

SPECIAL SECTION

Synthetic Biology

INTRODUCTION

1235 The Allure of Synthetic Biology

NEWS

1236 The Life Hacker

1238 Algae's Second Try

1240 A Lab of Their Own

1242 Visions of Synthetic Biology

REVIEWS

1244 Synthetic Biology:
Integrated Gene Circuits

N. Nandagopal and M. B. Elowitz

1248 Synthetic Biology Moving into the Clinic

W. C. Ruder et al.

PERSPECTIVE

1252 Bottom-Up Synthetic Biology:
Engineering in a Tinkerer's World
P. Schwillie

POLICY FORUM

1254 Synthetic Biology:
Regulating Industry Uses
of New Biotechnologies
B. Erickson et al.

>> Editorial p. 1200; Reports pp. 1292, 1307, and 1315; Science Careers content and Science Podcast p. 1197 and www.sciencemag.org/special/syntheticbio



page 1216

EDITORIAL

1200 A Grand Challenge in Biology

Bruce Alberts

>> *Synthetic Biology section p. 1235*

NEWS OF THE WEEK

1204 A roundup of the week's top stories

NEWS & ANALYSIS

1207 NASA to Launch Guidelines
to Protect Lunar Artifacts

1208 Mystery Pioneer Anomaly Is Real
But Still a Mystery

1209 Biological Dark Matter Exerts
Irresistible Pull in Yunnan

1210 China Aims to Turn Tide
Against Toxic Lake Pollution

1211 Panel Blasts Ethics, Science
of 1940s Guatemala Studies

1213 Sweet Here, Salty There: Evidence for
a Taste Map in the Mammalian Brain

>> *Research Article p. 1262*

NEWS FOCUS

1214 BIODEFENSE: 10 YEARS AFTER
Taking Stock of the Biodefense Boom

1216 Reinventing Project BioShield

1219 Helping Hollywood Create and Battle
a Pandemic

LETTERS

1220 Retraction

J. L. Tomkins et al.

>> *Technical Comment by E. Postma*

Education Research: Call for Controls
C. Torgerson

Education Research: Set a High Bar
T. Derting et al.

Response

L. Deslauriers and C. E. Wieman

1221 TECHNICAL COMMENT ABSTRACTS

BOOKS ET AL.

1222 The Believing Brain

M. Shermer, reviewed by J. T. Jost

1223 Man-Made Minds

*Panel discussion moderated by F. Salie,
reviewed by G. Wayne and A. Pasternack*

POLICY FORUM

1225 The Overlooked Back End
of the Nuclear Fuel Cycle
A. M. Macfarlane

PERSPECTIVES

1227 Let There Be Dust
C. F. McKee

>> *Research Article p. 1258*

1228 Switching Light by Vacuum
M. Fleischhauer

>> *Report p. 1266*

1229 Demystifying DNA Demethylation

C. S. Nabel and R. M. Kohli

>> *Reports pp. 1300 and 1303*

1230 Through Thick and Thin

E. Brown and H. M. Jaeger

>> *Report p. 1276*

1231 Food and Biodiversity

H. C. J. Godfray

>> *Report p. 1289*

1233 Retrospective: John Harmen Marburger III
(1941–2011)

R. L. Orbach

CONTENTS continued >>



COVER

Bacteria constructed from toy building bricks represent the potential of synthetic biology to design and construct genetic modules that can be used to introduce new functions into existing organisms or even to engineer new biological systems. A special section highlights how this field is contributing to our understanding of biology and harnessing this understanding to benefit humanity. See page 1235 and www.sciencemag.org/special/syntheticbio.

Image: Equinox Graphics/Photo Researchers, Inc.

DEPARTMENTS

- 1199 This Week in *Science*
- 1201 Editors' Choice
- 1203 *Science* Staff
- 1320 New Products
- 1321 *Science* Careers

BREVIA

- 1257** Recently Formed Polyploid Plants Diversify at Lower Rates
I. Mayrose et al.
The doubling of genomes does not cause increased plant speciation unless the progenitor lineages are highly fit.

