How Earth Got Wet | Physics of Immunity | Polar Bears on Thin Ice

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MAGAZINE OF TH SCIEN PUBLIC ■ JANUARY 15, 2011

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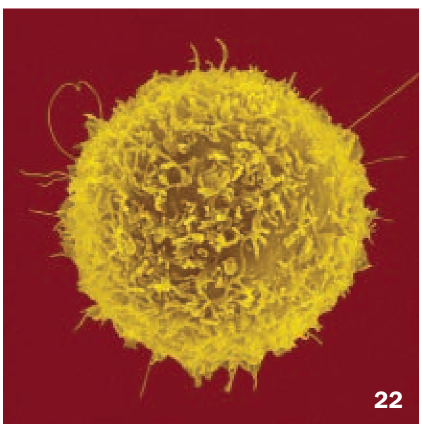

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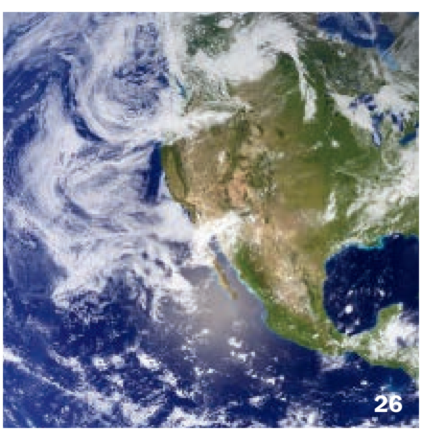

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## In The News



## Features



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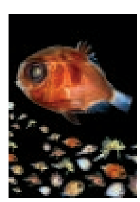

**COVER** Larvae such as this butterfly fish (top) are leading marine biologists to a deeper understanding of how the next generation of the sea's inhabitants gets established.
*G. David Johnson*

# Science News

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC

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Texterity Digital edition provided by Texterity, www.texterity.com
*Science News* (ISSN 0036-8423) is published biweekly, for $54.50 for 1 year or $98 for 2 years (international rate $80.50 for 1 year or $161 for 2 years) by Society for Science & the Public, 1719 N Street NW Washington, D.C. 20036.
Preferred periodicals postage paid at Washington, D.C., and an additional mailing office.

**Subscription Department:** PO Box 1205, Williamsport, PA 17703-1205. For new subscriptions and customer service, call 1-800-552-4412.

**Postmaster:** Send address changes to *Science News*, PO Box 1205, Williamsport, PA 17703-1205. Two to four weeks' notice is required. Old and new addresses, including zip codes, must be provided.



FROM THE EDITOR

# For defending the body, physics has a game plan

Ordinarily it's a good idea not to confuse a physicist with a physician. One is a student of the laws of nature, the other is a healer of the flaws of biology. But every once in a while nature's laws can illuminate biology's flaws, and physics can offer a valuable supplement to pharmacies.

That's especially true when coping with biological complexity requires quantification. Physicists have long known that logically simple principles underlie the complex phenomena of ordinary experience. For the motion of a single particle, Newton's laws (with Einsteinian corrections if needed) can answer any question you'd like to ask. If huge numbers of particles are bouncing around, the simplicity of the laws is masked by the multitude of motions.

Fortunately for much of the modern world, physicists pondering the gulf between lawful simplicity and real-life complexity have developed a method for mass predictability. Known as statistical mechanics (more colloquially, statistical physics), this approach depends on the reliably average behavior that emerges from untrackable interactions among individuals. Scientists use statistical mechanics to analyze chemical reactions, the behavior of gases, the properties of materials and even patterns in stock trading and traffic jams.

Similar complexities show up in many realms of biology, nowhere more notably than in the body's cellular battalions for fighting disease, the immune system. As contributing correspondent Susan Gaidos writes in this issue (Page 22), the immune system comprises a team of cells every bit as specialized as players at various football positions, operating under a game plan much more complicated than anything you'll find in the NFL. Basic medical biology has not mastered all the intricacies of the immune system's struggles to preserve healthy bodies. Statistical mechanics could help medical researchers predict how the immune system will respond to agents of disease, how drugs will alter the course of an infection or how vaccines could fortify the body's defenses.

