

MANUAL OF  
**CLINICAL**  
**MICROBIOLOGY**  
FIFTH EDITION

---

ALBERT BALOWS  
WILLIAM J. HAUSLER, JR.  
KENNETH L. HERRMANN  
HENRY D. ISENBERG  
H. JEAN SHADOMY

MANUAL OF  
**CLINICAL**  
**MICROBIOLOGY**  
FIFTH EDITION

2,90

---

EDITOR IN CHIEF

**ALBERT BALOWS**

*Emory University School of Medicine, Atlanta, Georgia*

---

EDITORS

**WILLIAM J. HAUSLER, JR.**

*University of Iowa Hygienic Laboratory, Iowa City, Iowa*

**KENNETH L. HERRMANN**

*Centers for Disease Control, Atlanta, Georgia*

**HENRY D. ISENBERG**

*Long Island Jewish Medical Center,  
Long Island Campus for Albert Einstein College of Medicine, New Hyde Park, New York*

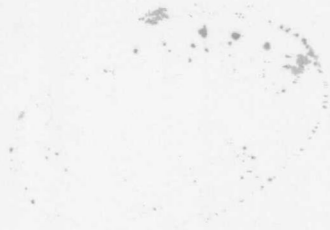
**H. JEAN SHADOMY**

*Virginia Commonwealth University, Richmond, Virginia*

---

**AMERICAN SOCIETY FOR MICROBIOLOGY**

**Washington, D.C.**



MANUAL OF  
CLINICAL  
MICROBIOLOGY  
FIFTH EDITION

Copyright © 1970, 1974, 1980, 1985, 1991  
American Society for Microbiology  
1325 Massachusetts Ave., N.W.  
Washington, DC 20005

**Library of Congress Cataloging-in-Publication Data**

Manual of clinical microbiology.—5th ed. : editor in chief, Albert Balows; editors, William J. Hausler, Jr. . . . [et al.]

p. cm.  
Includes bibliographical references and indexes.

ISBN 1-55581-029-2 (hardcover).—ISBN 1-55581-030-6 (softcover)

1. Diagnostic microbiology—Handbooks, manuals, etc. 2. Medical microbiology—Handbooks, manuals, etc. I. Balows, Albert. II. American Society for Microbiology.

[DNLM: 1. Microbiology. QW 4 M294]

QR67.M36 1991

616'.01—dc20

DNLM/DLC

for Library of Congress

90-14499  
CIP

*All Rights Reserved*  
*Printed in the United States of America*

## Editorial Board

- Daniel Amsterdam** **Section II**  
Departments of Microbiology and Medicine, School of Medicine, SUNY at Buffalo, and  
Division of Clinical Microbiology and Immunology, Erie County Medical Center, Buffalo,  
New York 14215
- Ellen Jo Baron** **Section IV**  
Department of Medicine, UCLA School of Medicine, Los Angeles, California 90024, and  
VA Medical Center Research Service, Los Angeles, California 90073
- Edward J. Bottone** **Section II**  
Department of Microbiology, Mt. Sinai Hospital, New York, New York 10029
- Richard F. D'Amato** **Section IV**  
Division of Microbiology, The Catholic Medical Center of Brooklyn and Queens, Inc.,  
Jamaica, New York 11432
- Gary V. Doern** **Section I**  
Department of Clinical Microbiology, University of Massachusetts Medical Center,  
Worcester, Massachusetts 01655
- Robert A. Fromtling** **Section V**  
Project Planning and Management: Infectious Diseases, Merck Institute for Therapeutic  
Research, Rahway, New Jersey 07065
- Russell C. Johnson** **Section IV**  
Department of Microbiology, University of Minnesota, Minneapolis, Minnesota 55455
- David A. Lennette** **Section VII**  
Virolab, Inc., Berkeley, California 94710
- Joseph E. McDade** **Section VIII**  
Center for Infectious Diseases, Centers for Disease Control, Atlanta, Georgia 30333
- Marilyn A. Menegus** **Section VII**  
Clinical Microbiology Laboratories, University of Rochester Medical Center, Rochester,  
New York 14642
- Patrick R. Murray** **Section IV**  
Department of Pathology and Medicine, Washington University School of Medicine,  
St. Louis, Missouri 63110
- Peter Nash** **Section X**  
CAMAS Diagnostic Co., Minneapolis, Minnesota 55414
- C. George Ray** **Section VII**  
Department of Pathology, University of Arizona College of Medicine, Tucson, Arizona  
85724
- Frank G. Rodgers** **Section IV**  
Department of Microbiology, University of New Hampshire, Durham, New Hampshire  
03824
- James W. Smith** **Section VI**  
Department of Pathology, Indiana University School of Medicine, Indianapolis, Indiana  
46202
- Roy W. Stevens** **Section II**  
Wadsworth Center for Laboratories and Research, New York State Department of Health,  
Albany, New York 12201
- Clyde Thornsberry** **Section IX**  
Institutes for Microbiology Research, Franklin, Tennessee 37064
- Alexander von Graevenitz** **Section IV**  
Department of Medical Microbiology, University of Zurich, CH-8028 Zurich, Switzerland
- Richard P. Wenzel** **Section III**  
Division of General Medicine, Clinical Epidemiology, and Health Services Research, De-  
partment of Internal Medicine, University of Iowa College of Medicine, and Program of  
Epidemiology, University of Iowa Hospitals and Clinics, Iowa City, Iowa 52242