RESEARCH ARTICLES

- 1258** Herschel Detects a Massive Dust Reservoir in Supernova 1987A
M. Matsuura et al.
The large amount of dust produced by this supernova may help explain the dust observed in young galaxies.
>> *Perspective p. 1227*
- 1262** A Gustotopic Map of Taste Qualities in the Mammalian Brain
X. Chen et al.
Nonoverlapping hot spots for different classes of taste stimuli map topographically in the mouse insular cortex.
>> *News story p. 1213*

REPORTS

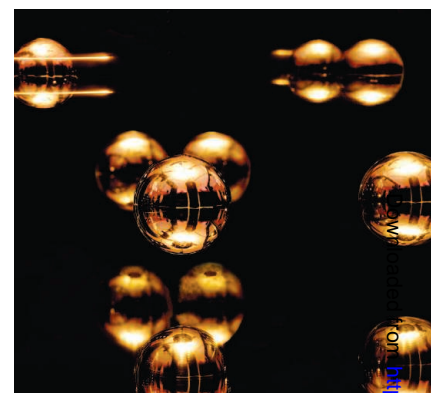
- 1266** Vacuum-Induced Transparency
H. Tanji-Suzuki et al.
The transmission of light through an atomic gas can be controlled by manipulating the confining cavity.
>> *Perspective p. 1228*
- 1269** Single-Shot Correlations and Two-Qubit Gate of Solid-State Spins
K. C. Nowack et al.
Independent readout of two single-spin qubits in quantum dots is achieved in an all-electrical setup.
- 1273** Femtoscale Magnetically Induced Lattice Distortions in Multiferroic TbMnO_3
H. C. Walker et al.
Ferroelectric order in a multiferroic compound is probably caused by small displacements of ions in its crystal lattice.
- 1276** Imaging the Microscopic Structure of Shear Thinning and Thickening Colloidal Suspensions
X. Cheng et al.
Confocal microscopy reveals changes in structures formed by suspended particles under different flow conditions.
>> *Perspective p. 1230*
- 1279** Traffic Jams Reduce Hydrolytic Efficiency of Cellulase on Cellulose Surface
K. Igarashi et al.
High-speed atomic force microscopy tracks single-molecule dynamics of cellulose degradation into fermentable sugar molecules.
- 1282** Isotopic Signature of N_2O Produced by Marine Ammonia-Oxidizing Archaea
A. E. Santoro et al.
Archaea may account for the majority of marine nitrous oxide emissions to the atmosphere.

- 1285** Out of Tibet: Pliocene Woolly Rhino Suggests High-Plateau Origin of Ice Age Megaherbivores
T. Deng et al.
The Tibetan Plateau acted as a cradle of adaptation to cold for Pleistocene megafauna.
- 1289** Reconciling Food Production and Biodiversity Conservation: Land Sharing and Land Sparing Compared
B. Phalan et al.
Protecting the largest possible area of natural habitats while growing food on the smallest area can reconcile food production with conservation.
>> *Perspective p. 1231*
- 1292** Chemical and Genetic Engineering of Selective Ion Channel–Ligand Interactions
C. J. Magnus et al.
Engineered ion channels enable manipulation of cellular function by selective chemical control of ionic conductance.
>> *Synthetic Biology section p. 1235*
- 1296** Potential for Chemolithoautotrophy Among Ubiquitous Bacteria Lineages in the Dark Ocean
B. K. Swan et al.
Bacteria isolated from a deep seawater mass seem to fix carbon using energy from the oxidation of inorganic sulfur.
- 1300** Tet Proteins Can Convert 5-Methylcytosine to 5-Formylcytosine and 5-Carboxylcytosine
S. Ito et al.
- 1303** Tet-Mediated Formation of 5-Carboxylcytosine and Its Excision by TDG in Mammalian DNA
Y.-F. He et al.
Evidence for a possible route for DNA demethylation in animals is suggested.
>> *Perspective p. 1229*
- 1307** Multi-Input RNAi-Based Logic Circuit for Identification of Specific Cancer Cells
Z. Xie et al.
A synthetic biomolecular circuit identifies abnormal cell states by the integration of multiple endogenous microRNA inputs.
>> *Synthetic Biology section p. 1235*
- 1311** Epigenetic Licensing of Germline Gene Expression by Maternal RNA in *C. elegans*
C. L. Johnson and A. M. Spence
Expression of a gene in an offspring needs an RNA (but not the protein it codes for) provided by its mother.
- 1315** Entrainment of a Population of Synthetic Genetic Oscillators
O. Mondragón-Palomino et al.
A positive-feedback loop in a biological oscillator allows effective setting of the clock by external cues.
>> *Synthetic Biology section p. 1235*

