HANDBOOK OF Cell Signaling

Volume 1

Editors-in-Chief
RALPH A. BRADSHAW
EDWARD A. DENNIS



Handboo

ell Signaling

Second Edition

Volume 1

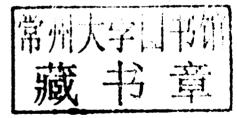
Editors-in-Chief

Ralph A. Bradshaw

Department of Pharmaceutical Chemistry, University of California, San Francisco, San Francisco, California

Edward A. Dennis

Department of Chemistry and Biochemistry, University of California, San Diego, La Jolla, California







Academic Press is an imprint of Elsevier 30 Corporate Drive, Suite 400, Burlington, MA 01803, USA 32 Jamestown Road, London NW1 7BY, UK 525 B Street, Suite 1900, San Diego, CA 92101-4495, USA 360 Park Avenue South, New York, NY 10010-1710, USA

First edition 2004 Second edition 2010

Copyright © 2004, 2010 Elsevier Inc. All rights reserved

No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means electronic, mechanical, photocopying, recording or otherwise without the prior written permission of the publisher

Permissions may be sought directly from Elsevier's Science & Technology Rights Department in Oxford, UK: phone (+44) (0) 1865 843830; fax (+44) (0) 1865 853333; email: permissions@elsevier.com. Alternatively visit the Science and Technology Books website at www.elsevierdirect.com/rights for further information

Notice

No responsibility is assumed by the publisher for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions or ideas contained in the material herein. Because of rapid advances in the medical sciences, in particular, independent verification of diagnoses and drug dosages should be made

Library of Congress Cataloging in Publication Data

A catalog record for this book is available from the Library of Congress

British Library Cataloging in Publication Data

A catalog record for this book is available from the British Library

ISBN: 978-0-12-374145-5 (set) ISBN: 978-0-12-374146-2 (Volume 1) ISBN: 978-0-12-374147-9 (Volume 2) ISBN: 978-0-12-374148-6 (Volume 3)

For information on all Academic Press publications visit our website at www.elsevierdirect.com

Typeset by Macmillan Publishing Solutions (www.macmillansolutions.com)

Printed and bound in the United States of America

09 10 11 12 13 10 9 8 7 6 5 4 3 2 1

Working together to grow libraries in developing countries

www.elsevier.com | www.bookaid.org | www.sabre.org

ELSEVIER

BOOK AID

Sabre Foundation

- **John M. Abrams (261)**, Department of Cell Biology, University of Texas Southwestern Medical Center, Dallas, Texas
- Patricia V. Agostino (194), Laboratory of Chronobiology, Department of Science and Technology, National University of Quilmes, Buenos Aires, Argentina
- **Rexford S. Ahima (332)**, University of Pennsylvania School of Medicine, Department of Medicine, Division of Endocrinology, Diabetes and Metabolism, Philadelphia, Pennsylvania
- Daniel A. Albert (337), Dartmouth Medical School and Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire
- Emil Alexov (2), Department of Biochemistry and Molecular Biophysics, Howard Hughes Medical Institute, Columbia University, New York
- Simon Alford (210), Department of Biological Sciences, University of Illinois at Chicago, Chicago, Illinois
- Steven C. Almo (10), Department of Biochemistry, and Center for Synchrotron Biosciences, Albert Einstein Collge of Medicine, Bronx, New York, New York
- **Géza Ambrus (304)**, Department of Cell Biology, Scripps Research Institute, La Jolla, California
- Sally A. Amundson (257), Center for Radiological Research, Columbia University Medical Center, New York
- Carl W. Anderson (264), Biology Department, Brookhaven National Laboratory, Upton, New York
- Kenneth C. Anderson (325, 326), Department of Medical Oncology, Jerome Lipper Multiple Myeloma Center, Dana-Farber Cancer Institute, Harvard Medical School, Boston, Massachusetts
- Peter Angel (251), Deutsches Krebsforschungszentrum, Division of Signal Transduction and Growth Control, Heidelberg, Germany
- **Frann Antignano** (134), The Terry Fox Laboratory, BC Cancer Agency, Vancouver, BC, Canada
- Marc Antonyak (219), Department of Molecular Medicine, Department of Chemistry and Chemical Biology, Cornell University, Ithaca, New York

- Ettore Appella (264), Laboratory of Cell Biology, National Cancer Institute, National Institutes of Health, Bethesda, Maryland
- William J. Arendshorst (318), Department of Cell and Molecular Physiology, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina
- Liliana Attisano (70), Institute of Medical Sciences and Department of Biochemistry, University of Toronto, and Donnelly Centre for Cellular and Biomolecular Research, University of Toronto, Toronto, Ontario, Canada
- **Anjon Audhya** (138), Weill Institute for Cell and Molecular Biology, Department of Molecular Biology and Genetics, Cornell University, Ithaca, New York
- Manfred Auer (47), Novartis Institutes for BioMedical Research – Vienna, Innovative Screening Technologies Unit, Vienna, Austria
- Juan Ausió (289), Department of Biochemistry and Microbiology, University of Victoria, Victoria, British Columbia, Canada
- **Brandon J. Baird** (273), Laboratory of Molecular Pharmacology, Center for Cancer Research, National Cancer Institute, National Institutes of Health, Bethesda, Maryland
- Jesús Balsinde (149), Institute of Molecular Biology and Genetics, Spanish National Research Council (CSIC) and University of Valladolid School of Medicine, Valladolid, Spain
- **Dwayne L. Barber** (63), Division of Stem Cells and Developmental Biology, Faculty of Medicine, University of Toronto, Toronto, Ontario, Canada
- David Barford (86), Section of Structural Biology, Institute of Cancer Research, Chester Beatty Laboratories, London, England, UK
- Alastair J. Barr (107), Structural Genomics Consortium, Botnar Research Centre, University of Oxford, Oxford, England, UK
- **Dafna Bar-Sagi (217)**, Department of Molecular Genetics and Microbiology, State University of New York at Stony Brook, Stony Brook, New York

- Blaine Bartholomew (282), Department of Biochemistry and Molecular Biology, Southern Illinois University School of Medicine, Springfield, Illinois
- H. Batiaens (155), Cell Biology and Cell Biophysics Program, European Molecular Biology Laboratory, Heidelberg, Germany
- Anthony J. Baucum II (167), Department of Molecular Physiology and Biophysics, Center for Molecular Neuroscience, Vanderbilt-Kennedy Center for Research on Human Development, Vanderbilt University School of Medicine, Nashville, Tennessee
- J. Fernando Bazan (41), Department of Protein Engineering, Mail Stop 27, Genentech, South San Francisco, California
- **Joshua M. Beatty** (248), Center for Biotechnology, Genomics, and Health Research, University of North Carolina at Greensboro, Greensboro, North Carolina
- Joseph A. Beavo (173, 187), Department of Pharmacology, University of Washington School of Medicine, Seattle, Washington
- Elsa Bello-Reuss (318), Department of Internal Medicine, Division of Nephrology and Department of Cell Physiology and Molecular Biophysics, Texas Tech University Health Science Center Lubbock, Texas
- Anton M. Bennett (92), Department of Pharmacology, Yale University School of Medicine, New Haven, Connecticut
- Craig B. Bennett (260), Duke University Medical Center, Department of Surgical Sciences, Durham, North Carolina
- **Penny J. Beuning (258)**, Department of Chemistry and Chemical Biology, Northeastern University, Boston, Massachusetts
- Ramji K. Bhandari (314), Center for Reproductive Biology, School of Molecular Biosciences, Washington State University, Pullman, Washington
- Alicia A. Bicknell (299), University of California San Diego, Division of Biological Sciences, La Jolla, California
- Martin Biel (185), Munich Center for Integrated Protein Science CIPS^M and Department of Pharmacy, Center for Drug Research, Ludwig-Maximilians-Universität München, Munich, Germany
- Vincent A. Bielinski (168), Department of Pharmacology, University of Texas Southwestern Medical Center, Dallas, Texas
- Lutz Birnbaumer (197), Laboratory of Neurobiology, National Institute of Environmental Health Sciences, Research Triangle Park, North Carolina

