

Cancer Research

Driving Innovation to Prevent and Cure Cancer

AACR

American Association
for Cancer Research

AN OFFICIAL JOURNAL OF THE AMERICAN ASSOCIATION FOR CANCER RESEARCH

Editor-in-Chief

Chi Van Dang

Executive Editor

Judy N. Quong

Advisory Editors

Joan S. Brugge
Joe W. Gray
Olufunmilayo I. Olopade
Bert Vogelstein
Karen H. Vousden

Breaking Insights

Deputy Editor

William A. Weiss

Editors

Marie Arsenian-Henriksson
Val Brunton
Timothy Burns
Michel Dupage
Paul B. Fisher
Rani George
Vijay Ramaswamy
David J. Robbins

Controversy and Consensus

Deputy Editor

Raghu Kalluri

Editor

Marcelo G. Kazanietz

Reviews

Deputy Editor

Danny R. Welch

Editors

Jeremy R. Graff
Harikrishna Nakshatri

Senior Editors

Genome and Epigenome

George A. Calin
Kojo S.J. Elenitoba-Johnson
Jean-Pierre J. Issa
Katherine Nathanson
Bing Ren

Metabolism and Chemical Biology

Giulio F. Draetta
Eyal Gottlieb
Brendan D. Manning
William G. Nelson
Linda Z. Penn
Joseph Salvino
David B. Solit
Eileen White

Molecular Cell Biology

Mark W. Dewhirst
Eric R. Fearon
Mien-Chie Hung
Brian C. Lewis
Masanobu Oshima
Ben Z. Stanger
Saraswati Sukumar

Tumor Biology and Immunology

Hellmut G. Augustin
Robert Clarke
Mario P. Colombo
Dean W. Felsher
Elsa R. Flores
Dmitry I. Gabrilovich
Silvia Giordano
Fumihiko Ishikawa
Kornelia Polyak
Jonathan D. Powell
Jeffrey C. Rathmell
Phuoc T. Tran

Translational Science

Kathleen R. Cho
George D. Demetri
Maura L. Gillison
James G. Herman
Theodore S. Lawrence
Xin Lu
Anirban Maitra
Maureen E. Murphy
Yves Pommier
Hyunsuk Shim

Convergence and Technologies

Sarah E. Bohndiek
Claudia Fischbach-Teschl
Robert A. Gatenby
John Quackenbush
David W. Speicher

Population and Prevention Science

Robert A. Hiatt
Trevor Penning

Biostatistics

Qi Long

Editorial Staff

Scientific Editor

Amanda Valeta-Magara

Managing Editor

Catherine Wilson

Assistant Managing Editor

Jeremy Rosenberg

Special Content Manager

Chris Vesci

Editorial Staff

Rachel Alfiero
Eileen Echikson
Catherine Rachfalski

Production Manager

Brenda Roberson

Editorial Office: *Cancer Research* [ISSN: 0008-5472 (Print); ISSN: 1538-7445 (Online)] is published twice a month, one volume per year, by the American Association for Cancer Research, Inc.; 615 Chestnut Street, 17th Floor, Philadelphia, PA 19106-4404. Periodicals postage paid at Philadelphia, PA, and additional mailing offices. POSTMASTER: Send address changes to *Cancer Research*, Member Services, AACR, 615 Chestnut Street, 17th Floor, Philadelphia, PA 19106-4404 or E-mail: membership@aacr.org. Copyright 2019 the American Association for Cancer Research, Inc. © The paper used in this publication meets the requirements of ANSI/NISO Z39.48-1992 (Permanence of Paper).

Cancer Research

Driving Innovation to Prevent and Cure Cancer

AACR

American Association
for Cancer Research

AN OFFICIAL JOURNAL OF THE AMERICAN ASSOCIATION FOR CANCER RESEARCH

Editorial Board

Cory Abate-Shen
Kari Alitalo
Shrikant Anant
Alexander R.A. Anderson
Andrea Anichini
Lionel Apetoh
Andrew E. Aplin
Manuela Baccarini
Frances Balkwill
William T. Baumann
Gregory L. Beatty
Fariba Behbod
Simon Bekker-Jensen
Nathalie Bendriss-Vermare
Mohamed Bentires-Alj
Gabriele Bergers
Rupal S. Bhatt
Nelson E. Brown
Kerry L. Burnstein
Lisa H. Butterfield
Peter T. Campbell
Elias Campo
Jason S. Carroll
Timothy A. Chan
Alain Charest
Murali K. Cherukuri
Soumitra Kumar Choudhuri
Lena Claesson-Welsh
Justin A. Colacino
Michael Cole
David V. Conti
Ryan B. Corcoran
Michele L. Cote
Phillip K. Darcy
Olivier De Wever
Nicholas Denko
Pier Paolo Di Fiore
J. Alan Diehl
Dan A. Dixon
Frank C. Dorsey
Ronny Drapkin
Bertrand Dubois
Jeanette E. Eckel-Passow
Kristin A. Eckert
Wafik El-Deiry
Leisha Emens
Heiko Enderling
Matthias Ernst
Felix Y. Feng
Martin E. Fernandez-Zapico
Adolfo A. Ferrando
Soldano Ferrone
Barbara Fingleton
Paul B. Fisher
David A. Frank
Simone Fulda

