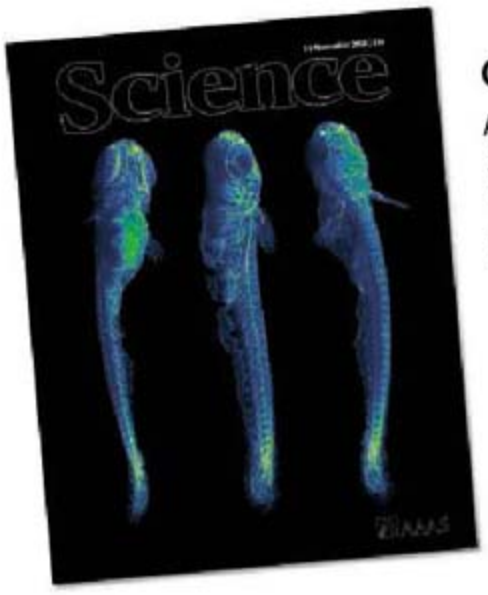
14 November 2008 | $10

Science

AAAS

Volume 322, Issue 5904



COVER

A montage showing three views of a 5-millimeter-long juvenile medaka, with the nervous system imaged with a digital scanned laser light sheet fluorescence microscope. This technique has been used to reconstruct embryogenesis in zebrafish. See page 1065.

Image: Philipp Keller, Lazaro Centanin, Annette Schmidt/EMBL

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www.sciencexpress.org

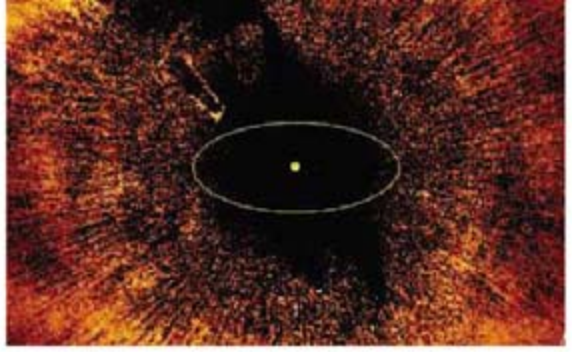
ASTRONOMY

Optical Images of an Exosolar Planet 25 Light-Years from Earth
P. Kalas et al.
Images from the Hubble Space Telescope reveal a Jupiter-sized planet, perhaps with a surrounding dust disk, orbiting about 115 astronomical units from a nearby main sequence star.
10.1126/science.1166609

ASTRONOMY

Direct Imaging of Multiple Planets Orbiting the Star HR 8799
C. Marois et al.
Infrared images from the Keck and Gemini telescopes reveal three giant planets orbiting counterclockwise around a young star, in a scaled-up version of our solar system.
>> Science *Podcast*
10.1126/science.1166585

PERSPECTIVE: Exoplanets—Seeing Is Believing
M. S. Marley
10.1126/science.1167569



MEDICINE

Genomic Loss of microRNA-101 Leads to Overexpression of Histone Methyltransferase EZH2 in Cancer
S. Varambally et al.
In some human prostate cancers, a genomic deletion eliminates a key regulatory microRNA, which results in disruption of gene silencing mechanisms.
10.1126/science.1165395

CELL BIOLOGY

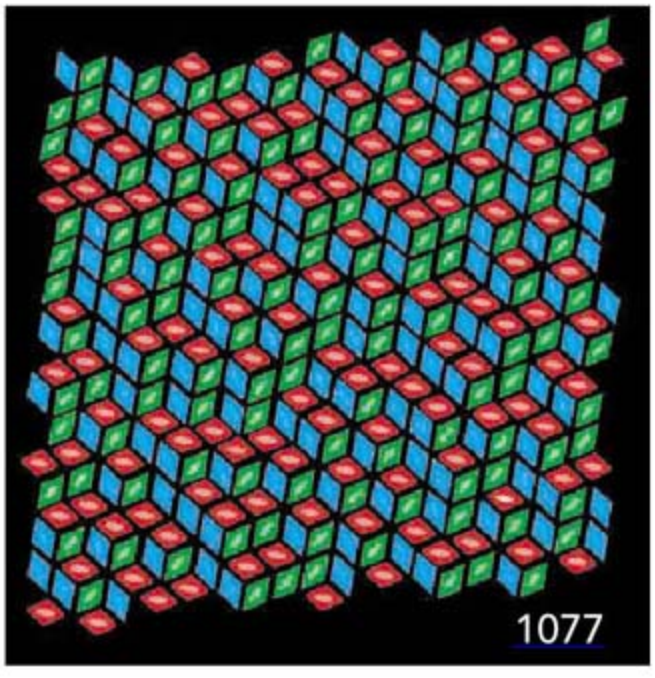
A Role for the ESCRT System in Cell Division in Archaea
R. Y. Samson, T. Obita, S. M. Freund, R. L. Williams, S. D. Bell
A class of proteins required for membrane trafficking and cytokinesis in eukaryotes is also unexpectedly required in some Archaea for cell division.
10.1126/science.1165322

TECHNICAL COMMENT ABSTRACTS

PLANETARY SCIENCE

BREVIA

ECOLOGY



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CHEMISTRY

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Science

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AAAS
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Keratin in claws.

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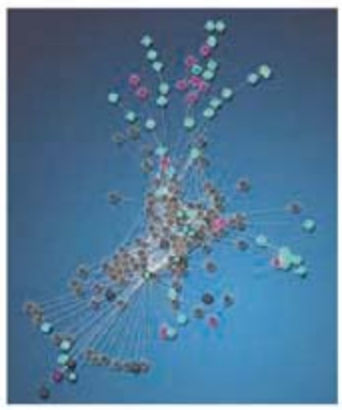
HIGHLIGHTS FROM OUR DAILY NEWS COVERAGE

So That's Why Chickens Have Combs
Birds and reptiles make hair proteins, just like mammals do.

Earth's Strange Tango With the Sun
Mysterious magnetic portals link our planet to its star.

Bird Brains Split Lookout Duty
A migrating bird rests half of its brain while the other half remains alert.



A Wnt pathway interaction.

CHRIS BICKEL

SCIENCE **SIGNALING**

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RESEARCH ARTICLE: Cripto Localizes Nodal at the Limiting Membrane of Early Endosomes
M.-H. Blanchet, J. A. Le Good, V. Oorschot, S. Baflast, G. Minchiotti, J. Klumperman, D. B. Constam
Cripto facilitates ALK4 signaling by attenuating intraendosomal sorting of internalized Nodal.

RESEARCH ARTICLE: New Regulators of Wnt/β-Catenin Signaling Revealed by Integrative Molecular Screening
M. B. Major, B. S. Roberts, J. D. Berndt, S. Marine, J. Anastas, N. Chung, M. Ferrer, X. Yi, C. L. Stoick-Cooper, P. D. von Haller, L. Kategaya, A. Chien, S. Angers, M. MacCoss, M. A. Cleary, W. T. Arthur, R. T. Moon
Integration of protein-protein interaction networks and human genome-wide RNAi screens produces mechanistic insight into Wnt/β-catenin signaling.

PODCAST
M. B. Major, R. T. Moon, A. M. VanHook
Ben Major and Randall Moon discuss their screen for cell type–specific modifiers of Wnt signaling.

E-LETTER: Calcium-Sensing Receptor Function in the Skeleton—Alternative Interpretations
L. D. Quarles and M. Pi

E-LETTER: Response to Quarles and Pi
W. Chang, C. Tu, T.-H. Chen, D. Bikle, D. Shoback
A letters exchange debates an alternative interpretation of the observations recently presented by Chang *et al*. (*Sci. Signal.* **1** (35), ra1).

CREDITS: (*SCIENCE NOW*) KARIN JAEGER/MEDICAL UNIVERSITY OF VIENNA; (*SCIENCE CAREERS*) COMSTOCK; (*SCIENCE SIGNALING*)

Conflict of interest: A big career gamble.

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Conflicts of Interest and Physician-Scientists
J. B. Finkelstein
Clinician-researchers need to take threats from conflicts of interest seriously.

A Career Niche at the Interface of Academe and Industry
E. Pain
Spanish biologist David Ràfols used his technology and industry experience to create his open-innovation company.

Learning to Let Go While Trusting Your Data
S. Webb
New investigators must take responsibility for the integrity of their lab's data, even as direct control over that data declines.

From the Archives: Do You Really Want Your Name on That Paper?
K. Cottingham et al.
Science Careers looks at the ethics of authorship, responsibility, and keeping careful records in the lab.

SCIENCE**PODCAST**

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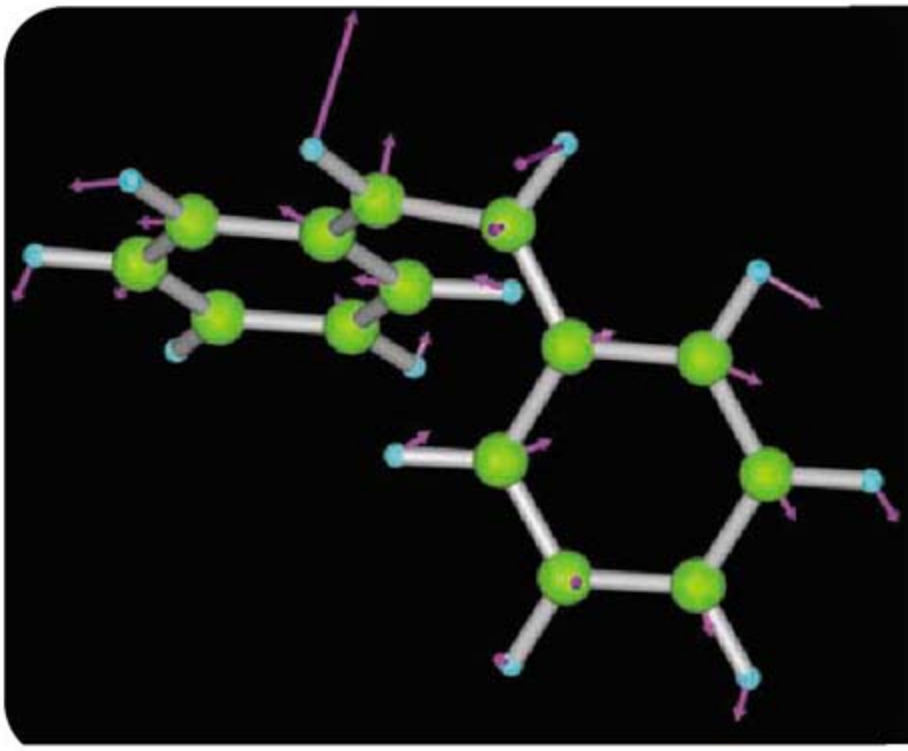
EDITED BY STELLA HURTLEY

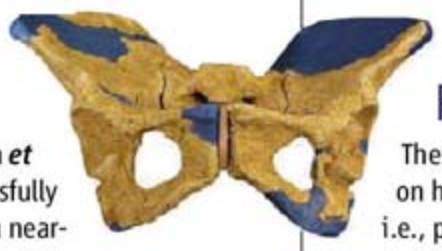


<< How Stilbene Twists

Over the last decade, ultrafast vibrational spectroscopy has offered detailed glimpses into how molecules rearrange upon excitation. However, the available information tends to be confined to the small segment of the molecule that is most actively changing. **Takeuchi *et al.*** (p. 1073; see the Perspective by **Blank**) used a coherent Raman technique to track vibrations more globally across the framework of stilbene during its photoinduced *cis*-to-*trans* isomerization about the central C=C double bond. Tracking the steady frequency shift of a skeletal vibration and then modeling the process theoretically produced a thorough picture of the order in which different portions of the molecule move, starting with a lengthening of the double bond and extending to the twisting of pendant H atoms out of plane.

Homo erectus Hips

Human pelvic morphology is central to the understanding of obstetrics, sexual dimorphism, and neonatal brain size and patterns of brain growth, as well as the evolution of body form and its relation to locomotor refinements and adaptation to tropical environments. However, sufficiently preserved pelvic bones are very rare in the fossil record, and only few such hominid fossils are known from the entire Plio-Pleistocene record of Africa. **Simpson *et al.*** (p. 1089) have successfully recovered, and restored a near-complete adult female *Homo erectus* pelvis from Gona, Afar, Ethiopia, dated to ~ 0.9 to 1.4 million years ago. The *H. erectus* pelvis was much more australopithecine-like than hitherto thought, and allowed a neonate brain size 25 to 30% larger than earlier estimates, suggesting that *H. erectus* lacked a fully human-like phase of infant dependency. Additionally, *H. erectus* did not have the tall narrow body form of modern humans adapted to tropical, semi-arid environments or hips adapted for long distance running, previously thought to characterize *H. erectus*.



Oxygen Torn Apart

When molecules are photoionized with excess energy, they can relax by ejecting a second electron. However, photoionized oxygen has appeared to relax in this way only after the nuclei spread a substantial distance apart. By pairing recently developed attosecond x-ray pulse generation techniques with precise ion imaging, **Sandhu *et al.*** (p. 1081) uncover the detailed dynamics underlying this behavior. The initially generated O^{2+} ion quickly drops below the energy threshold for formation of the dication, but, as the nuclei repel one another, the dication becomes accessible at a separation distance of roughly 30 angstroms. At that stage, a transient state (a Feshbach resonance) can be observed, which persists due to spin-orbit coupling before eventually decaying through further ionization or radiative relaxation.