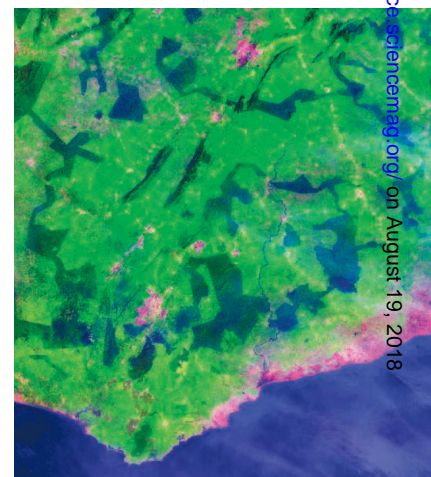
CONTENTS continued >>



page 1222



pages 1273



pages 1231 & 1289

SCIENCEONLINE

SCIENCEEXPRESS

www.sciencexpress.org

Light Propagation with Phase Discontinuities: Generalized Laws of Reflection and Refraction
N. Yu et al.

Light propagation can be controlled with plasmonic interfaces that introduce abrupt phase shifts along the optical path.

10.1126/science.1210713

Linking Long-Term Dietary Patterns with Gut Microbial Enterotypes

G. D. Wu et al.

The basic composition of the human gut microbiome is influenced by long-term diet: high fat and protein versus high fiber.

10.1126/science.1208344

ER Tubules Mark Sites of Mitochondrial Division
J. R. Friedman et al.

Mitochondrial division occurs at positions where endoplasmic reticulum tubules contact mitochondria and mediate constriction.

10.1126/science.1207385

Glutamatergic and Dopaminergic Neurons Mediate Anxiogenic and Anxiolytic Effects of CRHR1

D. Refojo et al.

Imbalance in the bidirectional role of corticotropin-releasing hormone receptor 1 in anxiety might lead to emotional disorders.

10.1126/science.1202107

Implementing the Quantum von Neumann Architecture with Superconducting Circuits
M. Mariantoni et al.

A quantum version of a central processing unit was created with superconducting circuits and elements.

10.1126/science.1208517

Universal Digital Quantum Simulation with Trapped Ions

B. P. Lanyon et al.

A series of trapped calcium ions was used to simulate the complex dynamics of an interacting spin system.

10.1126/science.1208001

TECHNICALCOMMENTS

Comment on "Additive Genetic Breeding Values Correlate with the Load of Partially Deleterious Mutations"

E. Postma

Full text at www.sciencemag.org/cgi/content/full/333/6047/1221-b

>> Retraction p. 1220

SCIENCENOW

www.sciencenow.org

Highlights From Our Daily News Coverage

'Time Cells' Weave Events Into Memories

Neurons in the hippocampus keep track of empty moments.

<http://scim.ag/timecells>

'Jurassic Mother' Found in China

An ancestor of placental mammals appeared while dinosaurs roamed.

