

SPECIAL SECTION

Epigenetics

INTRODUCTION

611 What Is Epigenetics?

REVIEWS

612 Molecular Signals of Epigenetic States
R. Bonasio et al.

617 A Small-RNA Perspective on Gametogenesis, Fertilization, and Early Zygotic Development
D. Bourc'his and O. Voinnet

622 Epigenetic Reprogramming in Plant and Animal Development
S. Feng et al.

PERSPECTIVES

628 Paramutation's Properties and Puzzles
V. L. Chandler

629 Epigenetics in the Extreme: Prions and the Inheritance of Environmentally Acquired Traits
R. Halfmann and S. Lindquist

>> *News story p. 576; Perspective p. 598; Report p. 680; Science Translational Medicine; Science Signaling; Science Careers; Video; and Science Podcast at www.sciencemag.org/special/epigenetics/*



page 568

EDITORIAL

559 Driving U.S. Energy Leadership
Bruce Alberts

NEWS OF THE WEEK

568 Campaign for U.K. Science Helps Deflect Budget Ax

571 Liquid Water Found on Mars, But It's Still a Hard Road for Life

571 From the *Science* Policy Blog

572 Nobelist 'Coach' Takes On U.S. Science Education

573 From *Science's* Online Daily News Site

574 1000 Genomes Project Gives New Map of Genetic Diversity
>> *Research Article p. 641*

575 Leaked Documents Provide Bonanza for Researchers

NEWS FOCUS

576 Epigenetic Drugs Take On Cancer Genes Link Epigenetics and Cancer
>> *Epigenetics section p. 611; Science Podcast*

579 Gene Variants Affect Hepatitis C Treatment, But Link Is Elusive

580 Data Say Retention Is Better Answer to Shortage Than Recruitment
What's in a Number?

582 Society of Vertebrate Paleontology Meeting
Going Back to the Future to Understand Climate Change
Snapshots From the Meeting
When Rodents Marched Into Paris

LETTERS

584 Mass Fruiting in Borneo: A Missed Opportunity
C. J. Kettle et al.
Asian Water Towers: More on Monsoons
F. Piethan

Response
W. W. Immerzeel and M. F. P. Bierkens

The Best Test of Ph.D. Student Success
G. Newquist

Response
D. F. Feldon et al.

BOOKS ET AL.

588 Dance of the Photons
A. Zeilinger, reviewed by J. L. O'Brien

589 The Extended Mind
R. Menary, Ed., reviewed by E. Myrin

590 Insectos em Ordem [Insects in Order]
P. G. Pereira and E. Monteiro, curators

POLICY FORUM

592 Sustaining the Data and Bioresource Commons
P. N. Schofield et al.

PERSPECTIVES

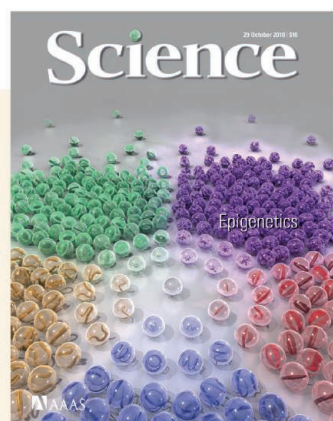
594 Innate Lymphoid Cell Relations
M. Veldhoen and D. R. Withers
>> *Report p. 665*

595 Caging Carbon Dioxide
C. Lastoskie
>> *Report p. 650*

597 Forced to Be Unequal
S. W. Grill
>> *Report p. 677*

598 Epigenome Disruptors
M. Hemberger and R. Pedersen
>> *Epigenetics section p. 611*

CONTENTS continued >>



COVER

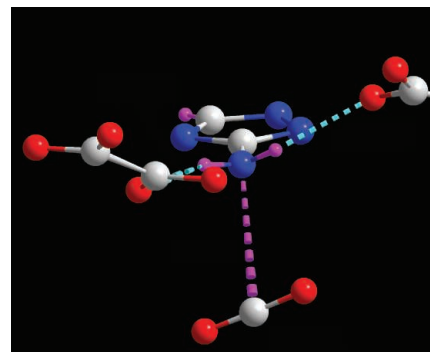
During development, a multicellular organism generates many different cell types (colored marbles) from a single progeny cell (clear marble in the center), yet all of the cells have nominally identical DNA sequences (and, therefore, the same genetic instruction sets). The maintenance and inheritance of these distinct cellular phenotypes is the basis of epigenetics (the prefix "epi-" is Greek for over or above), the subject of a special section beginning on page 611.