Applying statistical physics to immunity is a new endeavor — it's still the first quarter, so to speak. And it will never fully substitute for biological insight into the shifting strategies of disease-inducing microbes and viruses. But the merging of perspectives from physics with those from biology could improve the odds that humans will someday outwit those microbes and viruses much more successfully, much more often. *—Tom Siegfried, Editor in Chief*

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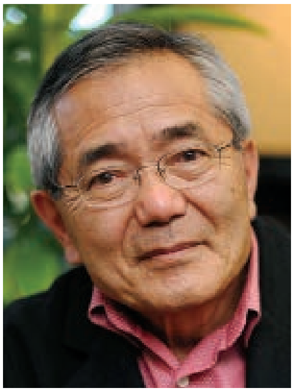

"Our work in palladium-catalyzed cross-couplings in organic synthesis has been ongoing for many years and it will continue. But the full impact of it is not yet realized. Others will use what we have learned, build on what we have discovered and use this to help people and technology in ways that we can only imagine today. The final reward for any researcher is to see his or her lifetime of work extend beyond academia and laboratories, into the mainstream of our global society where it can breathe hope into the world. Our pursuit in research must not be for rewards. Our pursuit in whatever we do must always be for excellence, and if we accomplish excellence, it is its own reward and recognition will follow. This great honor inspires us to continue our quest for excellence." **—2010 CHEMISTRY NOBEL LAUREATE EI-ICHI NEGISHI, IN HIS DECEMBER 10 NOBEL BANQUET SPEECH**

## Science Past | FROM THE ISSUE OF JANUARY 14, 1961

MAN-MADE DIAMONDS ONE-CARAT SIZE PRODUCED — Large, man-made diamonds, more than a carat in size, have been produced for the first time. The diamonds are dark in color and cannot now be used for industrial purposes because of structural imperfections. They were made at the General Electric Research Laboratory, Schenectady, N. Y., where the first man-made diamonds were also made. Small man-made diamonds have been perfected to the point where they are superior to natural diamonds for many uses. These small diamonds are used for cutting, grinding and polishing. Industry uses carat-size diamonds for drills, dressing tools, dies and single point cutting tools. The major source of natural diamonds is the Congo.


SCIENCE NEWS LETTER

## Science Future

**January 22**
Tweens work with engineers in Boise, Idaho, to design cities. See www.futurecityidaho.org

**January 26**
Science historian Steven Shapin discusses ancient and modern concepts of food science, in New York City. Go to www.nyas.org

**January 26**
Raise a glass to the science of cocktails at San Francisco's Exploratorium fundraiser. Go to www.exploratorium.edu

## SN Online

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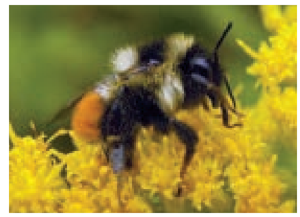
**BODY & BRAIN**
Trained rats sniff out TB in patients' sputum faster than modern lab tests. Read "Giant rats detect tuberculosis."

**LIFE**
Wild pollinators may pick up viruses from their domesticated kin via plants. See "Flower sharing may be unsafe for bees."



**ATOM & COSMOS**
Scientists finish building a huge neutrino-hunting facility far below Antarctic ice. See "South Pole neutrino detector complete."

**SCIENCE & SOCIETY**
Researchers use digitized books to track the English language's evolution on an unprecedented scale. Read "Google project launches new field of culture study."

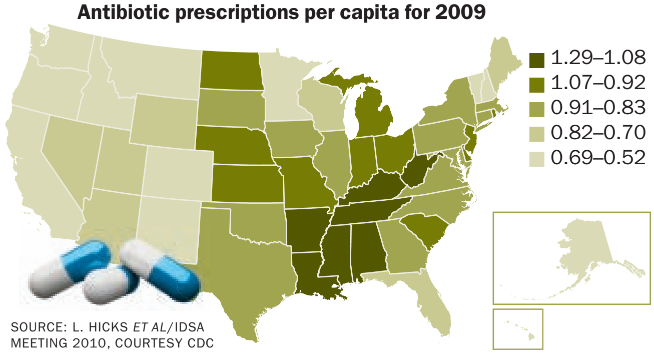
## For Daily Use

Don't ask people with Parkinson's to explain something while they're walking. Researchers at Florida State University in Tallahassee report in the October *International Journal of Speech-Language Pathology* that when individuals with Parkinson's walk and talk concurrently, they don't spend as much time stabilizing their gaits as other people do. Study participants trod on a souped-up walkway while completing verbal tasks, such as counting by ones and subtracting by threes. While both groups changed their gaits as tasks became harder, people without Parkinson's spent more time stabilizing on two feet during harder tasks than those with the disease. Placing similar cognitive demands on elderly patients may contribute to falls.

## Science Stats | TOO MANY PRESCRIPTIONS?

U.S. antibiotic prescription rates vary by state, with areas of the South having the highest rates.