## Contributors

- Sharon L. Abbott**  
Microbial Diseases Laboratory, California Department of Health Services, Berkeley,  
California 94704
- Libero Ajello**  
Division of Mycotic Diseases, Centers for Disease Control, Atlanta, Georgia 30333
- Aaron D. Alexander**  
Department of Microbiology, Chicago College of Osteopathic Medicine, Chicago,  
Illinois 60615
- Stephen D. Allen**  
Department of Pathology, University Hospital, Indiana University School of Medicine,  
Indianapolis, Indiana 46202
- Martin Altwegg**  
Department of Medical Microbiology, University of Zurich, CH-8028 Zurich,  
Switzerland
- Daniel Amsterdam**  
Departments of Microbiology and Medicine, School of Medicine, SUNY at Buffalo, and  
Division of Clinical Microbiology and Immunology, Erie County Medical Center,  
Buffalo, New York 14215
- John P. Anhalt**  
Section of Microbiology, Mayo Clinic, Rochester, Minnesota 55905
- Ray R. Arthur**  
Department of Immunology and Infectious Diseases, Johns Hopkins School of Public  
Health, Baltimore, Maryland 21205
- Ann M. Arvin**  
Department of Pediatrics, Stanford University School of Medicine, Stanford, California  
94305
- Lawrence R. Ash**  
Department of Epidemiology, School of Public Health, University of California at Los  
Angeles, Los Angeles, California 90024
- David M. Asher**  
Laboratory of Central Nervous System Studies, National Institute of Neurological  
Disorders and Stroke, Bethesda, Maryland 20892
- Albert Balows**  
Department of Pathology and Laboratory Medicine, Emory University School of  
Medicine, Atlanta, Georgia 30303
- Susan W. Barnett**  
Cancer Research Institute, School of Medicine, University of California, San Francisco,  
California 94143
- Ellen Jo Baron**  
Department of Medicine, UCLA School of Medicine, Los Angeles, California 90024, and  
VA Medical Center Research Service, Los Angeles, California 90073
- Arthur L. Barry**  
The Clinical Microbiology Institute Inc., Tualatin, Oregon 97062
- Marilyn S. Bartlett**  
Department of Pathology, Indiana University School of Medicine, Indianapolis, Indiana  
46202
- Raymond C. Bartlett**  
Division of Microbiology, Department of Pathology, Hartford Hospital, Hartford,  
Connecticut 06115
- Jacques Bille**  
Clinical Bacteriology Laboratory, University Hospital, Centre Hospitalier Universitaire  
Vaudois, BH19-1011 Lausanne, Switzerland
- Walter W. Bond**  
Hospital Infections Program, Centers for Disease Control, Atlanta, Georgia 30333
- Edward J. Bottone**  
Department of Microbiology, Mt. Sinai Hospital, New York, New York 10029
- Don J. Brenner**  
Division of Bacterial Diseases, Centers for Disease Control, Atlanta, Georgia 30333
- Barbara A. Brown**  
Department of Microbiology, University of Texas Health Center at Tyler, Tyler, Texas  
75710

- Willy Burgdorfer**  
Rocky Mountain Laboratories, National Institute of Allergy and Infectious Diseases,  
Hamilton, Montana 59840
- Kimberle Chapin-Robertson**  
Clinical Microbiology Laboratory, Yale-New Haven Hospital, and Department of  
Laboratory Medicine, Yale University School of Medicine, New Haven, Connecticut  
06510
- Max A. Chernesky**  
Regional Virology Laboratory, St. Joseph's Hospital, Hamilton, Ontario L8N 4A6,  
Canada
- Mary L. Christensen**  
Department of Pathology, Northwestern University Medical School, Chicago, Illinois  
60611, and Virology Laboratory, Department of Pathology, Children's Memorial  
Hospital, Chicago, Illinois 60614
- Diane M. Citron**  
R. M. Alden Research Laboratory, Santa Monica Hospital Medical Center, Santa  
Monica, California 90404
- James M. Conroy**  
Wadsworth Center for Laboratories and Research, New York State Department of  
Health, Albany, New York 12201
- Robert C. Cooksey**  
Hospital Infections Program, Centers for Disease Control, Atlanta, Georgia 30333
- Richard F. D'Amato**  
Division of Microbiology, The Catholic Medical Center of Brooklyn and Queens, Inc.,  
Jamaica, New York 11432
- Jacqueline E. Dawson**  
Division of Viral and Rickettsial Diseases, Centers for Disease Control, Atlanta, Georgia  
30333
- Edward P. Desmond**  
Doctor's Hospital, Pinole, California 94564
- Dennis M. Dixon**  
Laboratories for Mycology, Wadsworth Center for Laboratories and Research, New  
York State Department of Health, Albany, New York 12201-0509
- Gary V. Doern**  
Department of Clinical Microbiology, University of Massachusetts Medical Center,  
Worcester, Massachusetts 01655
- Michael P. Doyle**  
Department of Food Microbiology and Toxicology, University of Wisconsin—Madison,  
Madison, Wisconsin 53706
- Stephen C. Edberg**  
Clinical Microbiology Laboratory, Yale-New Haven Hospital, and Department of  
Laboratory Medicine, Yale University School of Medicine, New Haven, Connecticut  
06510
- M. Nixon Ellis**  
Wellcome Research Laboratories, Burroughs Wellcome Co., Research Triangle Park,  
North Carolina 27709
- Mario R. Escobar**  
Department of Pathology, Medical College of Virginia, Richmond, Virginia 23298
- Joseph J. Esposito**  
Division of Viral and Rickettsial Diseases, Centers for Disease Control, Atlanta, Georgia  
30333
- Richard R. Facklam**  
Division of Bacterial Diseases, Centers for Disease Control, Atlanta, Georgia 30333
- J. J. Farmer III**  
Division of Bacterial Diseases, Centers for Disease Control, Atlanta, Georgia 30333
- Martin S. Favero**  
Hospital Infections Program, Centers for Disease Control, Atlanta, Georgia 30333
- Sydney M. Finegold**  
Research and Medical Services, VA Wadsworth Medical Center, Los Angeles, California  
90073, and Departments of Medicine and Microbiology and Immunology, UCLA School  
of Medicine, Los Angeles, California 90024
- Daniel B. Fishbein**  
Division of Viral and Rickettsial Diseases, Centers for Disease Control, Atlanta, Georgia  
30333