- Gail A. Bishop (50), Departments of Microbiology and Internal Medicine, The University of Iowa, and the VA Medical Center, Iowa City, Iowa
- **Trillium Blackmer (210)**, Department of Biological Sciences, University of Illinois at Chicago, Chicago, Illinois
- Mordecai P. Blaustein (119), Departments of Physiology and Medicine, University of Maryland School of Medicine, Baltimore, Maryland
- Wojciech C. Blonski (338), Division of Gastroenterology, University of Pennsylvania, Philadelphia, Pennsylvania, and Department of Gastroenterology and Hepatology, Wroclaw Medical University, Wroclaw, Poland
- Naomi Bogenschutz (283), Molecular and Cellular Biology Program, University of Washington and Fred Hutchinson Cancer Research Center, Seattle, Washington
- Frank-D. Böhmer (267), Leibniz Institute for Age Research, Fritz Lipmann Institute, Jena, Germany, and Institute of Molecular Cell Biology, CMB-Center for Molecular Biomedicine, Jena, Germany
- Gary M. Bokoch (106, 216), Departments of Immunology and Cell Biology, The Scripps Research Institute, La Jolla, California
- **Kent Bondensgaard (46)**, Biopharmaceuticals Research Unit, Novo Nordisk A/S, Måløv, Denmark
- **Lynda. F. Bonewald (313)**, Bone Biology Program, University of Missouri-Kansas City, Kansas City, Missouri
- William M. Bonner (273), Laboratory of Molecular Pharmacology, Center for Cancer Research, National Cancer Institute, National Institutes of Health, Bethesda, Maryland
- Martin D. Bootman (109, 117), Calcium Group, Laboratory of Molecular Signalling, The Babraham Institute, Babraham, Cambridge, England, UK
- Johannes L. Bos (186), Department of Physiological Chemistry and Centre for Biomedical Genetics, University Medical Centre Utrecht, Utrecht, The Netherlands
- Rohit Bose (70), Department of Molecular Genetics, University of Toronto, and Program in Molecular Biology and Cancer, Samuel Lunenfeld Research Institute, Mt Sinai Hospital, Toronto, Ontario, Canada
- Istvan Botos (21), Laboratory of Molecular Biology, National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health, Bethesda, Maryland
- Kanika A. Bowen (311), Department of Surgery, The University of Texas Medical Branch, Galveston, Texas

Contributors (xxiii)

- Ralph A. Bradshaw (1, 55, 307), Department of Pharmaceutical Chemistry, University of California San Francisco, San Francisco, California; and Department of Physiology and Biophysics & Department of Anatomy and Neurobiology, University of California, Irvine, California
- Patrick Bregy (189), Institute of Cell Biology, University of Bern, Bern, Switzerland
- Anne R. Bresnick(10), Department of Biochemistry, Albert Einstein Collge of Medicine, Bronx, New York, New York
- Paul K. Brindle (253), Department of Biochemistry, St. Jude Children's Research Hospital, Memphis, Tennessee
- Marisa Brini (118), Department of Biochemistry, University of Padova, Padova, Italy; and Department of Experimental Veterinary Sciences, University of Padova, Legnaro, Padova, Italy
- Ross I. Brinkworth (182), School of Molecular and Microbial Sciences and Institute for Molecular Bioscience, University of Queensland, Brisbane, Queensland, Australia
- Kenneth D. Bromberg (203), Department of Pharmacology and Systems Therapeutics, Mt Sinai School of Medicine, New York, New York
- **Felrecia Brown (180)**, Department of Physiology, College of Medicine, University of South Alabama, Mobile, Alabama
- Michael S. Brown (298), Department of Molecular Genetics, University of Texas Southwestern Medical Center at Dallas, Dallas, Texas
- Anne Brunet (250), Division of Neuroscience, Children's Hospital and Department of Neurobiology, Harvard Medical School, Boston, Massachusetts
- Matthew H. Brush (89), Department of Pharmacology and Cancer Biology, Duke University Medical Center, Durham, North Carolina
- Robert Bucki (141), Institute for Medicine and Engineering, Department of Physiology, University of Pennsylvania, Philadelphia, Pennsylvania
- Dmitry V. Bulavin (271), Institute of Molecular and Cell Biology, Proteos, Singapore
- Robert D. Burgoyne (122), The Physiological Laboratory, School of Biomedical Sciences, University of Liverpool, Liverpool, England, UK
- Tara L. Burke (285), Department of Biochemistry and Molecular Genetics, University of Virginia School of Medicine, Charlottesville, Virginia

Janice E. Buss (213), Department of Pharmaceutical Sciences, University of Kentucky, Lexington, Kentucky

- Michael D. Cahalan (31), Department of Physiology and Biophysics, and the Center for Immunology, University of California, Irvine, California
- **Karyn B. Cahill (177)**, Department of Biochemistry and Molecular Biology, University of New Hampshire, Durham, New Hampshire
- Paul M. Campbell (329), Lee Moffitt Cancer Center and Research Institute, Tampa, Florida
- Ernesto Carafoli (118), Department of Biochemistry, University of Padova, Padova, Italy; and Venetian Institute of Molecular Medicine, Padova, Italy
- **Graham Carpenter (110)**, Department of Biochemistry, Vanderbilt University School of Medicine, Nashville, Tennessee
- Catherine Carrière (310), Departments of Medicine, and Pharmacology and Toxicology, Dartmouth Medical School, Norris Cotton Cancer Center and Dartmouth Hitchcock Medical Center, Lebanon, New Hampshire
- Patrick J. Casey (202), Department of Pharmacology and Cancer Biology, and Department of Biochemistry, Duke University Medical Center, Durham, North Carolina
- Amanda Caster (220), Department of Biochemistry and Neuroscience Graduate Program, Emory University School of Medicine, 1510 Clifton Rd, Atlanta, Georgia
- William A. Catterall (112), Department of Pharmacology, University of Washington, Seattle, Washington
- Richard A. Cerione (218, 219), Department of Molecular Medicine, Department of Chemistry and Chemical Biology, Cornell University, Ithaca, New York
- Denise A. Chan (269), Division of Radiation Biology, Department of Radiation Oncology, Stanford University School of Medicine, Stanford, California
- Gordon Chan (98), Ontario Cancer Institute, Toronto, Ontario, Canada
- Moses V. Chao (234), Molecular Neurobiology Program, Skirball Institute of Biomolecular Medicine, New York University School of Medicine. New York, New York
- **Harry Charbonneau (96)**, Department of Biochemistry, Purdue University, West Lafayette, Indiana
- Nilanjana Chatterjee (282), Department of Biochemistry and Molecular Biology, Southern Illinois University School of Medicine, Springfield, Illinois

- Chyi-Ying A. Chen (277), Department of Biochemistry and Molecular Biology, University of Texas, Medical School at Houston, Houston, Texas
- Jau-Nian Chen (230), Department of Molecular, Cell and Developmental Biology, University of California, Los Angeles, California
- Mingming Chen (284), Department of Carcinogenesis, Science Park Research Division, University of Texas M.D. Anderson Cancer Center, Smithville, Texas
- Philip Chen (263), Queensland Cancer Fund Research Laboratory, Queensland Institute of Medical Research, Brisbane, Australia
- S. R. Wayne Chen (116), Department of Physiology and Biophysics, University of Calgary, Calgary, Alberta, Canada
- Xin Chen (193), Department of Orthopaedics, Case Western Reserve University & Case Medical Center, Cleveland, Ohio
- Yi-Yun Chen (105), Institute of Biological Chemistry, and National Core Facility for Proteomic Research, Academia Sinica, Taipei, Taiwan; and Institute of Biochemical Sciences, College of Life Sciences, National Taiwan University, Taipei, Taiwan
- Zhijian J. Chen (83), Department of Molecular Biology, and Howard Hughes Medical Institute, University of Texas Southwestern Medical Center, Dallas, Texas
- **Peter Cheung (288)**, Department of Medical Biophysics, University of Toronto, and Division of Signaling Biology, Ontario Cancer Institute, Toronto, Ontario, Canada
- Anne Elisabeth Christensen (191), Department of Biomedicine, Medical Faculty, University of Bergen, Norway
- Chung-Sik Choi (180), Department of Physiology, College of Medicine, University of South Alabama, Mobile, Alabama
- Jerold Chun (147), Department of Molecular Biology, Helen L. Dorris Child and Adolescent Neuropsychiatric Disorder Institute, The Scripps Research Institute, La Jolla, California
- **Grant C. Churchill (111)**, Department of Pharmacology, Oxford University, Oxford, England, UK
- Aaron Ciechanover (255), Vascular and Tumor Biology Research Center, Bruce Rappaport Faculty of Medicine, Technion-Israel Institute of Technology, Haifa, Israel
- Andrew H.A. Clayton (48), Ludwig Institute for Cancer Research, Royal Melbourne Hospital, Victoria, Australia
- **Lena Claesson-Welsh (236)**, Department of Genetics and Pathology, Rudbeck Laboratory, Uppsala University, Uppsala, Sweden