Quantifying Global Photosynthesis

The utility of climate models rests in part on how well the uptake of CO_2 by plants, i.e., photosynthesis, can be represented, because carbon and climate are so inextricably entwined. However, how much photosynthesis actually occurs on a global scale is very difficult to measure, because the available techniques are either indirect, or direct but not amenable to large-scale application. **Campbell *et al.*** (p. 1085) show using measurements made during the North American growing season that carbonyl sulfide, COS, is a good surrogate for CO_2, and that the quantitative relationship between the two that has been measured in the laboratory also extends to the bulk atmosphere. Thus, the measurement of vertical atmospheric concentration gradients of COS should reflect how much photosynthesis is occurring over continents during the growing season.

Digitizing Development

Current microscopes provide neither the speed nor the low phototoxicity required for recordings of entire embryos over long periods of time, which would be required to reconstruct a complete picture of vertebrate development. **Keller *et al.*** (p. 1065, published online 9 October; see 10 October news story by **Vogel**; cover) developed digital scanned laser light sheet fluorescence microscopy that overcomes these limitations and delivers quantitative information for entire zebrafish embryos at subcellular resolution. The data provide a developmental blueprint of a vertebrate species and simultaneously track about 20,000 cells up to a stage in which major organs show function.

Disordering of Surface Tiles

Molecular networks on surfaces could provide a readily interrogated model for understanding the structural basis of glasses, but often the interactions between molecules lead to well-ordered arrays. **Blunt *et al.*** (p. 1077) used scanning tunneling microscopy to investigate an intermediate case between crystals and glasses in which an organic molecule (*p*-terphenyl-3,5,3′,5′-tetracarboxylic acid) absorbed on graphite locally organizes into rhombus tiles. The tiles have a nonperiodic arrangement and are not ordered translationally. Networks formed as junctions of three to six molecules with hexagonal symmetry, and triangular defects could form and move through the network causing reordering oh the local arrangement.

Putting the Brakes on Inflammation

Numerous adhesion receptors of the selectin, integrin, or immunoglobulin family promote inflammatory cell recruitment. In contrast, inhibitors of the leukocyte adhesion cascade are

Continued on page 1023

CREDITS (TOP TO BOTTOM): TAKEUCHI *ET AL.*; SIMPSON *ET AL.*

Continued from page 1021

not well known. Now **Choi *et al.*** (p. 1101) have characterized developmental endothelial locus–1 (Del-1) as an endogenous inhibitor of the leukocyte adhesion cascade. Del-1, which is an endothelially expressed, secreted molecule, is a ligand of the major leukocyte adhesion receptor LFA-1. Soluble Del-1 inhibited neutrophil adhesion under both static and physiologic flow conditions. Endothelial Del-1 deficiency promoted increased leukocyte adhesion, and mice lacking Del-1 displayed significantly higher neutrophil accumulation during lung inflammation, which was reversed in Del-1/LFA-1 double deficient mice. Thus Del-1 interacts with LFA-1 preventing inflammatory cell recruitment.

Ubiquitin's Pup(py)?

Ubiquitin is a universal modifier used by eukaryotes to tag proteins for degradation. Now **Pearce *et al.*** (p. 1104, published online 2 October; see the Perspective by **Mukherjee and Orth**) describe a ubiquitin-like protein system they call Pup in prokaryotes. Pup appears to be required for protein degradation by the *Mycobacterium tuberculosis* (Mtb) proteasome. Because proteasome function is essential for the virulence of Mtb, the Pup conjugation pathway could potentially be targeted for the development of antituberculosis drugs.

CREDIT: KIM ET AL.

From Flower to Flower

Although horizontal gene transfer has been extensively studied in bacteria, its role in the evolution of multicellular plants and animals has been explored little. **M. Kim *et al.*** (p. 1116) analyze a key morphological and ecological trait transferred naturally between two higher eukaryotic species, flowers of the genus *Senecio*. The transfer involves introgression of a cluster of regulatory genes that control flower morphology. The genes are expressed in the outer regions of the developing flower where they promote the production of asymmetric florets with large petals, yielding a daisy-like head that confers higher levels of outcrossing. Thus, regulatory genes can allow a key morphological and ecological trait to be gained, lost, and regained during evolution, providing a more dynamic view of evolutionary change than the traditional one which considers each lineage as evolving independently.

Sole Food

Termites have a formidable capacity for digesting dead wood. Consequently they have become major pests destroying man-made structures around the world. The biochemical talents required for digesting wood are much sought after by humans for processing biofuels, but because wood is an unbalanced foodstuff and lacks nitrogen, no simple solution is available. Termites owe their success to arrays of symbiotic microorganisms possessing complementary metabolisms. **Hongoh *et al.*** (p. 1108) have sequenced the genome of a dominant bacterial symbiont living within a dominant protozoan that lives in termite guts. The sequence reveals genes that allow the bacterium to fix atmospheric nitrogen, to recycle nitrogen from waste nitrogen products from its protozoan host, and to make amino acids for its own and both its host's and its host's host's use. The energy required for nitrogen fixation is considerable and the bacterium obtains this not only from hydrogen produced during nitrogen fixation but also from the anaerobic fermentation of sugars released from cellulose by the protozoan.

To Be or Not to Be?

The tiny pores, or stomata, that open and close on a leaf's surface allow for the exchange of gases according to the needs of the plant's physiology. The number of stomata formed during development is a result of competing signals that activate or repress pore formation. **Lampard *et al.*** (p. 1113) now show how these competing signals converge so that their inputs result in one question: Will there or won't there be a stoma placed here? The transcription factor SPEECHLESS, which activates stomatal development programs, can be phosphorylated by certain mitogen-activated protein kinases (MAPKs), a group of kinases that, among myriad other functions, repress formation of stomata. All the phosphorylation sites are contained within the 93–amino acid MAPK target domain of SPEECHLESS, which thus integrates positive and negative signals.

William A. Wulf is a University Professor in the Department of Computer Science at the University of Virginia, Charlottesville, VA; president emeritus of the U.S. National Academy of Engineering; and former Assistant Director of the U.S. National Science Foundation.

Anita K. Jones is a University Professor in the Department of Computer Science at the University of Virginia, Charlottesville, VA; former Director of Defense Research and Engineering at the U.S. Department of Defense; and former vice chair of the U.S. National Science Board.

A Call to Serve

ONCE BARACK OBAMA BECOMES THE 44TH PRESIDENT OF THE UNITED STATES IN JANUARY 2009, he will, sooner or later, appoint individuals to science and technology policy positions within the executive branch of government. It seems as though every science- and engineering-related think tank either has published, or shortly will, a report calling on the new administration to appoint these people quickly and give them the authority and tools to do their job.

But it is not just an administration choice; qualified scientists and engineers need to be willing to take those jobs. The quality of the decisions and actions of an administration directly depends on the quality of those appointees and others who serve. Our premise is that every engineer and every scientist ought to include service to their country in their career plan.

Too often we have heard "I am too busy," or "my research is my service to the country," or various disparaging remarks about government bureaucrats and not wanting to be associated with them. There are several reasons why technically literate people should serve. First, they are needed. The world is more technologically sophisticated than it has ever been, and today most public policy issues have technical dimensions. Without sound technical input, some bad public policy will result. Without unrelenting oversight by individuals with technical expertise to ensure sound implementation, foolish actions will be taken.

The U.S. population broadly supports the nation's research and, frankly, in return the research community owes it to society to ensure that the best possible policy decisions are made. And there is a self-interest factor. This community believes that increased support for research would benefit the nation in the long term, but that case needs to be made from within the government as well as from the outside. The same argument is valid for other nations as well. Lastly, government service can be intellectually interesting. Executive agencies have resources to deal with problems. The challenge is to address them creatively and effectively.

Scientists and engineers think about problems differently. For example, lawyers, who disproportionately populate government positions, are trained to marshal an argument to support a predetermined conclusion (e.g., the client is innocent). In contrast, scientists and engineers are taught to analyze and design so that the outcome is not predetermined but is derived from the constraints of the problem. They collect relevant information, and only solutions that fit the data are acceptable. Scientists and engineers also think in terms of the total problem—for today and for tomorrow. An engineer will design a bridge to be taken down cost-effectively at the end of its life. This culture of thought and analytic tools and decision-making methods needs to have a stronger influence in decisions made about issues that at their root involve science or technology.

So how might one try out such service? One approach is to volunteer to advise some element of the government. Once a person is seen to contribute, they are increasingly called on to advise at higher levels. This can lead to appointment to more senior advisory bodies. Alternatively, an individual can apply to be a program officer in a federal or state government agency. Universities routinely grant leaves of absence for such service. Although one does not begin as the head of an agency, these program officer positions wield considerable resources and can materially address important challenges.

We believe that the scientists and engineers of all countries need to step up. Every one has a contribution to make. Shouting from the sidelines does not work. And if the technical community does not engage, we will get what we deserve.

– William A. Wulf and Anita K. Jones

10.1126/science.1167218

EDITED BY GILBERT CHIN AND JAKE YESTON

PHYSICS

Polarization Puzzle

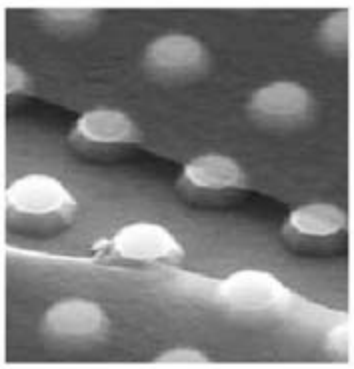
When very high-intensity light strikes a solid surface, it can liberate multiple electrons and ions that then continue to collide rapidly with one another, forming a plasma state. These collisions in turn lead to emission across a broader spectrum of wavelengths, as kinetic and electromagnetic energy steadily interconvert. The chaos of such a process might be expected to distribute the emitted light across completely random orientations. However, Liu *et al.* make the surprising observation that under certain conditions, the plasma produced from a silicon (Si) surface initially emits a continuum of ultraviolet light that is >95% polarized. The optimal conditions involved focusing a pair of ultrashort laser pulses spaced 80 ps apart in time onto a Si(111) crystal face; this dual pulse sequence proved key to maximizing the effect. The degree of polarization was also highly sensitive to the distance between the surface and the laser focus, and scaled inversely with pulse intensity (at least within the range sufficient to induce plasma emission). — JSY

Appl. Phys. Lett. **93**, 161502 (2008).

MATERIALS SCIENCE

Graphene Oxide Resonators

One potential application for graphene (sheets of graphite only one or several layers thick) is as a resonator in nanoelectromechanical systems, in part because of the high ratio of stiffness to mass. However, the formation of large-area films of exfoliated graphene and manipulation of the graphene flakes are experimentally challenging.



An alternative is to use a related material, graphene oxide, in which the graphene film is chemically modified with oxygenated substituents. Robinson *et al.* rapidly deposited graphene oxide platelets onto glass by spin casting along with rapid solvent evaporation, which formed ultrathin continuous films. These films could then be chemically reduced, and despite being as thin as 4 nm, could be released from the substrate by being dipped into basic solution. They could then be suspended onto substrates patterned with circular holes (between about 3 and 7 μm in diameter) in order to form drum resonators. Laser interferometry revealed that these membranes resonate in the radiofrequency range and have quality factors up to 4000, which is comparable to those of diamond oscillators and exceeds typical values for graphene oscillators (10 to 200). This increase relative to graphene reflects the enhanced adhesion of graphene oxide to glass surfaces through surface oxygen groups. — PDS

Nano Lett. **8**, 3441 (2008).

PHYSIOLOGY

Four Wings Are Better Than Two

The hindwings of butterflies and moths are necessary for agility, but not for flight itself. In experiments in which the hindwings of cabbage butterflies and gypsy moths were removed, Jantzen and Eisner found that the forewings were sufficient for these lepidopterans to remain airborne, despite the fact that they constitute only half the total wing area. However, video recordings showed that removal of the hindwing, which is mechanically coupled to the forewing, resulted in substantial deficits in several measures of flight performance, such as linear and turning acceleration. Hence, the hindwing may have evolved as an adaptation for rapid maneuverability in the face of pursuit by predators, chiefly bats and birds. — AMS

Proc. Natl. Acad. Sci. U.S.A. **105**, 16636 (2008).

MOLECULAR BIOLOGY

Keeping One's Identity

The phenotype of a cell is in part defined by its pattern of active versus inactive gene expression. During development, progenitor cells divide and differentiate down specific lineages, and daughter cells retain the same activity profile as the cell from which they were derived. It is necessary to preserve these markers of cell identity through mitosis, when transcription ceases and many chromatin-binding proteins that determine gene activity dissociate from the DNA. Most of the chromatin becomes tightly compacted, but some active regions remain open, due to the binding of specific factors to gene promoters. This enables transcription to resume more easily after cell division and is known as gene bookmarking, being analogous to the way a bookmark allows one to open a book at a specific page; gene-specific bookmarking factors have been identified. TATA-binding protein (TBP) is an essential basal transcription factor, which remains bound to active promoters during mitosis, and Xing *et al.* show that TBP acts as a general bookmarking factor by recruiting the phosphatase PP2A. This enzyme inactivates condensin, which is a large protein complex involved in compacting chromosomes during mitosis. Understanding general mecha-

CREDITS (TOP TO BOTTOM): JACK THOMAS/ALAMY; ROBINSON *ET AL.*, *NANO LETT.* 8, 3441 (2008)

nisms of bookmarking could be important for controlling cellular behavior during reprogramming, when differentiated cells need to be wiped clean of their previous identity. — HP*

Nat. Cell Biol. **10**, 1318 (2008).