Joel R. Garbow
Kevin Gardner
Stephan Gasser
Irwin H. Gelman
Edward P. Gelmann
Francois Ghiringhelli
David Gius
Jeremy R. Graff
Steven Grant
Florian Greten
Tim F. Greten
Heidi E. Greulich
Sergei Grivennikov
Marc J. Gunter
William C. Hahn
Kevin M. Haigis
John Hanover
Reuben S. Harris
Mathias Heikenwälder
Beate Heissig
Kristian Helin
Thomas Helleday
Mary J.C. Hendrix
Stephan Herzig
Haojie Huang
Ruby Yun-Ju Huang
Ying Huang
Kent Hunter
M. Luisa Iruela-Arispe
Jennifer S. Isaacs
Tomoo Iwakuma
Jos Jonkers
Vijai Joseph
David M. Kaetzel
Antoine E. Karnoub
Joseph L. Kissil
Jan K. Kitajewski
Jorg Kleeff
Celina G. Kleer
Alexander L. Klibanov
Gou Young Koh
Mikhail G. Kolonin
Natalia Komarova
Yutaka Kondo
Wilhelm Krek
Guido Kroemer
Kenneth A. Krohn
Marieke L. Kuijjer
Charlotte Kuperwasser
Natalia Kyprianou
James V. Lacey
Marikki Laiho
Lucia R. Languino
John Laterra
Valerie LeBleu
Doron Levy

Claire E. Lewis
Da-Qiang Li
Jonathan Licht
Hui-Kuan Lin
Carlos López-Otin
James B. Lorens
Zhenkun Lou
M. Scott Lucia
David Lyden
Conor C. Lynch
James Lyons-Weiler
David MacPherson
Carlo C. Maley
Richard Marais
Andrea M. Mastro
Masao Matsuoka
Massimiliano Mazzone
Sandra S. McAllister
Cornelis J.M. Melief
Yubin Miao
John D. Minna
Michael A. Morgan
Lindsay M. Morton
Muriel Moser
Hidayatullah G. Munshi
Junko Murai
Ruth J. Muschel
Senthil K. Muthuswamy
Harikrishna Nakshatri
Yulia Nefedova
Kenneth P. Nephew
Daniel Normolle
Steffi Oesterreich
Hideho Okada
Monilola A. Olayoye
Gilbert S. Omenn
Arne Östman
Akhilesh Pandey
Klaus Pantel
Gray W. Pearson
Gerd P. Pfeifer
Wayne A. Phillips
Thuy L. Phung
Kristian Pietras
Sean Post
Ludmila Prokunina-Olsson
Derek C. Radisky
Dan Raftery
Ajay Rana
V. Ashutosh Rao
Gregory J. Riggins
Julien Sage
Jann N. Sarkaria
Dieter Saur
Edward Sausville

Matthew B. Schabath
Andrew E. Schade
Clemens A. Schmitt
Santiago Schnell
Katia Scotlandi
Ralph Scully
Oliver John Semmes
Natalie J. Serkova
Louise C. Showe
Xiao-Ou Shu
Maria Sibilia
Jill M. Siegfried
Pierre Sonveaux
Douglas R. Spitz
M. Sharon Stack
John Stagg
Anil Suri
Hiromu Suzuki
Kristin R. Swanson
Joann B. Sweasy
Russell S. Taichman
Rulla M. Tamimi
Patrick Tan
Eric Tartour
Daniela Taverna
Jeremy M.G. Taylor
Beverly A. Teicher
Rajeshwar R. Tekmal
Anna Teti
Dan Theodorescu
Anish Thomas
Alex Toker
Vladimir Tolmachev
Richard W. Tothill
Danyelle M. Townsend
Claudio Tripodo
Melissa A. Troester
Kenneth Tsai
Viktor Umansky
Pierre van der Bruggen
Guus A.M.S. van Dongen
Jo A. Van Ginderachter
Thierry Walzer
Jeffrey S. Weber
Ashani T. Weeraratna
Wenyi Wei
Alana L. Welm
Jedd D. Wolchok
Gerburg Wulf
Yasuhiro Yamada
Srinivasan Yegnasubramanian
Xiaochun Yu
Lin Zhang
Lee Zou
Weiping Zou