- Robert Clarke (317), Department of Oncology, Lombardi Comprehensive Cancer Center, Georgetown University, Washington, DC
- Charles V. Clevenger (36), Department of Pathology, Northwestern University Medical School, Robert H. Lurie Comprehensive Cancer Center, Chicago, Illinois
- Shamshad Cockcroft (142), Department of Physiology, Rockefeller Building, University College London, University Street, London, England, UK
- Patrice Codogno (306), INSERM U756, Faculté de Pharmacie, Université Paris-Sud 11, Châtenay-Malabry, France
- Patricia T.W. Cohen (85), Medical Research Council Protein Phosphorylation Unit, College of Life Sciences, University of Dundee, Dundee, Scotland, UK
- **Philip Cohen** (76), MRC Protein Phosphorylation Unit, University of Dundee, Dundee, Scotland, UK
- Roger J. Colbran (167), Department of Molecular Physiology and Biophysics, Center for Molecular Neuroscience, Vanderbilt-Kennedy Center for Research on Human Development, Vanderbilt University School of Medicine, Nashville, Tennessee
- Marco Conti (174), Center for Reproductive Sciences, Department of Obstetrics and Gynecology, University of California San Francisco, San Francisco, California
- Peter J. Cook (245), Howard Hughes Medical Institute, Department and School of Medicine, University of California, San Diego, La Jolla, California
- Max D. Cooper (22), Department of Pathology and Laboratory Medicine, Emory Vaccine Center of Emory University School of Medicine, Atlanta, Georgia
- **Jackie D. Corbin** (176, 178), Department of Molecular Physiology and Biophysics, Vanderbilt University School of Medicine, Nashville, Tennessee
- **Daniela Corda (204)**, Department of Cell Biology and Oncology, Consorzio Mario Negri Sud, Santa Maria Imbaro, Chieti, Italy
- Seth J. Corey (327, 328), Division of Pediatric Hematology/ Oncology/Stem Cell Transplantation, Children's Memorial Hospital, Chicago, Illinois, Department of Pediatrics, Northwestern University Feinberg School of Medicine, Chicago, Illinois, and Robert H. Lurie Comprehensive Cancer Center, Northwestern University, Chicago, Illinois
- **Rick H. Cote** (177, 178), Department of Biochemistry and Molecular Biology, University of New Hampshire, Durham, New Hampshire
- **Shaun R. Coughlin (26)**, Departments of Medicine and Cellular and Molecular Pharmacology, Cardiovascular

- Research Institute, University of California, San Francisco, California
- Adrienne D. Cox (214, 222), Departments of Pharmacology and Radiation Oncology, Lineberger Comprehensive Cancer Center, and Curriculum in Genetics and Molecular Biology, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina
- Scott D. Cramer (323), Department of Cancer Biology, Wake Forest University School of Medicine, Winston-Salem, North Carolina
- **Fernando Cruz-Guilloty (254)**, Department of Pathology, Harvard Medical School and the Immune Disease Institute, Boston, Massachusetts
- Xiaopoing Cui (262), University of Southern California Keck School of Medicine, USC Norris Comprehensive Cancer Center, Los Angeles, California
- Sami Damak (209), Nestlé Research Center, Vers-chez-les-Blanc, Lausanne, Switzerland
- **Steven M. Damo (49)**, Department of Biochemistry, Weill Medical College of Cornell University, York Avenue, New York, New York
- Mary Dasso (215), Laboratory of Gene Regulation and Development/National Institute of Child Health and Human Development, Bethesda, Maryland
- David R. Davies (21), Laboratory of Molecular Biology, National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health, Bethesda, Maryland
- Anthony J. Davis (168), Department of Pharmacology, University of Texas Southwestern Medical Center, Dallas, Texas
- Roger J. Davis (164), Howard Hughes Medical Institute and Program in Molecular Medicine, University of Massachusetts Medical School, Worcester, Massachusetts
- Nicholas O. Deakin (156), Department of Cell and Developmental Biology, State University of New York, Upstate Medical University, Syracuse, New York, New York
- **Tushar B. Deb** (317), Department of Oncology, Lombardi Comprehensive Cancer Center, Georgetown University, Washington, DC
- **Eva Degerman** (175), Department of Cell and Molecular Biology, Lund University, Lund, Sweden
- Lanika DeGraffenreid (329), Lineberger Comprehensive Cancer Center, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina
- **Katrin Deinhardt** (234), Molecular Neurobiology Program, Skirball Institute of Biomolecular Medicine,

- New York University School of Medicine. New York, New York
- Mark L. Dell'Acqua (165), Department of Pharmacology, University of Colorado Denver School of Medicine, Aurora, Colorado
- Bruce Demple (259), Department of Genetics and Complex Diseases, Harvard School of Public Health, Boston, Massachusetts
- **Jeroen den Hertog** (101), Hubrecht Institute, Uppsalalaan 8, Utrecht, The Netherlands
- Larry Denner (320), McCoy Stem Cells and Diabetes Mass Spectrometry Research Laboratory, Stark Diabetes Center, and Sealy Center for Molecular Medicine, Department of Internal Medicine, University of Texas Medical Branch, Galveston, Texas
- Edward A. Dennis (1, 149), Department of Chemistry and Biochemistry, Department of Pharmacology, School of Medicine and Revelle College, University of California at San Diego, La Jolla, California
- Anna A. DePaoli-Roach (88), Department of Biochemistry and Molecular Biology and Center for Diabetes Research, Indiana University School of Medicine, Indianapolis, Indiana
- Channing J. Der (214, 322, 329), Department of Pharmacology, Lineberger Comprehensive Cancer Center, and Curriculum in Genetics and Molecular Biology, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina
- Céline DerMardirossian (106), Department of Immunology, The Scripps Research Institute, La Jolla, California
- E. M. De Robertis (243), Howard Hughes Medical Institute and Department of Biological Chemistry, University of California, Los Angeles, California
- **Johan de Rooij** (186), The Netherlands Cancer Institute, Division of Cell Biology, Amsterdam, The Netherlands
- **Veronica De Sanctis (265)**, Centre for Integrative Biology, CIBIO, University of Trento, Italy
- Frederic de Sauvage (229), Department of Molecular Biology Genentech, Inc., South San Francisco, California
- **Lakshmi A. Devi (28)**, Department of Pharmacology and Systems Therapeutics, Mount Sinai School of Medicine, New York, New York
- Victor C. de Vries (51), Department of Microbiology and Immunology, Dartmouth Medical School and The Norris Cotton Cancer Center, Lebanon, New Hampshire
- Peter N. Devreotes (207), Department of Cell Biology, Johns Hopkins University School of Medicine, Baltimore, Maryland