<http://scim.ag/jurassicmom>

Mind-Altering Bugs

Bacteria in the gut alter brain chemistry and behavior in mice.

<http://scim.ag/mind-altering>

SCIENCE SIGNALING

www.sciencesignaling.org

The Signal Transduction Knowledge Environment

30 August issue: <http://scim.ag/ss083011>

RESEARCH ARTICLE: AKT Promotes rRNA Synthesis and Cooperates with c-MYC to Stimulate Ribosome Biogenesis in Cancer

J. C. Chan et al.

In addition to promoting translation, AKT also stimulates protein synthesis and cell growth by enhancing ribosome biogenesis.

REVIEW: Inositol Pyrophosphates as Mammalian Cell Signals

A. Chakraborty et al.

Identification and knockout of their biosynthetic enzymes has shed light on the diverse functions of the inositol pyrophosphates.

PRESENTATION: Merlin/NF2 Functions Upstream of the Nuclear E3 Ubiquitin Ligase CRL4^{DCAF1} to Suppress Oncogenic Gene Expression

J. Cooper et al.

The closed conformer of Merlin inhibits tumorigenesis by inhibiting a ubiquitin ligase implicated in promoting cell cycle progression and inhibiting growth arrest, apoptosis, and adhesion.

SCIENCE TRANSLATIONAL MEDICINE

www.sciencetranslationalmedicine.org

Integrating Medicine and Science

31 August issue: <http://scim.ag/stm083111>

RESEARCH ARTICLE: Identification of a Disease-Defining Gene Fusion in Epithelioid Hemangioendothelioma

M. R. Tanas et al.

PERSPECTIVE: Understanding the Enemy

V. E. Velculescu and L. A. Diaz Jr.

A genomics approach shortens the path to discovery of a diagnostic gene fusion for a specific vascular cancer.

RESEARCH ARTICLE: A Computational Model to Predict the Effects of Class I Anti-Arrhythmic Drugs on Ventricular Rhythms

J. D. Moreno et al.

Two- and three-dimensional models of cardiac excitability based on sodium-channel kinetics can predict the adverse effects of class I anti-arrhythmic drugs.

RESEARCH ARTICLE: Noninvasive Electroanatomic Mapping of Human Ventricular Arrhythmias with Electrocardiographic Imaging (ECGI)

Y. Wang et al.

FOCUS: Imaging Cardiac Arrhythmias

K. Shivkumar and S. M. Narayan

Electrocardiographic imaging can noninvasively provide an activation map of the heart's surface to help treat arrhythmias.

SCIENCE CAREERS

www.sciencereers.org/career_magazine

Free Career Resources for Scientists

What Is Wrong With High-Skill Immigration Policy?

B. L. Benderly

A Senate hearing highlights the split between institutions' and workers' interests.

http://scim.ag/TFG_Skilled

A Father-and-Son Journey Into Synthetic Biology
E. Pain

Justin Siegel rationally engineered unnatural enzymes partly thanks to technology his dad helped develop.

<http://scim.ag/JustinSiegel>

>> *Synthetic Biology* section p. 1235 and www.sciencemag.org/special/syntheticbio

SCIENCE PODCAST

www.sciencemag.org/multimedia/podcast

Free Weekly Show

On the 2 September *Science* Podcast: a special show all about synthetic biology, from clinical applications and regulatory issues to the do-it-yourself biology movement.

>> *Synthetic Biology* section p. 1235 and www.sciencemag.org/special/syntheticbio

SCIENCE INSIDER

news.sciencemag.org/scienceinsider

Science Policy News and Analysis

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 © 2011 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): \$149 (\$74 allocated to subscription). Domestic institutional subscription (51 issues): \$990; 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 \$25.00 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

333 (6047)

Science **333** (6047), 1199-1320.

ARTICLE TOOLS

<http://science.sciencemag.org/content/333/6047>

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.