

APPLIED AND ENVIRONMENTAL MICROBIOLOGY

VOLUME 59 • JULY 1993 • NUMBER 7

Lars G. Ljungdahl, *Editor in Chief* (1995)
University of Georgia
Athens

Robert A. Bender, *Editor* (1997)
University of Michigan
Ann Arbor

Jane Gibson, *Editor* (1994)
Cornell University
Ithaca, N.Y.

Robert J. Maier, *Editor* (1995)
The Johns Hopkins University
Baltimore, Md.

Kenneth W. Nickerson, *Editor* (1997)
University of Nebraska
Lincoln

Jim C. Spain, *Editor* (1997)
U.S. Air Force
Tyndall Air Force Base, Fla.

Barrie F. Taylor, *Editor* (1994)
University of Miami
Miami, Fla.

Richard F. Unz, *Editor* (1995)
Pennsylvania State University
University Park

Judy D. Wall, *Editor* (1997)
University of Missouri
Columbia

EDITORIAL BOARD

Donald G. Ahearn (1993)
Jan R. Andreesen (1994)
Tamar Barkay (1995)
David R. Benson (1995)
Claire M. Berg (1994)
Kostia Bergman (1993)
Deepak Bhatnagar (1993)
Linda F. Bisson (1995)
Robert Blanchette (1995)
Hans Blaschek (1995)
David R. Boone (1993)
Robert E. Brackett (1995)
James Brierley (1994)
Daniel R. Caldwell (1994)
Douglas G. Capone (1993)
Carl E. Cerniglia (1994)
Arun Chatterjee (1995)
G. Rasul Chaudhry (1995)
Tyrrell Conway (1994)
Everly Conway de Macario (1994)
Donald A. Cooksey (1994)
Donald Crawford (1994)
Kurt Dahlberg (1995)
Edward F. DeLong (1993)
Richard Devereux (1995)
Martin Dickman (1993)
Harold Drake (1994)
Gabriel Drapeau (1993)
David W. Emerich (1995)
Stanley L. Eriandson (1993)
Douglas Eveleigh (1994)
Scott Feighner (1994)
Gerald F. Fitzgerald (1994)
Madilyn M. Fletcher (1993)

James C. Fogleman (1993)
Larry Forney (1993)
Cecil W. Forsberg (1994)
Shelby N. Freer (1994)
Michael S. Gilmore (1993)
Bonita Glatz (1995)
Richard V. Greene (1995)
D. Jay Grimes (1993)
Charles N. Haas (1993)
Bärbel Hahn-Hägerdal (1994)
Kenneth E. Hammel (1995)
Caroline S. Harwood (1993)
George Hegeman (1994)
Walter E. Hill (1995)
Alan Hooper (1993)
Christon J. Hurst (1994)
Robert W. Hutkins (1995)
Lonnie O. Ingram (1995)
Thomas W. Jeffries (1994)
Michael G. Johnson (1995)
Anna Johnson-Winegar (1994)
Ronald D. Jones (1993)
David M. Karl (1994)
Jeffrey Karns (1994)
Eva Kaskhet (1993)
Gary M. King (1993)
Brian K. Kinkle (1995)
Staffan Kjelleberg (1994)
Linda Kohn (1994)
Allan E. Konopka (1994)
John M. Kuchta (1995)
Rajiv K. Kulkarni (1994)
Cletus Kurtzman (1994)
R. Victor Lachica (1995)
Thomas Langworthy (1995)

Robert A. LaRossa (1994)
Donald J. LeBlanc (1993)
Jane A. Z. Leedle (1994)
John F. Leslie (1994)
Derek R. Lovley (1995)
Peter Lüthy (1995)
Eugene L. Madsen (1995)
Edward O. Mason, Jr. (1993)
Thomas L. Mason (1993)
Ann G. Matthysse (1995)
Michael J. McInerney (1995)
Richard D. Miller (1994)
Aaron L. Mills (1993)
Charles Moran (1993)
David P. Nagle, Jr. (1994)
Louise M. Nelson (1995)
Walter G. Niehaus, Jr. (1994)
Fergal O'Gara (1995)
James D. Oliver (1993)
Eric Olson (1994)
Tairo Oshima (1993)
Hans W. Paerl (1993)
William J. Page (1995)
Samuel A. Palumbo (1994)
Leo Parks (1995)
Bruce Paster (1994)
Christine Paszko-Kolva (1994)
Gary Payne (1995)
Ian L. Pepper (1994)
James J. Pestka (1995)
Allen T. Phillips (1995)
Wesley O. Pipes (1995)
John I. Pitt (1993)
Malcolm Potts (1993)
J. T. Pronk (1995)