- Thomas J. Fitzgerald**  
Department of Medical Microbiology and Immunology, University of Minnesota—  
Duluth, Duluth, Minnesota 55812
- Thomas M. Folks**  
Division of Viral and Rickettsial Diseases, Centers for Disease Control, Atlanta, Georgia  
30333
- Harvey M. Friedman**  
Department of Medicine, Hospital of the University of Pennsylvania, Philadelphia,  
Pennsylvania 19104
- Robert A. Fromtling**  
Project Planning and Management: Infectious Diseases, Merck Institute for Therapeutic  
Research, Rahway, New Jersey 07065
- Alice Gatson**  
Department of Pathology, University of Texas Medical Branch, Galveston, Texas 77550
- Anne A. Gershon**  
Department of Pediatrics, Columbia Presbyterian Medical Center, New York, New  
York 10032
- Gerald L. Gilardi**  
Department of Laboratories, North General Hospital, New York, New York 10035
- Mary J. R. Gilchrist**  
Clinical Microbiology, VA Medical Center, Cincinnati, Ohio 45220
- Norman L. Goodman**  
Department of Pathology, College of Medicine, University of Kentucky, Lexington,  
Kentucky 40536
- Michael B. Gregg**  
Epidemiology Program Office, Centers for Disease Control, Atlanta, Georgia 30333
- Dieter H. M. Gröschel**  
Department of Pathology, University of Virginia Medical Center, Charlottesville,  
Virginia 22908
- Maurice W. Harmon**  
Division of Viral and Rickettsial Diseases, Centers for Disease Control, Atlanta, Georgia  
30333
- W. J. Hausler, Jr.**  
University of Iowa Hygienic Laboratory, Iowa City, Iowa 52242
- Jean E. Hawkins**  
Reference Laboratory, VA Medical Center, West Haven, Connecticut 06516
- George R. Healy**  
905 Vistavia Circle, Decatur, Georgia 30033 (U.S. Public Health Service [retired])
- Karim E. Hechemy**  
Wadsworth Center for Laboratories and Research, New York State Department of  
Health, Albany, New York 12201
- Donald A. Hendrickson**  
Department of Biology, Ball State University, Muncie, Indiana 47306
- F. W. Hickman-Brenner**  
Division of Bacterial Diseases, Centers for Disease Control, Atlanta, Georgia 30333
- John C. Hierholzer**  
Division of Viral and Rickettsial Diseases, Centers for Disease Control, Atlanta, Georgia  
30333
- Edgar L. Hill**  
Wellcome Research Laboratories, Burroughs Wellcome Co., Research Triangle Park,  
North Carolina 27709
- Sharon Hillier**  
Department of Obstetrics and Gynecology, University of Washington, Seattle,  
Washington 98195
- Richard L. Hodinka**  
Clinical Virology, Children's Hospital of Philadelphia, Philadelphia, Pennsylvania  
19104
- L. A. Holcomb**  
University of Iowa Hygienic Laboratory, Iowa City, Iowa 52242
- Dannie G. Hollis**  
Division of Bacterial Diseases, Centers for Disease Control, Atlanta, Georgia 30333
- Cynthia Howard**  
Virology Laboratory, Department of Pathology, Children's Memorial Hospital, Chicago,  
Illinois 60614

**Henry D. Isenberg**

Long Island Jewish Medical Center, Long Island Campus for Albert Einstein College of Medicine, New Hyde Park, New York 11042

**Peter B. Jahrling**

United States Army Medical Research Institute of Infectious Diseases, Fort Detrick, Frederick, Maryland 21701

**J. Michael Janda**

Microbial Diseases Laboratory, California Department of Health Services, Berkeley, California 94704

**William M. Janda**

Department of Pathology, University of Illinois at Chicago, Chicago, Illinois 60612

**Russell C. Johnson**

Department of Microbiology, University of Minnesota, Minneapolis, Minnesota 55455

**Ronald N. Jones**

Department of Pathology, University of Iowa Hospitals and Clinics, Iowa City, Iowa 52242

**James H. Jorgensen**

Department of Pathology, University of Texas Health Science Center, San Antonio, Texas 78284

**Hannele R. Jousimies-Somer**

Anaerobe Reference Unit, National Public Health Institute, Helsinki, Finland

**Julius Kane**

St. Joseph Health Center, Toronto, Ontario M6R 1B5, Canada

**Michael T. Kelly**

Division of Medical Microbiology, University Hospital-Shaughnessy Site, Vancouver, British Columbia V6H 3N1, Canada

**Alan P. Kendal**

Division of Viral and Rickettsial Diseases, Centers for Disease Control, Atlanta, Georgia 30333

**Michael J. Kennedy**

Microbiology and Nutrition Research, The Upjohn Company, Kalamazoo, Michigan 49001

**George E. Kenny**

Department of Pathobiology, University of Washington, Seattle, Washington 98195

**Rima F. Khabbaz**

Division of Viral and Rickettsial Diseases, Centers for Disease Control, Atlanta, Georgia 30333

**Mogens Kilian**

Department of Oral Biology, The Royal Dental College, DK-8000 Arhus C, Denmark

**Yoo K. Kim**

Department of Laboratory Medicine and Pathology, Mayo Clinic and Mayo Foundation, Rochester, Minnesota 55905

**W. E. Kloos**

Department of Genetics, North Carolina State University, Raleigh, North Carolina 27695

**Elmer W. Koneman**

Clinical Microbiology Laboratory, Denver Veterans Administration Hospital, Denver, Colorado 80220

**J. M. Kramer**

Food Hygiene Laboratory, Central Public Health Laboratory, London NW9 5HT, United Kingdom

**T. Krech**

Risch Medical Laboratories, FL-9494 Schaan, Liechtenstein

**Michelle M. Krenz**

R&D Systems, Inc., Minneapolis, Minnesota 55413

**Donald J. Krogstad**

Departments of Pathology and Internal Medicine, Washington University School of Medicine, St. Louis, Missouri 63110

**Michael D. Lairmore**

Division of Viral and Rickettsial Diseases, Centers for Disease Control, Atlanta, Georgia 30333

**D. W. Lambe, Jr.**

Department of Microbiology, East Tennessee State University, Johnson City, Tennessee 27614



