayo Medical School; Rochester, Minnesota

Robert L. Frye, M.D.

Consultant, Division of Cardiovascular Diseases and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Rose M. and Maurice Eisenberg Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

F. Earl Fyke III, M.D.

Cardiovascular Association,
Jacksonville, Mississippi
(Formerly, Fellow in Cardiovascular Diseases, Mayo
Graduate School of Medicine)

Kirk N. Garratt, M.D.

Senior Associate Consultant, Division of Cardiovascular
Diseases and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Instructor in Medicine,
Mayo Medical School; Rochester, Minnesota

Gerald T. Gau, M.D.

Consultant, Division of Cardiovascular Diseases and
Internal Medicine,
Mayo Clinic and Mayo Foundation;
Associate Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Raymond J. Gibbons, M.D.

Consultant, Division of Cardiovascular Diseases and
Internal Medicine,
Mayo Clinic and Mayo Foundation;
Associate Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Stephen C. Hammill, M.D.

Consultant, Division of Cardiovascular Diseases and
Internal Medicine,
Mayo Clinic and Mayo Foundation;
Associate Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Lyndon M. Hill, M.D.

Magee Women's Hospital,
Pittsburgh, Pennsylvania
(Formerly, Consultant, Department of Obstetrics and
Gynecology, Mayo Clinic and Mayo Foundation)

David R. Holmes, Jr., M.D.

Consultant, Division of Cardiovascular Diseases and
Internal Medicine,
Mayo Clinic and Mayo Foundation;
Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Michael J. Joyner, M.D.

Resident in Anesthesiology,
Mayo Graduate School of Medicine,
Rochester, Minnesota

Paul R. Julsrud, M.D.

Consultant, Department of Diagnostic Radiology,
Mayo Clinic and Mayo Foundation;
Associate Professor of Radiology,
Mayo Medical School; Rochester, Minnesota

Arthur J. Kennel, M.D.

Emeritus Head of a Section in the Division of
Community Internal Medicine,
Mayo Clinic and Mayo Foundation;
Emeritus Assistant Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Jack D. Key, M.A., M.S.

Librarian, Mayo Medical Library,
Mayo Clinic and Mayo Foundation;
Instructor in History of Medicine and Professor of
Biomedical Communications,
Mayo Medical School; Rochester, Minnesota

Bijoy K. Khandheria, M.D.

Consultant, Division of Cardiovascular Diseases and
Internal Medicine,
Mayo Clinic and Mayo Foundation;
Instructor in Medicine,
Mayo Medical School; Rochester, Minnesota

Franklyn G. Knox, M.D.

Consultant, Department of Physiology and Biophysics,
Mayo Clinic and Mayo Foundation;
Professor of Physiology and of Medicine,
Mayo Medical School; Rochester, Minnesota

Thomas E. Kottke, M.D.

Senior Associate Consultant, Division of Cardiovascular
Diseases and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Associate Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

J. T. Lie, M.D.

Consultant, Department of Pathology, and Consultant,
Division of Cardiovascular Diseases and Internal
Medicine,
Mayo Clinic and Mayo Foundation;
Professor of Pathology,
Mayo Medical School; Rochester, Minnesota

Douglas D. Mair, M.D.

Consultant, Section of Pediatric Cardiology, and
Consultant, Division of Cardiovascular Diseases and
Internal Medicine,
Mayo Clinic and Mayo Foundation;
Professor of Pediatrics and Associate Professor of
Medicine,
Mayo Medical School; Rochester, Minnesota

Harold T. Mankin, M.D.

Emeritus member, Division of Cardiovascular Diseases
and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Emeritus Assistant Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Maurice J. Martin, M.D.

Senior Consultant, Section of Psychiatry,
Mayo Clinic and Mayo Foundation;
Professor of Psychiatry,
Mayo Medical School; Rochester, Minnesota

Christopher G. A. McGregor, M.D.