Robert Ramaley (1995)
Donald J. Reasoner (1995)
John N. Reeve (1993)
John L. Richard (1993)
Donald C. Robertson (1993)
Joseph A. Robinson (1993)
John P. N. Rosazza (1994)
James B. Russell (1995)
Michael Jay Sadowsky (1994)
Abigail A. Salyers (1995)
Peter M. Scott (1993)
Barry F. Sherr (1994)
C. Jeffrey Smith (1994)
James Steele (1995)
Michael E. Stiles (1995)
Anne O. Summers (1995)
John B. Sutherland (1995)
P. G. Thiel (1994)
Linda S. Thomashow (1995)
John Thompson (1994)
Edward Topp (1995)
Peter Van Berkum (1995)
Vincent H. Varel (1994)
Ross A. Virginia (1994)
Edward Voss (1993)
Mark Wach (1995)
Larry Wackett (1994)
Marleen Wekell (1995)
Carol L. Wells (1994)
Bryan A. White (1993)
Michael G. Wolfersberger (1994)
Stephen H. Zinder (1994)
David A. Zuberer (1995)

Barbara H. Iglewski, *Chairman, Publications Board*
John N. Bell, *Production Editor*

Linda M. Illig, *Director, Journals*
Diane Smith, *Assistant Production Editor*

Applied and Environmental Microbiology, a publication of the American Society for Microbiology (ASM), 1325 Massachusetts Ave., N.W., Washington, DC 20005-4171, is devoted to the advancement and dissemination of applied knowledge as well as ecological knowledge, both applied and fundamental, concerning microorganisms. Instructions to authors are published in the January issue each year; reprints are available from the editors and the Journals Division. *Applied and Environmental Microbiology* is published monthly, one volume per year. The nonmember print subscription prices are \$252 (U.S.) (Canadians add 7% GST) and \$299 (other countries) per year; single copies are \$40 (Canadians add 7% GST). The member print subscription prices are \$50 (U.S.) (Canadians add 7% GST) and \$86 (other countries); single copies are \$10 (Canadians add 7% GST). For prices of CD-ROM versions, contact the Subscriptions Unit, ASM. Correspondence relating to subscriptions, defective copies, missing issues, and availability of back issues should be directed to the Subscriptions Unit, ASM; correspondence relating to reprint orders should be directed to the Reprint Order Unit, ASM; and correspondence relating to disposition of submitted manuscripts, proofs, and general editorial matters should be directed to the Journals Division, American Society for Microbiology, 1325 Massachusetts Ave., N.W., Washington, DC 20005-4171. Phone: (202) 737-3600.

Claims for missing issues from residents of the United States, Canada, and Mexico must be submitted within 3 months after publication of the issues; residents of all other countries must submit claims within 6 months of publication of the issues. Claims for issues missing because of failure to report an address change or for issues "missing from files" will not be allowed.

Second-class postage paid at Washington, DC 20005, and at additional mailing offices.
POSTMASTER: Send address changes to *Applied and Environmental Microbiology*, ASM, 1325 Massachusetts Ave., N.W., Washington, DC 20005-4171.

Made in the United States of America. Printed on acid-free paper.
Copyright © 1993, American Society for Microbiology.
All Rights Reserved.

ISSN 0099-2240
CODEN: AEMIDF

The code at the top of the first page of an article in this journal indicates the copyright owner's consent that copies of the article may be made for personal use or for personal use of specific clients. This consent is given on the condition, however, that the copier pay the stated per-copy fee through the Copyright Clearance Center, Inc., 27 Congress St., Salem, MA 01970, for copying beyond that permitted by Sections 107 and 108 of the U.S. Copyright Law. This consent does not extend to other kinds of copying, such as copying for general distribution, for advertising or promotional purposes, for creating new collective works, or for resale.