PSYCHOLOGY

Don't Get Even, Stay Mad

Declarations of unintentionality ("I didn't mean to hurt you") often suffice to defuse tense situations and to reduce or eliminate vengeful responses to a harmful act. But does the reining in of aggressive behavior reflect deliberate and effortful control of those impulses, or does the claim of a lack of purpose serve to dissolve one's anger? Using a social evaluation setting, Krieglmeyer *et al.* obtain evidence linking the attribution of intention to a conscious overriding of impulsive aggression. They presented students with positive or negative ratings (from an unseen partner) of their ideas for naming a new energy drink; half of the students who had received negative feedback were then told that their partner had mistaken the high-low direction of the rating scale and had in fact intended to assign them positive marks. When assessed specifically for anger using an implicit measure and for behavior by means of the same rating scale, this set of students displayed a lower level of aggression as compared to the students whose negative assessments had been intentional (although they still exhibited a higher level of hostility than the students who had received positive ratings initially). In contrast, learning that the negative ratings had been delivered in error and that the actual intent had been to send positive feedback had no effect on the levels of implicit anger. — GJC

J. Exp. Soc. Psych. **44**, 10.1016/j/jesp.2008.10.003 (2008).

CELL BIOLOGY

Can You Hear Me Now?

It's a bit like talking to your neighbor at a dinner party with a megaphone, but Tovey *et al.* report that the stimulation of calcium release through inositol 1,4,5-trisphosphate receptors (IP_3R) results from enormous amounts (1000 times greater than the amount needed to activate protein kinase A) of the second messenger cAMP produced by adenylyl cyclase (AC) molecules that are closely apposed to the IP_3R channel. The authors were led to this unorthodox interpretation by their exploration of the mechanisms by which parathyroid hormone (PTH), which itself does not cause the release of calcium, enhanced the effects of other hormones on the release via IP_3Rs of calcium from internal stores. Only PTH analogs that activated AC potentiated calcium release. High concentrations of cAMP analogs were sufficient to reproduce the effects of PTH and were not additive with the effects of the hormone. The authors propose that AC and IP_3Rs are in such close proximity that activation of the cyclase produces a massive all-or-none response of the channel that is resistant to modulation by agents that alter cytoplasmic concentrations of cAMP; immunoprecipitation experiments confirmed the prediction that IP_3Rs and AC were associated physically. Such signaling complexes would have on-off or switchlike properties and could allow graded responses by recruitment of more activated complexes rather than graded response at an individual complex. To add to the complexity, the IP_3R-associated isoform of AC is inhibited by calcium. Thus, localized concentrations of cAMP and calcium might oscillate as a result of feedback inhibition. — LBR

J. Cell Biol. **183**, 297 (2008).

CHEMISTRY

Delivering More Than Charge

A small platinum or carbon wire inserted into a solution environment can yield substantial chemical insight through charge exchange with local compounds. One limitation of such electrode sensing, however, is that only electrons can be shuttled back and forth. Chen *et al.* have engineered a microfluidic apparatus, which they term a chemistrode, that can deliver or remove complex molecules from specific sites with a spatial resolution of 15 μm. The system relies on a fluorocarbon carrier fluid that pulls well-separated aqueous droplets through a channel that briefly opens to contact a substrate surface for molecular exchange. Analytes absorbed from the substrate can then be subjected to a wide range of traditional spectrometric probing techniques. The authors demonstrate the device through a measurement of insulin secretion kinetics by murine islet of Langerhans cells. — JSY

Proc. Natl. Acad. Sci. U.S.A. **105**, 16843 (2008).

CREDIT: NIALL MCDIARMID/ALAMY

*Helen Pickersgill is a locum editor in *Science*'s editorial department.

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Information for Authors
See pages 634 and 635 of the 1 February 2008 issue or access www.sciencemag.org/about/authors

EDITED BY CONSTANCE HOLDEN

Fish Online

At right are the dried remains of *Haemulon sciurus*, in one of the beautiful high-resolution photos, now online, of 168 fish specimens classified by 18th century Swedish naturalist Carl Linnaeus. The fish are in the collection of the Linnean Society of London (www.linnean.org), which sponsored the project with the help of Japan's Emperor Akihito, an ardent amateur ichthyologist known for his contributions to the taxonomy of gobioid fishes. Linnaeus's *Systema Naturae*, the recognized starting point for biological classification, was published in 1735. Linnean plant and insect databases are already online.

Oil and Mud

Was the continuing eruption of Lusi, the Indonesian mud volcano that began 30 months ago, triggered by a distant earthquake or by the drilling of a nearby gas well? The question has spurred fierce arguments among scientists (*Science*, 13 June, p. 1406).

CREDITS (TOP TO BOTTOM): BY PERMISSION OF THE LINNEAN SOCIETY OF LONDON; REUTERS/SIGIT PAMUNGKAS; SOURCE: WHO

Opponents squared off in a debate last month at a meeting of the American Association of Petroleum Geologists in Cape Town, South Africa. Geologists Richard Davies of Durham University in the U.K. and Mark Tingay of Curtin University of Technology in Perth, Australia, argued that drillers had tapped into a highly pressurized aquifer that fractured weak rock in the unprotected borehole and that the magnitude-6.3 earthquake occurring 2 days before Lusi's eruption was too small and remote to have any effect. Rocky Sawolo, drilling adviser for the oil company Lapindo Brantas, and geologist Adriano Mazzini of the University of Oslo, Norway, claimed that well pressures were within acceptable limits and that the earthquake reactivated a nearby fault.

At the end, the moderator, geologist John Underhill of the University of Edinburgh, U.K., called for a vote. Of 74 scientists voting, 42 agreed that drilling triggered the eruption. Only three opted for the earthquake scenario, 13 favored both factors, and the rest found the evidence inconclusive.

The issue is more than academic. If Indonesian courts agree with the scientists, Lapindo Brantas could have to pay tens of millions of dollars in compensation to 10,000 families and dozens of business owners who have lost properties to the rising tide of mud.

Saving Michael Caine

It's a criminal conundrum: $4 million in stolen gold and the crooks who just pulled off the heist teeter in a bus off the edge of a mountaintop. "Hang on, lads, I've got an idea," says actor Michael Caine. Then the 1969 movie *The Italian Job* cuts to the credits.

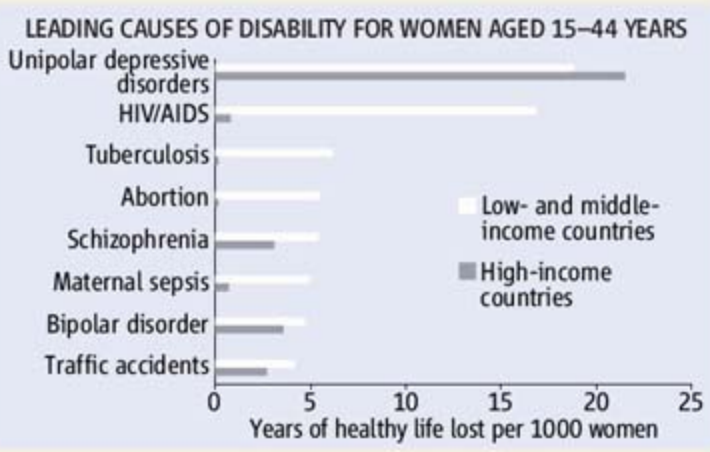
Now, to celebrate the movie's 40th anniversary, the Royal Chemistry Society (RCS) in London is asking fans to come up with an engineering idea to get Caine and his cronies out of their dilemma. "It's a way of pointing out that science is all around us—including a bank robbery," says RCS spokesperson Brian Emsley.

Entrants have until 1 January to submit a solution that includes a description of the physics and engineering challenges involved. Drawings and schematics are encouraged; no deus ex machina—such as a convenient helicopter—allowed.

The winner will receive a 3-night visit to Turin, Italy, where the movie's action takes place. Daniel Frey, a mechanical engineer at the Massachusetts Institute of Technology in Cambridge, who is not involved in the competition, says the challenge underscores the ingenuity required in science. "There's more than one way to skin this cat," he says. He says principles such as equilibrium and inertia could help entrants tackle the problem. For example, the bus's toppling might be delayed briefly, allowing time for some intervention, if the balance between the gold and the people were changed.

WORLDWIDE BLIGHT

Depression is the most disabling condition in the world, according to the World Health Organization. In its annual report issued last month, *Global Burden of Disease: 2004 Update*, authors found that unipolar depressive disorders account for more years of disability than any other condition—for both sexes, but especially females (see chart)—in rich and poor countries alike. Also high on the list are alcohol-use disorders (particularly for males), hearing and vision problems, and migraines. In a ranking of causes of years of healthy life lost, depression is surpassed only by lower respiratory infections and diarrheal diseases.



EDITED BY YUDHIJIT BHATTACHARJEE

<< Campaigns

NANOBAMA. Let's hope there's a microscope at the White House, because one of the first gifts Barack Obama will receive once he becomes president is a batch of these miniportraits, about half a millimeter wide and made out of about 150 million carbon nanotubes each. They were created a week before the 4 November election by mechanical engineer John Hart and his colleagues at the University of Michigan, Ann Arbor. Hart says he wasn't making a political statement, although he does support Obama. "I just wanted to draw attention to the importance of research for economic development and to promote public interest in science and technology," he says. For more images, go to www.nanobliss.com.

INSIDE GOVERNMENT

CHANGES AT NIH. Alan Krensky has resigned from his job overseeing a new office coordinating research across the U.S. National Institutes of Health (NIH) as part of a realignment of the director's office.

Krensky was brought in by NIH Director Elias Zerhouni in July 2007 to head its Office of Portfolio Analysis and Strategic Initiatives (OPASI), launched a year earlier (*Science*, 17 August 2007, p. 887). But observers told *Science* that Krensky clashed with institute directors. Krensky denies any tension, saying that he found NIH to be "as collaborative as you get."

Krensky's exit follows Zerhouni's on 31 October and a directive from Congress to fold OPASI into a new division that will also oversee NIH offices of social sciences, women's health, and AIDS. "We all agreed that this was a good time for a change in leadership," says NIH acting Director Raynard Kington. Lana Skirboll, who heads NIH's science policy office, will serve as acting director of the new division. Krensky says that OPASI was "a small, flexible think tank" and adds that the new division "is very different" because of its broader oversight, which makes it more bureaucratic. His "plan right now" is to work full-time in his NIH cancer immunology lab, where he had been spending half a day a week.

MOVERS

PAYING HIS DUES. Two years before Fred Spilhaus became executive director of the American Geophysical Union (AGU) in 1970, the association raised its annual dues to $20. This month, the 70-year-old Spilhaus announced he will step down from his post in June 2009, and, incredibly enough, the dues haven't budged.

"There were a few things I did that really worked," says Spilhaus, who cites that bargain-basement price as one reason the association's membership rose from 10,000 to 55,000 during his tenure. "The strategy was to keep the members and make room for everybody around the world." About 30% of its members reside outside the United States, and most also maintain an allegiance to a specialty society of seismologists, geologists, oceanographers, or meteorologists.

Trained as a physical oceanographer, Spilhaus took over in 1970 when AGU was a committee of the U.S. National Academy of Sciences with 40 full-time employees. Within 2 years, he helped transform it into an independent society that now publishes 5300 articles per year and supports 178 staffers. Next month, its annual meeting will attract 16,000 attendees to San Francisco, California.

IN THE COURTS

BAYING FOR BLOOD. Biopure, a Massachusetts biotech company that makes a blood substitute called Hemopure, has filed a defamation suit against U.S. National Institutes of Health (NIH) researcher Charles Natanson over a study highlighting the risks from using the product. Hemopure is sold in South Africa and is under development in the United States and Europe.

Biopure charges that it suffered "significant financial harm" as a result of Natanson's article published online 28 April in the *Journal of the American Medical Association* (*JAMA*) and letters he wrote to health officials in the United Kingdom and South Africa alerting them to the paper. The suit, filed 10 October in U.S. District Court in Washington, D.C., also notes that the *JAMA* article did not disclose that Natanson had applied for a patent on technology to make artificial blood safer and "seeks to benefit financially from widespread adoptions of the contentions he makes," Biopure wrote in its suit. Natanson revealed the patent in *JAMA* in July.

Natanson's meta-analysis of 16 trials on five blood-substitute products, including Hemopure, concluded that the products increased the risk of death by 30% (*Science*NOW, 28 April: sciencenow.sciencemag.org/cgi/content/full/2008/428/1). Natanson declined to comment for this story but noted in April that "we need to move from humans back to animals, until we find a formulation that has less toxicity." On 4 November, Natanson asked the judge to dismiss the case.

Deaths

SHELF LIFE. Science fiction author Michael Crichton, who wrote bestsellers such as *Jurassic Park* and *The Andromeda Strain*, died of cancer 5 November. He was 66.

