

# APPLIED AND ENVIRONMENTAL MICROBIOLOGY

VOLUME 64 • JANUARY 1998 • NUMBER 1

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

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

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

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

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

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

**Jim C. Spain**, *Editor* (2002)  
*U.S. Air Force  
Tyndall Air Force Base, Fla.*

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

**Barrie F. Taylor**, *Editor* (1999)  
*University of Miami  
Miami, Fla.*

**Linda S. Thomashow**, *Editor* (2000)  
*ARS, Washington State University  
Pullman, Wash.*

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

## EDITORIAL BOARD

Michael J. Adang (2000)  
Donald G. Ahearn (1999)  
Jose A. Amador (2000)  
Rudolf Amann (1999)  
Judith P. Armitage (1999)  
Arthur Aronson (1998)  
Daniel Arp (1999)  
Brian Austin (1999)  
Hubert Bahl (2000)  
Paul Baumann (2000)  
J. Thomas Beatty (2000)  
Donna Bedard (1999)  
Colin Berry (1999)  
Deepak Bhatnagar (1999)  
Linda F. Bisson (1998)  
Paul Blum (1998)  
Peter J. Bottomley (2000)  
Robert E. Brackett (1998)  
Gunnar Bratbak (1999)  
John Breznak (2000)  
Fred J. Brockman (1999)  
Michael Calcutt (1999)  
Douglas G. Capone (1999)  
Enrique Cerda-Olmedo (2000)  
Tyrrell Conway (2000)  
Keith E. Cooksey (1999)  
Tim Coolbear (2000)  
Kurt Dahlberg (1998)  
Edward F. DeLong (1999)  
Richard Devereux (1998)  
Martin Dickman (1999)  
David W. Emerich (1998)  
Stanley L. Erlandsen (1999)  
Samuel R. Farrah (1999)  
Robert Findlay (2000)  
Ulrich Fischer (1999)  
Graham H. Fleet (2000)  
Harry J. Flint (1999)  
James C. Fogleman (1999)

Brian Folsom (2000)  
Larry Forney (1999)  
Jed A. Fuhrman (1999)  
Katharine J. Gibson (1998)  
Michael S. Gilmore (1999)  
Steve J. Giovannoni (1999)  
Bonita Glatz (1998)  
Friedrich Goetz (1999)  
James Gossett (1999)  
Richard V. Greene (1998)  
Denis Groleau (1999)  
Max Häggblom (2000)  
Kenneth E. Hammel (1998)  
Theo Hansen (1998)  
Linda J. Harris (1999)  
Joan Henson (1998)  
Ayala Hochman (2000)  
Alan Hooper (1999)  
Michael R. Hyman (1999)  
Edward L. Jarroll (1998)  
Michael G. Johnson (1998)  
Ronald D. Jones (1999)  
Louis Kaplan (1999)  
Sophia Kathariou (2000)  
Ronald P. Kiene (1999)  
Brian K. Kinkle (1998)  
Keith K. Klein (2000)  
Stephen J. Knabel (1999)  
Guy R. Knudsen (1999)  
John M. Kuchta (1998)  
Jerome J. Kukor (1999)  
L. David Kuykendall (1999)  
R. Victor Lachica (1998)  
Robert A. LaRossa (2000)  
Allen I. Laskin (1999)  
Peter C. K. Lau (1999)  
Mark W. LeChevallier (1998)  
Laura G. Leff (1999)

John A. Leigh (2000)  
John E. Linz (1998)  
J. R. Lobry (2000)  
Dorothy M. Lösel (1999)  
Derek R. Lovley (1998)  
Paul W. Ludden (2000)  
Eugene L. Madsen (1998)  
Walter F. O. Marasas (1998)  
Robert E. Marquis (1999)  
Phyllis Martin (1998)  
Edward O. Mason, Jr. (1999)  
Thomas L. Mason (1999)  
Ann G. Matthysse (1998)  
Terry L. Miller (1999)  
Soren Molin (2000)  
Charles P. Moran, Jr. (1999)  
Mary Ann Moran (2000)  
Donald A. Morrison (1999)  
Mark Morrison (1999)  
Charles R. Myers (2000)  
Walter G. Niehaus, Jr. (2000)  
Anrew Ogram (2000)  
Oladele A. Ogunseitan (1999)  
Tairo Oshima (1999)  
William J. Page (1998)  
Brian Palenik (1998)  
Carol J. Palmer (1999)  
Leo Parks (1998)  
Christine Paszko-Kolva (2000)  
John H. Paul (2000)  
Gary Payne (1998)  
Allen T. Phillips (1998)  
Leland S. Pierson III (1999)  
Peter W. Piper (1999)  
John I. Pitt (1999)  
Malcolm Potts (1999)  
James F. Preston (1998)  
J. T. Pronk (1998)

Robert Ramaley (1998)  
Douglas E. Rawlings (2000)  
Donald J. Reasoner (1998)  
Gregor Reid (1999)  
Ian D. Reid (2000)  
Isabel Sá-Correia (1999)  
Michael Jay Sadowsky (2000)  
Francis Schmidt (2000)  
Vaithilingam Sekar (2000)  
Gregory R. Siragusa (2000)  
John Sokatch (1998)  
Linda D. Stetzenbach (2000)  
Herbert Strobel (1999)  
William R. Strohl (1998)  
John B. Sutherland (1998)  
John R. Tagg (1999)  
Mark L. Tamplin (2000)  
Ulf Thrane (1999)  
Christopher F. Thurston (1999)  
Edward Topp (1998)  
Jack T. Trevors (2000)  
Eric W. Triplett (1999)  
Jan Dirk van Elsas (2000)  
Pieter T. Visscher (2000)  
Gerrit Voordouw (1999)  
Edward Voss (1999)  
Marleen Wekell (1998)  
Carol L. Wells (2000)  
Jeremy M. Wells (1999)  
Bryan A. White (1999)  
Juergen Wiegel (2000)  
Michael G. Wolfersberger (2000)  
Janet M. Wood (1998)  
Campbell Wyndham (1998)  
Kimiko Yabe (1999)  
Jonathan P. Zehr (2000)  
Daniel R. Zeigler (1999)  
Gerben Zylstra (1999)

**Barbara H. Iglewski**, *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), 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 Department. *Applied and Environmental Microbiology* is published monthly, one volume per year. Nonmember print subscription prices (per year) are: \$342, U.S.; \$355, Canada (plus 7% GST, or 7% GST + 8% HST where applicable); \$410, Europe; \$415, Latin America; \$424, rest of world. Member print subscription prices (per year) are: \$58, U.S.; \$68, Canada (plus 7% GST, or 7% GST + 8% HST where applicable); \$111, Europe; \$115, Latin America; \$121, rest of world. Single copies are: \$47, nonmember; \$15, member (Canadians add 7% GST, or 7% GST + 8% HST where applicable). 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 Department, 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.

Periodicals 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 © 1998, 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.