Author Index

- Abdul-Raouf, U. M., 1999
Akhtar, M., 2210
Amann, Rudolf, 2293
Ammar, M. S., 1999
Aono, Rikizo, 2311
Arvin, Erik, 2286
Atlas, Ronald M., 2139
- Bae, Hee Dong, 2132
Bamford, D. H., 2190
Bernier, Denis, 2034
Berry, David A., 2332
Berry, Duane F., 2332
Beuchat, L. R., 1999
Bezmalinović, Tajana, 2220
Bhatnagar, D., 2264
Bockelmann, Wilhelm, 2049
Bodelier, Paul L. E., 2317
Börmann-El Kholy, Elke R., 2329
Brooks, Myron H., 2304
Brown, Matthew L., 2320
Bruce, Neil C., 2166
Button, Don K., 2150
- Candrian, U., 2161
Casillas, Robert P., 2145
Cerniglia, Carl E., 2145
Champagne, Claude P., 2022
Cheng, K.-J., 2132
Clark, D. L., 2271
Cleveland, T. E., 2264
Colbert, Stephen F., 2056, 2064, 2071
Crawford, Don L., 2171
Crawford, Ronald L., 2171
Criddle, Craig S., 2126
Crow, Sidney A., 2145
Cullum, John, 2220
Cutter, Catherine Nettles, 2326
- Dallmier, Anthony W., 2082
Daly, J. G., 2178
de Vries, Egbert J., 2150
Dhawale, Shree S., 2335
Dierkes, Wilfried, 2029
Domínguez, Angel, 2087
Dostal, Larry, 2244
Duyts, Hendrik, 2099
Dybas, Michael J., 2126
- Eikmanns, Bernhard J., 2329
Ericsson, Per, 2293
- Färdig, M., 2204
Fedorak, Phillip M., 2229
Ferri, Mario, 2056, 2071
Flyvbjerg, John, 2286
Forsten, T., 2190
Fu, Peter P., 2145
Fujimura, Setsuo, 2107
Funk, Stephen B., 2171
- Gardner, Nancy, 2022
Gauthier, Joseph J., 2320
Goodnough, Michael C., 2339
Gottschal, Jan C., 2150
Gram, Lone, 2197
Gravius, Birgit, 2220
Guo, L. Y., 2323
Gutmann, Marcella, 2329
- Haandrikman, Alfred, 2049
Haigler, Billy E., 2239
Hales, Anne M., 2166
Hale, Alan B., 2214
Hammer, Beth, 2339
Handelsman, Jo, 2184
Hantula, J., 2190
Harder, Wim, 2150
Harvey, Ronald W., 2304
Hayatsu, Masahito, 2121
Hébert, Jacques, 2034
Hendson, Mavis, 2056, 2064, 2071
Hopkins, G. D., 2277
Horikoshi, Koki, 2311
Hranueli, Daslav, 2220
Huang, Zhixian, 2244
Hyvärinen, T., 2190
- Iglesias, Francisco J., 2087
Isakeit, Thomas, 2056
Ito, Takeru, 2343
- Janssen, Dick B., 2041
Jensen, Bjørn K., 2286
Jobin, Marie, 2034
Johnson, Eric A., 2339
Jørgensen, Claus, 2286
- Klaenhammer, Todd R., 2034
Klieve, Athol V., 2299
Ko, W. H., 2323
Kok, Jan, 2049
- Laanbroek, Hendrikus J., 2099
- Leenhouts, Kees J., 2049
Lohmeyer, Michael, 2029
Londry, Kathleen L., 2229
Loper, J. E., 2112
Lüthy, J., 2161
Luukkainen, R., 2204
- Maloney, S. E., 2007
Manz, Werner, 2293
Martin, Scott E., 2082
Martins, M. T., 2271
Maule, A., 2007
Mayo, Baltasar, 2049
McAllister, Tim A., 2132
McCarty, P. L., 2277
Metge, David W., 2304
Moineau, Sylvain, 2034
Moore, L. W., 2112
Muir, A. D., 2132
Myers, Eric R., 2082
- Nagarajan, A., 2251
Nagata, Tadahiro, 2121
Nakai, Ryuichiro, 2311
Nakamura, Satoshi, 2311
Nakamura, Takeshi, 2107
Namikoshi, M., 2204
Nielsen, Lars Peter, 2093
Niemelä, S. I., 2190, 2204
Niemi, R. M., 2190
- O'Connell, Kevin P., 2184
Olsen, Susan K., 2286
Olson, B. H., 2271
- Pandian, Sithian, 2034
Park, C. E., 2210
Prins, Rudolf A., 2150
- Raateland, A., 2190
Ramanand, K., 2251
Rasmussen, Mark A., 2077
Rayman, M. K., 2210
Rehm, Hans-Jürgen, 2029
Revsbech, Niels Peter, 2093
Rinehart, K. L., 2204
Risgaard-Petersen, Nils, 2093
Rivera, I. G., 2271
Roberts, Deborah J., 2171
Robertson, Betsy R., 2150
Rodrigue, Natalie, 2022
Ronson, Clive W., 2014
Rosazza, John P. N., 2244
Ross, Karen F., 2014
- Rothenburger, Stephen, 2139
Rysgaard, Søren, 2093
- Saeger, Jennifer L., 2214
Sahm, Hermann, 2329
Sánchez, Manuel, 2087
Santamaría, Carlos, 2087
Schleifer, K.-H., 2293
Schroth, Milton N., 2056, 2064, 2071
Schut, Frits, 2150
Semprini, L., 2277
Shibata, Yukinaga, 2107
Siragusa, Gregory R., 2326
Sivonen, K., 2204
Smit, Eric, 2257
Smith, A. R. W., 2007
Smith, Richard L., 2304
Spain, Jim C., 2239
Stenström, Thor-Axel, 2293
Stevenson, R. M. W., 2178
Stewart, M. H., 2271
Stockwell, V. O., 2112
Suffita, Joseph M., 2251
Sugiyama, Hiroshi, 2339
Sutherland, John B., 2145
Swain, Rosalind A., 2299
Szewzyk, Ulrich, 2293
- Tagg, John R., 2014
Taraban, Ronald H., 2332
Tatara, Gregory M., 2126
- van den Wijngaard, Arjan J., 2041
van Elsas, Jan D., 2257
Venema, Gerard, 2049
Venne, Dorine, 2257
Verhagen, Frank J. M., 2099
Vogels, Godfried D., 2317
Von Tungeln, Linda S., 2145
- Wakabayashi, Kenji, 2311
Walker, Hubert L., Jr., 2332
Weekers, Peter H. H., 2317
Wegmüller, B., 2161
Weinhold, Albert R., 2056, 2064
Wijen, John P. H., 2317
Wind, Richèle D., 2041
Wolfe, R. L., 2271
- Yang, Shen K., 2145
Yanke, Jay, 2132
- Zeringue, H. J., Jr., 2264