Consultant, Section of Cardiovascular Surgery,
Mayo Clinic and Mayo Foundation;
Associate Professor of Surgery,
Mayo Medical School; Rochester, Minnesota

Jim I. Mertz, M.D.

University of Kansas,
Kansas City, Missouri
(Formerly, Fellow in Physiology, Mayo Graduate School
of Medicine)

Virginia V. Michels, M.D.

Consultant, Department of Medical Genetics,
Mayo Clinic and Mayo Foundation;
Associate Professor of Medical Genetics,
Mayo Medical School; Rochester, Minnesota

Fletcher A. Miller, Jr., M.D.

Consultant, Division of Cardiovascular Diseases and
Internal Medicine,
Mayo Clinic and Mayo Foundation;
Assistant Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Todd D. Miller, M.D.

Senior Associate Consultant,
Division of Cardiovascular Diseases and Internal
Medicine,
Mayo Clinic and Mayo Foundation;
Instructor in Medicine,
Mayo Medical School; Rochester, Minnesota

Michael B. Mock, M.D.

Consultant, Division of Cardiovascular Diseases and
Internal Medicine,
Mayo Clinic and Mayo Foundation;
Associate Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

James P. Morgan, M.D., Ph.D.

Beth Israel Hospital,
Boston, Massachusetts
(Formerly, Senior Clinical Fellow, Division of
Cardiovascular Diseases and Internal Medicine, Mayo
Clinic and Mayo Foundation)

Charles J. Mullany, M.B., B.S.

Consultant, Section of Cardiovascular Surgery,
Mayo Clinic and Mayo Foundation,
Assistant Professor of Surgery,
Mayo Medical School; Rochester, Minnesota

Barbara A. Nichols, R.N., R.D.C.S.

Supervisor, Division of Cardiovascular Diseases and
Internal Medicine,
Mayo Clinic and Mayo Foundation,
Rochester, Minnesota

Kenneth L. Noller, M.D.

Department of Obstetrics and Gynecology,
University of Massachusetts Medical School,
Worcester, Massachusetts
(Formerly, Consultant, Department of Obstetrics and
Gynecology, Mayo Clinic and Mayo Foundation)

M. Kevin O'Connor, M.D.

Consultant, Section of Psychiatry,
Mayo Clinic and Mayo Foundation;
Assistant Professor of Psychiatry,
Mayo Medical School; Rochester, Minnesota

Jae K. Oh, M.D.

Consultant, Division of Cardiovascular Diseases and
Internal Medicine,
Mayo Clinic and Mayo Foundation;
Assistant Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Byron A. Olney, M.D.

Consultant, Division of Cardiovascular Diseases and
Internal Medicine,
Mayo Clinic and Mayo Foundation;
Assistant Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Michael J. Osborn, M.D.

Consultant, Division of Cardiovascular Diseases and
Internal Medicine,
Mayo Clinic and Mayo Foundation;
Assistant Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Philip J. Osmundson, M.D.

Consultant, Division of Cardiovascular Diseases and
Internal Medicine,
Mayo Clinic and Mayo Foundation;
Associate Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Douglas L. Packer, M.D.

Senior Associate Consultant, Division of Cardiovascular Diseases and Internal Medicine, Mayo Clinic and Mayo Foundation; Assistant Professor of Medicine, Mayo Medical School; Rochester, Minnesota

J. Norman Patton, M.D.

Health Sciences Centre, Winnipeg, Manitoba, Canada (Formerly, Senior Clinical Fellow, Division of Cardiovascular Diseases and Internal Medicine, Mayo Clinic and Mayo Foundation)

Patricia A. Pellikka, M.D.

Senior Associate Consultant, Division of Cardiovascular Diseases and Internal Medicine, Mayo Clinic and Mayo Foundation; Instructor in Medicine, Mayo Medical School; Rochester, Minnesota

Jeffrey M. Piehler, M.D.