Image: *Chris Bickel/Science*

DEPARTMENTS

- 556 This Week in *Science*
- 561 Editors' Choice
- 564 *Science* Staff
- 567 Random Samples
- 607 AAAS News & Notes
- 692 New Products
- 693 *Science* Careers

- 599 **A Little Chemistry Helps the Big Get Bigger**
J. W. Evans and P. A. Thiel
- 601 **The Tao of Chloride Transporter Structure**
J. A. Mindell
>> *Research Article p. 635*
- 602 **Infection Protection and Natural Selection**
L. B. Martin and C. A. C. Coon
>> *Report p. 662*
- 604 **Retrospective: Georges Charpak (1924–2010)**
Y. Quéré
- SCIENCE PRIZE ESSAY**
- 605 **Physical Phenomena in Real Time**
D. Brookes and E. Etkina
- BREVIA**
- 634 **Magnitude of the 2010 Gulf of Mexico Oil Leak**
T. J. Crone and M. Tolstoy
Modeling videos suggest that around 4.4 million barrels of oil escaped from the broken Deepwater Horizon well.
- RESEARCH ARTICLES**
- 635 **Structure of a Eukaryotic CLC Transporter Defines an Intermediate State in the Transport Cycle**
L. Feng et al.
The structure of a chloride transporter and its regulatory domain provides insight into the ion-exchange mechanism.
>> *Perspective p. 601*
- 641 **Diversity of Human Copy Number Variation and Multicopy Genes**
P. H. Sudmant et al.
Specific gene copies can be identified in regions of high copy number variability in the human genome.
>> *News story p. 574*
- REPORTS**
- 646 **Rate of Gas Phase Association of Hydroxyl Radical and Nitrogen Dioxide**
A. K. Mollner et al.
Laboratory measurements of a critical atmospheric rate constant should improve predictions of tropospheric ozone formation.
- 650 **Direct Observation and Quantification of CO₂ Binding Within an Amine-Functionalized Nanoporous Solid**
R. Vaidhyanathan et al.
Crystallographic resolution of bound carbon dioxide in a porous solid validates methods of theoretically predicting binding behavior.
>> *Perspective p. 595*
- 653 **The Occurrence and Mass Distribution of Close-in Super-Earths, Neptunes, and Jupiters**
A. W. Howard et al.
About one-quarter of observed Sun-like stars harbors a close-in terrestrial-mass planet.
>> *Science Podcast*
- 655 **Transferable GaN Layers Grown on ZnO-Coated Graphene Layers for Optoelectronic Devices**
K. Chung et al.
Graphene can replace sapphire crystals as the substrate for the growth of gallium nitride layers.
- 658 **Large $\delta^{13}\text{C}$ Gradients in the Preindustrial North Atlantic Revealed**
A. Olsen and U. Ninnemann
The preanthropogenic distribution of carbon isotopes in the North Atlantic provides a correct baseline for climate studies.
- 659 **Early Use of Pressure Flaking on Lithic Artifacts at Blombos Cave, South Africa**
V. Mourre et al.
Tools dating to ~75,000 years ago show evidence of pressure flaking, long before the technique became widespread.
- 662 **Fitness Correlates of Heritable Variation in Antibody Responsiveness in a Wild Mammal**
A. L. Graham et al.
In Soay sheep, self-reactive antibodies are indicators of an evolutionary trade-off between survival and reproduction.
>> *Perspective p. 602*
- 665 **Lineage Relationship Analysis of ROR γ^+ Innate Lymphoid Cells**
S. Sawa et al.
Immune cells develop to preempt intestinal colonization by microbial symbionts.
>> *Perspective p. 594*
- 669 **Filtering of Visual Information in the Tectum by an Identified Neural Circuit**
F. Del Bene et al.
A neural circuit in zebrafish is preferentially activated by small visual stimuli, facilitating the capture of prey.
- 673 **Visualizing Ribosome Biogenesis: Parallel Assembly Pathways for the 30S Subunit**
A. M. Mulder et al.
A time-resolved electron microscopy method provides snapshots that reveal the mechanism of ribosome self-assembly.
- 677 **Polarized Myosin Produces Unequal-Size Daughters During Asymmetric Cell Division**
G. Ou et al.
Motor proteins help to produce developmentally distinct daughter cells during development.
>> *Perspective p. 597*