- **Nupur Dey** (180), Department of Physiology, College of Medicine, University of South Alabama, Mobile, Alabama
- Salim Dhanji (98), Ontario Cancer Institute, Toronto, Ontario, Canada
- Jennifer S. Dickey (273), Laboratory of Molecular Pharmacology, Center for Cancer Research, National Cancer Institute, National Institutes of Health, Bethesda, Maryland
- Robert B. Dickson (deceased) (317), Department of Oncology, Lombardi Comprehensive Cancer Center, Georgetown University, Washington, DC
- K.M. Dibb (128), Unit of Cardiac Physiology, University of Manchester, Manchester, England, UK
- Pier Paolo Di Fiore (305), IFOM, Fondazione Istituto FIRC di Oncologia Molecolare, and Dipartimento di Medicina, Chirurgia ed Odontoiatria, Universita' degli Studi di Milano, and Dipartimento di Oncologia Sperimentale, Istituto Europeo di Oncologia, Milan, Italy
- Ivan Dikic (69), Institute of Biochemistry II, Goethe University School of Medicine, Frankfurt am Main, Germany
- Francesca Di Leva (118), Department of Biochemistry, University of Padova, Padova, Italy; and Department of Experimental Veterinary Sciences, University of Padova, Legnaro, Padova, Italy
- Anna Dimberg (236), Department of Genetics and Pathology, Rudbeck Laboratory, Uppsala University, Uppsala, Sweden
- Zhao Ding (115), Department of Pharmacology, Tennis Court Road, Cambridge, England, UK
- Julie Diplexcito (87), MRC Protein Phosphorylation Unit, College of Life Sciences, University of Dundee, Dundee, Scotland, UK
- Ben Distel (296), Department of Medical Biochemistry, Academic Medical Center, University of Amsterdam Amsterdam, The Netherlands
- Jack E. Dixon (133), The Life Science Institute and Department of Biological Chemistry, University of Michigan Medical School, Ann Arbor, Michigan
- Teuta Domi (118), Department of Biochemistry, University of Padova, Padova, Italy; and Department of Experimental Veterinary Sciences, University of Padova, Legnaro, Padova, Italy
- Ian M. Donaldson (170), The Biotechnology Centre of Oslo, and the Department for Molecular Biosciences, University of Oslo, Blindern, Oslo, Norway
- Daniel J. Donoghue (237), Department of Chemistry and Biochemistry, University of California San Diego, La

- Jolla, California; and Moores University of California San Diego Cancer Center, La Jolla, California
- Russell F. Doolittle (17), Departments of Molecular Biology and Chemistry & Biochemistry, University of California, San Diego, La Jolla, California
- **Thomas Dörner** (336), Department of Medicine, Rheumatology, and Clinical Immunology, Charite University Medicine Berlin, Germany
- Stein Ove Døskeland (191), Department of Biomedicine, Medical Faculty, University of Bergen, Norway
- Wolfgang R. Dostmann (181), Department of Pharmacology, University of Vermont, College of Medicine, Burlington, Vermont
- Ryan J.O. Dowling (281), Department of Biochemistry, McGill Cancer Centre, McGill University, Montreal, Quebec, Canada
- Kristine A. Drafahl (237), Department of Chemistry and Biochemistry, University of California San Diego, La Jolla, California
- Matthias K. Dreyer (43), Sanofi-Aventis Deutschland GmbH, Structural Biology, Industriepark Höchst, Frankfurt, Germany
- Michael R. Duchen (121), Department of Physiology and UCL Mitochondrial Biology Group, University College London, London, England, UK
- Michael L Dustin (11), Department of Pathology, New York University School of Medicine, Program in Molecular Pathogenesis, Helen L and Martin S Kimmel Center for Biology and Medicine of the Skirball Institute for Biomolecular Medicine, New York, New York
- Edward Eivers (243), Howard Hughes Medical Institute and Department of Biological Chemistry, University of California, Los Angeles, California
- Raul Elgueta (51), Department of Microbiology and Immunology, Dartmouth Medical School and The Norris Cotton Cancer Center, Lebanon, New Hampshire
- Elaine A. Elion (163), Department of Biological Chemistry and Molecular Pharmacology, Harvard Medical School, Boston, Massachusetts
- **D.A. Eisner** (128), Unit of Cardiac Physiology, University of Manchester, Manchester, England, UK
- Christian D. Ellson (137), Koch Institute for Integrated Cancer Research, Massachusetts Institute of Technology, Cambridge, Massachusetts
- Scott D. Emr (138), Weill Institute for Cell and Molecular Biology, Department of Molecular Biology and Genetics, Cornell University, Ithaca, New York

Contributors (xxvii

- Peter J. Espenshade (298), Department of Cell Biology, Johns Hopkins University School of Medicine, Baltimore, Maryland
- Edward D. Esplin (168), Department of Pharmacology, University of Texas Southwestern Medical Center, Dallas, Texas
- **B.** Mark Evers (311), Department of Surgery, The University of Texas Medical Branch, Galveston, Texas
- **Andrei D. Fagarasanu (303)**, Department of Cell Biology, University of Alberta, Edmonton, Alberta, Canada
- Yanshan Fang (108), Howard Hughes Medical Institute, Department of Neuroscience, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania
- Marilyn G. Farquhar, Department of Cellular and Molecular Medicine, University of California San Diego, La Jolla, California (Part IV Introduction)
- Laura Fedrizzi (118), Department of Biochemistry, University of Padova, Padova, Italy; and Department of Experimental Veterinary Sciences, University of Padova, Legnaro, Padova, Italy
- Carol A. Feghali-Bostwick (335), University of Pittsburgh, Pittsburgh, Pennsylvania
- Qiyu Feng (218), Department of Molecular Medicine, Department of Chemistry and Chemical Biology, Cornell University, Ithaca, New York
- James J. Fiordalisi (222), Departments of Radiation Oncology and Pharmacology and the Lineberger Comprehensive Cancer Center, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina
- **Rodolphe Fischmeister (195)**, INSERM UMR-S 769, and Université Paris-Sud 11, Châtenay-Malabry, France
- Garret A. FitzGerald (150), Institute for Translational Medicine and Therapeutics, University of Pennsylvania, Philadelphia, Pennsylvania
- Albert J. Fornace Jr. (257), John B. Little Center for the Radiation Sciences and Environmental Health, Harvard School of Public Health, Boston, Massachusetts, and Lombardi Comprehensive Cancer Center, and Department of Biochemistry and Molecular and Cellular Biology, Georgetown University, Washington, DC
- James J. Foti (258), Department of Biology, Massachusetts Institute of Technology, Cambridge, Massachusetts
- **Sheelagh Frame (76)**, MRC Protein Phosphorylation Unit, University of Dundee, Dundee, Scotland, UK
- Johns Hopkins University School of Medicine, Baltimore, Maryland

Sharron H. Francis (176, 178), Department of Molecular Physiology and Biophysics, Vanderbilt University School of Medicine, Nashville, Tennessee

- Robert E. Friesel (308), Center for Molecular Medicine, Maine Medical Center Research Institute, Portland, Maine
- Günter Fritz (124), Department of Biology, University of Konstanz, Konstanz, Germany
- Michael A. Frohman (144), Center for Developmental Genetics, Graduate Program in Molecular and Cellular Pharmacology, and the Department of Pharmacology, Stony Brook University, Stony Brook, New York, New York
- **David A. Fruman** (132), Department of Molecular Biology & Biochemistry, and Center for Immunology, University of California, Irvine, California
- Luis C. Fuentealba (243), Howard Hughes Medical Institute and Department of Biological Chemistry, University of California, Los Angeles, California
- Muneyoshi Futami (327, 328), Division of Pediatric Hematology/Oncology/Stem Cell Transplantation, Children's Memorial Hospital, Chicago, Illinois, Department of Pediatrics, Northwestern University Feinberg School of Medicine, Chicago, Illinois, and Robert H. Lurie Comprehensive Cancer Center, Northwestern University, Chicago, Illinois
- Antony Galione (111), Department of Pharmacology, Oxford University, Oxford, England, UK
- Stepan Gambaryan (192), Institute of Clinical Biochemistry and Pathobiochemistry, University of Wurzburg, Würzburg, Germany
- Magtouf Gatei (263), Queensland Cancer Fund Research Laboratory, Queensland Institute of Medical Research, Brisbane, Australia
- Larry Gerace (304), Department of Cell Biology, Scripps Research Institute, La Jolla, California
- Tatyana Gerachshenko (210), Department of Biological Sciences, University of Illinois at Chicago, Chicago, Illinois
- Aurnab Ghose (94), Indian Institute of Science Education and Research (IISER), NCL Innovation Park, Pune, India
- Amato J. Giaccia (269), Division of Radiation Biology, Department of Radiation Oncology, Stanford University School of Medicine, Stanford, California
- **Davide Gianni (216)**, Departments of Immunology and Cell Biology, The Scripps Research Institute, La Jolla, California