- Geoffrey Land**  
Department of Microbiology and Immunology, Methodist Medical Center, Dallas, Texas 75222
- Marie L. Landry**  
Virology Reference Laboratory, Veterans Administration Medical Center, West Haven, Connecticut 06516
- Francis K. Lee**  
Department of Pediatrics, Emory University School of Medicine, Atlanta, Georgia 30303
- David A. Lennette**  
Virolab, Inc., Berkeley, California 94710
- Evelyne T. Lennette**  
Virolab, Inc., Berkeley, California 94710
- Jay A. Levy**  
Cancer Research Institute, School of Medicine, University of California, San Francisco, California 94143
- James B. Mahony**  
Regional Virology Laboratory, St. Joseph's Hospital, Hamilton, Ontario L8N 4A6, Canada
- Dennis J. McCance**  
Department of Microbiology and Immunology, University of Rochester, Rochester, New York 14642
- Joseph E. McDade**  
Center for Infectious Diseases, Centers for Disease Control, Atlanta, Georgia 30333
- Michael R. McGinnis**  
Department of Pathology, University of Texas Medical Branch, Galveston, Texas 77550
- John E. McGowan, Jr.**  
Clinical Microbiology, Grady Memorial Hospital, Atlanta, Georgia 30335
- Kenneth McIntosh**  
Department of Pediatrics, Children's Hospital, Boston, Massachusetts 02115
- Joseph L. Melnick**  
Division of Molecular Virology, Baylor College of Medicine, Houston, Texas 77030
- Marilyn A. Menegus**  
Clinical Microbiology Laboratories, University of Rochester Medical Center, Rochester, New York 14642
- William G. Merz**  
Department of Laboratory Medicine (Pathology), Johns Hopkins University, Baltimore, Maryland 21205
- J. Michael Miller**  
Hospital Infections Program, Centers for Disease Control, Atlanta, Georgia 30333
- Thomas G. Mitchell**  
Department of Microbiology and Immunology, Duke University Medical Center, Durham, North Carolina 27710
- Robert C. Moellering, Jr.**  
Department of Medicine, New England Deaconess Hospital, Boston, Massachusetts 02215
- Bernard J. Moncla**  
Department of Oral Biology and Department of Periodontics, University of Washington, Seattle, Washington 98195
- Josephine A. Morello**  
Departments of Pathology, Medicine, and Molecular Genetics and Cell Biology, University of Chicago, Chicago, Illinois 60637
- N. P. Moyer**  
University of Iowa Hygienic Laboratory, Iowa City, Iowa 52242
- Patrick R. Murray**  
Departments of Pathology and Medicine, Washington University School of Medicine, St. Louis, Missouri 63110
- James H. Nakano**  
Division of Viral and Rickettsial Diseases, Centers for Disease Control, Atlanta, Georgia 30333 (deceased)
- Peter Nash**  
Camas Diagnostic Company, Minneapolis, Minnesota 55414
- Phuc Nguyen-Dinh**  
Division of Parasitic Diseases, Centers for Disease Control, Atlanta, Georgia 30333

- David E. Normansell**  
Department of Pathology, University of Virginia Health Sciences Center,  
Charlottesville, Virginia 22908
- Thomas C. Orihel**  
School of Public Health and Tropical Medicine, Tulane University, New Orleans,  
Louisiana 70122
- Arvind A. Padhye**  
Division of Mycotic Diseases, Centers for Disease Control, Atlanta, Georgia 30333
- Lester Pasarell**  
Department of Pathology, University of Texas Medical Branch, Galveston, Texas 77550
- A. William Pasculle**  
Presbyterian-University Hospital, University of Pittsburgh School of Medicine,  
Pittsburgh, Pennsylvania 15216
- J. R. Pattison**  
Department of Medical Microbiology, University College, London WC1E 6JJ, United  
Kingdom
- John L. Penner**  
Department of Microbiology, Faculty of Medicine, Banting Institute, Toronto, Ontario  
M5G 1L5, Canada
- Michael A. Pfaller**  
Department of Pathology, University of Iowa College of Medicine, and Veterans  
Administration Medical Center, Iowa City, Iowa 52242
- M. John Pickett**  
Department of Microbiology, University of California, Los Angeles, California 90024
- Peter Plot**  
Department of Microbiology, Institute of Tropical Medicine, B-2000 Antwerp, Belgium
- Harry D. Pratt**  
879 Glen Arden Way, N.E., Atlanta, Georgia 30306
- Charles G. Prober**  
Department of Pediatrics, Stanford University School of Medicine, Stanford, California  
94305
- C. George Ray**  
Department of Pathology, University of Arizona College of Medicine, Tucson, Arizona  
85724
- Michael G. Rinaldi**  
Department of Pathology, University of Texas Health Science Center at San Antonio,  
and Mycology Reference Laboratory, Audie L. Murphy Memorial Veterans' Hospital,  
San Antonio, Texas 78274
- Glenn D. Roberts**  
Department of Laboratory Medicine and Pathology, Mayo Clinic and Mayo Foundation,  
Rochester, Minnesota 55905
- Frank G. Rodgers**  
Department of Microbiology, University of New Hampshire, Durham, New Hampshire  
03824
- Alvin L. Rogers**  
Departments of Botany and Plant Pathology, Microbiology and Public Health, and  
Medical Technology, Michigan State University, East Lansing, Michigan 48824
- Joseph A. Rosebrock**  
Zeus Scientific Inc., Raritan, New Jersey 08869
- Daniel F. Sahn**  
University of Chicago Medical Center, Chicago, Illinois 60637
- Ira F. Salkin**  
Wadsworth Center for Laboratories and Research, New York State Department of  
Health, Albany, New York 12201
- Aimo A. Salmi**  
Department of Virology, University of Turku, SF-20520 Turku, Finland
- Myron Sasser**  
Microbial Identification System, Newark, Delaware 19711
- Julius Schachter**  
Chlamydia Laboratory, San Francisco General Hospital, San Francisco, California  
94110
- Peter Schantz**  
Division of Parasitic Diseases, Centers for Disease Control, Atlanta, Georgia 30333
- Wiley A. Schell**  
Department of Hospital Laboratories, Duke University Medical Center, Durham, North  
Carolina 27710

