

APPLIED AND ENVIRONMENTAL MICROBIOLOGY

VOLUME 65 • NOVEMBER 1999 • NUMBER 11

Judy D. Wall, *Editor in Chief* (2000)
University of Missouri

Richard Devereux, *Editor* (2003)
U.S. Environmental Protection Agency

Harold L. Drake, *Editor* (2001)
Universität Bayreuth

Caroline S. Harwood, *Editor* (2001)
University of Iowa

Christian P. Kubicek, *Editor* (2002)
Technische Universität Wien

John F. Leslie, *Editor* (2001)
Kansas State University

Gary P. Roberts, *Editor* (2001)
University of Wisconsin

Michael J. Sadowsky, *Editor* (2003)
University of Minnesota

Michael E. Stiles, *Editor* (2002)
University of Alberta

Richard F. Unz, *Editor* (2000)
Pennsylvania State University

Peter A. Williams, *Editor* (2004)
University of Wales

EDITORIAL BOARD

Keietsu Abe ('01)
Michael J. Adang ('00)
Donald G. Ahearn ('99)
Jose A. Amador ('00)
Rudolf Amann ('99)
David Archer ('01)
Judith P. Armitage ('99)
Arthur Aronson ('01)
Daniel Arp ('99)
Brian Austin ('99)
Charles W. Bacon ('01)
Hubert Bahl ('00)
Mark Bailey ('01)
József Baranyi ('01)
Paul Baumann ('00)
J. Thomas Beatty ('00)
Donna Bedard ('99)
Colin Berry ('99)
Deepak Bhatnagar ('99)
Robert C. Blake II ('01)
Michael Blaust ('01)
Paul Blum ('01)
Peter J. Bottomley ('00)
Botho Bowen ('01)
Axel Brakhage ('01)
Gunnar Bratbak ('99)
John Breznak ('00)
Fred J. Brockman ('99)
Neil C. Bruce ('01)
Andreas Brune ('01)
Thomas D. Bruns ('01)
Douglas G. Capone ('99)
Jeffrey W. Cary ('01)
Enrique Cerda-Olmedo ('00)
Patricia J. S. Colberg ('01)
Tyrrell Conway ('00)
Keith E. Cooksey ('99)
Tim Coolbear ('00)
Michael A. Cotta ('01)

Sarah Covert ('01)
Daniel Cullen ('01)
Thomas J. Daniels ('01)
Edward F. DeLong ('99)
Edward DeMoll ('01)
Sylvie Dequin ('01)
Martin Dickman ('99)
Jan Dolfig ('01)
Richard Eaton ('01)
Henry L. Ehrlich ('01)
Lindsay Eltis ('01)
Stanley L. Erlandsen ('99)
Samuel R. Farrah ('99)
Robert Findlay ('00)
Ulrich Fischer ('99)
Graham H. Fleet ('00)
Harry J. Flint ('99)
James C. Fogleman ('99)
Brian Folsom ('00)
Larry Forney ('99)
Jed A. Fuhrman ('99)
Bruce Geller ('01)
Katharine J. Gibson ('01)
Michael S. Gilmore ('99)
Steve J. Giovannoni ('99)
Bonita Glatz ('01)
Friedrich Götz ('99)
James Gossett ('99)
Denis Groleau ('99)
Max Häggblom ('00)
Dittmar Hahn ('01)
Kenneth E. Hammel ('01)
Theo A. Hansen ('01)
Linda J. Harris ('99)
Joan Henson ('01)
Ayala Hochman ('00)
Christof Holliger ('01)
Michael R. Hyman ('99)
Walter Jakubowski ('01)

Dick Janssen ('01)
Edward L. Jarroll ('01)
Eric A. Johnson ('01)
Ronald D. Jones ('99)
Diann Jordan ('01)
David Kaplan ('01)
Louis Kaplan ('99)
Talma Katan ('01)
Sophia Kathariou ('00)
Michael G. Kaufman ('01)
Ronald P. Kiene ('99)
Brian K. Kinkle ('01)
Keith K. Klein ('00)
Stephen J. Knabel ('99)
Guy R. Knudsen ('99)
Tyler Kokjohn ('01)
Joseph A. Krzycki ('01)
John M. Kuchta ('01)
Jerome J. Kukor ('99)
Charles F. Kulpa, Jr. ('01)
L. David Kuykendall ('99)
Allen I. Laskin ('99)
Peter C. K. Lau ('99)
Mark W. LeChevallier ('01)
Laura G. Leff ('99)
John A. Leigh ('00)
Thomas G. Lessie ('01)
Gunnar Lidén ('01)
Werner Liesack ('01)
John E. Linz ('01)
J. R. Lobry ('00)
J. Londesborough ('01)
Derek R. Lovley ('01)
Roderick I. Mackie ('01)
Raina Maier ('01)
Walter F. O. Marasas ('01)
Robert E. Marquis ('99)
Phyllis Martin ('01)
Edward O. Mason, Jr. ('99)