Mid America Thoracic Association, Kansas City, Missouri (Formerly, Consultant, Section of Thoracic and Cardiovascular Surgery, Mayo Clinic and Mayo Foundation)

James R. Pluth, M.D.

Head, Section of Cardiovascular and Thoracic Surgery, Mayo Clinic Scottsdale, Scottsdale, Arizona; Professor of Surgery, Mayo Medical School; Rochester, Minnesota

Francisco J. Puga, M.D.

Head, Section of Cardiovascular Surgery, Mayo Clinic and Mayo Foundation; Professor of Surgery, Mayo Medical School; Rochester, Minnesota

Guy S. Reeder, M.D.

Consultant, Division of Cardiovascular Diseases and Internal Medicine, Mayo Clinic and Mayo Foundation; Associate Professor of Medicine, Mayo Medical School; Rochester, Minnesota

Erik L. Ritman, M.D., Ph.D.

Head, Biodynamics Research Unit, Mayo Clinic and Mayo Foundation; Professor of Physiology and of Medicine, Mayo Medical School; Rochester, Minnesota

Richard A. Robb, Ph.D.

Consultant, Department of Physiology and Biophysics, Mayo Clinic and Mayo Foundation; Professor of Biophysics, Mayo Medical School; Rochester, Minnesota

Joseph R. Rodarte, M.D.

Baylor College of Medicine, Houston, Texas (Formerly, Consultant, Division of Thoracic Diseases and Internal Medicine, and Consultant, Department of Physiology and Biophysics, Mayo Clinic and Mayo Foundation)

Richard J. Rodeheffer, M.D.

Consultant, Division of Cardiovascular Diseases and Internal Medicine, Mayo Clinic and Mayo Foundation; Assistant Professor of Medicine, Mayo Medical School; Rochester, Minnesota

J. Carlos Romero, M.D.

Consultant, Department of Physiology and Biophysics, and Consultant, Division of Hypertension and Internal Medicine, Mayo Clinic and Mayo Foundation; Professor of Physiology and Associate Professor of Medicine, Mayo Medical School; Rochester, Minnesota

Thom W. Rooke, M.D.

Senior Associate Consultant, Division of Cardiovascular Diseases and Internal Medicine, Mayo Clinic and Mayo Foundation; Assistant Professor of Medicine, Mayo Medical School; Rochester, Minnesota

Edward C. Rosenow III, M.D., M.S.

Chairman, Division of Thoracic Diseases and Internal Medicine, Mayo Clinic and Mayo Foundation; Arthur M. and Gladys D. Gray Professor of Medicine, Mayo Medical School; Rochester, Minnesota

John A. Rumberger, Ph.D., M.D.

Consultant, Division of Cardiovascular Diseases and Internal Medicine, Mayo Clinic and Mayo Foundation; Assistant Professor of Medicine, Mayo Medical School; Rochester, Minnesota

Jay H. Ryu, M.D.

Consultant, Division of Thoracic Diseases and Internal Medicine,

Mayo Clinic and Mayo Foundation;
Assistant Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

William P. Santamore, Ph.D.

Director of Research, Section of Cardiology,
Presbyterian University of Pennsylvania Medical Center,
Philadelphia, Pennsylvania

Thomas T. Schattenberg, M.D.

Consultant, Division of Cardiovascular Diseases and Internal Medicine,

Mayo Clinic and Mayo Foundation;
Associate Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Robert S. Schwartz, M.D.

Senior Associate Consultant, Division of Cardiovascular Diseases and Internal Medicine,

Mayo Clinic and Mayo Foundation;
Assistant Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

James B. Seward, M.D.

Consultant, Division of Cardiovascular Diseases and Internal Medicine, and Consultant, Section of Pediatric Cardiology,

Mayo Clinic and Mayo Foundation;
Professor of Medicine and of Pediatrics,
Mayo Medical School; Rochester, Minnesota

Patrick F. Sheedy II, M.D.