NEW FROM ASM BOOKS



"This book is a solid success; it vividly captures and describes in clear detail the current and future role of molecular biotechnology in the clinical microbiology laboratory."

*Albert Balows
(from the Foreword)*

DIAGNOSTIC MOLECULAR MICROBIOLOGY

PRINCIPLES AND APPLICATIONS

Editors: David Persing, M.D., Ph.D.,
Thomas F. Smith, Ph.D., Fred C. Tenover,
Ph.D., Thomas J. White, Ph.D.

Written and edited by leading international experts, this text provides both the theoretical and practical framework for understanding the powerful uses of nucleic acid amplification technologies and for applying these techniques to the rapid detection and characterization of microbial pathogens in the clinical laboratory. The nine chapters in part I (**Principles**) summarize the basic scientific theory underlying the emerging discipline of molecular diagnostics. The sixty-six protocols in part II (**Applications**) offer proven applications of molecular diagnostic techniques for the diagnosis of infectious diseases — essentially a compendium of "molecular recipes" from leading laboratories around the world.

Written in the tradition of ASM's other classic manuals, **Diagnostic Molecular Microbiology** is a valuable reference and teaching tool for any clinical microbiology laboratory.

May 1993. Softcover ISBN 1-55581-056-X.
660 pages (est.), 70 figures. List and ASM Member price, \$59.00. Shipping charges: U.S., \$2.50/book; Non-U.S., \$4.50/book.

ASM accepts VISA, MasterCard, American Express, EuroCard, purchase orders, and checks drawn on U.S. banks in U.S. dollars. Canadian orders must include 7% G.S.T. ASM Press, P.O. Box 605, Herndon, VA 22070 USA. Phone: (703) 787-3305. Fax: (703) 689-0660.

AMERICAN SOCIETY FOR MICROBIOLOGY

3ABM

15 reasons

... why you should join your professional colleagues in the American Society for Microbiology, the world's largest single life science membership organization ...

- 1 Member rates on ASM journals
- 2 Member rates for all ASM meetings and conferences
- 3 A monthly subscription to ASM News
- 4 Member rates for all ASM books and laboratory manuals
- 5 Outstanding continuing educational workshops at member rates
- 6 Superb education materials including audioconferences
- 7 An influential voice in Washington with an effective public relations program
- 8 A year-round job placement service available to members at a nominal fee
- 9 Certification and registration programs through the National Registry of Microbiologists, the American Board of Medical Microbiology, and the American Board of Medical Laboratory Immunology
- 10 An honors and awards program
- 11 Current information on careers in microbiology and related fields
- 12 Optional life, disability, and health insurance for qualified members
- 13 An opportunity to network with your peers
- 14 A schedule for all local, regional, national, and international meetings involving microbiology, biology, and chemistry
- 15 An opportunity to participate in the scientific division of your choice and join over 39,000 members in the promotion of the microbiological sciences

If these 15 reasons (and there are many more) sound good to you, why not find out how you can join ASM today?

For more information, complete the coupon below and mail to:

Chairman, Membership Committee
American Society for Microbiology
1325 Massachusetts Avenue, N.W.
Washington, DC 20005-4171

ASM

I'm interested in membership in the American Society for Microbiology. Please send information and a Membership Application to:

Name _____

Address _____

City _____

State _____ Zip Code _____

Country _____

Student: Yes No Date _____