- Vincent Giguère (246), McGill Cancer Centre, Faculty of Medicine, McGill University, Montréal, Québec, Canada
- Nicolas Girard (82), Human Oncology and Pathogenesis Program, Memorial Sloan-Kettering Cancer Center, New York, New York
- Maria Di Girolamo (204), Department of Cell Biology and Oncology, Consorzio Mario Negri Sud, Santa Maria Imbaro, Chieti, Italy
- Emanuele Giurisato (160), Department of Pathology and Immunology, Washington University School of Medicine, Howard Hughes Medical Institute, Saint Louis, Missouri
- Christopher K. Glass (244), Department of Cellular and Molecular Medicine, School of Medicine, University of California, San Diego, La Jolla, California
- Werner Göbel (321), Department of Neurophysiology, Brain Research Institute, Zurich, Switzerland
- Matthew G. Gold (153), University of Washington, School of Medicine, Department of Pharmacology, Seattle, Washington
- Joseph L. Goldstein (298), Department of Molecular Genetics, University of Texas Southwestern Medical Center at Dallas, Dallas, Texas
- **Diego A. Golombek (194)**, Laboratory of Chronobiology, Department of Science and Technology, National University of Quilmes, Buenos Aires, Argentina
- **Venkatesh K. Gopal (178)**, Department of Molecular Physiology and Biophysics, Vanderbilt University School of Medicine, Nashville, Tennessee
- Myriam Gorospe (270), Laboratory of Cellular and Molecular Biology, National Institute on Aging-IRP, Baltimore, Maryland
- Patrick A. Grant (285), Department of Biochemistry and Molecular Genetics, University of Virginia School of Medicine, Charlottesville, Virginia
- Patrick W. Gray (24), Macrogenics, Inc., Seattle, Washington
- **Douglas R. Green (301)**, Division of Cellular Immunology, La Jolla Institute for Allergy and Immunology, San Diego, California
- Michael E. Greenberg (250), Division of Neuroscience, Children's Hospital and Department of Neurobiology, Harvard Medical School, Boston, Massachusetts
- Edward M. Greenfield (193), Department of Orthopaedics, Department of Pathology, and Department of Physiology & Biophysics, Case Western Reserve University & Case Medical Center, Cleveland, Ohio

- Christopher J. Greenhalgh (64), Division of Molecular Medicine, Walter and Eliza Hall Institute of Medical Research, Parkville, Victoria, Australia
- Vikas Gupta (95), Department of Medicine, Howard Hughes Medical Institute, University of California, San Francisco, California
- J. Silvio Gutkind (201), Oral and Pharyngeal Cancer Branch, National Institute of Dental and Craniofacial Research, National Institutes of Health, Bethesda, Maryland
- Jesper Z. Haeggström (151), Department of Medical Biochemistry and Biophysics, Division of Chemistry II, Karolinska Institutet, Stockholm, Sweden
- Michael N. Hall (274), Biozentrum, University of Basel, Basel, Switzerland
- Otto Haller (226), Department of Virology, Institute of Medical Microbiology and Hygiene, University of Freiburg, Freiburg, Germany
- **Edaeni Hamid (210)**, Department of Biological Sciences, University of Illinois at Chicago, Chicago, Illinois
- **Melisa Hamilton** (134), The Terry Fox Laboratory, BC Cancer Agency, Vancouver, BC, Canada
- Sam Hanash (339), Fred Hutchinson Cancer Research Center, Seattle, Washington
- Ariella B. Hanker (214, 322), Lineberger Comprehensive Cancer Center, and Curriculum in Genetics and Molecular Biology, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina
- Carl A. Hansen (205), Department of Biological and Allied Health Sciences, Bloomsburg University, Bloomsburg, Pennsylvania
- D. Grahame Hardie (73), Division of Molecular Physiology, College of Life Sciences, University of Dundee, Dundee, Scotland, UK
- **Dagmar Harzheim** (117), The Babraham Institute, Babraham, Cambridge, England, UK
- Phillip T. Hawkins (140), The Inositide Laboratory, The Babraham Institute, Babraham Research Campus, Cambridge, England, UK
- Lee P Haynes (122), The Physiological Laboratory, School of Biomedical Sciences, University of Liverpool, Liverpool, England, UK
- **Timothy A.J. Haystead** (154), Department of Pharmacology and Cancer Biology, Duke University, Durham, North Carolina
- **Clemens C. Heikaus (187)**, Department of Biochemistry, University of Washington, Seattle, Washington

Claus W. Heizmann (124), Department of Pediatrics, Division of Clinical Chemistry and Biochemistry, University of Zürich, Zürich, Switzerland

- Carl-Henrik Heldin (59), Ludwig Institute for Cancer Research, Uppsala, Sweden
- **Fritjof Helmchen (321)**, Department of Neurophysiology, Brain Research Institute, Zurich, Switzerland
- **Linda Hendershot** (294), Department of Genetics and Tumor Cell Biology, St. Jude Children's Research Hospital, Memphis, Tennessee
- Vincent C. Henrich (248), Center for Biotechnology, Genomics, and Health Research, University of North Carolina at Greensboro, Greensboro, North Carolina
- Michelle L. Hermiston (95), Department of Pediatrics, Howard Hughes Medical Institute, University of California, San Francisco, California
- **Brantley R. Herrin (22)**, Department of Pathology and Laboratory Medicine, Emory Vaccine Center of Emory University School of Medicine, Atlanta, Georgia
- Peter Herrlich (267), Leibniz Institute for Age Research, Fritz Lipmann Institute, Jena, Germany, and Institute of Toxicology and Genetics, Karlsruhe Institute of Technology, Karlsruhe, Germany
- **Jochen Hess** (251), Deutsches Krebsforschungszentrum, Division of Signal Transduction and Growth Control, Heidelberg, Germany
- **Elizabeth A. Hewat (14)**, Institut de Biologie Structurale J-P Ebel, Grenoble, France
- **Bertil Hille** (32), University of Washington School of Medicine, Department of Physiology and Biophysics, Seattle, Washington
- **Douglas J. Hilton (64)**, Division of Molecular Medicine, Walter and Eliza Hall Institute of Medical Research, Parkville, Victoria, Australia
- **K. A. Hinchliffe** (130), Department of Pharmacology University of Cambridge, Cambridge, England, UK
- Siv A. Hjorth (46), Biopharmaceuticals Research Unit, Novo Nordisk A/S, Måløv, Denmark
- Eric Ho (71), Samuel Lunenfeld Research Institute, Mt Sinai Hospital, Toronto, Ontario, Canada
- Victor Ho (134), The Terry Fox Laboratory, BC Cancer Agency, Vancouver, BC, Canada
- Mark Hochstrasser (161), Department of Molecular Biophysics & Biochemistry, Yale University, New Haven, Connecticut
- **Daniela Hoeller (69)**, Institute for Medical Biochemistry, Innsbruck Biocentre, Innsbruck, Austria

Siegfried Höfinger (47), Forschungszentrum Jülich, John von Neumann Institut für Computing, Jülich, Germany