Crichton entertained millions, and many say his lifetime's work raised the public's interest in science. But Crichton also received his share of criticism from scientists, most notably for a 2004 novel, *State of Fear*, which portrayed global warming as a hoax. Kendrick Frazier, editor of *Skeptical Inquirer*, says the book "probably caused a lot of mischief and misunderstanding about the seriousness of global warming and climate change." But, Frazier says, no one can deny Crichton's skills as a storyteller.

Got a tip for this page? E-mail people@aaas.org

CREDITS (TOP TO BOTTOM): J. HART, S. TAWFICK, M. DE VOLDER, W. WALKER; AGU; AP

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SCIENCE AND THE ELECTION

Obama Victory Raises Hopes for New Policies, Bigger Budgets

Make no mistake: U.S. scientists hope that the election last week of Barack Obama as president and a larger Democratic majority in both houses of Congress will usher in an era of sustained, healthy increases in the federal funding of basic research. But money isn't everything, and in a time of yawning deficits and urgent demands on the federal treasury, those increases may not happen anytime soon.

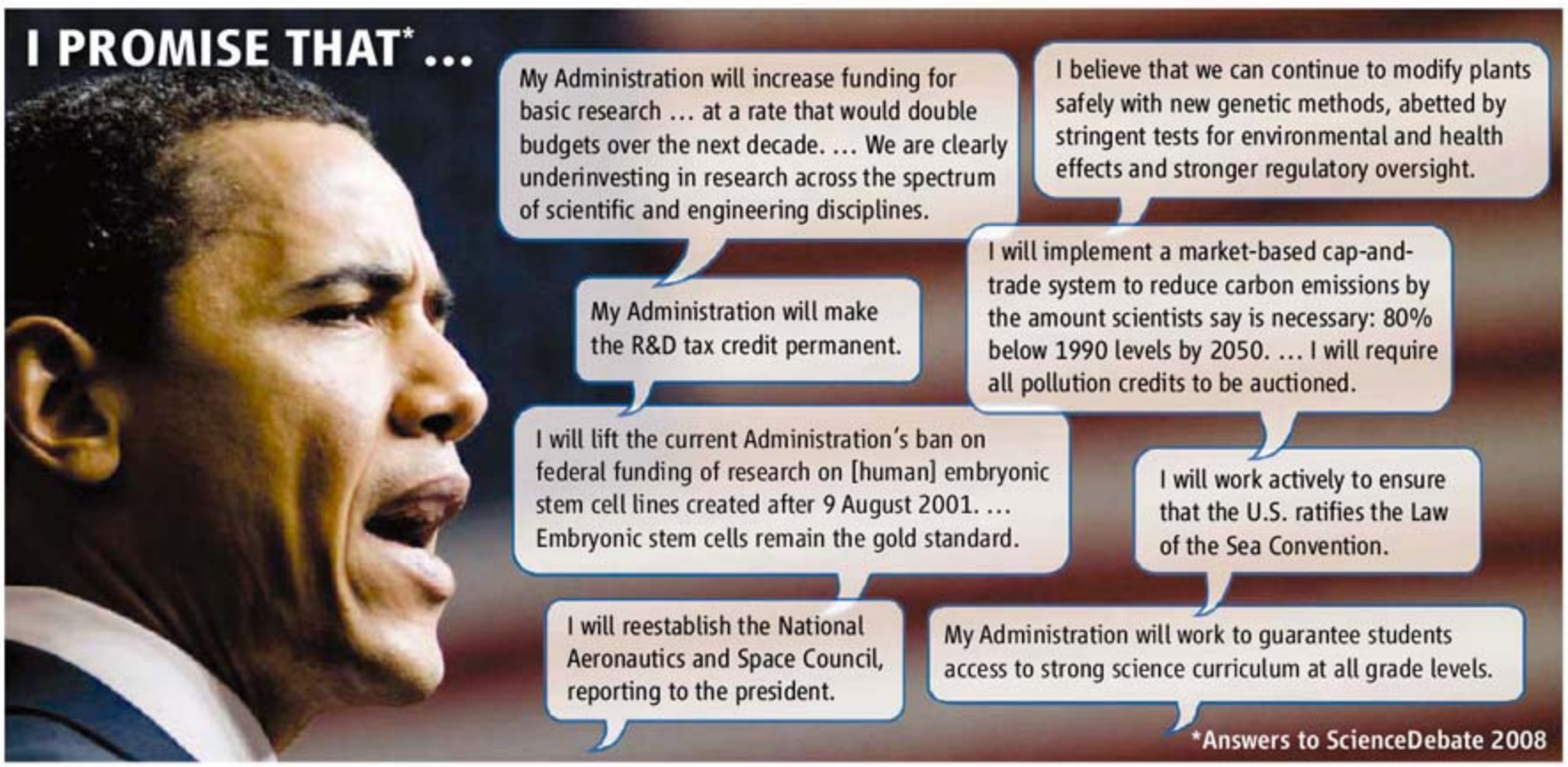
Propping up a shaky economy will be job #1 for Obama once he takes the oath of office on 20 January 2009. So scientists and science policymakers will be looking to the new president to first make good on campaign promises that don't require big outlays, such as elevating the status of the president's science adviser, lifting a ban on new human embryonic stem (ES) cell lines, and restoring the integrity of federal decision making, including scrapping some environmental regulations based on questionable science.

At the top of the list for many is the early appointment of a science adviser with the additional title of assistant to the president. (The current adviser, John Marburger, wasn't nominated until June 2001 and ranks a step below assistant on the White House pecking order.) Those actions would be a sign that the president-elect recognizes the importance of science to the country, says Ralph Cicerone, president of the U.S. National Academy of Sciences. "The world still loves and respects U.S. science, and it can be an instrument of good will—and good policies," says Cicerone. "When we wrote to both campaigns this summer, we did not say, 'Put more money into science.' What we said is that they need science to govern effectively."

Some want Obama to go further and make the director of the Office of Science and Technology Policy (historically a second job for the science adviser) part of his Cabinet. Neal Lane, who held both posts during President Bill Clinton's second term, doesn't think that's necessary. But he agrees that regular access to the president and his Cabinet secretaries is essential. "The Cabinet table is pretty full already," says Lane, who emphasizes that Obama hasn't solicited his advice. "As long as you're invited to all the meetings, that's all the status you need."

Stem cell researchers are confident that Obama will act swiftly on his promise to reverse President George W. Bush's policy of restricting federal funding for research on human ES cells to lines derived before 9 August 2001. Science lobbyists are shooting for a two-pronged attack: a speedy executive order, followed by legislation that would allow federally funded researchers to work with any lines derived from embryos that would otherwise be discarded by fertility clinics. Bush vetoed such legislation twice. But Representative Diana DeGette (D–CO) already has a new version ready. Introduced in the waning days of this Congress, it would allow research to be conducted on human ES cells "regardless of the date" they were derived and require the Department of Health and Human Services to issue research guidelines.

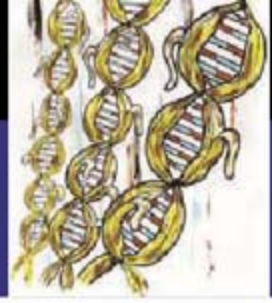
R. Alta Charo, a lawyer and bioethicist at the University of Wisconsin Law School in Madison, says Obama could simply tell the U.S. National Institutes of Health (NIH) to go ahead and fund research on newer lines. But Tony Mazzaschi of the Association of American Medical Colleges in Washington, D.C., thinks an executive order would be the best way to clarify a picture complicated by a 2007 presidential directive that urges NIH to



CREDIT: MICHAEL CZERWONKA/EPA/CORBIS

Why does childhood last so long?

1040



The threatened banana

1046

explore "alternative" ways of generating pluripotent ES-like cells.

Environmental advocates are also hoping that Obama will overturn several rules and regulations put into place over the past 8 years. For example, David Wilcove, an ecologist at Princeton University, and others are pushing to reinstate into the National Forest Management Act of 1976 a regulatory requirement to maintain viable populations of vertebrates; that provision was removed in 2005 to provide greater flexibility, to the benefit of the logging industry.

In the meantime, environmentalists are nervously watching as the Department of the Interior tries to finalize several rules, including one that relaxes the requirement for federal agencies to consult with biologists at the Fish and Wildlife Service about actions that would impact endangered species (*Science*, 22 August, p. 1030). "This rule really is a dramatic weakening of the safety net that protects endangered species," says Andrew Wetzler of the Natural Resources Defense Council in New York City. In August, a campaign official said Obama opposes the changes. If the department completes its work before Bush leaves office, however, reversing the last-minute rulemaking will take considerable time and effort.

Scientists haven't forgotten about money, of course—especially Obama's campaign pledge to double federal spending for basic research over the next decade. University and research lobbyists are hoping the new president's backing, combined with strong bipartisan support, will help them achieve the ramp-up in funding for the National Science Foundation, the Department of Energy's Office of Science, and the National Institute of Standards and Technology that's authorized in the America COMPETES Act of 2007 but that has been an empty promise so far.

Some help could come as early as next week, during a lame-duck session of the outgoing Congress, if Democratic leaders and Republican Bush can agree on a short-term stimulus package. There's an outside chance that the package could include something to shore up the nation's research infrastructure in the current 2009 fiscal year, which runs through 30 September. "Funding for the COMPETES Act is still a high priority, whether it gets done in a stimulus package for 2009 or as part of next year's [2010] budget," says Robert Berdahl, president of the 62-member Association of American Universities in New York City. "The point is that none of the goals of the new Administration—on energy, on the economy, on climate change—can be realized without an increased investment in science."

With a federal deficit that could hit $1 trillion next year, however, such an investment is a hard sell. "Mr. Obama has promised so many things, but they all cost money," says Representative Vern Ehlers (R–MI), one of the most insistent voices for research and education in Congress. Still, Ehlers says that adequate funding for the COMPETES Act is his top priority, too.

Obama's campaign promises included a pledge to give NASA $2 billion to cover the transition from the space shuttle to a new launcher. A new report from the Government Accountability Office identifies the shuttle transition as one of 13 critical issues facing the next Administration and Congress, and the loss of thousands of high-paying jobs in the electorally important state of Florida is a political challenge as well. But it may not be clear until early spring, when Obama rolls out his 2010 budget request, whether the money would be a one-time boost or spread out over several years, and how it would affect NASA's regular budget.

Speaking last week to a National Research Council panel reviewing civilian space policy, NASA Administrator Michael Griffin said the agency requires between $2 billion and $3 billion more annually to retire the shuttle, build the new launcher, and keep science programs on track. Griffin, who told the panel that he doesn't expect to be asked to stay on, said he hopes Obama and the new Congress will, nevertheless, stick with current plans for a new launcher and human missions to the moon. Griffin also hopes that the new president won't let his budget officials block the program. Characteristically blunt, he also advised the president-elect to rethink his promise to reestablish an Aeronautics and Space Council within the White House, saying that an earlier version under President George H.W. Bush was ineffective because it lacked budgetary authority.

With the election won, the high-profile group of scientists that funneled advice to the Obama campaign has been disbanded. Some of its members, however, hope that his transition team may still be willing to listen to their thoughts on science-related appointments and issues, especially if packaged as proposed vehicles to help revive a badly slumping economy. Otherwise, scientists will have to be content joining the throng that's rooting for better times come Inauguration Day.

–CONSTANCE HOLDEN, ANDREW LAWLER, ELI KINTISCH, JEFFREY MERVIS, AND ERIK STOKSTAD

NEW CONGRESS LOOKS FAMILIAR

Democratic science powerbrokers in Congress have retained their seats. But a major reshuffling of Senate committee posts is under way that could affect research and training issues.

In the 435-member House of Representatives, where incomplete returns show Democrats gaining 20 seats, the leadership of the House Science Committee will remain unchanged after victories by representatives Bart Gordon (D–TN), the chair, and Ralph Hall (R–TX), the ranking minority member. The chairs of the 12 House appropriations subcommittees, who together oversee all federal research budgets, were also reelected, as was Representative David Obey (D–WI), the head of the full committee. The House retained its contingent of three Ph.D. physicists. Representatives Vern Ehlers (R–MI) and Rush Holt (D–NJ) won easily, and Representative Bill Foster (D–IL) parlayed a victory in a March special election into a full 2-year term with help from hundreds of physicists at Fermi National Accelerator Laboratory in Batavia, Illinois, where Foster worked until 2006.

In contrast, a more heavily Democratic Senate will see several new faces in leadership positions. Senator Daniel Inouye (D–HI) will succeed the ailing Senator Robert Byrd (D–WV), who turns 91 next week, atop the full appropriations committee. His move frees up the chairmanship of the Commerce, Science, and Transportation Committee, which is expected to go to Senator Jay Rockefeller (D–WV). Senator Joe Lieberman (I–CT) could be ousted as chair of the Homeland Security and Government Affairs panel for his vigorous support of Republican John McCain, who remains in the Senate. In addition, Democratic governors in Illinois and Delaware will name replacements for Obama and Vice President–elect Joe Biden.

–JEFFREY MERVIS

Scientific lobbying. Primatologist Jane Goodall (*left*) and members of the Dr Hadwen Trust, here addressing the European Parliament, urged E.U. politicians to restrict animal experimentation.

CREDIT: DR HADWEN TRUST

ANIMAL RESEARCH

European Union Floats Tighter Animal-Research Rules

European researchers have responded with a mixture of relief and anxiety to a long-awaited proposal for new regulations on animal research in the European Union (E.U.). Released last week by the European Commission, the executive body of the E.U., the proposal* would ban the use of great apes in medical experiments, but it does not include a complete prohibition on all research on nonhuman primates, for which many animal-welfare groups had vigorously lobbied. The new proposal would, however, extend E.U. oversight for the first time to experiments involving certain invertebrates.