Cancer Research

Publishing Information

AACR

American Association
for Cancer Research

Print ISSN: 0008-5472 • Online ISSN: 1538-7445

AACR Officers

Elizabeth M. Jaffee,
President
Elaine R. Mardis,
President-Elect
Michael A. Caligiuri,
Past President
William N. Hait, Treasurer
Margaret Foti, Chief Executive
Officer

Publications Committee

Mary Helen Barcellos-Hoff
Dafna Bar-Sagi
Michael E. Berens
John D. Carpten
Maura L. Gillison
Rakesh K. Jain
Pasi A. Jänne
Gerrit A. Meijer
Gordon B. Mills
Steffi Oesterreich
William Pao
Gloria M. Petersen
David R. Piwnica-Worms
Charles W.M. Roberts
Alice T. Shaw
Lillian L. Siu
Saraswati V. Sukumar
Toshikazu Ushijima
Victor E. Velculescu,
Chairperson

Publishing Staff

Publisher
Christine B. Rullo
Director, Journal Operations and Systems
Daniel S. Evanko
Director, Journal Sales and Marketing
Nicola L. Hill
Director, Digital Publishing
Robert Spanier
Associate Director, Production
Charlene Squibb
Assistant Director, Journal Marketing
Joanna Arnold
Assistant Director, Institutional Sales & Outreach
Karola Rac
Marketing and Creative Services
Senior Director
Paul Driscoll
Design Staff
Susan Moore

Scope

Cancer Research publishes original studies, reviews, and opinion pieces offering significance and broad impact to a diverse audience. *Cancer Research* seeks manuscripts that offer pathobiological and translational impact to inform the personal, clinical, and societal problems posed by cancer. The main scope of the Journal is captured in its primary subsections: Genome and Epigenome, Metabolism and Chemical Biology, Molecular Cell Biology, Tumor Biology and Immunology, Translational Science, Convergence and Technologies, and Population and Prevention Science.

Cancer Research is abstracted and/or indexed in Current Contents/Clinical Medicine, MEDLINE, Science Citation Index, Scopus, and Web of Science.

Submission of Manuscripts

Online submission of manuscripts is welcomed at <http://can.msubmit.net>. Before submitting a manuscript, please read the Instructions for Authors, which are available from the Journal's home page at <http://cancerres.aacrjournals.org>.

Publication Charges

Beginning with manuscripts submitted January 1, 2016 or after, articles will be published with the understanding that the author(s) will pay both a publication fee plus a color figure handling fee. Please see the Instructions for Authors, which are available from the Journal's home page at <http://cancerres.aacrjournals.org>.

Subscription Information

Nonmember Individuals
Subscriptions include print version with online access. Contacts listed below are for nonmember individual subscriptions.

USA and Rest of World (excluding Japan)
American Association for Cancer Research, 615 Chestnut Street, Philadelphia, PA 19106; 1-855-744-4667; pubsales@aacr.org

Japan

e-support@maruzen.co.jp;
journal@kinokuniya.co.jp; usaco@usaco.co.jp

International print subscriptions include cost of surface mail. Expedited mailing is available. Contact the American Association for Cancer Research for rates.

Site Licenses

For information about institutional site licenses, contact pubsales@aacr.org.

AACR Members

AACR members may opt to receive either a print subscription with online access to content or an online-only subscription. Contact membership@aacr.org or visit the membership page at www.aacr.org for more information.

Single Issue Sales

Subject to their availability, single or back issues may be purchased for \$60 (U.S.) or \$65 (outside the U.S.) each. The cost must be prepaid. Contact pubsales@aacr.org.

Claims

One-time claims for missing issues made within 120 days of the issue's publication will be honored, subject to availability. No credit or refund will be given if an issue is out of print at the time of claim.

AACR Members

membership@aacr.org

Nonmembers and Institutions

pubsales@aacr.org

Advertising Information

For information about advertising in AACR journals, contact Pharmaceutical Media Inc., 30 East 33rd St., 4th Floor, New York, NY, 10016; 212-904-0360; Dsimone@pminy.com.

Copyright and Permissions

Content printed in or disseminated by *Cancer Research* is protected by copyright. Authors who wish to publish material in *Cancer Research* must formally transfer copyright to the AACR. All authors must sign copyright transfer forms before the AACR can proceed with publication.

To read the complete AACR Copyright and Permissions Policy, visit <http://aacrjournals.org/content/authors/copyright-permissions-and-access>.