Consultant, Department of Diagnostic Radiology,
Mayo Clinic and Mayo Foundation;
Professor of Radiology,
Mayo Medical School; Rochester, Minnesota

John T. Shepherd, M.D., D.Sc.

Emeritus member, Department of Physiology and Biophysics,

Mayo Clinic and Mayo Foundation;
Emeritus Professor of Physiology,
Mayo Medical School; Rochester, Minnesota

Clarence Shub, M.D.

Consultant, Division of Cardiovascular Diseases and Internal Medicine,

Mayo Clinic and Mayo Foundation;
Associate Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

J. Christopher Sill, M.D.

Consultant, Department of Anesthesiology,
Mayo Clinic and Mayo Foundation;
Associate Professor of Anesthesiology,
Mayo Medical School; Rochester, Minnesota

Hugh C. Smith, M.D.

Chairman, Division of Cardiovascular Diseases and Internal Medicine,

Mayo Clinic and Mayo Foundation;
Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Thomas C. Spelsberg, Ph.D.

Chairman, Department of Biochemistry and Molecular Biology,

Mayo Clinic and Mayo Foundation;
Professor of Biochemistry and Molecular Biology,
Mayo Medical School; Rochester, Minnesota

John A. Spittell, Jr., M.D.

Emeritus member, Division of Cardiovascular Diseases and Internal Medicine,

Mayo Clinic and Mayo Foundation;
Emeritus Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Ray W. Squires, Ph.D.

Director, Cardiovascular Health Clinic,

Mayo Clinic and Mayo Foundation;
Instructor in Medicine,
Mayo Medical School; Rochester, Minnesota

Anthony W. Stanson, M.D.

Consultant, Department of Diagnostic Radiology,
Mayo Clinic and Mayo Foundation;

Associate Professor of Radiology,
Mayo Medical School; Rochester, Minnesota

James M. Steckelberg, M.D.

Senior Associate Consultant, Division of Infectious Diseases and Internal Medicine,

Mayo Clinic and Mayo Foundation;
Assistant Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

A. Jamil Tajik, M.D.

Consultant, Division of Cardiovascular Diseases and Internal Medicine, and Consultant, Section of Pediatric Cardiology,

Mayo Clinic and Mayo Foundation;
Professor of Medicine and of Pediatrics,
Mayo Medical School; Rochester, Minnesota

Robert G. Tancredi, M.D.

Consultant, Division of Cardiovascular Diseases and Internal Medicine, and Consultant, Department of Physiology and Biophysics,

Mayo Clinic and Mayo Foundation;
Associate Professor of Medicine and Assistant Professor of Physiology,
Mayo Medical School; Rochester, Minnesota

Stephen C. Textor, M.D.

Senior Associate Consultant, Division of Hypertension and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Assistant Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Juergen E. Thomas, M.D.

Emeritus member, Department of Neurology,
Mayo Clinic and Mayo Foundation;
Emeritus Professor of Neurology,
Mayo Medical School; Rochester, Minnesota

Paul M. Vanhoutte, M.D., Ph.D.

Baylor College of Medicine,
Houston, Texas
(Formerly, Consultant, Department of Physiology and Biophysics, and Consultant, Division of Cardiovascular Diseases and Internal Medicine, Mayo Clinic and Mayo Foundation)

Ronald E. Vlietstra, M.B., Ch.B.

The Watson Clinic,
Lakeland, Florida
(Formerly, Consultant, Division of Cardiovascular Diseases and Internal Medicine, Mayo Clinic and Mayo Foundation)

Carole A. Warnes, M.D.

Consultant, Division of Cardiovascular Diseases and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Instructor in Medicine,
Mayo Medical School; Rochester, Minnesota

William H. Weidman, M.D.

Consultant, Section of Pediatric Cardiology,
Mayo Clinic and Mayo Foundation;
Professor of Pediatrics,
Mayo Medical School; Rochester, Minnesota

Roger D. White, M.D.