- Nathalie J. Schmidt**  
Viral and Rickettsial Disease Laboratory, California Department of Health Services,  
Berkeley, California 94704 (deceased)
- Tom G. Schwan**  
Rocky Mountain Laboratories, National Institute of Allergy and Infectious Diseases,  
Hamilton, Montana 59840
- H. Jean Shadomy**  
Department of Microbiology and Immunology, Virginia Commonwealth University,  
Richmond, Virginia 23298
- Smith Shadomy**  
Department of Internal Medicine, Medical College of Virginia, Virginia Commonwealth  
University, Richmond, Virginia 23248
- Keerti V. Shah**  
Department of Immunology and Infectious Diseases, Johns Hopkins School of Public  
Health, Baltimore, Maryland 21205
- Robert E. Shope**  
Yale Arbovirus Research Unit, Yale University School of Medicine, New Haven,  
Connecticut 06510
- Robert M. Smibert**  
Department of Anaerobic Microbiology, Virginia Polytechnic Institute and State  
University, Blacksburg, Virginia 24061
- James W. Smith**  
Department of Pathology, Indiana University School of Medicine, Indianapolis, Indiana  
46202
- Jean S. Smith**  
Division of Viral and Rickettsial Diseases, Centers for Disease Control, Atlanta, Georgia  
30333
- Joseph Stanek**  
Department of Pathology, University Hospital, University of Cincinnati Medical Center,  
Cincinnati, Ohio 45267
- Sharon P. Steinberg**  
Columbia Presbyterian Medical Center, New York, New York 10032
- Roy W. Stevens**  
Wadsworth Center for Laboratories and Research, New York State Department of  
Health, Albany, New York 12201
- John A. Stewart**  
Division of Viral and Rickettsial Diseases, Centers for Disease Control, Atlanta, Georgia  
30333
- Scott J. Stewart**  
Rocky Mountain Laboratories, National Institute of Allergy and Infectious Diseases,  
Hamilton, Montana 59840
- Barbara A. Strain**  
Department of Pathology, University of Virginia Health Sciences Center, School of  
Medicine, Charlottesville, Virginia 22908
- Charles W. Stratton**  
Vanderbilt University School of Medicine, Nashville, Tennessee 37232
- Paul D. Swenson**  
Division of Laboratories, Seattle-King County Department of Public Health, Seattle,  
Washington 98104
- Ella M. Swierkosz**  
Department of Pediatrics, School of Medicine, St. Louis University Medical Center, St.  
Louis, Missouri 63104
- Andrea Talis**  
Division of Infectious Diseases, Department of Pediatrics, Children's Hospital, Boston,  
Massachusetts 02115
- Fred C. Tenover**  
Hospital Infections Program, Centers for Disease Control, Atlanta, Georgia 30333
- Clyde Thornsberry**  
Institutes for Microbiology Research, Franklin, Tennessee 37064
- Thomas J. Tinghitella**  
Department of Pathology, Bridgeport Hospital, Bridgeport, Connecticut 06610
- P. C. B. Turnbull**  
Public Health Laboratory Service Centre for Applied Microbiology and Research,  
Porton Down, Salisbury, Wiltshire SP4 0JG, England
- Govinda S. Visvesvara**  
Division of Parasitic Diseases, Centers for Disease Control, Atlanta, Georgia 30333

**Alexander von Graevenitz**

Department of Medical Microbiology, University of Zurich, CH-8028 Zurich,  
Switzerland

**Richard J. Wallace, Jr.**

Department of Microbiology, University of Texas Health Center at Tyler, Tyler, Texas  
75710

**Kenneth W. Walls**

4006 Northlake Creek Court, Tucker, Georgia 30084 (U.S. Public Health Service  
[retired])

**Thomas J. Walsh**

Infectious Diseases Section, National Cancer Institute, Bethesda, Maryland 20892

**Joseph L. Waner**

Pediatric Infectious Diseases, University of Oklahoma Health Sciences Center,  
Oklahoma City, Oklahoma 73190

**Nancy G. Warren**

Commonwealth of Virginia Division of Consolidated Laboratory Services, Richmond,  
Virginia 23219

**John A. Washington II**

Department of Microbiology, Cleveland Clinic Foundation, Cleveland, Ohio 44106

**Emilio Weiss**

Naval Medical Research Institute, Bethesda, Maryland 20014

**Irene Weitzman**

Mycology Laboratory, City of New York Department of Health, Bureau of Laboratories,  
New York, New York 10016

**Richard P. Wenzel**

Division of General Medicine, Clinical Epidemiology, and Health Services Research,  
Department of Internal Medicine, University of Iowa College of Medicine, and Program  
of Epidemiology, University of Iowa Hospitals and Clinics, Iowa City, Iowa 52242

**Hannah M. Wexler**

Research Service, VA Wadsworth Medical Center, and Department of Medicine, UCLA  
School of Medicine, Los Angeles, California 90073

**Michael D. Wichman**

University of Iowa Hygienic Laboratory, Iowa City, Iowa 52242

**Marianna Wilson**

Division of Parasitic Diseases, Centers for Disease Control, Atlanta, Georgia 30333

**Joseph D. C. Yao**

Calgary General Hospital, Calgary, Alberta, Canada T2E 0A1



## Preface

In the past two decades we have witnessed a remarkable growth in the breadth and depth of clinical microbiology. Documentation of the increasing scope of technological advances during the past 20 years is evidenced in the first four editions of the *Manual of Clinical Microbiology* (MCM). This edition, MCM5, proudly joins its predecessors in documenting currently accepted practices in clinical microbiology as we enter the last decade of the 20th century. The excitement and challenges associated with MCM5 were evident from the beginning and have resulted in a remarkable collaborative effort among editors, authors, and the publisher. The result is a totally revised version that we hope retains a mark of distinction, as did the earlier editions.

The first edition of MCM, published in 1970 with 76 chapters in 727 pages, set the pace and was warmly welcomed by clinical microbiologists, infectious disease specialists, pathologists, medical technologists, clinicians, and students and their teachers as a useful and practical source of information on the detection, isolation, and identification of virtually all important agents of infectious diseases. MCM5, published 21 years later, has 122 chapters in approximately 1,400 pages and documents the dynamic changes that have occurred in all aspects of clinical microbiology.

Innovation is evident throughout MCM5. The number of volume and section editors was increased to accommodate the growth in size and scope. In the early planning stages of this edition, the decision was made to retain the flavor and style of previous editions and to involve and indoctrinate as many young scientists as possible to serve as editorial board members and chapter authors. As a result, at least 107 individuals served as first-time editors and authors for MCM5. The total effort of editors, authors, and an energetic ASM publications staff has resulted in a revised edition that we believe will be user friendly and helpful.