- Franz Hofmann (184), Institut für Pharmakologie und Toxikologie, TU München, Munich, Germany
- **Hubert Hondermarck (169)**, Institut National de la Santé et de la Recherche Médicale, Université de Lille, Villeneuve d'Ascq, France
- Barry Honig (2), Department of Biochemistry and Molecular Biophysics, Howard Hughes Medical Institute, Columbia University, New York
- **Bruce S. Hostager** (50), Department of Pediatrics, The University of Iowa, Iowa City, Iowa
- Margaret Howe (320), McCoy Stem Cells and Diabetes Mass Spectrometry Research Laboratory, and Stark Diabetes Center, Department of Internal Medicine, University of Texas Medical Branch, Galveston, Texas
- Ming-Fo Hsu (105), Institute of Biological Chemistry, Academia Sinica, Taipei, Taiwan; and Institute of Biochemical Sciences, College of Life Sciences, National Taiwan University, Taipei, Taiwan
- **Timothy Y. Huang (106)**, Department of Immunology, The Scripps Research Institute, La Jolla, California
- Stevan R. Hubbard (45, 58), Skirball Institute of Biomolecular Medicine and Department of Pharmacology, New York University School of Medicine, New York, New York
- Rainbo C. Hultman (202), Department of Biochemistry, Duke University Medical Center, Durham, North Carolina
- **Tony Hunter (56)**, Molecular and Cell Biology Laboratory, The Salk Institute, La Jolla, California
- **Amjad Husain (163)**, Department of Biological Chemistry and Molecular Pharmacology, Harvard Medical School, Boston, Massachusetts
- Daniel R. Hyduke (257), Department of Bioengineering, University of California-San Diego, La Jolla, California, and John B. Little Center for the Radiation Sciences and Environmental Health, Harvard School of Public Health, Boston, Massachusetts
- Sarah G. Hymowitz (40), Department of Protein Engineering, Genentech Inc., South San Francisco, California
- Yann Hyvert (159), Centre National de la Recherche Scientifique and Faculté des Sciences de la Vie, Université Louis Pasteur, Institut de Biologie Moléculaire et Cellulaire, Strasbourg, France
- Miho Iijima (297), Department of Cell Biology, Johns Hopkins University School of Medicine, Baltimore, Maryland

- Jean-Luc Imler (159), Centre National de la Recherche Scientifique and Faculté des Sciences de la Vie, Université Louis Pasteur, Institut de Biologie Moléculaire et Cellulaire, Strasbourg, France
- Alberto Inga (265), Unit of Molecular Mutagenesis and DNA repair, Department of Translational Oncology, National Institute for Cancer Research, IST, Genoa, Italy
- M. Luisa Iruela-Arispe (235), Department of Molecular, Cell and Developmental Biology, University of California, Los Angeles, California
- **R. F. Irvine** (130), Department of Pharmacology University of Cambridge, Cambridge, England, UK
- **Toyotaka Ishibashi (289)**, Department of Biochemistry and Microbiology, University of Victoria, Victoria, British Columbia, Canada
- Sumiyasu Ishii (247), Department of Molecular and Cellular Biology and Program of Development, Baylor College of Medicine, Houston, Texas
- Marcin Iwanicki (66), Department of Microbiology, University of Virginia Health System, Charlottesville, Virginia
- Ravi Iyengar (203), Department of Pharmacology and Systems Therapeutics, Mount Sinai School of Medicine, New York, New York
- Veli-Pekka Jaakola (20), Department of Molecular Biology, The Scripps Research Institute, La Jolla, California
- **Stephen P. Jackson** (77), Wellcome Trust and Cancer Research UK, and Institute of Cancer and Developmental Biology and Department of Zoology, University of Cambridge, Cambridge, England, UK
- Lily Yeh Jan (211), Howard Hughes Medical Institute, Departments of Physiology and Biochemistry, University of California San Francisco, San Francisco, California
- Paul A. Janmey (141), Institute for Medicine and Engineering, Department of Physiology, University of Pennsylvania, Philadelphia, Pennsylvania
- Sophie Jarriault (231), IGBMC (Institut de Génétique et de Biologie Moléculaire et Cellulaire), Department of Cell and Developmental Biology, Illkirch, France; and Université Louis Pasteur, Strasbourg, France
- **Mojib Javadi Javed (63)**, Division of Stem Cells and Developmental Biology, Ontario Cancer Institute, Toronto, Ontario, Canada
- Benjamin C. Jennings (200), Department of Cell Biology and Physiology, Washington University School of Medicine, St Louis, Missouri

- Michael D. Johnson (317), Department of Oncology, Lombardi Comprehensive Cancer Center, Georgetown University, Washington, DC
- E. Yvonne Jones (8), Cancer Research UK Receptor Structure Research Group, University of Oxford, Oxford, England, United Kingdom
- Jennifer J. Jordan (265), Laboratory of Molecular Genetics, National Institute of Environmental Health Sciences, NIH, Research Triangle Park, North Carolina, and Curriculum in Genetics and Molecular Biology, University of North Carolina, Chapel Hill, North Carolina
- **Sofi G. Julien (99)**, McGill Cancer Center, McGill University, Montreal, Quebec, Canada
- **Louis B. Justement (316)**, Department of Microbiology, University of Alabama at Birmingham, Birmingham, Alabama
- Richard A. Kahn (220), Department of Biochemistry and Neuroscience Graduate Program, Emory University School of Medicine, 1510 Clifton Rd, Atlanta, Georgia
- **Björn M. Kampa** (321), Department of Neurophysiology, Brain Research Institute, Zurich, Switzerland
- **Lishan Kang (46)**, Biopharmaceuticals Research Unit, Novo Nordisk A/S, Måløv, Denmark
- Yu-Ya Kao (216), Departments of Immunology and Cell Biology, The Scripps Research Institute, La Jolla, California
- Michael Karin, Department of Pharmacology and Pathology, Moores Cancer Center, UCSD School of Medicine, La Jolla, California (Part III Introduction)
- Arthur Karlin (33), Departments of Biochemistry and Molecular Biophysics, Physiology and Cellular Biophysics, and Neurology, Center for Molecular Recognition, Columbia University, New York, New York
- Alla O. Kaserer (78), Department of Chemistry and Biochemistry, University of Oklahoma, Norman, Oklahoma
- Randal J. Kaufman (276), Departments of Biological Chemistry, Internal Medicine, and Howard Hughes Medical Institute, University of Michigan Medical School, Ann Arbor, Michigan
- Sakari Kauppinen (340), Santaris Pharma, Hørsholm, Denmark, and Wilhelm Johannsen Centre for Functional Genome Research, Department of Cellular and Molecular Medicine, University of Copenhagen, Copenhagen, Denmark
- Bruce E. Kemp (74, 182), St Vincent's Institute, Fitzroy, Victoria, Australia

- Rolf Kemler (228), Department of Molecular Embryology, Max-Planck Institute of Immunobiology, Freiburg, Germany
- Mary B. Kennedy (75, 158), Division of Biology, California Institute of Technology, Pasadena, California
- Norman J. Kennedy (164), Howard Hughes Medical Institute and Program in Molecular Medicine, University of Massachusetts Medical School, Worcester, Massachusetts
- Stephen M. Keyse (97), Cancer Research UK Stress Response Laboratory, Biomedical Research Institute, Ninewells Hospital and Medical School, Dundee, Scotland, UK
- Amanda Kijas (263), Queensland Cancer Fund Research Laboratory, Queensland Institute of Medical Research, Brisbane, Australia
- **Ushio Kikkawa** (129), Biosignal Research Center, Kobe University, Kobe, Japan
- Jong Heon Kim (278), Program in Molecular Medicine, University of Massachusetts Medical School, Worcester, Massachusetts, and Research Institute, National Cancer Center, Goyang, Gyeonggi, Korea
- Jun-Sub Kim (216), Departments of Immunology and Cell Biology, The Scripps Research Institute, La Jolla, California
- Soo-A. Kim (133), The Life Science Institute and Department of Biological Chemistry, University of Michigan Medical School, Ann Arbor, Michigan
- Sung-Hou Kim (29), Department of Chemistry and Lawrence Berkeley National Laboratory, University of California, Berkeley, California
- Michelle E. Kimple (202), Department of Pharmacology and Cancer Biology, Duke University Medical Center, Durham, North Carolina
- Claude B. Klee (90), Laboratory of Biochemistry, National Cancer Institute, National Institutes of Health, Bethesda, Maryland
- **Thomas Kleppisch** (184), Institut für Pharmakologie und Toxikologie, TU München, München, Germany
- **Stefan Knapp** (107), Structural Genomics Consortium, Botnar Research Centre, University of Oxford, Oxford, England, UK
- **Bostjan Kobe** (74, 182), School of Molecular and Microbial Sciences and Institute for Molecular Bioscience, University of Queensland, Brisbane, Queensland, Australia
- **Brian K. Kobilka (25)**, Department of Molecular and Cellular Physiology, Stanford University School of Medicine, Palo Alto, California