**Antibiotic prescriptions per capita for 2009**




SOURCE: L. HICKS *ET AL*/IDSA MEETING 2010, COURTESY CDC

CLOCKWISE, FROM TOP LEFT: PURDUE UNIV.; BEATRIZ MOISSET/WIKIMEDIA COMMONS; MAP: CARDHOUSE.COM, PILLS: ONURDONGEL/ISTOCKPHOTO

“What is interesting about hair — while it has been with us for a long time, it is still very unknown.” — GUSTAVO LUENGO, PAGE 8



# In the News

STORY ONE

## Swift action to cut greenhouse emissions could save polar bears

### Reductions could stabilize shrinking sea ice, study finds

By Alexandra Witze

Cutting greenhouse gas emissions over the next few decades may stabilize the rapidly shrinking Arctic sea ice sufficiently to provide a sustainable habitat for polar bears, a paper in the Dec. 16 *Nature* reports. And if emissions do keep rising, another new study finds, the only species that has officially been declared threatened by the U.S. government due to global warming may still be able to hang on for a while in a few pockets of the northern Arctic.

Polar bears need sea ice to hunt their prey, but the frozen skin that floats atop the Arctic Ocean has been thinning and shrinking in recent decades as global temperatures rise. Between 1979 and 2010, Arctic sea ice cover at the end of the summer melt season dropped an average of 11.5 percent per decade. Many researchers think that end-summer Arctic ice could be almost entirely gone by the middle of this century.

In 2007, the U.S. Geological Survey reported that two-thirds of the world’s 25,000 polar bears could disappear within 50 years if greenhouse gas emissions continue unabated. The following year, U.S. Department of Interior Secretary Dirk Kempthorne relied on that report when putting the bear, *Ursus maritimus*, on the government’s list of threatened species.

Steven Amstrup, an Anchorage, Alaska–based senior scientist with Polar Bears International in Bozeman, Mont., who was a coauthor on the 2007 USGS report, decided to look at whether cutting emissions could preserve enough of the Arctic sea ice to save polar bears from extinction. In the *Nature* paper, his team reports scenarios for five projections of greenhouse gas emissions over the next century.

Using a widely accepted climate model, the researchers analyzed potential futures for several measures of sea ice habitability — such as the amount of sea ice extending over continental shelves, the number of months each year those shelves are free of ice and the distance between that ice and the more northerly pack ice that bears also use to hunt.

The results don’t support the idea that Arctic sea ice is necessarily headed for a catastrophic “tipping point” beyond which the ice disintegrates completely, Amstrup says. Instead, if greenhouse gas emissions and hence temperatures can

**Threatened by a recent and dramatic reduction in sea ice hunting grounds, polar bears may be able to survive if greenhouse gas emissions are curtailed.**

S. AMSTRUP

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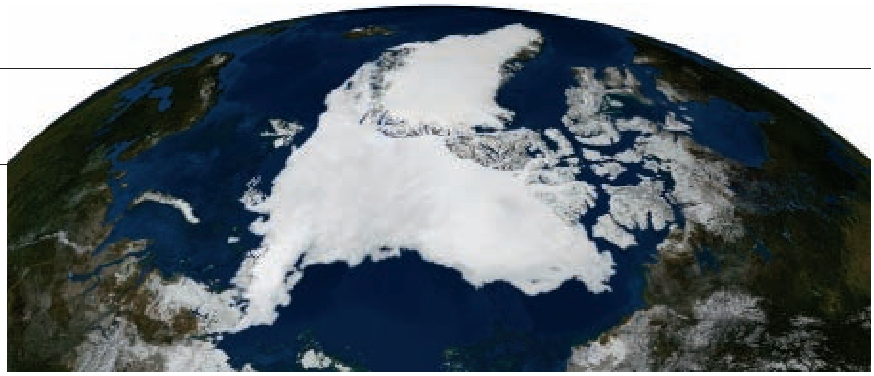


**Warming has already reduced Arctic sea ice extent and thickness. The ice extent at its annual minimum in 2007 (shown) reached a record low; complete summer melting may occur by midcentury in the absence of greenhouse gas reductions.**

be stabilized, the sea ice stabilizes too.

"If we act, it isn't too late to save the polar bear," Amstrup says.

As it thins, sea ice reaches a point where it becomes more responsive to the water temperature below and is better able to regrow in winter, says Marika Holland, a sea ice specialist at the National Center for Atmospheric Research in Boulder, Colo. This enhanced growth helps stabilize the shrinking ice.

Still, the more that people can limit greenhouse gas emissions, the less melting will happen in the first place, says Amstrup.