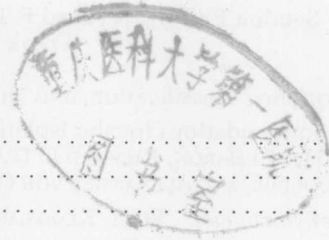
We express our thanks to the many secretaries who diligently produced the drafts and ultimately the final version of each chapter. Similarly, we thank the unsung support staff who did so many different but necessary tasks that contributed to the published manuscript and the successful book. We are appreciative of the efforts of the editorial board, who recruited authors, pressed them to adhere to schedules, and reviewed drafts and final versions of chapters until each chapter was at its scientific prime. Special thanks are due to the staff of the ASM Publications Department, who did everything and anything to assist the editors, editorial board, authors, and others connected with MCM5 in bringing it to fruition. We especially wish to recognize Kirk Jensen, Dennis Burke, and Susan Birch at ASM Publications, who worked patiently with editors and authors to resolve problems as they surfaced and to ensure timely publication.

We also wish to express our appreciation to Helen Whiteley, who was chairman of the ASM Publications Board when MCM5 was embryonic. The wisdom of her leadership and her dedication to ASM publications were of benefit to us. In a different vein, we also acknowledge and express our gratitude for the exemplary contributions of Edwin H. Lennette, whose imprimatur is evident in each of the first four editions of MCM and who set the tone for MCM5.

Finally, and with equal, if not greater, appreciation, we are grateful to the dedicated authors who tolerated the push for producing manuscripts that conformed to style, format, and design. They gave of their time, wisdom, and knowledge to make MCM5 the success that we believe it will be.

**Albert Balows  
William J. Hausler, Jr.  
Kenneth L. Herrmann  
Henry D. Isenberg  
H. Jean Shadomy**

# Contents



Editorial Board .....	ix
Contributors .....	xi
Preface .....	xix

## Section I. GENERAL ISSUES IN CLINICAL MICROBIOLOGY

Section Editor: Gary V. Doern

1. Introduction to the Fifth Edition of the <i>Manual of Clinical Microbiology</i> . ALBERT BALOWS .....	1
2. Indigenous and Pathogenic Microorganisms of Humans. HENRY D. ISENBERG AND RICHARD F. D'AMATO .....	2
3. Specimen Collection and Handling. HENRY D. ISENBERG, JOHN A. WASHINGTON II, GARY V. DOERN, AND DANIEL AMSTERDAM .....	15
4. Microscopy. KIMBERLE CHAPIN-ROBERTSON AND STEPHEN C. EDBERG .....	29
5. Quality Assurance in the Clinical Microbiology Laboratory. RAYMOND C. BARTLETT .....	36
6. Assessment of New Technology. JOHN A. WASHINGTON II AND GARY V. DOERN .....	44
7. Laboratory Safety in Clinical Microbiology. DIETER H. M. GRÖSCHEL AND BARBARA A. STRAIN .....	49

## Section II. DIAGNOSTIC TECHNOLOGIES IN CLINICAL MICROBIOLOGY

Section Editors: Daniel Amsterdam, Roy W. Stevens, and Edward J. Bottone

8. Introduction and Overview. DANIEL AMSTERDAM, ROY W. STEVENS, AND EDWARD J. BOTTONE .....	59
9. Agglutination Tests and <i>Limulus</i> Assay for the Diagnosis of Infectious Diseases. THOMAS J. TINGHITELLA AND STEPHEN C. EDBERG .....	61
10. Hemolytic Assays: Complement Fixation and Antistreptolysin O. MARIO R. ESCOBAR .....	73
11. Labeled-Antibody Techniques: Fluorescent, Radioisotopic, Immunochemical. JOSEPH A. ROSEBROCK .....	79
12. Enzyme Immunoassay. JAMES M. CONROY, ROY W. STEVENS, AND KARIM E. HECHEMY .....	87
13. Immunoelectroblot Techniques. KARIM E. HECHEMY, ROY W. STEVENS, AND JAMES M. CONROY .....	93
14. Immunoprecipitation: Passive Immunodiffusion, Electroimmunodiffusion. DAVID E. NORMANSELL .....	99
15. Detection and Quantitation of Specific Immunoglobulin Responses. FRANCIS K. LEE .....	105
16. Identification of Microorganisms through Use of Gas Chromatography and High-Performance Liquid Chromatography. MYRON SASSER AND MICHAEL D. WICHMAN .....	111
17. Molecular Methods for the Clinical Microbiology Laboratory. FRED C. TENOVER .....	119
18. Substrate Profile Systems for the Identification of Bacteria and Yeasts by Rapid and Automated Approaches. RICHARD F. D'AMATO, EDWARD J. BOTTONE, AND DANIEL AMSTERDAM .....	128
19. Animal and Animal Cell Culture Systems. J. MICHAEL JANDA, EDWARD P. DESMOND, AND SHARON L. ABBOTT .....	137

## Section III. NOSOCOMIAL AND COMMUNITY INFECTIONS: THE ROLE OF THE CLINICAL MICROBIOLOGY LABORATORY

Section Editor: Richard P. Wenzel

20. Epidemiology of Hospital-Acquired Infection. RICHARD P. WENZEL .....	147
21. Communication with Hospital Staff. JOHN E. MCGOWAN, JR. ....	151
22. Procedures for Investigating a Community Outbreak. MICHAEL B. GREGG .....	159
23. Typing Methods for Epidemiologic Investigation. MICHAEL A. PFALLER .....	171
24. Sterilization, Disinfection, and Antisepsis in the Hospital. MARTIN S. FAVERO AND WALTER W. BOND .....	183
25. Waste Management. DIETER H. M. GRÖSCHEL .....	201

**Section IV. BACTERIA**

Section Editors: Richard F. D'Amato, Ellen Jo Baron, Russell C. Johnson, Patrick R. Murray,  
Frank G. Rodgers, and Alexander von Graevenitz