pages 595 & 650



page 683

- 680 **A Size Threshold Limits Prion Transmission and Establishes Phenotypic Diversity**
A. Derdowski et al.
Yeast prion conformations specify phenotypes by affecting the size distribution of aggregates.
>> *Epigenetics section p. 611*
- 683 **Cognitive Illusions of Authorship Reveal Hierarchical Error Detection in Skilled Typists**
G. D. Logan and M. J. C. Crump
One error-detection mechanism monitors the correctness of one's action, whereas a second mechanism monitors the output.
>> *Science Podcast*
- 686 **Evidence for a Collective Intelligence Factor in the Performance of Human Groups**
A. W. Woolley et al.
A metric for group performance on a battery of cognitive tasks yields a group intelligence quantity: collective intelligence.

CONTENTS continued >>

SCIENCEONLINE

SCIENCEEXPRESS

www.sciencexpres.org

Probing the Ultimate Limit of Fiber-Optic Strain Sensing

G. Gagliardi et al.

The precisely spaced teeth of an optical frequency comb can be used as a highly accurate strain gauge. 10.1126/science.1195818

The Impact of Conservation on the Status of the World's Vertebrates

M. Hoffmann et al.

Though the threat of extinction is increasing, overall declines would have been worse in the absence of conservation. 10.1126/science.1194442

Scenarios for Global Biodiversity in the 21st Century

H. M. Pereira et al.

A range of measures predicts continuing declines of biodiversity, highlighting opportunities for policy development and action. 10.1126/science.1196624

Calcium-Permeable AMPA Receptor Dynamics Mediate Fear Memory Erasure

R. L. Clem and R. L. Huganir

The subunit composition of AMPA receptors at lateral amygdala synapses changes after the acquisition of associative fear. 10.1126/science.1195298

PML Regulates Apoptosis at Endoplasmic Reticulum by Modulating Calcium Release

C. Giorgi et al.

The promyelocytic leukemia protein likely influences apoptosis by influencing a calcium channel in the endoplasmic reticulum. 10.1126/science.1189157

SCIENCENOW

www.sciencenow.org

Highlights From Our Daily News Coverage

Robot 'Hands' Write Without Fingers

Grain-filled sacks help robots get a grip on cumbersome objects.

Attention Passengers: Please Keep Your Shoes On

New sensor array quickly sniffs out shoe-bomber explosive.

Malaria in India May Be 13 Times Worse Than Feared

New estimates of 200,000 deaths per year prompt shock and skepticism.

SCIENCE SIGNALING

www.sciencesignaling.org

The Signal Transduction Knowledge Environment

RESEARCH ARTICLE: PI3K Signaling Through the Dual GTPase-Activating Protein ARAP3 Is Essential for Developmental Angiogenesis

L. Gambardella et al.

PODCAST

S. Vermeren and A. M. VanHook

The guanosine triphosphatase-activating protein ARAP3 may be a target for antiangiogenic therapies.

RESEARCH ARTICLE: Antagonistic Regulation of Actin Dynamics and Cell Motility by TRPC5 and TRPC6 Channels

D. Tian et al.

Coupling TRPC5 and TRPC6 calcium channels to different Rho GTPases allows calcium to both promote and inhibit cell migration.

RESEARCH ARTICLE: Regulation of 3-Phosphoinositide-Dependent Protein Kinase 1 Activity by Homodimerization in Live Cells

T. A. Masters et al.

Spatial and temporal regulation of the homodimerization of PDK1 modulates its activity.

PERSPECTIVE: Delivering the Lateral Inhibition Punchline—It's All About the Timing

J. D. Axelrod

New ways to understand lateral inhibition in patterning sensory bristles in the fruit fly are proposed.

REVIEW: Apoptosis, Stem Cells, and Tissue Regeneration

A. Bergmann and H. Steller

Cells undergoing stress- or injury-induced apoptosis can stimulate tissue regeneration by promoting stem or progenitor cell proliferation.