Even if emissions keep rising, sea ice will stick around in certain areas of the Arctic longer than others, Stephanie Pfirman, an Arctic specialist at Barnard College in New York City, and her colleagues reported December 16 in San Francisco at the fall meeting of the American Geophysical Union. The work meshes nicely with the new *Nature* paper, she says: "They're asking what happens if we act to mitigate. We're looking at the base case: What if we don't act?"

Winds and ocean circulation regularly pile ice up in the Canadian Arctic archipelago and north of Greenland, Pfirman says. Sea ice is thick there today and may persist long after it has melted elsewhere.

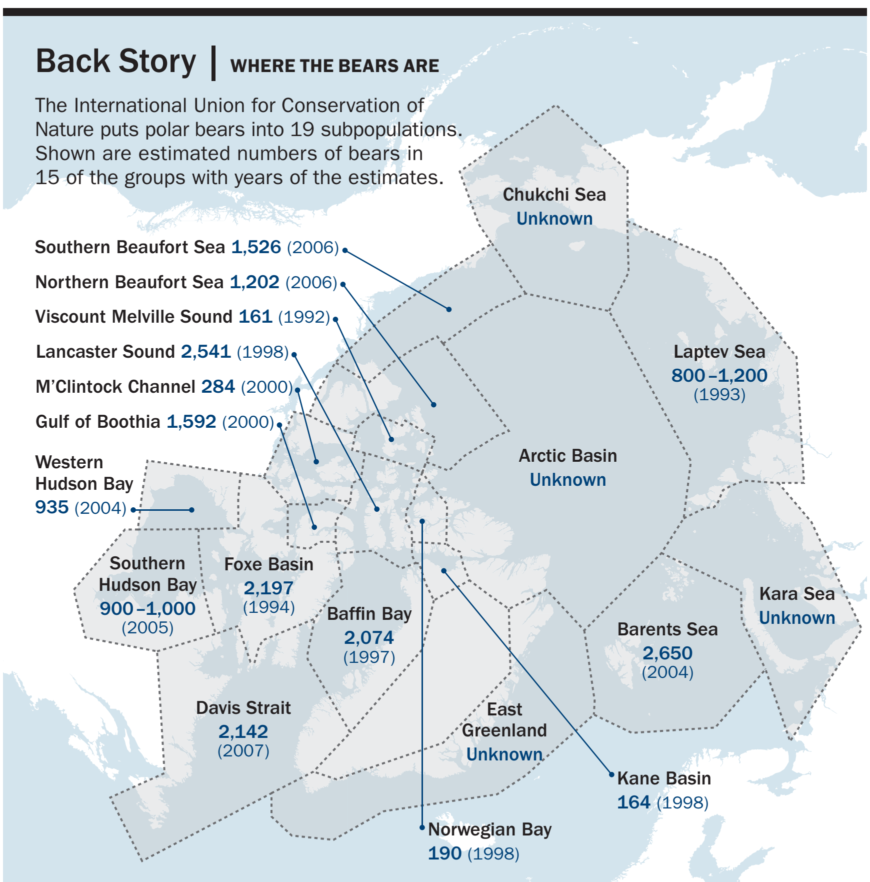
Competing priorities will also come into play, says George Durner, a wildlife biologist with the USGS Alaska Science Center in Anchorage. He and his colleagues, including Amstrup, are working to compare the predicted locations of future polar bear habitats with the distribution of unexploited petroleum reserves.

Polar bears aren't the only creatures that may depend on those last remnants of ice cover, Pfirman noted. An entire ecosystem, including seals and walrus, depends on sea ice. On December 3, the National Oceanic and Atmospheric Administration proposed listing four subspecies of ringed seal and two populations of bearded seal as threatened because of shrinking ice. It is the first such proposal since the polar bear listing that is based solely on the threat of climate change.

By 2100 only the northern fringes of Canada and Greenland — the same areas Pfirman's group identified in its polar bear study — will have snow deep enough to shelter ringed seal pups, suggests research presented at the AGU meeting by Brendan Kelly, an Alaska-based research biologist with NOAA's National Marine Mammal Laboratory, and Cecilia Bitz, a sea ice physicist at the University of Washington in Seattle. Each spring, these seals make snow caves atop the ice to shelter their newborn pups; to do so, they need snow at least 50 centimeters deep.

But in a warmer world even these high Arctic pockets will last only so long, says Robert Newton, an oceanographer at Lamont-Doherty Earth Observatory in Palisades, N.Y.

"This [refuge] is not expected to last forever," Newton says. "As the planet keeps warming, it will eventually be lost." ■

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# Molecules

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## There's locks to learn about hair

### Probing interactions between strands could offer insights

**By Rachel Ehrenberg**

Scientists are closer to understanding the forces that conspire to create a bad hair day, thanks to a new technique that allows researchers to measure friction and other forces between two hairs.