Consultant, Department of Anesthesiology,
Mayo Clinic and Mayo Foundation;
Professor of Anesthesiology,
Mayo Medical School; Rochester, Minnesota

Eric D. Wieben, Ph.D.

Consultant, Department of Biochemistry and Molecular Biology,
Mayo Clinic and Mayo Foundation;
Associate Professor of Biochemistry and Molecular Biology,
Mayo Medical School; Rochester, Minnesota

Walter R. Wilson, M.D.

Chairman, Division of Infectious Diseases and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Douglas L. Wood, M.D.

Consultant, Division of Cardiovascular Diseases and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Assistant Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Earl H. Wood, M.D., Ph.D.

Emeritus member, Department of Physiology and Biophysics,
Mayo Clinic and Mayo Foundation;
Emeritus Professor of Medicine,
Mayo Medical School; Rochester, Minnesota

Prince K. Zachariah, M.D., Ph.D.

Consultant, Division of Hypertension and Internal Medicine,
Mayo Clinic and Mayo Foundation;
Associate Professor of Medicine and Assistant Professor of Pharmacology,
Mayo Medical School; Rochester, Minnesota

Foreword

We hold this book today and wonder about its impact on the future of Cardiology in much the same way a voyager planning an expedition into wild, uncharted country prepares for that experience. That voyager must provide for protection from the elements, for regular sustenance, and for a reasonable amount of comfort. His potential for success will be enhanced by having even partial maps of the region and knowledge of its hazards, of its beauty spots, of its history, and of the experiences of travelers who have preceded him.

Foremost, however, the voyager must have a keen desire for exploration and a curiosity about the hidden. The desire will offset the inevitable hardships; the curiosity will allow openness to new, perhaps as yet undescribed, phenomena and thus permit better delineation and understanding of what others have observed earlier.

Not the least of the requirements for the successful and rewarding experience is that the voyager share with those who have gone before and with those who will follow, share not only in the excitement of witnessing phenomena but also in understanding their meaning. With such sharing, even the novice is not a complete novice. Without such sharing, a swelling apparent at the top of a Norway pine, for example, is an unexplained swelling. With sharing, even the novice may recognize that it is a bald eagle perched on the tree. And recognizing and watching, he may prove to himself that it is so even as the bird flies away from its perch. Without sharing, all waters may look alike. With sharing, the novice may know ahead of time about shallow, rocky bottoms and avoid their potential hazards.

The voyager who has prepared adequately and who maintains a keen awareness comes back having achieved personal fulfillment and having become a source of valuable information

and help to others who someday will travel the same area. In a manner, any student in Medicine, the Cardiologist included, is a voyager into country that is only partially charted. This book may be considered a comprehensive guide for the Cardiology voyager. Among those who will use it as a guide, experience in Cardiology will be of the greatest possible diversity; these voyagers will range from the novice to the highly experienced physician. Despite this broad array of experience, this book will have knowledge new to each. No voyager, however experienced, will have seen every element of the terrain.

This book is a handbook, comprehensive and detailed, designed to invite, excite, and guide the Cardiologist. Its foundation is the extensive experience of its many authors, experience that collectively is as broad as the entire field of medicine. The many areas of interest among the authors might have led, without proper coordination, to many unintegrated chapters. But that has been avoided by the close teamwork and interdigitation of ideas among members of the Staff of the Mayo Clinic.

The result of this teamwork is even more positive: a collection of facts and concepts that are coordinated beautifully, presented clearly, and illustrated elegantly. Of biblical type, it holds both facts and implications for deductions, so that it is both a source of illumination and a stimulus of thought.

To those who make use of it in the future, this book will supply facts about phenomena, will show how seemingly subtle phenomena can be woven into diagnoses, and will describe what can be done to help the patient affected by cardiac disease. The book will do more. Its approach is such as to magnify curiosity, and this is one of the elements of its greatness because it is only through curiosity that the unknown of today will be revealed tomorrow.