26. Taxonomy, Classification, and Nomenclature of Bacteria. DON J. BRENNER .....	209
27. Recommendations for the Isolation of Bacteria from Clinical Specimens. HENRY D. ISENBERG, ELLEN JO BARON, RICHARD F. D'AMATO, RUSSELL C. JOHNSON, PATRICK R. MURRAY, FRANK G. RODGERS, AND ALEXANDER VON GRAEVENITZ .....	216
28. <i>Staphylococcus</i> . W. E. KLOOS AND D. W. LAMBE, JR. ....	222
29. <i>Streptococcus</i> and Related Catalase-Negative Gram-Positive Cocci. RICHARD R. FACKLAM AND JOHN A. WASHINGTON II .....	238
30. <i>Neisseria</i> and <i>Branhamella</i> . JOSEPHINE A. MORELLO, WILLIAM M. JANDA, AND GARY V. DOERN .....	258
31. <i>Corynebacterium</i> and Related Organisms. T. KRECH AND DANNIE G. HOLLIS .....	277
32. <i>Listeria</i> and <i>Erysipelothrix</i> . JACQUES BILLE AND MICHAEL P. DOYLE .....	287
33. <i>Bacillus</i> . P. C. B. TURNBULL AND J. M. KRAMER .....	296
34. <i>Mycobacterium</i> . GLENN D. ROBERTS, ELMER W. KONEMAN, AND YOO K. KIM .....	304
35. Aerobic Pathogenic <i>Actinomycetales</i> . GEOFFREY LAND, MICHAEL R. MCGINNIS, JOSEPH STANECK, AND ALICE GATSON .....	340
36. <i>Enterobacteriaceae</i> . J. J. FARMER III AND MICHAEL T. KELLY .....	360
37. <i>Vibrio</i> . MICHAEL T. KELLY, F. W. HICKMAN-BRENNER, AND J. J. FARMER III .....	384
38. <i>Aeromonas</i> and <i>Plesiomonas</i> . ALEXANDER VON GRAEVENITZ AND MARTIN ALTWEGG .....	396
39. <i>Campylobacter</i> , <i>Helicobacter</i> , and Related Spiral Bacteria. JOHN L. PENNER .....	402
40. Miscellaneous Gram-Negative Bacteria. M. JOHN PICKETT, DANNIE G. HOLLIS, AND EDWARD J. BOTTONE .....	410
41. <i>Pseudomonas</i> and Related Genera. GERALD L. GILARDI .....	429
42. <i>Legionella</i> . FRANK G. RODGERS AND A. WILLIAM PASCULLE .....	442
43. <i>Francisella</i> . SCOTT J. STEWART .....	454
44. <i>Brucella</i> . N. P. MOYER, L. A. HOLCOMB, AND W. J. HAUSLER, JR. ....	457
45. <i>Haemophilus</i> . MOGENS KILIAN .....	463
46. <i>Bordetella</i> . MARY J. R. GILCHRIST .....	471
47. Mycoplasmas. GEORGE E. KENNY .....	478
48. <i>Gardnerella</i> , <i>Streptobacillus</i> , <i>Spirillum</i> , and <i>Calymmatobacterium</i> . PETER PIOT .....	483
49. General Processing of Specimens for Anaerobic Bacteria. PATRICK R. MURRAY AND DIANE M. CITRON .....	488
50. <i>Clostridium</i> . STEPHEN D. ALLEN AND ELLEN JO BARON .....	505
51. Anaerobic Gram-Positive Nonsporeforming Bacilli and Cocci. SHARON HILLIER AND BERNARD J. MONCLA .....	522
52. Anaerobic Gram-Negative Bacilli and Cocci. HANNELE R. JOUSIMIES-SOMER AND SYDNEY M. FINEGOLD .....	538
53. <i>Leptospira</i> . AARON D. ALEXANDER .....	554
54. <i>Borrelia</i> . WILLY BURGENDORFER AND TOM G. SCHWAN .....	560
55. <i>Treponema</i> . THOMAS J. FITZGERALD .....	567
56. Anaerobic Spirochetes. ROBERT M. SMIBERT .....	572

**Section V. FUNGI**

Section Editor: Robert A. Fromtling

57. Morphology, Taxonomy, and Classification of the Fungi. DENNIS M. DIXON AND ROBERT A. FROMTLING .....	579
58. Detection and Recovery of Fungi from Clinical Specimens. WILLIAM G. MERZ AND GLENN D. ROBERTS .....	588
59. Dermatophytes and Agents of Superficial Mycoses. IRENE WEITZMAN AND JULIUS KANE .....	601
60. Yeasts of Medical Importance. NANCY G. WARREN AND H. JEAN SHADOMY .....	617
61. Dimorphic Fungi Causing Systemic Mycoses. THOMAS J. WALSH AND THOMAS G. MITCHELL .....	630

62. Dematiaceous Fungi. MICHAEL R. MCGINNIS, IRA F. SALKIN, WILEY A. SCHELL, AND LESTER PASARELL .....	644
63. Opportunistic Hyaline Hyphomycetes. ALVIN L. ROGERS AND MICHAEL J. KENNEDY .....	659
64. Agents of Zygomycosis. NORMAN L. GOODMAN AND MICHAEL G. RINALDI .....	674
65. Fungi Causing Eumycotic Mycetomas. ARVIND A. PADHYE AND LIBERO AJELLO .....	693

### Section VI. PARASITES

Section Editor: James W. Smith

66. Diagnostic Parasitology: Introduction and Methods. JAMES W. SMITH AND MARILYN S. BARTLETT .....	701
67. Nonmorphologic Diagnosis of Parasitic Infections. MARIANNA WILSON AND PETER SCHANTZ .....	717
68. Blood and Tissue Protozoa. DONALD J. KROGSTAD, GOVINDA S. VISVESVARA, KENNETH W. WALLS, AND JAMES W. SMITH .....	727
69. Intestinal and Urogenital Protozoa. GEORGE R. HEALY AND JAMES W. SMITH .....	751
70. Tissue Helminths. THOMAS C. ORIHIEL AND LAWRENCE R. ASH .....	771
71. Intestinal Helminths. LAWRENCE R. ASH AND THOMAS C. ORIHIEL .....	782
72. Arthropods of Medical Importance. HARRY D. PRATT AND JAMES W. SMITH .....	796