Understanding such hair-on-hair interactions may lead to new cosmetic products for taming hair or to more realistic computer-animated coifs. It also may help researchers better understand interactions among other fibers, such as those used in clothing or bandages.

"What is interesting about hair — while it has been with us for a long time, it is still very unknown," says Gustavo Luengo, a research scientist with L'Oréal in Paris. Luengo and coauthors Mark Rutland and Hiroyasu Mizuno of KTH Royal Institute of Technology in Stockholm describe the new work online November 30 in *Langmuir*.

Much work has been done on the surface structure of hair, but getting at how hairs behave in each other's company has been more difficult. To spy on these interactions, the researchers delicately attached a hair snippet 60 micrometers long to the tip of an atomic force microscope probe, which measures forces present at a surface. Bringing that hair-topped tip into close proximity with other strands of hair allowed the team to assess how the strands attract and repel each other at various distances and under particular conditions.

The new work is an interesting proof of principle, says Jian Cao, a mechanical engineer at Northwestern University in Evanston, Ill., whose research focuses on interactions among lightweight fibers used in airplane wings and bicycle frames. "Friction forces are always something we have to deal with," she says.

The researchers found that ordinary washed hairs are standoffish with each other at a distance, but get them as close as 15 nanometers and attractive forces kick in. A protective layer of fatty acids sits on a hair's surface along with an unusual cocktail of molecules, says Rutland. Bleaching hair removes much of the fatty acid layer, which affects the resulting interaction: Charge builds up on bleached hair and seems to mask the closer-range attractive forces, the team reports. This can lead to flyaway hair.

Future work will look at the effects of high humidity — a notorious cause of bad hair days — on one hair's relationship to another.

## Hornet pigment can drive solar cell

### An insect's light-harvesting apparatus intrigues scientists

**By Rachel Ehrenberg**

The possibility that a hornet might be harvesting sunlight for energy has researchers abuzz. Scientists have constructed an electricity-generating solar cell using a pigment from the oriental hornet, a team reports in the December *Naturwissenschaften* — but much more evidence would be needed to link solar input to power output in the living beast.

Oriental hornets (*Vespa orientalis*) spend their days clearing soil from their underground nests. While many wasps would go about such business in the cooler morning hours, previous research led by the late Jacob Ishay of Tel Aviv University noted that this hornet's activity peaks in sweltering midday. Experiments also showed that shining a light on the hornets generated voltage differences across their hard exoskeletons.

**The yellow stripe on the backside of an oriental hornet (shown) contains a pigment capable of capturing light.**

These and other finds suggested that the hornets were maximizing exposure to sunlight. So Ishay's student, Marian Plotkin, decided to further investigate the brown and yellow pigment on the insect's cuticle.

Examination of the striped patch on the hornet's backside revealed a microstructure that traps incoming light. And when Plotkin and his colleagues extracted a yellow pigment called xanthopterin from the hornet's outer shell and plopped it into a solar cell that uses dyes to absorb light, the device squeaked out some electricity.

The find is interesting but not surprising, says Andrew Parker of the Natural History Museum in London. The skins and shells of organisms from butterflies to diatoms can have complex microstructures that manipulate light.

The researchers have a long way to go to demonstrate that the oriental wasp is solar-powered, says Parker. The team hasn't shown that xanthopterin is linked to production of ATP, the energy-storing molecule of cells. And any number of pigments might eke out some electricity if stuck in a dye-sensitized solar cell.

Even if it turns out that this wasp uses the sun in a more ordinary manner, the idea that insects might get an energy buzz from sunlight isn't so farfetched. "Virtually everything that's been engineered in the physics world," Parker says, "turns up in nature."

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# Genes & Cells

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## Mice missing protein burn more fat

### Research suggests molecular way to rev up body's furnace

**By Tina Hesman Saey**

Scientists are learning how they might stoke the body's fat-burning furnace by turning up a molecular thermostat.

Mice lacking a protein that responds to the hunger-promoting hormone ghrelin burn more energy in their brown fat than other mice, Yuxiang Sun of Baylor College of Medicine in Houston reported December 13. This revved-up brown fat helps keep mice lean and energetic into middle age. The finding could eventually lead to a way to help people fight obesity.

Brown fat burns energy instead of just storing it the way white fat does. This metabolically active fat is important in helping rodents and other animals maintain their body temperature. Recently researchers learned that adult humans have brown fat, and that the amount of energy burned by brown fat decreases with age and weight. The discovery has spurred interest in learning how to ramp up brown fat activity.

