

APPLIED AND ENVIRONMENTAL MICROBIOLOGY

VOLUME 56 • MARCH 1990 • NUMBER 3

Lars G. Ljungdahl, Editor in Chief (1990)
University of Georgia
Athens

Robert A. Bender, Editor (1992)
University of Michigan
Ann Arbor

Ronald L. Crawford, Editor (1992)
University of Idaho
Moscow

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

Robert J. Maier, Editor (1990)
The Johns Hopkins University
Baltimore, Md.

Kenneth W. Nickerson, Editor
(1992)
University of Nebraska
Lincoln

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

Robert P. Williams, Editor (1990)
Baylor College of Medicine
Houston, Tex.

EDITORIAL BOARD

Donald G. Ahearn (1990)
Jan R. Andreesen (1991)
Robert E. Andrews (1991)
Ronald M. Atlas (1992)
Tamar Barkay (1992)
David R. Benson (1992)
Claire M. Berg (1991)
Kostia Bergman (1990)
Linda F. Bisson (1992)
Robert Blanchette (1992)
Hans Blaschek (1992)
David R. Boone (1990)
Peter J. Bottomley (1992)
Robert E. Bracket (1992)
James Brierly (1991)
George M. Carman (1990)
Carl Cerniglia (1991)
A. Keith Charnley (1992)
Arun Chatterjee (1992)
G. Rasul Chaudhry (1992)
Everly Conway de Macario (1991)
Donald Cooksey (1991)
Donald Crawford (1991)
Kurt Dahlberg (1992)
Harold Drake (1991)
David W. Emerich (1992)
Stanley L. Erlandsen (1990)
Douglas Eveleigh (1991)
Scott Feighner (1991)
James G. Ferry (1991)
Howard Fields (1990)
Gerald F. Fitzgerald (1991)

Madilyn M. Fletcher (1990)
Cecil W. Forsberg (1991)
Shelby N. Freer (1991)
Barbel E. Friedrich (1991)
William C. Ghiorse (1990)
Michael S. Gilmore (1990)
Richard V. Greene (1992)
D. Jay Grimes (1990)
Dennis C. Gross (1991)
Charles N. Haas (1990)
Barbel Hahn-Hagerdal (1991)
George Hegeman (1991)
Walter E. Hill (1992)
John C. Hoff (1991)
Alan Hooper (1990)
Christon J. Hurst (1991)
Robert W. Hutkins (1992)
Lonnie O. Ingram (1992)
Thomas W. Jeffries (1991)
Michael G. Johnson (1992)
Anna Johnson-Winegar (1991)
David M. Karl (1991)
Jeffrey Karns (1991)
Gary M. King (1990)
Staffan Kjelleberg (1991)
Todd R. Klaenhammer (1992)
Allan E. Konopka (1991)
Roger Korus (1992)
Rajiv K. Kulkarni (1991)
Cletus Kurtzman (1991)
R. Victor Lachica (1992)
Thomas Langworthy (1992)

Robert A. LaRossa (1991)
Donald J. LeBlanc (1990)
Jane Leedle (1991)
David A. Low (1990)
Peter Lüthy (1992)
Eugene L. Madsen (1992)
George L. Marchin (1990)
Edward O. Mason, Jr. (1990)
Thomas L. Mason (1990)
Ann G. Matthyse (1992)
Michael J. McInerney (1992)
Aaron L. Mills (1990)
David Nagle (1991)
Kenneth H. Neelson (1990)
Louise M. Nelson (1992)
Walter G. Niehaus, Jr. (1991)
Dale Noel (1991)
Fergal O'Gara (1992)
James D. Oliver (1990)
Eric Olson (1991)
Tairo Oshima (1990)
Hans W. Paerl (1990)
William J. Page (1992)
Samuel A. Palumbo (1991)
Bruce Paster (1991)
Peter A. Pattee (1990)
Ian L. Pepper (1991)
James J. Pestka (1992)
John Pfeffer (1991)
Allen T. Phillips (1992)
Wesley O. Pipes (1992)
Robert Ramaley (1992)

John N. Reeve (1990)
John L. Richard (1990)
Scott R. Rippey (1991)
Donald C. Robertson (1990)
John P. Rosazza (1991)
Edward G. Ruby (1992)
James B. Russell (1992)
Michael Jay Sadowsky (1991)
Milton N. Schroth (1991)
Peter M. Scott (1990)
Barry F. Sherr (1991)
C. Jeffrey Smith (1991)
Mark D. Sobsey (1990)
Jim Spain (1990)
Gary Stacey (1991)
John B. Sutherland (1992)
Linda S. Thomashow (1992)
Edward Topp (1992)
Richard Unz (1990)
Peter Van Berkum (1992)
J. P. van Dijken (1992)
Vincent Varel (1991)
Ross A. Virginia (1991)
Edward Voss (1990)
Richard L. Ward (1991)
Carol L. Wells (1991)
Bryan A. White (1990)
David R. Wilcox (1992)
Tit-Yee Wong (1991)
A. Aristides Yayanos (1990)
Lily Young (1992)
David A. Zuberer (1992)

Helen R. Whiteley, Chairman, Publications Board

Linda M. Illig, Managing Editor, Journals

John N. Bell, Production Editor

Applied and Environmental Microbiology (ISSN 0099-2240), a publication of the American Society for Microbiology, 1325 Massachusetts Ave., N.W., Washington, DC 20005, 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 Publications Department. *Applied and Environmental Microbiology* is published monthly, one volume per year. The nonmember subscription prices are \$220 (U.S. and Canada) and \$255 (foreign; air drop shipping) per year; single copies are \$40. The member subscription prices are \$39 (U.S. and Canada) and \$74 (foreign; air drop shipping) per year; single copies are \$10. Correspondence relating to subscriptions, nonreceipt of journals, reprints, defective copies, availability of back issues, and lost or late proofs should be directed to the ASM Publications Department, 1325 Massachusetts Ave., N.W., Washington, DC 20005 (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.