JESSE E. EDWARDS, M.D.
SENIOR CONSULTANT,
DEPARTMENT OF PATHOLOGY,
UNITED HOSPITAL,
ST. PAUL, MINNESOTA;
PROFESSOR OF PATHOLOGY,
UNIVERSITY OF MINNESOTA,
MINNEAPOLIS, MINNESOTA

Preface

The philosophical perspective embodied in the first edition of *Cardiology: Fundamentals and Practice* emerged from the work of the original editors. They very successfully seized an opportunity to present one institution's integrated clinical approach to the management of the patient with cardiac disorders. The first edition was completed and arranged with the objective of providing clinicians in cardiology with a practical text. To that end, the chapters on management were contributed by physicians who themselves daily care for patients with cardiac problems. Because of abbreviated curricula in modern schools, the authors felt constrained to provide a historical perspective and sufficient basic information on presenting symptoms to ensure and facilitate integration of current technologic data.

The second edition is governed by the same basic philosophy and follows a similar general outline. In the mere 4 years that have elapsed since the publication of the first edition, we have witnessed continued rapid expansion of knowledge and technology. Accordingly, major additions and revisions were necessary for the second edition.

Part I of the text begins with the historical background, Part II covers basic structure and function necessary for the understanding of abnormal function and symptoms, and Parts III and IV deal in detail with diagnosis and pharmacology, respectively. The remaining chapters address specific cardiac disorders. Nine entirely new chapters have been added: "Ultrafast Computed Tomography," "Cardiac Magnetic Resonance Imaging," "Cardiac Transplantation," "Acquired Diseases of the Abdominal Aorta," "Cell and Molecular Biology for the Cardiologist," an Introduction to the echocardiography section, "Doppler Echocardiography," "Stress Echocardiography," and "Transesophageal and Innovative Echocardiographic Techniques."

Additional new material was included by combining chapters and adding sections to previous chapters: "Signal-Averaged Electrocardiography" was added to the chapter on standard electrocardiography; "Noninvasive Evaluation of Patients With Arrhythmias" was combined with "Ambulatory Electrocardiographic Recording" and a section on silent ischemia was included to produce "Noninvasive Evaluation of Patients With Arrhythmias and Silent Ischemia: Ambulatory and Transtele-

phonic Electrocardiographic Monitoring and Cardiac Functional Testing"; "Pacing" was divided into "Antibradycardia Devices" and "Antitachycardia Devices," the latter including a new section on automatic implantable cardioverter-defibrillators; and "Risk Factor Intervention in Pediatrics" was combined with "The Risk-Factor Concept" to become "Prevention of Coronary Heart Disease."

Significant revisions were made in most of the remaining chapters. In all chapters, references (although not exhaustive) are representative of the most important and the most recent. There are approximately 400 new figures and 100 new tables.

With the passage of time, change is inevitable. Some changes are not welcome but must be accepted. One such change is in the editors of this textbook. Dr. Robert Brandenburg, colleague, teacher, and friend, elected, because of distance and other major commitments, to pass his baton. Fortunately for us, he continued to give generously of his time and expertise. His contributions, evident in the first edition, continue in this edition. A welcome change is the addition of Dr. Bernard Gersh and Dr. Michael McGoön as editors. They bring to this book a new and exciting perspective. Our readers will be the beneficiaries of their expertise. The contributing editors—Dr. David Hayes, Dr. Rick Nishimura, and Dr. Hartzell Schaff—are equally welcome and important members of the team. They devoted innumerable hours to reading and improving the submitted manuscripts.

We are indebted to our contributors, who, working under the constraint of very tight time schedules, have, without exception, been receptive to the editors' suggested changes, met their time commitments, and allowed the editors to complete this monumental task in a timely fashion. It is therefore with great pleasure that we take this opportunity to express our appreciation to our contributors (listed at the front of this book) and to our many colleagues, each of whom made vital contributions to the completed work. The textbook is itself a compliment to them all.