### Section VII. VIRUSES

Section Editors: David A. Lennette, C. George Ray, and Marilyn A. Menegus

73. Taxonomy of Viruses. JOSEPH L. MELNICK .....	811
74. Preparation of Specimens for Virological Examination. DAVID A. LENNETTE .....	818
75. Herpes Simplex Viruses. ANN M. ARVIN AND CHARLES G. PROBER .....	822
76. Human Cytomegalovirus. RICHARD L. HODINKA AND HARVEY M. FRIEDMAN .....	829
77. Varicella-Zoster Virus. ANNE A. GERSHON, SHARON P. STEINBERG, AND NATHALIE J. SCHMIDT .....	838
78. Epstein-Barr Virus. EVELYNE T. LENNETTE .....	847
79. Other Herpesviruses. JOHN A. STEWART .....	853
80. Poxvirus Infections in Humans. JOSEPH J. ESPOSITO AND JAMES H. NAKANO .....	858
81. Influenza Viruses. MAURICE W. HARMON AND ALAN P. KENDAL .....	868
82. Parainfluenza Viruses. JOSEPH L. WANER .....	878
83. Respiratory Syncytial Virus. ANDREA TALIS AND KENNETH MCINTOSH .....	883
84. Rhinoviruses. MARIE L. LANDRY .....	887
85. Coronaviruses. C. GEORGE RAY .....	893
86. Adenoviruses. JOHN C. HIERHOLZER .....	896
87. Measles Virus. AIMO A. SALMI .....	904
88. Mumps Virus. ELLA M. SWIERKOSZ .....	912
89. Rubella Virus. MAX A. CHERNESKY AND JAMES B. MAHONY .....	918
90. Human Parvoviruses. J. R. PATTISON .....	924
91. Arboviruses. ROBERT E. SHOPE .....	930
92. Rabies Virus. JEAN S. SMITH .....	936
93. Enteroviruses. MARILYN A. MENEGUS .....	943
94. Reoviruses. MARILYN A. MENEGUS .....	948
95. Viruses Causing Gastroenteritis. MARY L. CHRISTENSEN AND CYNTHIA HOWARD .....	950
96. Hepatitis Viruses. PAUL D. SWENSON .....	959
97. Filoviruses and Arenaviruses. PETER B. JAHRLING .....	984
98. Papillomaviruses. DENNIS J. MCCANCE .....	998
99. Polyomaviruses. RAY R. ARTHUR AND KEERTI V. SHAH .....	1005
100. Human Immunodeficiency Viruses. SUSAN W. BARNETT AND JAY A. LEVY .....	1011
101. Other Human Retroviruses. MICHAEL D. LAIRMORE, RIMA F. KHABBAZ, AND THOMAS M. FOLKS .....	1024
102. Spongiform Encephalopathies. DAVID M. ASHER .....	1027



**Section VIII. RICKETTSIAE AND CHLAMYDIAE**

Section Editor: Joseph E. McDade

103. Taxonomy. EMILIO WEISS .....	1033
104. Rickettsiae. JOSEPH E. MCDADE .....	1036
105. Chlamydiae. JULIUS SCHACHTER .....	1045
106. Ehrlichiae. DANIEL B. FISHBEIN AND JACQUELINE E. DAWSON .....	1054

**Section IX. ANTIMICROBIAL AGENTS AND SUSCEPTIBILITY TESTS**

Section Editor: Clyde Thornsberry

107. Antimicrobial Susceptibility Testing: General Considerations. CLYDE THORNSBERRY .....	1059
108. Antibacterial Agents. JOSEPH D. C. YAO AND ROBERT C. MOELLERING, JR. ....	1065
109. Mechanisms of Resistance to Antimicrobial Agents. ROBERT C. COOKSEY .....	1099
110. Antibacterial Susceptibility Tests: Dilution Methods. DANIEL F. SAHM AND JOHN A. WASHINGTON II	1105
111. Susceptibility Tests: Diffusion Test Procedures. ARTHUR L. BARRY AND CLYDE THORNSBERRY .....	1117
112. Antimicrobial Susceptibility Tests: Fastidious and Unusual Bacteria. GARY V. DOERN AND RONALD N. JONES .....	1126
113. Antibacterial Susceptibility Tests: Anaerobic Bacteria. HANNAH M. WEXLER AND SYDNEY M. FINEGOLD .....	1133
114. Antibacterial Susceptibility Tests: Mycobacteria. JEAN E. HAWKINS, RICHARD J. WALLACE, JR., AND BARBARA A. BROWN .....	1138
115. Susceptibility Tests: Special Tests. CHARLES W. STRATTON AND ROBERT C. COOKSEY .....	1153
116. Antibacterial Susceptibility Tests: Automated or Instrument-Based Methods. JAMES H. JORGENSEN .....	1166
117. Laboratory Studies with Antifungal Agents: Susceptibility Tests and Quantitation in Body Fluids. SMITH SHADOMY AND MICHAEL A. PFALLER .....	1173
118. Antiviral and Antiparasitic Susceptibility Testing. EDGAR L. HILL, M. NIXON ELLIS, AND PHUC NGUYEN-DINH .....	1184
119. Assays for Antimicrobial Agents in Body Fluids. JOHN P. ANHALT .....	1192
Appendix 1: Preparation and Storage of Antimicrobial Solutions. JOHN P. ANHALT AND JOHN A. WASHINGTON II .....	1199
Appendix 2: Approximate Concentrations of Antimicrobial Agents Achieved in Blood. ROBERT C. MOELLERING, JR., JOSEPH D. C. YAO, AND CLYDE THORNSBERRY .....	1201

**Section X. QUALITY CONTROL, MEDIA, REAGENTS, AND STAINS**

Section Editor: Peter Nash

120. Quality Control of Media, Reagents, and Stains. J. MICHAEL MILLER .....	1203
121. Culture Media. PETER NASH AND MICHELLE M. KRENZ .....	1226
122. Reagents and Stains. DONALD A. HENDRICKSON AND MICHELLE M. KRENZ .....	1289
Author Index .....	1315
Subject Index .....	1317