

# Cancer Research

Driving Innovation to Prevent and Cure Cancer

# AAGR

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  
Charis Eng  
Jean-Pierre J. Issa  
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  
Maura L. Gillison  
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  
Benjamin Haiibe-Kains  
John Quackenbush  
David W. Speicher

### Population and Prevention Science

Robert A. Hiatt  
Trevor Penning

### Biostatistics

Qi Long

### Editorial Staff

#### Associate Editor

Amanda Valeta-Magara

#### Managing Editor

Catherine C. Wilson

#### Assistant Managing Editor

Joseph B. Schwartz

#### 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](mailto: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

# AAGR

American Association  
for Cancer Research

AN OFFICIAL JOURNAL OF THE AMERICAN ASSOCIATION FOR CANCER RESEARCH

## Editorial Board

Kari Alitalo  
Shrikant Anant  
Andrea Anichini  
Lionel Apetoh  
Andrew E. Aplin  
Manuela Baccarini  
William T. Baumann  
Fariba Behbod  
Simon Bekker-Jensen  
Nelson E. Brown  
Kerry L. Burnstein  
Peter T. Campbell  
Timothy A. Chan  
Alain Charest  
Murali K. Cherukuri  
Soumitra Kumar Choudhuri  
Lena Claesson-Welsh  
Michael Cole  
Michele L. Cote  
Olivier De Wever  
Nicholas Denko  
J. Alan Diehl  
Dan Dixon  
Ronny Drapkin  
Bertrand Dubois  
Jeanette E. Eckel-Passow  
Wafik El-Deiry  
Felix Y. Feng  
Martin E. Fernandez-Zapico  
Soldano Ferrone  
Paul B. Fisher  
Simone Fulda  
Joel R. Garbow

Kevin Gardner  
Francois Ghiringhelli  
David Gius  
Jeremy R. Graff  
Steven Grant  
Florian Greten  
Heidi E. Greulich  
Sergei Grivennikov  
John Hanover  
Mary J.C. Hendrix  
Stephan Herzig  
Haojie Huang  
Kent Hunter  
Tomoo Iwakuma  
David M. Kaetzel  
Joseph L. Kissil  
Jorg Kleeff  
Gou Young Koh  
Mikhail G. Kolonin  
Yutaka Kondo  
Kenneth A. Krohn  
Marieke L. Kuijjer  
Natasha Kyprianou  
James V. Lacey  
Lucia R. Languino  
Valerie LeBleu  
Doron Levy  
Claire E. Lewis  
Da-Qiang Li  
Jonathan Licht  
Hui-Kuan Lin  
Zhenkun Lou  
David Lyden

Conor C. Lynch  
Carlo C. Maley  
Masao Matsuoka  
Massimiliano Mazzone  
John D. Minna  
Michael A. Morgan  
Lindsay M. Morton  
Hidayatullah G. Munshi  
Junko Murai  
Ruth J. Muschel  
Harikrishna Nakshatri  
Yulia Nefedova  
Kenneth P. Nephew  
Daniel Normolle  
Steffi Oesterreich  
Hideho Okada  
Gilbert S. Omenn  
Arne Östman  
Klaus Pantel  
Gray W. Pearson  
Gerd P. Pfeifer  
Wayne A. Phillips  
Kristian Pietras  
Ludmila Prokunina-Olsson  
Derek C. Radisky  
V. Ashutosh Rao  
Jann N. Sarkaria  
Dieter Saur  
Edward Sausville  
Matthew B. Schabath  
Andrew E. Schade  
Clemens A. Schmitt  
Santiago Schnell

Katia Scotlandi  
Oliver John Semmes  
Natalie J. Serkova  
Louise C. Showe  
Xiao-Ou Shu  
Jill M. Siegfried  
Pierre Sonveaux  
M. Sharon Stack  
John Staggs  
Hiromu Suzuki  
Kristin R. Swanson  
Joann B. Sweasy  
Jeremy M.G. Taylor  
Beverly A. Teicher  
Anna Teti  
Anish Thomas  
Claudio Tripodo  
Kenneth Tsai  
Viktor Umansky  
Guus A.M.S. van Dongen  
Jo A. Van Ginderachter  
Thierry Walzer  
Jeffrey S. Weber  
Ashani T. Weeraratna  
Wenyi Wei  
Yasuhiro Yamada  
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

Victor E. Velculescu,  
Chairperson  
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

## 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

Mark Jacobson

### 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](mailto:pubsales@aacr.org)

### Japan

[e-support@maruzen.co.jp](mailto:e-support@maruzen.co.jp);  
[journal@kinokuniya.co.jp](mailto:journal@kinokuniya.co.jp); [usaco@usaco.co.jp](mailto: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](mailto: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](mailto:membership@aacr.org) or visit the membership page at [www.aacr.org](http://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](mailto: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](mailto:membership@aacr.org)

### Nonmembers and Institutions

[pubsales@aacr.org](mailto: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](mailto: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>.