Sun and her colleagues didn't start out trying to rev up brown fat. Because the hormone ghrelin has been shown to make animals eat more, the researchers reasoned that blocking the molecule's activity might reduce appetite and help animals and people lose weight. The team genetically engineered mice to completely lack either ghrelin or the ghrelin receptor, a protein that interacts with the hormone and sets off a series of biological reactions in cells.

Disappointingly, mice lacking either molecule ate and exercised just as much as normal mice. But mice lacking the ghrelin receptor burned more energy and stayed lean even as they aged, while normal mice and mice lacking ghrelin tended to gain weight as they got older.

Mice missing ghrelin had a hard time maintaining their body temperature in the cold. But mice without the ghrelin receptor stayed warm. Those pieces of evidence led Sun and her colleagues to examine brown fat in the mutant mice.

Sun's team found that removing the ghrelin receptor causes brown fat cells to make more of a protein called UCP1. That protein makes the cell's power plants less efficient and as a result, they release more heat. Inefficient brown fat cells may burn their own supply of fat and then gobble up fat that otherwise would be stored in white fat cells, leading to leaner rodents, Sun speculated.

> "There may be more than just exercise and willpower that can keep us in shape."
>
> YUXIANG SUN

If researchers can discover why removing the ghrelin receptor turns up brown fat's furnace, they may be able to design a drug to do the same thing. "There may be more than just exercise and willpower that can keep us in shape," Sun said.

There is no question that increasing the activity of brown fat can have a big effect on weight, said Lewis Landsberg, an endocrinologist at Northwestern University in Evanston, Ill. Brown fat is responsible for burning about 10 percent of a rodent's total calories. If brown fat were to burn the same percentage in a human who consumes 2,500 food calories per day, the fat would be burning 250 calories, about equal to the energy burned by walking 2.5 miles.

Landsberg said that it is not clear whether removing the receptor directly affects the energy expenditure of brown fat or if the mutation somehow spurs the nervous system to turn up the furnace.

Sun hopes to answer that question by removing the ghrelin receptor just in brown fat cells. ■

## MEETING NOTES

### New cellular 'bones' revealed

Cells harbor several newly found types of filaments, James Wilhelm of the University of California, San Diego reported December 12. These filaments, formed from strings of metabolic proteins, could give researchers clues about how the cell's internal skeleton evolved. In experiments with yeast, Wilhelm and colleagues discovered that an enzyme called CTP synthase can make filaments. Wilhelm said the researchers don't yet know if the filaments, found in human, fruit fly and yeast cells, help form the cellular skeleton. But another group showed that the filaments do affect the shape of some bacterial cells.
*—Tina Hesman Saey*

### Cells trained to make insulin

Sperm-forming stem cells in the testes can be converted to insulin-producing cells that could replace diseased ones in the pancreas, researchers from Georgetown University Medical Center in Washington, D.C., reported December 12. Ian Gallicano and his colleagues treated sperm-producing stem cells from the testes of organ donors with chemicals to coax the cells into mimicking beta-islet cells from the pancreas—the kind that are compromised in diabetes. The reprogrammed cells produced insulin and curbed diabetes in mice for about a week, and then insulin levels dropped again. But the cells would need to make much more insulin to cure diabetes in humans, and testes-derived stem cells would be useful only for men. Other stem cells might one day help women with diabetes too.
*—Tina Hesman Saey*

# Humans

“Now there’s a third group that’s neither Neandertal nor modern human.” —DAVID REICH

## Genes reveal mysterious group of hominids as Neandertal relatives

### DNA analysis suggests interbreeding with modern humans

**By Laura Sanders**


**A fossilized molar tooth (shown) and finger bone offer evidence for a distinct group of early humans.**

D. REICH *ET AL*/*NATURE* 2010

Neandertals need to make room for a new member in the early human family. By sequencing the full genome of a girl’s fossil finger bone found in a Siberian cave, researchers conclude that a distinct group of early hominids living in central Asia about 40,000 years ago was closely related to the Neandertals. Data from the finger and a molar tooth found in the cave also show that, like Neandertals, the mysterious group interbred with modern humans, in this case leaving behind a genetic legacy in modern-day Melanesians of Papua New Guinea and Bougainville Island.

Reported December 23 in *Nature*, the work underscores the fluidity of human evolution and hints that even more groups are waiting to be uncovered, says paleoanthropologist Milford Wolpoff of the University of Michigan in Ann Arbor, who was not involved in the research. “We’re just scraping the outside of what’s probably a much more complex picture.”

Even a year ago, evidence suggested that modern humans spread throughout the world in a single migration out of Africa that wiped out any genetic traces of other early hominids. But the new study suggests that the lineage of modern humans is much more intertwined.