- Melissa R. Koch (290), University of California, San Diego, Division of Biological Sciences, Section of Molecular Biology, UCSD Moores Cancer Center, La Jolla, California
- Georg Kochs (226), Department of Virology, Institute of Medical Microbiology and Hygiene, University of Freiburg, Freiburg, Germany
- Rolf König (315), Department of Microbiology and Immunology, The University of Texas Medical Branch, Galveston, Texas
- Albert C. Koong (269), Division of Radiation Biology, Department of Radiation Oncology, Stanford University School of Medicine, Stanford, California
- Murray Korc (310, 324, 333), Departments of Medicine, and Pharmacology and Toxicology, Dartmouth Medical School, Norris Cotton Cancer Center and Dartmouth Hitchcock Medical Center, Lebanon, New Hampshire
- Daniel Kornitzer (255), Department of Molecular Microbiology, Bruce Rappaport Faculty of Medicine, Technion-Israel Institute of Technology, Haifa, Israel
- Anthony A. Kossiakoff (36), Department of Biochemistry and Molecular Biology, University of Chicago, Gordon Center for Integrative Sciences, Chicago, Illinois
- Wolfgang J. Köstler (61), Department of Biological Regulation, The Weizmann Institute of Science, Rehovot, Israel
- Jun Kotera (178), Department of Molecular Physiology and Biophysics, Vanderbilt University School of Medicine, Nashville, Tennessee
- Jun Kotera (196), Target Discovery Research Department, Advanced Medical Research Laboratory, Mitsubishi Tanabe Pharma Corporation, Toda, Saitama, Japan
- **David S. Kotlyar (338)**, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania
- **Sergei Kozlov** (263), Queensland Cancer Fund Research Laboratory, Queensland Institute of Medical Research, Brisbane, Australia
- **Keith G. Kozminski (221)**, Departments of Biology and Cell Biology, University of Virginia, Charlottesville, Virginia
- Gerald Krystal (134), The Terry Fox Laboratory, BC Cancer Agency, Vancouver, BC, Canada
- **Stefan Kunz** (189), Institute of Cell Biology, University of Bern, Bern, Switzerland
- **Gary M. Kupfer (272)**, Departments of Pediatrics and Pathology, Yale University School of Medicine, New Haven, Connecticut

Etsushi Kuroda (134), The Terry Fox Laboratory, BC Cancer Agency, Vancouver, BC, Canada

xxxii

- Adam J. Kuszak (171), Department of Pharmacology, University of Michigan Medical School, Ann Arbor, Michigan
- Chulan Kwon (309), Gladstone Institute of Cardiovascular Disease and Departments of Pediatrics and Biochemistry & Biophysics, University of California at San Francisco, San Francisco, California
- **Peter D. Kwong (15)**, Vaccine Research Center, NIAID, National Institutes of Health, Bethesda, Maryland
- **Tracey Kwong (283)**, Molecular and Cellular Biology Program, University of Washington and Fred Hutchinson Cancer Research Center, Seattle, Washington
- Martin Lackmann (62), Department of Biochemistry and Molecular Biology, Monash University, Victoria, Australia
- Vivian Lam (134), The Terry Fox Laboratory, BC Cancer Agency, Vancouver, BC, Canada
- David G. Lambright (198), Program in Molecular Medicine and Department of Biochemistry and Molecular Pharmacology, University of Massachusetts Medical School, Worcester, Massachusetts
- Lorene K. Langeberg (166), Howard Hughes Medical Institute, Vollum Institute, Oregon Health & Sciences University, Portland, Oregon
- Adam D. Langenbacher (230), Department of Molecular, Cell and Developmental Biology, University of California, Los Angeles, California
- Paul Lasko (279), Department of Biology and Developmental Biology Research Initiative, McGill University, Montréal, Québec, Canada
- Priscilla Nga Ieng Lau (288), Department of Medical Biophysics, University of Toronto, and Division of Signaling Biology, Ontario Cancer Institute, Toronto, Ontario, Canada
- Martin F. Lavin (263), Queensland Cancer Fund Research Laboratory, Queensland Institute of Medical Research, Brisbane, Australia, and Department of Surgery, University of Queensland, Brisbane, Australia
- **Kevin A. Lease (80)**, Division of Biological Sciences, Bond Life Sciences Center, University of Missouri, St Louis, Missouri
- Hojoon X. Lee (243), Howard Hughes Medical Institute and Department of Biological Chemistry, University of California, Los Angeles, California
- Sunyoung Lee (235), Department of Molecular, Cell and Developmental Biology, University of California, Los Angeles, California

- **Hakon Leffler** (13), Section MIG, Department of Laboratory Medicine, University of Lund, Lund, Sweden
- Ludovic Leloup (126), Department of Pathology, University of Pittsburgh, Pittsburgh, Pennsylvania
- Mark A. Lemmon (136), Department of Biochemistry and Biophysics, University of Pennsylvania Medical Center, Philadelphia, Pennsylvania
- Susan E. Levin (68), Departments of Medicine and of Microbiology and Immunology, Rosalind Russell Medical Research Center for Arthritis, Howard Hughes Medical Institute, University of California, San Francisco, California
- Alexander Levitzki (65), Unit of Cellular Signaling, Department of Biological Chemistry, The Alexander Silberman Institute of Life Sciences, The Hebrew University of Jerusalem, Israel
- Andra Li (289), Department of Biochemistry and Microbiology, University of Victoria, Victoria, British Columbia, Canada
- Xialu Li (280), National Institute of Biological Sciences, Zhongguancun Life Science Park, Beijing, China
- Hong-Jun Liao (110), Department of Biochemistry, Vanderbilt University School of Medicine, Nashville, Tennessee
- Lucy Liaw (308), Center for Molecular Medicine, Maine Medical Center Research Institute, Portland, Maine
- **Gary R. Lichtenstein (338)**, Division of Gastroenterology, University of Pennsylvania, Philadelphia, Pennsylvania
- **Robert C. Liddington (18)**, Program on Cell Adhesion, The Burnham Institute, La Jolla, California
- Michael R. Lieber (262), University of Southern California Keck School of Medicine, USC Norris Comprehensive Cancer Center, Los Angeles, California
- Su-Chang Lin (49), Department of Biochemistry, Weill Medical College of Cornell University, York Avenue, New York, New York
- **Thomas M. Lincoln** (180), Department of Physiology, College of Medicine, University of South Alabama, Mobile, Alabama
- **Jürgen U. Linder** (188), Department of Pharmacology, Weill Medical College of Cornell University, New York, New York
- Maurine E. Linder (53, 200), Department of Cell Biology and Physiology, Washington University School of Medicine, St Louis, Missouri
- Volkhard Lindner (308), Center for Molecular Medicine, Maine Medical Center Research Institute, Portland, Maine