A special thank you is extended to Dr. Bernard K. Forscher, Head of the Section of Publications, for his constant and dedicated support; to Roberta Schwartz, Supervisor in the Section of Publications, for her energy, enthusiasm, optimism,

and managerial expertise; her contribution and commitment were essential for success; to John L. Prickman, Editor, for his professionalism in enhancing the readability of the new material; to Sharon Wadleigh, Lead Editorial Assistant and coordinator for this textbook, for her dedication in organizing, reading, typing, checking, and rechecking to avoid errors; to Rose Ann Ptacek-Vitse and Margery Lovejoy, who devoted many hours to manuscript production; to Jen Schlotthauer, Office Assistant, who handled the printer's proofs; to Mary Schwager, Lead Proofreader and expert in detecting oversights; and to Robert Benassi, master medical illustrator and reviewer of all Mayo art appearing in this textbook.

The personnel of Mosby-Year Book are acknowledged for the major contributions they made despite the handicap of geographic distance, which denied them the almost daily interactions enjoyed by members of our Section of Publications. A special thanks to Nancy Megley of Mosby-Year Book, who reflected and represented all her colleagues well. It was a distinct pleasure to work with her on this project.

"Books are the treasured wealth of the world and the fit inheritance of generations and nations," said Henry David Thoreau. Our sincere hope is that this textbook, *Cardiology: Fundamentals and Practice*, merits inclusion by that definition.

Emilio R. Giuliani, M.D.

of the Department of Cardiology, Mayo Clinic, and the Mayo Foundation. The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors. The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors.

The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors. The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors.

The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors. The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors. The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors.

The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors. The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors. The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors.

The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors. The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors. The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors.

The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors. The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors. The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors.

The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors. The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors. The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors.

The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors. The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors. The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors.

The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors. The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors. The book is a product of the Mayo Clinic, which has been a source of inspiration and support for the authors.

Contents

Volume 2

<i>Contributors</i>	vii
<i>Foreword by Jesse E. Edwards, M.D.</i>	xiv
<i>Preface</i>	xt
32 / Surgery for Cardiac Arrhythmias	1114
A. Supraventricular Tachycardia	
<i>Hartzell V. Schaff, M.D., Gordon K. Danielson, M.D.,</i>	
<i>and Stephen C. Hammill, M.D.</i>	1114
B. Ventricular Tachyarrhythmia	
<i>Hartzell V. Schaff, M.D., and Francisco J. Puga, M.D.</i>	1121
PART VII. Coronary Heart Disease	1129
33 / Coronary Circulation	1131
A. Physiology of the Coronary Circulation	
<i>Alfred A. Bove, M.D., Ph.D., and William P. Santamore, Ph.D.</i>	1131
B. Pathophysiology of Myocardial Ischemia and Reperfusion	
<i>Kirk N. Garratt, M.D., and James P. Morgan, M.D., Ph.D.</i>	1150
C. Pharmacology of Large Coronary Arteries	
<i>Paul M. Vanhoutte, M.D., Ph.D., and John T. Shepherd, M.D., D.Sc.</i>	1159
34 / Atherosclerosis	1172
A. Pathogenesis, Pathology, and Presentation of Atherosclerosis	
<i>Valentin Fuster, M.D.</i>	1172
B. Pathology of Coronary Artery Disease	
<i>J. T. Lie, M.D.</i>	1211
C. Prevention of Coronary Heart Disease	
<i>Thomas E. Kottke, M.D., and William H. Weidman, M.D.</i>	1232
35 / Myocardial Ischemia Syndromes	1276
A. Angina Pectoris and Coronary Heart Disease	
<i>Clarence Shub, M.D.</i>	1276
B. Coronary Artery Spasm and Vasotonicity	
<i>Michael D. McGoon, M.D., and Valentin Fuster, M.D.</i>	1307
36 / Acute Myocardial Infarction	1318
A. Diagnosis and Prognosis	
<i>Bernard J. Gersh, M.B., Ch.B., D.Phil., Ian P. Clements, M.D.,</i>	
<i>and James H. Chesebro, M.D.</i>	1318