Scientific organizations say some of the draft regulations threaten to slow research without providing clear benefits to animals. And activists on both sides of the debate have vowed to push for changes before the rules become final, a process that could take more than a year. "We still have concerns," says Simon Festing of the Research Defence Society in London, which represents medical researchers and opposed the push for the full primate ban.

The E.U. adopted its current animal-research regulations in 1986, and officials have been discussing an update since 2001. One of the most contentious issues has been experiments on nonhuman primates. Animal-welfare groups have been lobbying for a ban on the use of monkeys and great apes, and last year the European Parliament passed a nonbinding resolution calling for a gradual phaseout of all experiments on nonhuman primates. But the commission's proposal calls only for an end to scientific "procedures" on great apes, with exceptions for behavioral studies, research that could prevent the extinction of the species, or in the case of outbreaks of human disease. Because no medical research on great apes has taken place in the E.U. since 2002, many observers see the ban as a token move. The draft does include a proposal to phase out the use of any primates caught in the wild, eventually allowing research only with captive-bred animals, a shift that could raise the cost of primate experiments.

The new directive sets out detailed requirements for ethical and scientific review of research involving animals, stressing the "3Rs" of reducing the number of animals used, refining techniques to lessen pain and discomfort, and replacing animal studies with alternatives. For the first time, the E.U. would require researchers to receive ethics committee approval for research on fetal nonhuman vertebrates in the final third of their development and on several groups of invertebrates, including lampreys, octopuses, squid, and decapod crustaceans such as crabs and lobsters, that have shown evidence of being able to experience pain and distress.

Wolfgang Stein, a neuroscientist at the University of Ulm in Germany who works with crabs, says he is not yet sure what to make of the proposal. He studies invertebrates in part because the moral questions are easier, he says; the animals don't feel pain the way vertebrates do. "If you cut a leg off, 5 seconds later they don't seem to mind that much. It doesn't mean they don't feel ▸

*ec.europa.eu/environment/chemicals/lab_animals/proposal_en.htm

SCIENCESCOPE

China Looks Ahead

BEIJING—China's scientific community is accustomed to planning in 5-year or even 15-year increments. Now, an elite panel of 100-odd scientists organized by the Chinese Academy of Sciences (CAS) is compiling a report on vital research directions over the next 50 years. "In China, we sometimes don't know where we want to go. People like to be guided," says panelist Gao Fu of CAS's Institute of Microbiology here. Although it's impossible to know which research areas will be hot in 2058, the report, expected to be finalized next month, will flag sure bets for long-term investment such as research on chronic diseases.

–RICHARD STONE

Military Science, Reloaded

The U.S. Department of Defense (DOD) plans to award $80 million in grants this fiscal year to academic scientists as part of a new $400 million investment over 5 years in basic research. The 5-year grants will fund work in emerging areas such as countering weapons of mass destruction, network sciences, energy and power management, quantum information sciences, and bio-inspired systems. The Pentagon's $208 million increase for basic research in 2009 was a lone bright spot among science agencies, which otherwise saw their budgets frozen through at least March 2009. DOD also hopes to fund 40 additional researchers in the Presidential Early Career Award for Scientists and Engineers program, under which DOD currently gives out a few dozen 3- to 5-year grants of $100,000 per year.

–YUDHIJIT BHATTACHARJEE

This Jaguar's Built for Speed

Oak Ridge National Laboratory's upgraded supercomputer, dubbed Jaguar, has broken the petaflops barrier. Jaguar's ability to perform 1.3 quadrillion calculations per second leaves it second only to the Road Runner at Lawrence Livermore nuclear weapons lab in California, and Jaguar's accessible to the entire scientific community. Oak Ridge astrophysicist Bronson Messer says the petascale machine will allow scientists to track up to 150 isotopes created during a supernova; current terascale computers can follow only 13. "We should be able to go from getting a general picture of supernovas to being able to predict things," he says. Now officials with the Department of Energy and the U.S. National Science Foundation hope to establish petascale machines at Oak Ridge and elsewhere to serve more scientists.

–ELI KINTISCH

discomfort, but it is different" from what a vertebrate experiences, he says. Stein is open to some oversight, but he is wary of having to go through the same sort of review required of vertebrate experiments. "The species we work with is considered food," he says. "From what I can see, they have a better life in our tanks than in the supermarket."

Emily McIvor, policy director for the Dr Hadwen Trust in Hitchin, U.K., which lobbies for alternatives to animal research, says the proposal is a step in the right direction, although she says that she would have preferred to see a complete ban on the use of primates. The commission's attention to research into alternatives to primate use is "very inadequate," she says.

Scientific organizations, however, have expressed concern that the new levels of regulation will add bureaucratic headaches for researchers without reducing animal suffering. "We are in favor of good regulations," says Festing. "But if you're spending all your time filling out paperwork, that doesn't help the animals." Still, he says, the draft is better than some expected based on early rumors that had emerged from Brussels.

The fight is far from over. The commission's proposal still has to receive approval from the European Parliament and the European Council of Ministers before becoming official E.U. policy. "We have more concerns about the Parliament" adding burdensome amendments, Festing says, noting that a number of European politicians opposed to animal research have refused to meet with scientific organizations. "We have seen little evidence that [members of Parliament] are ensuring that they are informed on the science."

–GRETCHEN VOGEL

EVOLUTION

Vatican Science Conference Offers an Ambiguous Message

Scientists who gathered at the Vatican last week for a closed-door conference* on evolutionary origins are giving the event mixed reviews. Those who hoped for a clear statement of support for evolution from the Catholic Church went home empty-handed. Others, expecting little, were happy with a détente between science and faith. But a few criticize what they heard from the Vatican's controversial point man on evolution, Austrian Cardinal Christoph Schönborn. "He believes there are gaps in evolution and [that] God acts in those gaps," says John Abelson, a molecular biologist at the University of California, Davis, who gave a talk at the meeting. This is a "nearly 19th century" view, Abelson says, amounting to support for the intelligent design movement. Pope Benedict XVI did not clarify his own ambiguous statements on evolution.

The meeting was organized by the Pontifical Academy of Sciences, an international group of scientists who advise the pope. Astrophysicist Stephen Hawking of the University of Cambridge in the U.K., Nobel Prize–winning biochemist Marshall Nirenberg, and others gave lectures on the origins of everything from galaxies in the early universe to cellular life on Earth. It was like many scientific conferences except that the pope showed up to bless the proceedings, and the first talk, titled "The Reflections of Joseph Ratzinger Pope Benedict XVI on Evolution," was given by Schönborn, a theologian.

Hands on. Pope Benedict with astrophysicist Stephen Hawking, one of several famous scientists who spoke at the Pontifical Academy of Sciences.

CREDIT: AP PHOTO/L'OSSERVATORE ROMANO, HO

Schönborn's prepared talk at the conference was not the source of controversy. "It was so very abstract," says Gereon Wolters, a philosopher of science at the University of Konstanz, Germany. "It offered the standard view that evolution is okay" but that "evolutionism"—a term used by religious conservatives for the promotion of atheism through evolutionary biology—"is not." Some scientists even saw signs of progress in the talk. "I was relieved to hear the cardinal clearly distancing himself from intelligent design," says Francis Collins, former director of the U.S. National Human Genome Research Institute in Bethesda, Maryland, "referring to that 'school' as having made mistakes."

The sparks flew when the cardinal fielded questions. "He still expressed reservations about whether evolution can account for all aspects of biology," says Collins, including whether Darwinian evolution can account for the generation of species. "It was preposterous," says Abelson, who says that the meeting took "a step backwards" in the church's relationship with science. Wolters was disappointed, too: "Schönborn has the same intention as the pope has—to fight evolutionism," he says, but "he is just repeating this creationist gibberish" used by U.S. proponents of intelligent design. Wolters adds: "Fighting science in this way is a losing game."

Other scientists at the meeting disagree. The cardinal's doubts about evolution do not represent a conflict between the church and science, says Werner Arber, a geneticist at the University of Basel, Switzerland, who co-organized the meeting. "Relations continue to be good." Schönborn gave "a confused lecture," says Peter Raven, director of the Missouri Botanical Garden in St. Louis and a member of the academy, but "the church's position on evolution, insofar as it can be said to have one, is unchanged. … There is a belief in a creator who existed before the big bang and set the universe in motion, which is something that cannot be proved or disproved by science."

–JOHN BOHANNON

*Scientific Insights into the Evolution of the Universe and of Life, Vatican City, 31 October–4 November 2008.

Arteries at risk. In a massive study, people with high blood levels of c-reactive protein benefited from a cholesterol-lowering drug.

CREDIT: MEDICALRF.COM/CORBIS

CARDIOVASCULAR HEALTH

Statin Therapy Reduces Disease in Healthy Volunteers—But How, Exactly?

The 17,800-person JUPITER trial, a major test of drug therapy to prevent heart disease, enjoyed a blitz of attention this week. Some experts—including the trial's leaders—celebrated it as a huge success in preventing cardiovascular disease and proving the value of c-reactive protein (CRP), an indicator of inflammation, as a risk marker for heart disease. Proponents hail the trial for carving out a new class of people who could benefit from cholesterol drugs but who now don't get them because their cholesterol levels are normal.

The JUPITER trial comes with a host of caveats, however, muddying the picture of what we know and don't know about inflammation's role in cardiovascular disease. Most important, no one can say why the anti-cholesterol drug it tested, the potent statin Crestor, actually helped the participants, all of whom had elevated CRP levels.

Crestor had two effects in the nearly 9000 people who took it (the rest received a placebo): It lowered CRP by 37%, and it lowered LDL, or "bad," cholesterol by 50%. Heart attacks and strokes in the treated group were roughly half those in the placebo cohort, and mortality was 20% lower. Most argue that the statin helped because it reduced normal LDL cholesterol to even lower levels. The more controversial theory is that the benefit came at least in part from the reduction of CRP levels. JUPITER—funded by Crestor's manufacturer, AstraZeneca—was not designed to answer questions about CRP, but speculation has begun.

Cardiologists have long debated whether CRP should be included in their arsenal of risk indicators, and despite its nuances, JUPITER is likely to edge them in that direction. Studies over the past decade have found that people with high CRP levels tend to suffer more heart attacks and strokes, but the picture is murky because CRP is nonspecific—high CRP levels are linked to any number of diseases. "It's a marker for not being a healthy individual," says Mark Pepys of University College London. Even so, could CRP levels help pick up people at risk of heart disease who are now flying under the radar?

Yes, the authors of JUPITER say unequivocally. "By focusing on inflammation, we seemed to hit the sweet spot" in identifying and helping at-risk patients who are otherwise missed, says Paul Ridker, a cardiologist at Brigham and Women's Hospital in Boston, who led the trial and holds a patent on a method for testing CRP. JUPITER's results were reported online 9 November in *The New England Journal of Medicine* (*NEJM*) and presented the same day at the American Heart Association meeting in New Orleans, Louisiana.

Many others are more circumspect. One reason for caution, says Eric Topol, a cardiologist and director of the Scripps Translational Science Institute in San Diego, California, is that JUPITER's actual benefits are "a little hard to tease out." He wonders: "Were they really treating high CRP, or were they treating a potpourri of other risk factors" in people who also had high CRP levels? The study participants had normal cholesterol levels and were described as healthy volunteers, but most were also overweight, 15% were smokers, and 40% had metabolic syndrome. All these qualities are known to boost CRP levels. That raises a related question that has nothing to do with CRP, says cardiologist Benjamin Scirica of Brigham and Women's Hospital. Should patients who have normal cholesterol but some common risk factors, such as high blood pressure or obesity, be treated with statins to push their cholesterol to even lower levels? "I think [JUPITER] expands the thinking about risk factors," says Scirica, who, like Topol, was not involved in the trial.

But the fundamental question of whether high CRP levels actually cause disease—and whether JUPITER worked because it lowered CRP—remains unresolved. More and more scientists are rejecting this argument, in part because of a genetics study published on 30 October in *NEJM*. In that work, a Danish group analyzing DNA from more than 50,000 people found that variations in the CRP gene don't cause heart disease—suggesting that although CRP blood levels correlate with disease, the protein is not causing it. Børge Nordestgaard, a genetic epidemiologist and physician at Copenhagen University Hospital who led the genetics study and participated in the JUPITER trial, believes that CRP is a consequence, not a cause, of atherosclerosis. He suggests that cholesterol penetrates the walls of arteries and that white blood cells swoop in to remove it. That creates inflammation and raises CRP. Thus, by this line of thinking, high CRP levels indicate atherosclerosis that might not have shown itself in symptoms.

The genetics study has convinced some that "CRP doesn't appear to be a driving force" in heart disease, says Topol. He and others who endorse this view suspect that the benefits of JUPITER are due to lowering LDL cholesterol. JUPITER recruited only people with relatively healthy LDL levels—on average, about 100. But "we know there's a straight line from LDL cholesterol to cardiovascular risk," no matter what the starting number, says Pepys, who has studied CRP for decades. LDL came down about 50% in JUPITER—a drop that is consistent with the 54% reduction in heart attacks, Pepys says.