The presence of the ancient group’s genes in modern-day humans suggests that it was once widespread throughout Asia.

“This was a place where Neandertals and modern humans were already known to be living, right in this region,” says study coauthor David Reich of the Broad Institute of MIT and Harvard in Cambridge, Mass. “Now there’s a third group that’s neither Neandertal nor modern human.”

He and his colleagues call the group “Denisovans,” after the Denisova Cave in southern Siberia where the finger bone and tooth were found.

Last year, researchers studied the mitochondrial DNA from the finger bone (*SN: 4/24/10, p. 5*), leading them to conclude that the girl belonged to a group that split from the line leading to modern humans roughly a million years ago, well before the Neandertal-human split about 270,000 to 440,000 years ago. But mitochondrial DNA, a small loop of genetic material inherited only through the female line, isn’t as informative as the DNA packed into cells’ nuclei. So Reich and his colleagues decided to catalog the finger’s nuclear DNA.

Comparison of the ancient Denisovan genome with that of Neandertals, whose genome was completed in 2010 (*SN: 6/5/10, p. 5*), suggests a much closer relationship than shown by the mitochondrial DNA. A big surprise came, too, from comparing the Denisovan DNA with modern-day humans’: DNA samples from Melanesians carried about 4 to 6 percent of the Denisovan genome.

“It indicates there was gene flow from Denisovans into modern humans,” Reich says.

Such a Denisovan genetic stamp isn’t found in other modern human populations, suggesting a unique interbreeding event in Melanesian history that probably took place after a similar genome mingling between Neandertals and non-African modern humans.

The study is one of the first examples of genetic data defining a new ancient group. “This is kind of a topsy-turvy world, where now we’re starting from the genome and going from there to learn about a new group,” Reich says.

While details about the Denisovan girl’s life are lacking, her cave may have been a busy place: Artifacts suggest that modern humans and Neandertals lived in close proximity in the region. Mitochondrial DNA thought to belong to a Neandertal turned up in a site about 100 kilometers away from Denisova Cave.

Mitochondrial DNA studies of the molar tooth found in the cave show that it belonged to another Denisovan individual, not to the owner of the finger bone. The large and unusually shaped tooth is presumed to be an upper molar from a young adult. It’s “like nothing we’ve ever seen before,” Reich says.

But some disagree about the importance of the tooth. Anthropologist Erik Trinkaus of Washington University in St. Louis says that the tooth is almost identical to one from a hominid called Oase 2, which he says is “an unquestionable early modern human.” Reich contends that the tooth from Oase 2 was likely to be diseased, and therefore not useful for comparisons.

For now, details about the Denisovan group’s appearance and culture remain unknown. “All we have is this tooth, and this finger bone and this incredibly informative genome,” Reich says. But after this new group’s debut, he hopes more Denisovan bones will start to turn up.

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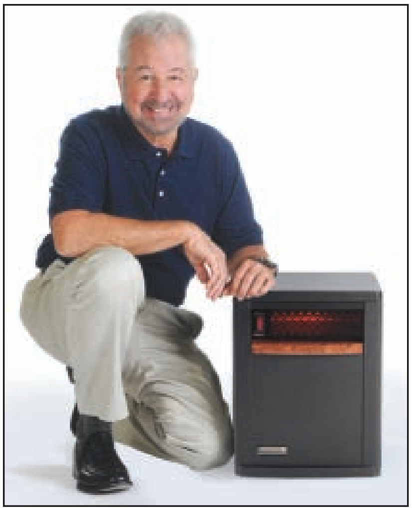

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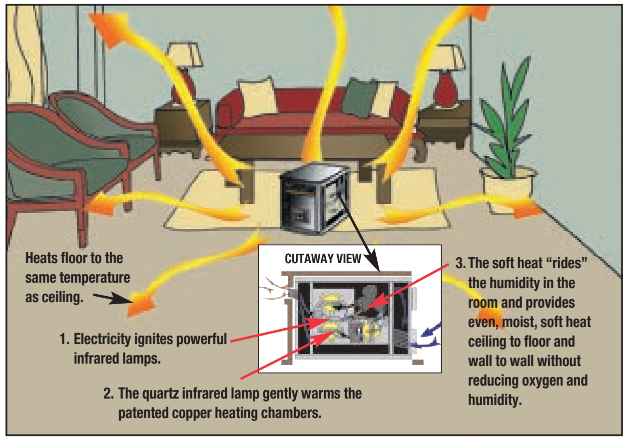