- Peter E. Lipsky (336), NIAMS, National Institutes of Health, Bethesda, MD
- Yu-Chih Lo (49), Department of Biochemistry, Weill Medical College of Cornell University, York Avenue, New York, New York
- Yi-Wei Lou (105), Institute of Biological Chemistry, Academia Sinica, Taipei, Taiwan; and Institute of Biochemical Sciences, College of Life Sciences, National Taiwan University, Taipei, Taiwan
- Wan-Jin Lu (261), Department of Cell Biology, University of Texas Southwestern Medical Center, Dallas, Texas
- Edith Luginbühl (189), Institute of Cell Biology, University of Bern, Bern, Switzerland
- Yongde Luo (38), Center for Cancer and Stem Cell Biology, Institute of Biosciences and Technology, Texas A&M Health Science Center, Houston, Texas
- Karen M. Lyons (233), Department of Molecular, Cell and Developmental Biology, Department of Orthopaedic Surgery, University of California, Los Angeles, California
- S. Lance Macaulay (44), CSIRO Health Sciences and Nutrition, 343 Royal Parade, Parkville, Victoria, Australia
- Michael Maceyka (146), Department of Biochemistry and Molecular Biology, Virginia Commonwealth University School of Medicine, Richmond, Virginia
- **Fernando Macian (254)**, Department of Pathology, Albert Einstein College of Medicine, Bronx, New York
- **David H. MacLennan** (116), Banting and Best Department of Medical Research, University of Toronto, Charles H. Best Institute, Toronto, Ontario, Canada
- Carol MacKintosh (87), MRC Protein Phosphorylation Unit, College of Life Sciences, University of Dundee, Dundee, Scotland, UK
- James P. Madigan (329), Lineberger Comprehensive Cancer Center, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina
- George Magklaras (183), Centre for Molecular Medicine Norway, Nordic EMBL Partnership, University of Oslo, Oslo, Norway
- Jyoti D. Malhotra (276), Department of Biological Chemistry, University of Michigan Medical School, Ann Arbor, Michigan
- Nadir A. Mahmood (168), Department of Pharmacology, University of Texas Southwestern Medical Center, Dallas, Texas
- Vincent C. Manganiello (175), Translational Medicine Branch, National Heart, Lung, and Blood Institute, National Institutes of Health, Bethesda, Maryland

James L. Manley (280), Department of Biological Sciences, Columbia University, New York

- **Gerard Manning (56)**, Razavi Newman Center for Bioinformatics, The Salk Institute, La Jolla, California
- Robert F. Margolskee (209), Department of Neuroscience, Mount Sinai School of Medicine, New York, New York
- Roy A. Mariuzza (6), Center for Advanced Research in Biotechnology, W.M. Keck Laboratory for Structural Biology, University of Maryland Biotechnology Institute, Rockville, Maryland
- Karen H. Martin (66), Department of Neurobiology and Anatomy, West Virginia University, Morgantown, West Virginia
- Sergio E. Martinez (187), Center for Advanced Biotechnology and Medicine, Rutgers, the State University of New Jersey, Piscataway, New Jersey
- Frank M. Mason (157), Department of Cell Biology, Duke University Medical Center, Durham, North Carolina
- Silvia Mateo-Lozano (330), Centre d'Oncología Molecular (COM), Institut d'Investigació Biomédica de Bellvitge (IDIBELL), Barcelona, Spain
- Sophia L. Maund (323), Department of Cancer Biology, Wake Forest University School of Medicine, Winston-Salem, North Carolina
- Bruce J. Mayer (67), Raymond and Beverly Sackler Laboratory of Genetics and Molecular Medicine, Department of Genetics and Developmental Biology, University of Connecticut Health Center, Farmington, Connecticut
- Christopher W. McAndrew (237), Department of Chemistry and Biochemistry, University of California San Diego, La Jolla, California
- Frank McCormick (212), Cancer Research Institute, University of California Comprehensive Cancer Center, San Francisco, California
- Clare H. McGowan (302), Department of Molecular Biology and Department of Cell Biology, Scripps Research Institute, La Jolla, California
- Jodi McKay (213), Department of Biochemistry, Biophysics and Molecular Biology, Iowa State University, Ames, Iowa
- Wallace L. McKeehan (38), Center for Cancer and Stem Cell Biology, Institute of Biosciences and Technology, Texas A&M Health Science Center, Houston, Texas
- **Anthony R. Means (123)**, Department of Pharmacology and Cancer Biology, Duke University Medical Center, Durham, North Carolina

- **Borna Mehrad** (334), Division of Pulmonary and Critical Care Medicine, University of Virginia, Charlottesville, Virginia
- Alfred J. Meijer (306), Department of Medical Biochemistry, Academic Medical Center, Amsterdam, The Netherlands
- **Tzu-Ching Meng (105)**, Institute of Biological Chemistry, Academia Sinica, Taipei, Taiwan; and Institute of Biochemical Sciences, College of Life Sciences, National Taiwan University, Taipei, Taiwan
- **Daniel Menendez** (265), Laboratory of Molecular Genetics, National Institute of Environmental Health Sciences, NIH, Research Triangle Park, North Carolina
- Frank Mercurio (252), Signal Research Division, Celgene, San Diego, California
- **Daniel Messerschmidt (228)**, Department of Molecular Embryology, Max-Planck Institute of Immunobiology, Freiburg, Germany
- Mihaela Minca (189), Institute of Cell Biology, University of Bern, Bern, Switzerland
- Guo-li Ming (239), The Salk Institute, La Jolla, California
- Daniel L. Minor Jr (30), Cardiovascular Research Institute, Departments of Biochemistry & Biophysics and Cellular & Molecular Pharmacology, California Institute for Quantitative Biosciences, University of California, San Francisco
- Natalia Mitin (214), Department of Pharmacology, Lineberger Comprehensive Cancer Center, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina
- **Janine A. Mok (84)**, Department of Genetics, Yale University School of Medicine, New Haven, Connecticut

Marc Montminy

- **Jocelyn Moore** (279), Department of Biology and Developmental Biology Research Initiative, McGill University, Montréal, Québec, Canada
- **Richard I. Morimoto** (268), Department of Biochemistry, Molecular Biology and Cell Biology, Rice Institute for Biomedical Research, Northwestern University, Evanston, Illinois
- Gary Z. Morris (178), Department of Molecular Physiology and Biophysics, Vanderbilt University School of Medicine, Nashville, Tennessee
- **Bedrich Mosinger** (209), Department of Neuroscience, Mount Sinai School of Medicine, New York, New York
- **Stephen E Moss** (125), Division of Cell Biology, UCL Institute of Ophthalmology, London, England, UK

- **Helen R. Mott** (223), Department of Biochemistry, University of Cambridge, Cambridge, England, UK
- **Thomas D. Mullen (148)**, Department of Medicine, Division of General Internal Medicine and Geriatrics, Medical University of South Carolina, Charleston, South Carolina
- Marc C. Mumby (168), Department of Pharmacology, University of Texas Southwestern Medical Center, Dallas, Texas
- **James M. Murphy (64)**, Division of Molecular Medicine, Walter and Eliza Hall Institute of Medical Research, Parkville, Victoria, Australia
- **Tetsuji Mutoh** (147), Department of Molecular Biology, Helen L. Dorris Child and Adolescent Neuropsychiatric Disorder Institute, The Scripps Research Institute, La Jolla, California
- Angus C. Nairn (79), Department of Psychiatry, Yale University School of Medicine, New Haven, Connecticut
- Asako J. Nakamura (273), Laboratory of Molecular Pharmacology, Center for Cancer Research, National Cancer Institute, National Institutes of Health, Bethesda, Maryland
- **Piers Nash (57)**, Ben May Department for Cancer Research, University of Chicago, Chicago, Illinois
- Gioacchino Natoli (293), Department of Experimental Oncology, European Institute of Oncology (IEO), Milan, Italy
- Benjamin G. Neel (98), Ontario Cancer Institute, Toronto, Ontario, Canada
- Alexandra C. Newton (103, 139), Department of Pharmacology, University of California at San Diego, La Jolla, California
- James T. Nichols (232), Department of Biological Chemistry, David Geffen School of Medicine, University of California, Los Angeles, California
- Christian K. Nickl (181), Department of Pharmacology, University of Vermont, College of Medicine, Burlington, Vermont
- Eric E. Nilsson (314), Center for Reproductive Biology, School of Molecular Biosciences, Washington State University, Pullman, Washington
- Yasutomi Nishizuka (deceased) (129), Biosignal Research Center, Kobe University, Kobe, Japan
- Maho Niwa (299), University of California San Diego, Division of Biological Sciences, La Jolla, California
- Randolph J. Noelle (51), Department of Microbiology and Immunology, Dartmouth Medical School and The Norris Cotton Cancer Center, Lebanon, New Hampshire