Ann G. Matthysse ('01)
Robert J. C. McLean ('01)
Terry L. Miller ('99)
Soren Molin ('00)
Charles P. Moran, Jr. ('99)
Mary Ann Moran ('00)
Donald A. Morrison ('99)
Mark Morrison ('99)
Jim Mueller ('01)
Volker Müller ('01)
Gerard Muyzer ('01)
Charles R. Myers ('00)
David Myrold ('01)
Kenneth Nickerson ('01)
Walter G. Niehaus, Jr. ('00)
Peter A. Noble ('01)
Jeanette Norton ('01)
Andrew Ogram ('00)
Oladele A. Ogunseitan ('99)
Gregory Olson ('01)
Tairo Oshima ('99)
William J. Page ('01)
Brian Palenik ('01)
Carol J. Palmer ('99)
Christine Paszko-Kolva ('00)
John H. Paul ('00)
Gary Payne ('01)
Philip Pienkos ('01)
Leland S. Pierson III ('99)
Joseph Piesman ('01)
Peter W. Piper ('99)
John I. Pitt ('99)
Malcolm Potts ('99)
James F. Preston ('01)
Douglas E. Rawlings ('00)
Bibek Ray ('01)
Donald J. Reasoner ('01)
Gregor Reid ('99)

Ian D. Reid ('00)
Eugene W. Rice ('01)
Thomas Ross ('01)
Edward G. Ruby ('01)
Isabel Sá-Correia ('99)
Francis Schmidt ('00)
Vaithilingam Sekar ('00)
Gregory R. Siragusa ('00)
Thad B. Stanton ('01)
Linda D. Stetzenbach ('00)
Herbert Strobel ('99)
Keller Suberkropp ('01)
John B. Sutherland ('01)
John R. Tagg ('99)
Mark L. Tamplin ('00)
Ulf Thrane ('99)
Christopher F. Thurston ('99)
Jack T. Trevors ('00)
Tony Trinci ('01)
Eric W. Triplett ('99)
Jan Roelof van der Meer ('01)
Tina K. Van Dyk ('01)
Jan Dirk van Elsas ('00)
Pieter T. Visscher ('00)
Gerrit Voordouw ('99)
Marleen Wekell ('01)
Carol L. Wells ('00)
Jeremy M. Wells ('99)
Irene V. Wesley ('01)
Bryan A. White ('99)
Juergen Wiegell ('00)
Brian Wilkinson ('01)
Michael G. Wolfersberger ('00)
Charles Woloshuk ('01)
Kimiko Yabe ('99)
Jonathan P. Zehr ('00)
Daniel R. Zeigler ('99)
Gerben Zylstra ('99)

Samuel Kaplan, *Chairman, Publications Board*
John N. Bell, *Production Editor*

Linda M. Illig, *Director, Journals*
Margaret S. Milhous, *Assistant Production Editor*

Applied and Environmental Microbiology (ISSN 0099-2240), a publication of the American Society for Microbiology (ASM), 1752 N St., N.W., Washington, DC 20036-2804, 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 Department. *Applied and Environmental Microbiology* is published monthly, one volume per year. Nonmember print subscription prices (per year) are: \$347, U.S.; \$360, Canada (plus 7% GST, or 7% GST + 8% HST where applicable); \$410, Europe; \$415, Latin America; \$428, rest of world. Member print subscription prices (per year) are: \$58, U.S.; \$70, Canada (plus 7% GST, or 7% GST + 8% HST where applicable); \$113, Europe; \$119, Latin America; \$129, rest of world. Single copies are: \$47, nonmember; \$15, member (Canadians add 7% GST, or 7% GST + 8% HST where applicable). For prices of electronic 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 Department, American Society for Microbiology, 1752 N St., N.W., Washington, DC 20036-2804. 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.

Periodicals postage paid at Washington, DC 20036, and at additional mailing offices.

POSTMASTER: Send address changes to *Applied and Environmental Microbiology*, ASM, 1752 N St., N.W., Washington, DC 20036-2804.

Made in the United States of America. Printed on acid-free paper.

Copyright © 1999, American Society for Microbiology.

All Rights Reserved.

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., 222 Rosewood Drive, Danvers, MA 01923, 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.