SCIENCE CAREERS

www.sciencereers.org/career_magazine

Free Career Resources for Scientists

Opening New Research Avenues in Epigenetics

E. Pain

Epigenetics provides a common theme to Spanish cancer researcher Manel Esteller's broad interests in basic and translational research.

Environmental Exposures Shape Human Health—and Careers

L. S. Chiu

Brown University scientist Carmen Marsit's unique training allows him to take an interdisciplinary and translational approach to epigenetics.

>> *Epigenetics* section p. 611 and www.sciencemag.org/special/epigenetics/

SCIENCE TRANSLATIONAL MEDICINE

www.sciencetranslationalmedicine.org

Integrating Medicine and Science

RESEARCH ARTICLE: The Inducible Costimulator (ICOS) Is Critical for the Development of Human T_H17 Cells

C. M. Paulos et al.

PERSPECTIVE: ICOS-timizing Immunotherapies with T_H17

J. Garaude and J. M. Blander

The inducible costimulator ICOS promotes the antitumor activity of human T_H17 cells.

RESEARCH ARTICLE: Thermal Enhancement with Optically Activated Gold Nanoshells Sensitizes Breast Cancer Stem Cells to Radiation Therapy

R. L. Atkinson et al.

Local heating with gold nanoshells sensitizes mouse and human breast cancer stem cells to radiation treatment.

SCIENCE PODCAST

www.sciencemag.org/multimedia/podcast

Free Weekly Show

Download the 29 October *Science* Podcast to hear about the distribution of exoplanets, cancer epigenetics, how people detect errors, and more.

SCIENCE INSIDER

news.sciencemag.org/scienceinsider

Science Policy News and Analysis

VIDEO FEATURE

video.sciencemag.org

Defining Epigenetics

Science Senior Editor Guy Riddihough taps experts for their definition of epigenetics.

>> *Epigenetics* section p. 611 and www.sciencemag.org/special/epigenetics/

SCIENCE (ISSN 0036-8075) is published weekly on Friday, except the last week in December, by the American Association for the Advancement of Science, 1200 New York Avenue, NW, Washington, DC 20005. Periodicals Mail postage (publication No. 484460) paid at Washington, DC, and additional mailing offices. Copyright © 2010 by the American Association for the Advancement of Science. The title SCIENCE is a registered trademark of the AAAS. Domestic individual membership and subscription (51 issues): \$146 (\$74 allocated to subscription). Domestic institutional subscription (51 issues): \$910; Foreign postage extra: Mexico, Caribbean (surface mail) \$55; other countries (air assist delivery) \$85. First class, airmail, student, and emeritus rates on request. Canadian rates with GST available upon request, GST #1254 88122. Publications Mail Agreement Number 1069624. Printed in the U.S.A.

Change of address: Allow 4 weeks, giving old and new addresses and 8-digit account number. Postmaster: Send change of address to AAAS, P.O. Box 96178, Washington, DC 20090-6178. Single-copy sales: \$10.00 current issue, \$15.00 back issue prepaid includes surface postage; bulk rates on request. Authorization to photocopy material for internal or personal use under circumstances not falling within the fair use provisions of the Copyright Act is granted by AAAS to libraries and other users registered with the Copyright Clearance Center (CCC) Transactional Reporting Service, provided that \$20.00 per article is paid directly to CCC, 222 Rosewood Drive, Danvers, MA 01923. The identification code for *Science* is 0036-8075. *Science* is indexed in the *Reader's Guide to Periodical Literature* and in several specialized indexes.



ADVANCING SCIENCE, SERVING SOCIETY

Science

330 (6004)

Science **330** (6004), 556-692.

ARTICLE TOOLS

<http://science.sciencemag.org/content/330/6004>

PERMISSIONS

<http://www.sciencemag.org/help/reprints-and-permissions>

Use of this article is subject to the [Terms of Service](#)

Science (print ISSN 0036-8075; online ISSN 1095-9203) is published by the American Association for the Advancement of Science, 1200 New York Avenue NW, Washington, DC 20005. 2017 © The Authors, some rights reserved; exclusive licensee American Association for the Advancement of Science. No claim to original U.S. Government Works. The title *Science* is a registered trademark of AAAS.