B. Management and Complications Bernard J. Gersh, M.B., Ch.B., D.Phil., James H. Chesebro, M.D., and Ian P. Clements, M.D.1362
C. Arrhythmias Bernard J. Gersh, M.B., Ch.B., D.Phil.1453
37 / Surgical Treatment of Coronary Artery Disease1479
A. Technical Aspects of Coronary Revascularization James R. Pluth, M.D.1479
B. Revascularization Versus Medical Management of Coronary Artery Disease Michael D. McGoon, M.D., Valentin Fuster, M.D., Bernard J. Gersh, M.B., Ch.B., D.Phil., and Charles J. Mullany, M.B., B.S.1490
PART VIII. Specific Disease Entities	1503
38 / Acquired Valvular Heart Disease	1505
A. Aortic Valvular Stenosis Emilio R. Giuliani, M.D., Valentin Fuster, M.D., Clarence Shub, M.D., and Dwight C. McGoon, M.D.	1505
B. Aortic Regurgitation Michael D. McGoon, M.D., Valentin Fuster, M.D., Clarence Shub, M.D., and Hartzell V. Schaff, M.D.	1524
C. Mitral Stenosis Robert O. Brandenburg, M.D., Emilio R. Giuliani, M.D., Rick A. Nishimura, M.D., and Dwight C. McGoon, M.D.	1543
D. Mitral Regurgitation Valentin Fuster, M.D., Michael D. McGoon, M.D., Mark J. Callahan, M.D., and Hartzell V. Schaff, M.D.	1556
E. Tricuspid Valve Disease Emilio R. Giuliani, M.D., Dwight C. McGoon, M.D., Mark J. Callahan, M.D., and Robert O. Brandenburg, M.D.	1580
F. Prosthetic Valves Hartzell V. Schaff, M.D.	1595
39 / Rheumatic Fever David J. Driscoll, M.D.	1610
40 / Congenital Heart Disease in Adolescents and Adults.	1617
A. Introduction Valentin Fuster, M.D., and Dwight C. McGoon, M.D.	1617
B. Atrial Septal Defect Carole A. Warnes, M.D., Valentin Fuster, M.D., David J. Driscoll, M.D., and Dwight C. McGoon, M.D.	1622
C. Ventricular Septal Defect Carole A. Warnes, M.D., Valentin Fuster, M.D., David J. Driscoll, M.D., and Dwight C. McGoon, M.D.	1639
D. Patent Ductus Arteriosus and Other Aorticopulmonary and Coronary Abnormal Communications Valentin Fuster, M.D., David J. Driscoll, M.D., and Dwight C. McGoon, M.D.	1653
E. Atrioventricular Canal Defect David J. Driscoll, M.D., Valentin Fuster, M.D., and Hartzell V. Schaff, M.D.	1664
F. Coarctation of the Aorta Valentin Fuster, M.D., Carole A. Warnes, M.D., and Dwight C. McGoon, M.D.	1670
G. Congenital Left-Sided Outflow Obstruction Valentin Fuster, M.D., Carole A. Warnes, M.D., David J. Driscoll, M.D., and Dwight C. McGoon, M.D.	1678
H. Pulmonary Stenosis With Intact Ventricular Septum Carole A. Warnes, M.D., Valentin Fuster, M.D., and Dwight C. McGoon, M.D.	1687
I. Ebstein's Anomaly of the Tricuspid Valve David J. Driscoll, M.D., Valentin Fuster, M.D., and Gordon K. Danielson, M.D.	1693
J. Tetralogy of Fallot David J. Driscoll, M.D., Valentin Fuster, M.D., and Francisco J. Puga, M.D.	1702