Ridker, however, believes that genetics can explain only so much and that the best way to determine whether CRP causes disease is by testing whether a drug that lowers it preserves health. Isis Pharmaceuticals in Carlsbad, California, is developing such a CRP inhibitor. CEO Stanley Crooke says, "The core question is less whether something causes the disease but whether selective reduction of that target reduces that disease." The company has already begun testing its CRP inhibitor for safety in healthy volunteers. **–JENNIFER COUZIN**

The Birth of Childhood

Unlike other apes, humans depend on their parents for a long period after weaning. But when—and why—did our long childhood evolve?

Mel was just 3.5 years old when his mother died of pneumonia in 1987 in Tanzania. He had still been nursing and had no siblings, so his prospects were grim. He begged weakly for meat, and although adults gave him scraps, only a 12-year-old named Spindle shared his food regularly, protected him, and let him sleep with him at night. When Spindle took off for a month, another adolescent, Pax, came to Mel's rescue, giving him fruit and a place to sleep until Spindle returned. Mel survived to age 10.

Fortunately for Mel, he was an orphan chimpanzee living in the Gombe Stream National Park rather than a small child living in the slums of a big city. With only sporadic care from older children, a 3-year-old human orphan would not have survived.

Mel's story illustrates the uniqueness of one facet of human life: Unlike our close cousins the chimpanzees, we have a prolonged period of development after weaning, when children depend on their parents to feed them, until at least age 6 or 7. Street children from Kathmandu to Rio de Janeiro do not survive on their own unless they are at least 6. "There's no society where children can feed themselves after weaning," says anthropologist Kristen Hawkes of the University of Utah in Salt Lake City. By contrast, "chimpanzees don't have childhoods. They are independent soon after weaning," says anthropologist Barry Bogin of Loughborough University in Leicestershire, U.K.

Online
sciencemag.org
Hear more about childhood's beginning in a podcast with author Ann Gibbons.

Humans are also the only animals that stretch out the teenage years, having a final growth spurt and delaying reproduction until about 6 years after puberty. On average, women's first babies arrive at age 19, with a worldwide peak of first babies at age 22.5. This lengthy period of development—comprised of infancy, juvenile years, and adolescence—is a hallmark of the human condition; researchers have known since the 1930s that we take twice as long as chimpanzees to reach adulthood. Even though we are only a bit bigger than chimpanzees, we mature and reproduce a decade later and live 2 to 3 decades longer, says Bogin.

Given that we are unique among mammals, researchers have been probing how this pattern of growth evolved. They have long scrutinized the few, fragile skulls and skeletons of ancient children and have now developed an arsenal of tools to better gauge how childhood has changed over the past 3 million years. Researchers are scanning skulls and teeth of every known juvenile with electron microscopes, micro–computed tomography scans, or powerful synchrotron x-rays and applying state-of-the-art methods to create three-dimensional virtual reconstructions of the skulls of infants and the pelvises of mothers. They're analyzing life histories in traditional cultures to help understand the advantages of the human condition. In addition, some new fossils are appearing. On page 1089 of this issue, researchers report the first nearly complete pelvis of a female *Homo erectus*, which offers clues to the prenatal growth of this key human species.

All of this is creating some surprises. One direct human ancestor, whose skeleton looks much like our own, turns out to have grown up much faster than we do. The life histories of our closest evolutionary cousins, the Neandertals, remain controversial, but some researchers suspect that they may have had the longest childhoods of all. The new lines of evidence are helping researchers close in on the time when childhood began to lengthen. "Evidence suggests

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Changing face of childhood. Childhood has more than doubled in length in modern humans as compared to chimpanzees and the Dikika baby australopithecine (*reconstructed in lower left*). Delaying childbirth allows for bigger, stronger mothers who can give birth more frequently, as seen for example in traditional hunter-gatherer societies (*upper right*).

that much of what makes our life history unique took shape during the evolution of the genus *Homo* and not before," says anthropologist Holly Smith of the University of Michigan, Ann Arbor.

Childhood Stages	Age at weaning (years)	Age at eruption of first molar (years)	Female age at first breeding (years) (estimated by 3rd molar eruption in fossils)	Average maximum life span (years)
Chimpanzees, *Pan troglodytes*	4.0	4.0	11.5	45
Lucy, *Australopithecus afarensis*	4.0?	4.0?	11.5	45
Homo erectus	?	4.5	14.5 (est.)	60? (est.)
Modern humans, *Homo sapiens*	2.5	6.0	19.3	70

Milestones. Key events show that modern humans live slower and die later than our ancestors did.

Live fast, die young

Back in 1925, Australian anatomist Raymond Dart announced the discovery of that rarest of rare specimens, the skull of an early hominin child. Dart estimated that the australopithecine he called the Taung baby had been about 6 years old when it died about 2 million years ago, because its first permanent molar had erupted. As modern parents know, the first of the baby teeth fall out and the first permanent molars appear at about age 6. Dart assumed that early hominins—the group made up of humans and our ancestors but not other apes—matured on much the same schedule as we do, an assumption held for 60 years. Growing up slowly was seen as a defining character of the human lineage.

Then in 1984, anatomists Christopher Dean and Timothy Bromage tested a new method to calculate the chronological ages of fossil children in a lab at University College London (UCL). Just as botanists add up tree rings to calculate the age of a tree, they counted microscopic lines on the surface of teeth that are laid down weekly as humans grow. The pair counted the lines on teeth of australopithecine children about as mature as the Taung child and were confounded: These hominin children were only about 3.5 years old rather than 6. They seemed to be closer to the chimpanzee pattern, in which the first permanent molar erupts at about age 3.5. "We concluded that [the australopithecines] were more like living great apes in their pace of development than modern humans," says Dean.

Their report in *Nature* in 1985 shook the field and focused researchers on the key questions of when and why our ancestors adopted the risky strategy of delaying reproduction. Many other slow-growing, large-bodied animals, such as rhinos, elephants, and chimpanzees, are now threatened with extinction, in part because they delay reproduction so long that their offspring risk dying before they replace themselves. Humans are the latest to begin reproducing, yet we seem immune from those risks, given that there are 6.6 billion of us on the planet. "When did we escape those constraints? When did we extend our childhood?" asks biological anthropologist Steven Leigh of the University of Illinois, Urbana-Champaign.

The Taung baby and the other australopithecine children, including the relatively recent discovery of a stunning fossil of a 3-year-old *Australopithecus afarensis* girl from Dikika, Ethiopia, show that it happened after the australopithecines. So researchers have zeroed in on early *Homo*, which appeared in Africa about 2 million years ago.

Unfortunately, there are only a few jaw bits of early *Homo* infants and young children to nail down their ages. Most of what we know comes from a single skeleton, a *H. erectus* boy who died about 1.6 million years ago near Lake Turkana, Kenya. *H. erectus* was among the first human ancestors to share many key elements of the modern human body plan, with a brain considerably larger than that of earlier hominins. And unlike the petite australopithecines, this Turkana youth was big: He weighed 50 kilograms, stood 163 centimeters tall, and looked like he was 13 years old, based on modern human standards. Yet two independent tooth studies suggested ages from 8 or 9 to 10.5 years old.

Big for his age. The 8-year-old Turkana Boy, reconstructed here, grew up faster than modern humans do.

Now a fresh look at the skeleton concludes that, despite the boy's size, he was closer to 8 years old when he died. Dean and Smith make this case in a paper in press in an edited volume, *The First Humans: Origin of the Genus* Homo. The skeleton and tooth microstructure of the boy and new data on other members of his species suggest that he attained more of his adult height and mass earlier than modern human children do. Today, "you won't find an 8-year-old boy with body weight, height, and skeletal age that are so much older," says Dean.

He and Smith concluded that the boy did not experience a "long, slow period of growth" after he was weaned but grew up earlier, more like a chimpanzee. They estimate the species' age at first reproduction at about 14.5, based on the eruption of its third molar, which in both humans and chimpanzees erupts at about the age they first reproduce. This 8-year-old Turkana Boy was probably more independent than a 13-year-old modern human, the researchers say, suggesting that *H. erectus* families were quite different from ours and did not stay together as long.

The new, remarkably complete female pelvis described in this issue, however, suggests that life history changes had begun in *H. erectus*. Researchers led by Sileshi Semaw of the Stone Age Institute at Indiana University, Bloomington, found the pelvis in the badlands of Gona, Ethiopia. They present a chain of inference that leads from pelvis, to brain size, to life history strategy.

They assume that the nearly complete

CREDITS (TOP TO BOTTOM): DATA FROM HOLLY SMITH, CHRIS DEAN, STEPHEN STEARNS; JOHN GURCHE

pelvis belongs to *H. erectus*, because other *H. erectus* fossils were found nearby and because it resembles fragmentary pelvises for the species. Lead author Scott Simpson of Case Western Reserve University in Cleveland, Ohio, paints a vivid picture of a short female with wide hips and an "obstetrically capacious" pelvic opening that could have birthed babies with brain sizes of up to 315 milliliters. That's 30% to 50% of the adult brain size for this species and larger than previously predicted based on a reconstruction of the Turkana Boy's incomplete pelvis. However, the new estimate does match with newborn brain size predicted by the size of adult brains in *H. erectus*, says Jeremy DeSilva of Worcester State College in Massachusetts, who made such calculations online in September in the *Journal of Human Evolution*.

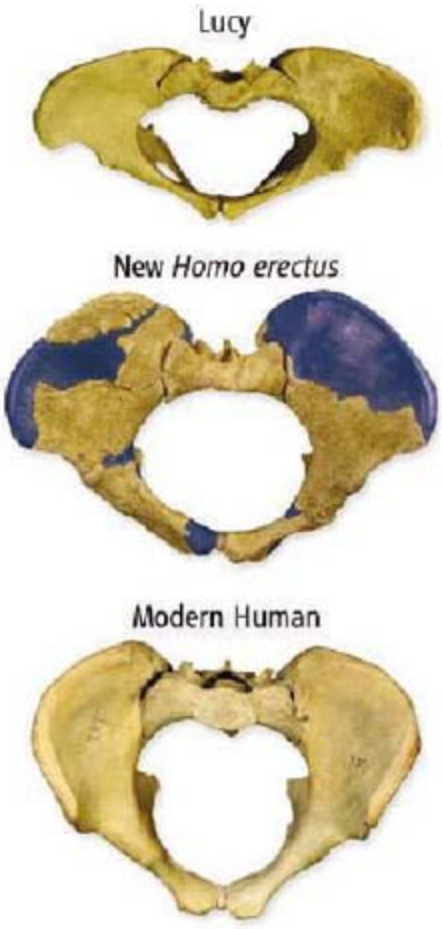
The wide pelvis suggests *H. erectus* got a head start on its brain development, putting on extra gray matter in utero rather than later in childhood. That's similar to living people, whose brains grow rapidly before birth, says Simpson. But if *H. erectus*'s fetal growth approached that of modern humans, it built proportionately more of its brain before birth, because its brain never became as massive as our own.

Thus, *H. erectus* grew its brain before birth like a modern human, while during childhood it grew up faster like an ape. With a brain developing early, *H. erectus* toddlers may have spent less time as helpless children than modern humans do, says paleoanthropologist Alan Walker of Pennsylvania State University in State College. This suggests *H. erectus* children were neither chimplike nor humanlike but perhaps somewhere in between: "Early *H. erectus* possessed a life history unlike any species living today," write Dean and Smith. "If you look at its morphology, it fits in our genus, *Homo*," says Smith. "But in terms of life history, they fit with australopithecines."

Live slow, die old?

If *H. erectus* was just beginning to slow down its life history, when did humans take the last steps, to our current late-maturing life plan? Three juvenile fossil members of *H. antecessor*, who died 800,000 years ago in Atapuerca, Spain, offer tantalizing clues. An initial study in 1999, based on rough estimates of tooth eruption, found that this species matured like a modern human, says José María Bermúdez de Castro of the Museo Nacional de Ciencias Naturales in Madrid. Detailed studies of tooth microstructure are eagerly awaited to confirm this.

In the meantime, another recent study has shown that childhood was fully extended by the time the first members of our species, *H. sapiens*, appeared in northern Africa about 200,000 years ago. In 2007, researchers examined the daily, internal tooth lines of a *H. sapiens* child who lived 160,000 years ago in Jebel Irhoud, Morocco. They used x-rays from a powerful particle accelerator in Grenoble, France (*Science*, 7 December 2007, p. 1546), to study the teeth without destroying them and found that the 8-year-old Jebel Irhoud child had grown as slowly as a modern 8-year-old, according to Harvard University paleoanthropologist Tanya Smith, who co-led the study.



Ancient hipsters. A fossil female pelvis from *Homo erectus* (*middle*) shows that the species could birth babies with bigger heads than Lucy's species (*top*) but smaller than a modern human's.

That analysis narrowed the window of time when humans evolved the last extension of our childhood to between 800,000 years ago and 200,000 years ago. To constrain it still further, Tanya Smith and her colleagues recently trained their x-ray vision on our closest relatives: the extinct Neandertals, who shared their last ancestor with us about 500,000 years ago. First, the researchers sliced a molar of a Belgian Neandertal that was at the same stage of dental development as the 8-year-old Jebel Irhoud child and counted its internal growth lines. They found that it had reached the same dental milestones more rapidly and proposed that Neandertals grew up faster than we do. That suggests that a fully extended childhood evolved only in our species, in the past 200,000 years.