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

Copyright © 1990, American Society for Microbiology.

All Rights Reserved.

日本：価格は外貨表示とは関係なく円建。

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., 21 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

- Abbas, Ala S., 675
Allison, Milton J., 590
Anderson, David J., 758
Arunpairajana, Vullapa, 628
Ashbolt, Nicholas J., 707
- Bartha, Richard, 646, 651
Bashan, Yoav, 769
Beremand, Marian N., 202
Brewer, D., 819
Brown, Harlan D., 601
Buck, John D., 826
- Cain, Wendy J., 623
Campbell, Warren L., 661
Carlson, J. R., 724
Cerniglia, Carl E., 661
Chen, Jiann-Shin, 607
Collins, John K., 803
Colwell, R. R., 812
- Daae, Frida Lise, 782
Davis, K., 812
Davos, Dianne E., 796
Day, Martin J., 758
De Rudder, Dirk, 788
Duniway, J. M., 669
- Edwards, Clive, 675
Evans, Frederick E., 661
- Ferreira, Joseph L., 808
Freeman, James P., 661
Fu, Peter P., 661
Fuhrman, Jed A., 739
Fukuzaki, Satoshi, 719
- Goksøyr, Jostein, 776, 782
- Gonzalez, Juan M., 583
Goodwin, P. H., 669
Grau, Craig R., 713
- Hamdy, Mostafa K., 808
Hammond, Andrew C., 590
Handelsman, Jo, 713
Hanlin, John H., 681
Harrison, S. Kent, 769
Hawkey, Peter M., 657
Hilton, Matthew D., 623
Hirai, Kazuto, 764
Hodgkinson, M. C., 628
Holst, Olle, 697
Honeyfield, D. C., 724
Honée, Guy, 823
Hurlbert, Ronald E., 815
Hutton, Micki T., 681
- Ichinoe, Masakatsu, 764
Ikebuchi, Hideharu, 764
Inagaki, Kenji, 693
Inkerman, Peter A., 707
Irbe, Robert M., 601
- Johnson, Eric A., 681
Jonas, Robert B., 747
Jones, Raymond J., 590
- Karlsson, Hans T., 697
Kerr, Kevin G., 657
Kihm, David J., 681
Kirkpatrick, B. C., 669
- Lacey, Richard W., 657
Lanser, Janice A., 796
Larsson, Liselotte, 697
Lee, SangHoon, 739
- MacDonald, Heather L., 640
Makemson, John C., 730
McCay, Steven G., 808
McCormick, Susan P., 702
McGlannan, Michael F., 730
Mester, Ellen H., 713
Molin, Göran, 686
Molina, Thomas C., 601
Moors, Michel, 788
Mugg, Philip A., 796
- Nagai, Shiro, 719
Neway, Justin O., 640
Nishio, Naomichi, 719
- O'Brien, M., 812
Olsson, Gunnel, 697
Oremland, Ronald S., 614
Osawa, Ro, 829
- Persson, Anders, 686
Pierson, Duane L., 601
Plattner, Ronald D., 702
Power, Ultan F., 803
- Raes, Filiep, 788
Raffel, Sandra, 713
Ratcliff, Rodney M., 796
Remon, Jean-Paul, 788
Rosson, Reinhardt A., 595
Rotowa, Nathaniel A., 657
Russell, Nicholas J., 758
- Salte, Kåre, 776
Sangster, Norma, 796
Sato, Michio, 764
Schwartzentruber, K., 819
Sherr, Barry F., 583
- Sherr, Evelyn B., 583
Shobayashi, Manabu, 719
Sly, L. I., 628
Song, Hong-Gyu, 646, 651
Straube, W. L., 812
Sugio, Tsuyoshi, 693
Sørheim, Roald, 776
- Tano, Tatsuo, 693
Taylor, A., 819
Taylor, Scott L., 702
Terao, Tadao, 764
Teshima, Reiko, 764
Thompson, Dorothea K., 607
Torsvik, Vigdis, 776, 782
Tsujita, Yoshihiko, 693
Tuttle, Jon H., 747
- Van Peteghem, Arsene, 788
Vanhaecke, Erwin, 788
Visser, Bert, 823
Vriezen, Wim, 823
- Wang, Xiaoping, 646
Weibull, Claes, 686
White, Graham F., 758
Whitmoyer, Robert E., 769
Wilkinson, Irene J., 796
Wunderlich, Lynn, 713
- Xu, Jimin, 815
- Yoon, Won Bae, 595
- Zapatka, Francis A., 808