But Tanya Smith's results conflict with earlier studies by Dean and colleagues who also sliced Neandertal teeth and found that they had formed slowly, like those of modern humans. The case is not closed: Smith and paleontologist Paul Tafforeau of the European Synchrotron Radiation Facility in Grenoble, France, spent weeks last year imaging juvenile Neandertals and early members of *H. sapiens*, and they expect to publish within a year.

Meanwhile, new data with implications for Neandertal growth rates are coming in from other sources. The brain sizes of a Neandertal newborn and two infants show that they were at the upper end of the size range for modern humans, suggesting that their brains grew faster than ours after birth, according to virtual reconstructions by Christoph Zollikofer and anthropologist Marcia Ponce de León of the University of Zurich (*Science*, 12 September, p. 1429).

Those rapidly growing brains don't necessarily imply a rapid life history, warn

More siblings? Hutterite families often had nine children each.

CREDITS (TOP TO BOTTOM): S. W. SIMPSON ET AL., *SCIENCE*; URSULA TILLMANN

Zollikofer and Ponce de León. They argue that because Neandertals' brains were more massive, they did not complete brain growth earlier than modern humans even though they grew at a faster rate. "They have to get those bigger brains somehow," says Holly Smith. For now, Neandertals' life history remains controversial.

Why wait?

If childhood began to change in *H. erectus* and continued to get longer in our own species and possibly Neandertals, then the next question is why. What advantage did our ancestors gain from delaying reproduction so long? Many researchers agree that childhood allows us to learn from others, in order to improve our survival skills and prepare us to be better parents. Historically, researchers have also argued that humans need a long childhood to allow enough time for our larger brain to mature.

But in fact, a big brain doesn't directly cause the extension of childhood, because the brain is built relatively early. "Everyone speaks about slow human development, but the human brain develops very fast," says Zollikofer. It doubles in size in the first year of life and achieves 95% of its adult size by the age of 5 (although white matter grows at least to age 18). "We get our brains done; then, we sit around for much longer than other species before we reproduce," says Leigh. "It's almost like humans are building the outside, getting the scaffolding of the house up early, and then filling in after that."

However, there's a less direct connection between brains and life history: Big brains are so metabolically expensive that primates must postpone the age of reproduction in order to build them, according to a paper last year in the *Journal of Human Evolution* (*Science*, 15 June 2007, p. 1560). "The high metabolic costs of rapid brain growth require delayed maturation so that mothers can bear the metabolic burdens associated with high brain growth," says Leigh. "Fast brain growth tells us that maturation is late."

That's why Ponce de León and Zollikofer think that the Neandertals' rapid brain growth implies late, rather than early, maturation: Neandertal mothers must have been large and strong—and by implication, relatively old—to support infants with such big, fast-growing brains. Indeed, say the Zurich pair, Neandertals may have had even longer childhoods than we do now. Childhood, like brain size, may have reached its zenith in Neandertals and early *H. sapiens*. As our brains got smaller over the past 50,000 years, we might have begun reproducing slightly earlier than Neandertals.

Tooth time. Tanya Smith uses a synchrotron accelerator to x-ray fossil teeth (*above*); molar eruption helps age other specimens such as Turkana Boy (*left*).

To explore such questions, recent interdisciplinary studies are teasing out the reproductive advantages of waiting to become parents. Many analyses cite an influential life history model by evolutionary biologist Eric Charnov of the University of New Mexico, Albuquerque. The model shows that it pays to have babies early if parents face a high risk of death. Conversely, mammals that face a lower risk of dying benefit if they wait to reproduce, because older mothers can grow bigger, stronger bodies that grow bigger babies, who are more likely to survive. "The driving force of a prolonged life history schedule is almost certainly a reduction in mortality rates that allows growth and life span to extend and allows for reproduction to extend further into adulthood in a more spread-out manner," says Dean.

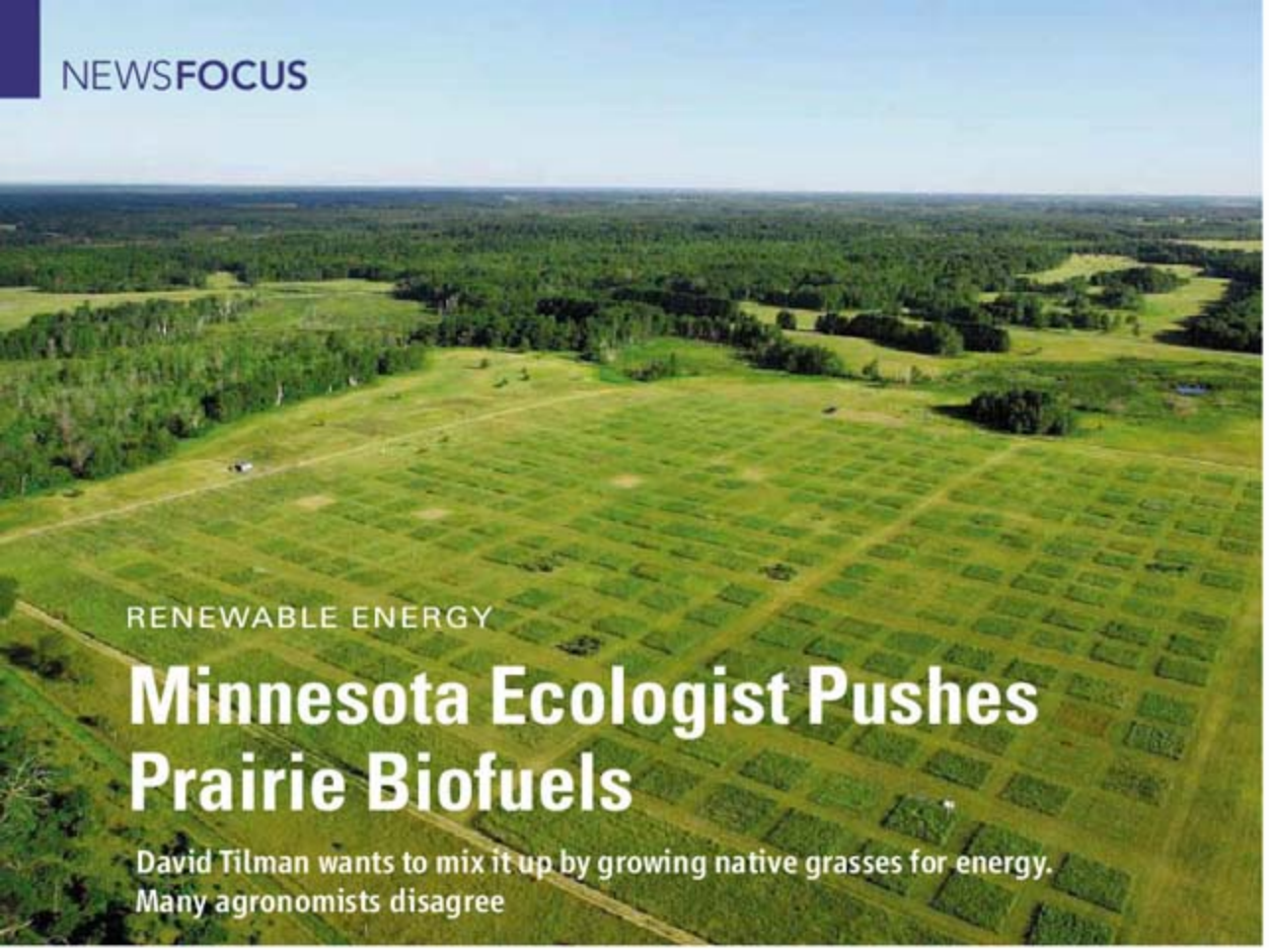
Researchers such as Loughborough's Bogin have applied Charnov's model to modern humans, proposing that delaying reproduction creates higher quality human mothers. Indeed, humans start having babies 8 years later than chimpanzees, and both species stop by about age 45 to 50. But once human mothers begin, they more than make up for their delayed start, pushing out babies on average 3.4 years apart in traditional forager societies without birth control, compared with 5.9 years for wild chimpanzees, says Bogin. This rapid-fire reproduction produces more babies for human hunter-gatherers, who have peak fertility rates of 0.31 babies per given year compared with 0.22 for chimpanzees. And human mothers who start even later than age 19 have more surviving babies. For example, in the 1950s, the Anabaptist Hutterites of North America, who eschewed birth control, had their first babies on average at age 22 and then bore children every 2 years. They produced an amazing nine children per mother, says Bogin, who has studied the group.

Such fecundity, however, requires a village or at least an extended family with fathers and grandmothers around to help provision and care for the young. That's something that other primates cannot provide consistently, if at all, says Hawkes (*Science*, 25 April 1997, p. 535). She proposed that grandmothers' provisioning allows mothers to wean early and have babies more closely together, a vivid example of the way humans use social connections to overcome biological constraints—and allow mothers to have more babies than they could raise on their own. "Late maturation works well for humans because culture lets us escape the constraints other primates have," says Leigh.

The key is to find out when our ancestors were weaned, says Holly Smith. Younger weaning implies that mothers had enough social support to feed weaned children and space babies more closely. "Weaning tells us when *Homo* species start stacking their young," says Smith. Indeed, Dean and Louise Humphrey of the Natural History Museum in London are testing a method that detects the chemical signature of weaning in human teeth. Humans may be slow starters, but our social safety net has allowed us to stack our babies closely together—and so win the reproductive sweepstakes, leaving chimpanzees, and the extinct Neandertals, far behind.

–ANN GIBBONS

CREDITS (TOP TO BOTTOM): CHANTAL ARGOUD/EUROPEAN SYNCHROTRON RADIATION FACILITY; FREDERICK E. GRINE/STONY BROOK UNIVERSITY



RENEWABLE ENERGY

Minnesota Ecologist Pushes Prairie Biofuels

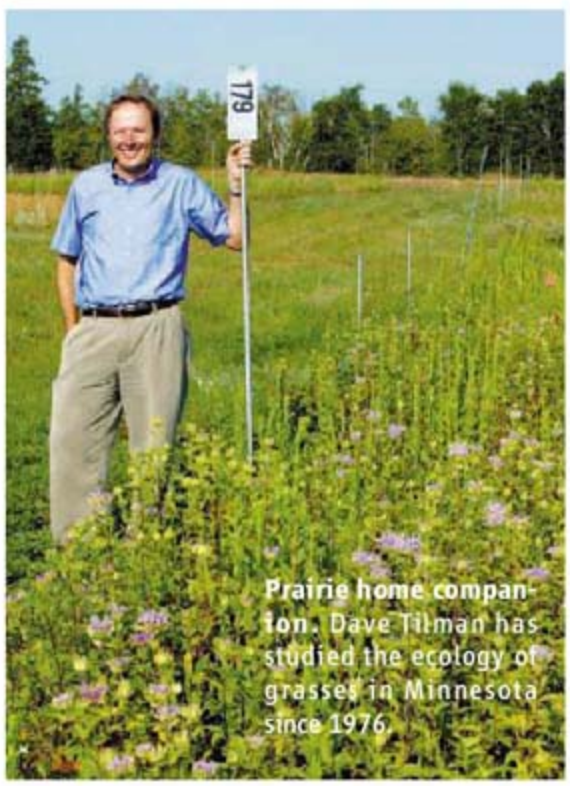
David Tilman wants to mix it up by growing native grasses for energy. Many agronomists disagree

EAST BETHEL, MINNESOTA—Over the past 3 decades, David Tilman has set up thousands of field experiments here, 70 km outside of Minneapolis, probing some of the most fundamental questions about prairie ecosystems. So, the University of Minnesota (UM), Twin Cities, ecologist never imagined he'd undertake the considerably more practical task of developing new climate-friendly crops for biofuels—that is, until 2005, when he realized he'd done it inadvertently, as part of a long-term ecological study at Cedar Creek Ecosystem Science Reserve.

On one 11-m-×-11-m square plot was a healthy stand of switchgrass, an abundantly growing perennial that the U.S. government is promoting as an alternative to corn as a feedstock for ethanol. Nearby was a plot of switchgrass mixed with 15 native perennial grasses that tend to grow less verdantly each year. Neither plot received irrigation or fertilizer. Yet, when Tilman and colleagues analyzed 12 years' worth of data, the mixed plots delivered more than twice the yearly biomass per hectare—suggesting a potentially much more efficient biofuel source with a much smaller "carbon footprint." "We expected higher productivity—maybe 50%. But nothing like the 238% we now see," said Tilman during a recent walk through his 121 hectares of field sites.

To Tilman, the findings suggest that for producing biofuel feedstocks, the mixtures are "more stable than monoculture, more reliable than monoculture, and more productive than monoculture"—and more environmentally friendly. Because different species occupy different ecosystem niches and perform different functions—say, adding nutrients to the soil or resisting drought—mixtures of prairie grasses can thrive on marginal lands without energy-intensive inputs such as fertilizer and irrigation. In addition, they can boost biodiversity and replenish depleted soils. "This is bigger than just biofuels," Tilman says.

Tilman's proposal to grow the mixtures as ethanol feedstocks, published in the 8 December 2006 issue of *Science* (p. 1598), won plaudits from top ecologists and inspired the U.S. Congress to include prairie biofuels in a $100 million national biomass-planting program. The Minnesota legislature kicked in roughly $3 million for state studies of prairie grasses. But Tilman's idea drew a firestorm of criticism from many agronomists, who said it overstated the potential climate benefits. They charged that Tilman's methodology exaggerated the productivity of mixed grasses and underestimated the expense and difficulty of scaling up test plots to commercial size. "Most people don't believe [his idea] could be practical," says agronomist and geneticist Stephen Moose of the University of Illinois, Urbana-Champaign.



Prairie home companion. Dave Tilman has studied the ecology of grasses in Minnesota since 1976.

Plots thickened. Scientists are examining the potential for biofuels of various prairie grass combinations.

The upbeat, fast-talking ecologist concedes that several questions must be answered before his strategy goes prime time. "I'm not one to believe we've found the be-all and end-all of biofuels," Tilman says. But he thinks it is worth a try. And so do a handful of ecologists and agronomists in seven Midwestern states; like Tilman, they are starting larger trials to test his concept under different conditions.

A mixed bag

Tilman's proposal contrasts sharply with the recent thrust of biofuels research. Today, U.S. farmers produce some 29 billion liters of ethanol a year from corn. But corn-based ethanol is no longer seen as a relatively cheap, environmentally friendly alternative to petroleum-based fuels. Experts say it's too carbon-intensive. Fertilizing, harvesting, and refining corn into fuel takes a lot of energy, and the sugar-conversion process wastes most of the plant's biomass, primarily cellulose. Using prime farmland to grow biofuels not only contributes to rising global food prices but also leads indirectly to cutting down trees for farmland overseas—and that, in turn, releases more carbon.

In search of a substitute for corn ethanol, President George W. Bush launched a $150 million, two-pronged federal research program in 2006 to identify cellulose feedstocks for biofuels, such as switchgrass, as well as the enzymatic and microbial methods to convert plant cellulose into fuels, an equally daunting challenge. Last year, the U.S. Congress passed a law requiring refiners to produce an estimated 61 billion liters of cellulosic biofuels by 2022.

In terms of potential new feedstocks, the part of the challenge on which Tilman is working, the U.S. departments of Energy and Agriculture have focused so far on switchgrass, waste-plant material from farms, poplar trees, and a tall European perennial grass called *Miscanthus*. Their emphasis has been to grow these crops as monocultures on large plots of prime farmland, using conventional high-input agricul-

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tural techniques. Tilman, by contrast, advocates growing biofuel stocks with minimal or no fertilizer on some of the nation's more than 5 million hectares of marginal soils—farmland with nutrient-depleted soils, worn-out hayfields, or on the edges of streams or highways, "using mixtures of plants which will grow there anyway," says ecologist Clarence Lehman, a research partner of Tilman's at UM.

The soils on Tilman's experimental plots are about as marginal as they come in the Midwest. They were too sandy for general farming to begin with, and then, in 1993, Tilman and his colleagues scooped off the top 15 centimeters of soil to ensure that each plot had roughly the same depleted levels of nutrients such as nitrogen and phosphorus. They measured the output of hundreds of mixed-species plots, publishing a string of high-profile papers that demonstrate the stability and productivity of biodiverse ecosystems.

Although Tilman didn't realize it at the time, he was also creating an ideal laboratory to test potential feedstock crops for biofuels that could grow on the world's 700 million hectares of degraded land. These days, that lab is abuzz with activity. Since 2006, the researchers have expanded the fieldwork to examine the agricultural and environmental implications of growing prairies for biofuels. They maintain test plots planted in various monocultures of prairie species, six-species mixtures, and 60-species mixtures. As Tilman reported in 2006, the mixed prairie grass plots produced the equivalent of 1500 liters of ethanol per hectare in net energy yield as opposed to 620 liters from switchgrass. (The net energy yield reflects the total amount of fuel produced minus the energy used to produce it, including energy required to make fertilizer and to run farm equipment.)

To gauge productivity, Tilman's team measures aboveground growth from samples cropped close to the ground. Obtaining accurate data requires a platoon of several dozen summer students, who spend hours a day sifting through thousands of kilograms of dried soil, leafs, and twigs to separate bits of each species for weighing. Others obtain underground biomass samples at various depths. "It's not easy," laughed Andrew Chua, a University of California, San Diego, undergraduate, who had removed his shirt as he pounded a steel probe through dry soil one afternoon in late August. The elbow grease will pay off in the winter, says Tilman, when full results from this fall's harvest will be available.

A question of benefits

But Tilman has a long way to go to convince mainstream agronomists. His critics say that his experiments inflate biomass yields, suggesting that prairie grass biofuels would be more carbon efficient than they actually are. And critics see big expenses to boot.

To maintain the correct mixture of species, Tilman's team hand-weeds the plots each year. Each autumn, they remove biomass for measurement from small sections of certain plots, which are burned in the spring. But burning may be giving the grasses an artificial advantage, allowing nutrients such as phosphorus and potassium to be incorporated back into the soil, says agronomist Kenneth Cassman of the University of Nebraska, Lincoln (UNL). A farmer seeking to sell biomass to an ethanol refinery, in contrast, would harvest the entire crop each year, removing the nutrients with a resultant decline in overall productivity, he contends. Tilman concedes that his test plots may be benefiting from conserved nutrients, although he notes that the amount of inputs required are nonetheless minimal.

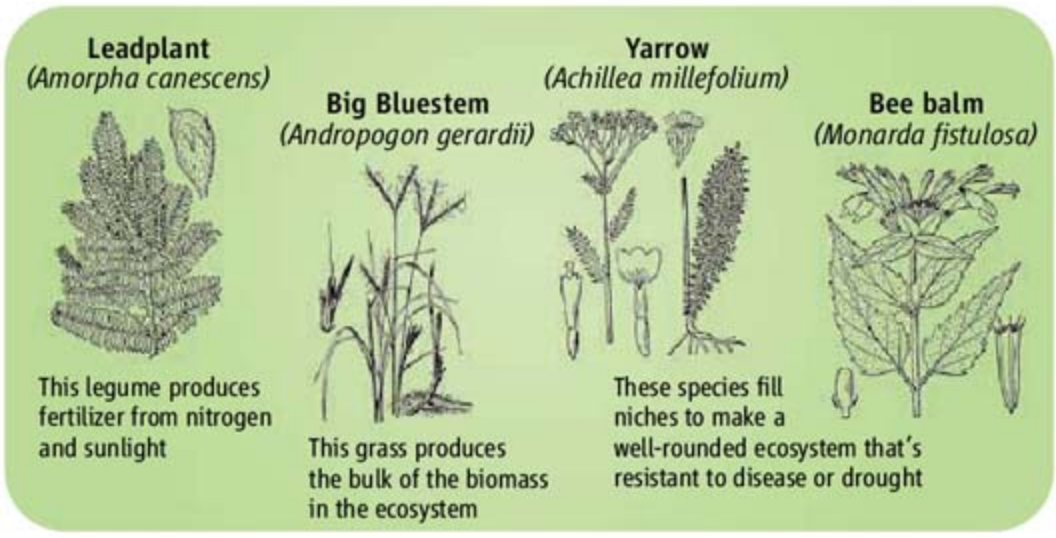
Leading switchgrass proponent Kenneth Vogel of UNL and the U.S. Department of Agriculture takes aim at the most salient finding of Tilman's 2006 work: that mixed grasses were more than twice as productive as switchgrass per hectare without inputs for either. Mixed species may have won out in Tilman's small plots, says Vogel, and watering and fertilizing switchgrass fields may require more energy. But with inputs, switchgrass monocultures have a higher net energy yield, he asserts. In work published this year in the *Proceedings of the National Academy of Sciences*, he showed that tests of switchgrass on full-scale plots on 10 Midwestern farms, treated with the standard 60 to 100 kg per hectare of nitrogen fertilizer each year, delivered net energy yields of between 2250 and 3300 liters of ethanol per hectare—more than twice the net benefit Tilman's mixtures provided.

Tilman is quick to point out that Vogel's soils were mostly richer than his, providing an inherent advantage, although he acknowledges that switchgrass could potentially offer net benefits. Large head-to-head experiments using the same soil are now under way to settle the question, with results expected next year. Vogel's team has grown mixed-species plots in recent years, and Tilman is comparing watered and fertilized plots of switchgrass with his mixtures.

Prairie grass mixtures will be expensive initially for farmers, Tilman acknowledges: The seeds can cost between two and 10 times more per kilogram than switchgrass. But he expects costs to fall as demand increases, and he hopes other environmental advantages will give mixtures a fair shot.

To pin down the biodiversity benefits of managed prairies, the state of Minnesota is supporting research on roughly 800 hectares of marginal lands across six sites to compare the effects of different harvesting techniques on game birds, insects, and other wildlife. Lehman is studying whether the grasses' root systems might take up excess chemicals that leach in from nearby agricultural fields. The U.S. Geological Survey is funding experiments using chemical tracers on several of Tilman's test plots to measure the uptake of nitrogen, endocrine disrupters, and antibiotics.

Although many agronomists remain skeptical, the overall environmental advantages of prairie grass biofuels have inspired some to test Tilman's approach. When the 2006 paper appeared, "people were saying this ecologist is doing a lot of talking but he doesn't have the data behind it," says UM agronomist Craig Sheaffer. But now he's setting up large-scale field trials of the mixtures himself. **–ELI KINTISCH**



We are family. These four plants are representative of the dozens of species that make up naturally biodiverse prairies.

SOURCES: USDA-NRCS PLANTS DATABASE/N. L. BRITTON AND A. BROWN; USDA-NRCS PLANTS DATABASE/A. S. HITCHCOCK

PLANT GENOMICS

A Bunch of Trouble

The banana is endangered and largely ignored by funding agencies, researchers, and breeders. But things might finally be going its way

2001 was supposed to be the year of the banana. That summer, a handful of researchers gathered in a small room at the U.S. National Science Foundation (NSF) in Arlington, Virginia, to form a consortium to sequence the fruit. Scientists had just deciphered the genome of *Arabidopsis*, with the rice genome close behind, and the banana community desperately wanted to be next. A new strain of soil fungus was threatening the commercial banana, and the community was convinced that a genome project could provide the genetic tools needed to save the crop. "The time was ripe," says Emile Frison, then head of the consortium. He predicted that within 5 years—a time period that would see the launch of major efforts to sequence corn, sorghum, and even green algae—banana buffs would have their genome.

Today, they're still waiting.

That's quite an indignity for one of the world's most popular fruits. Americans consume as many kilograms of bananas as apples and oranges combined, and in many African countries, bananas make up nearly half of all calories consumed. What's more, the banana most of us are familiar with—the Cavendish (*Musa acuminata*)—is in danger of disappearing. The soil fungus Frison fretted about in 2001 causes a nasty blight known as Panama disease that has devastated crops in Malaysia, the Philippines, and China. If the disease makes its way to Latin America, it could wipe out the Cavendish in less than 10 years. African bananas, too, have begun to disappear, victims of globalization and unsustainable farming practices.

Yet the banana continues to sit on the shelf while other crops benefit from research dollars and attention. Some blame the United States for failing to support the fruit as it has other major food crops. Others blame the banana community for being too fragmented to unite behind a single project. And still others blame the banana itself, for a bizarre biology that frustrates breeders and researchers alike.

At last, however, banana researchers may have found a benefactor: A French research agency will announce funding for the long-awaited genome project next week. The community just hopes it's not too late. "If the Cavendish is wiped out, there's nothing to replace it," says Nicolas Roux, Frison's successor as coordinator of the Global *Musa* Genomics Consortium. "We're sitting on a time bomb."

A crop in crisis

Juan Fernando Aguilar Moran has been trying to defuse that bomb for 7 years, not through sequencing but through breeding. As the chief breeder at the Honduran Agricultural Research Foundation (FHIA) in San Pedro Sula, the world's largest banana and plantain breeding center, Aguilar Moran is hoping to produce a variety that's hardier than the Cavendish. But the banana's not making it easy.

Unlike rice, wheat, and corn—the three crops that are eaten in larger quantities than the banana—most bananas are completely sterile. Unusual breeding in the Cavendish's past, for example, has led to a plant with three sets of chromosomes that has no seeds, no pollen, and no sex life. Farmers must hack off a piece of the plant and coax it into putting down roots, meaning a Cavendish eaten in Iowa today is genetically identical to one consumed in Ireland 30 years ago.

Faced with such a prudish plant, breeders like Aguilar Moran must instead turn to its wild relatives to create new varieties, and they, too, produce few viable seeds. Adding to the hassle, the plants grow at about one-fifth of the pace of rice, wheat, and corn, so experiments take years to complete. That may explain why there are only five breeding programs in the world dedicated to the banana versus hundreds for those other crops. "It's a lot of work," says Aguilar Moran.

So why does he persist? Two words: Gros Michel. The Cavendish's predecessor, "Big Mike," used to be the developed world's banana of choice. But an early incarnation of Panama disease known as Race 1 decimated the fruit—and nearly took the banana industry with it—in the mid-1900s. The Cavendish—a lucky, last-minute find originally from China—was resistant, but Aguilar Moran says its days are numbered. The new form of Panama disease that has invaded Asia, known as Race 4, takes no pity on the Cavendish. Because every plant is genetically identical, they're all equally susceptible to the same diseases. Once Race 4 hits the banana heartland in Latin America, says Aguilar Moran, it's game over for our favorite fruit.

Another dark shadow is black sigatoka, a fungus that turns banana leaves black and blocks photosynthesis. Over the 50 years the

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