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## Earth

**70 percent** Fraction of terrestrial species that vanished in Permian extinction

**22 percent** Fraction of mammals currently listed as globally threatened or extinct

# Gassy volcanoes tied to extinction

### Giant Siberian eruption may have destroyed ozone layer

**By Alexandra Witze**

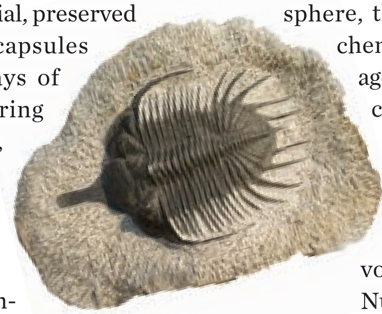
The greatest mass extinction in the history of life may have been caused, in part, by ozone-depleting gases spewed in a massive volcanic eruption. Geologists have found surprisingly high amounts of the elements fluorine and chlorine in Siberian lavas dating back 250 million years — when about 90 percent of marine species and 70 percent of terrestrial species went extinct.

MIT graduate student Benjamin Black and his colleagues described their theory December 13.

Researchers have long struggled to explain the "Great Dying" that occurred at the end of the Permian period. Some think the extinction was a drawn-out affair caused by multiple factors — perhaps gradual changes in oceanic or atmospheric chemistry (*SN: 5/28/05, p. 339*). Others blame a single catastrophic event such as a belch of methane from the seafloor, an asteroid impact (*SN: 2/24/01, p. 116*) like the one thought to have wiped out the dinosaurs 65 million years ago — or a volcanic eruption.

In Siberia about 250 million years ago, huge lava flows spread across more than 2 million square kilometers. Some scientists have blamed these eruptions, known as the Siberian Traps, for climate changes that contributed to the extinctions.

The Siberian rocks contain tiny blobs of once-molten material, preserved like chemical time capsules from the earliest days of the eruption. Measuring the amounts of sulfur, chlorine and fluorine in the blobs, Black found surprisingly high levels of those elements — in one sample, up to 0.75 percent chlorine and 1.95 percent fluorine by weight. That's significantly more than the amounts found in similar lava deposits like the Deccan Traps in India and the Columbia River flood basalts in Washington and Oregon.



Seafloor denizens for over 270 million years, trilobites died out at the end of the Permian.

TRAILMIX.NET/FLICKR

The chemicals probably weren't in the magma as it began traveling up from deep within the Earth, the researchers proposed, but melted into the molten rock as it passed through salt-rich deposits before erupting on the surface.

The concentrations in the Siberian rocks could translate to 9 trillion metric tons of sulfur, 8.5 trillion tons of fluorine and 5 trillion tons of chlorine spewing into the atmosphere during the eruptions. Such elements, when pumped out by power plants, can cause acid rain locally.

If the eruptions were violent enough to lift substances high into the atmosphere, the team proposed, the chemicals could have damaged the ozone layer just as chlorofluorocarbons do today — helping cause or at least exacerbate the mass extinction.

Stephen Self, a volcanologist at the U.S. Nuclear Regulatory Commission in Washington, D.C., said the big question is how long the chemicals would have stayed in the atmosphere. In 2008 Self and his colleagues reported finding high levels of sulfur and chlorine in the Deccan Trap lavas.

Black's team is now starting detailed calculations to see how high the chemicals would have gotten in the atmosphere. Regardless, the researchers said, Siberia at least would have had one very bad time of it.

## MEETING NOTES

### Lightning spotted in X-ray vision

Florida scientists have seen a lightning bolt as Superman would — in X-ray wavelengths — for the first time. A team led by Joseph Dwyer of the Florida Institute of Technology in Melbourne pointed a specially built X-ray camera at lightning bolts artificially triggered by rocket launches at Camp Blanding in Florida. Images from four such launches show the lightning's "dart leader," a descending stream of electrons that helps ionize the air and permit the flow of electricity. The work provides a new way of studying the little-understood processes governing how lightning moves, Dwyer reported December 13. *— Alexandra Witze*

### The memory of sea ice

Shipping companies and northern nations, among others, would like to know months or even years in advance how much Arctic sea ice will melt away each summer. In a new way to get at that question, researchers have identified a sort of oceanic "memory" that persists from year to year and can influence how much ice forms. Statistical analyses of sea ice trends suggest that sea-surface temperature at the ice's edge can remain abnormally warm or cold from year to year, influencing how much ice grows and retreats each seasonal cycle. In particular, just knowing one summer's sea ice minimum may be helpful in predicting the next summer's low, Edward Blanchard-Wrigglesworth of the University of Washington in Seattle reported December 16. The work will appear in the *Journal of Climate*. *— Alexandra Witze*

# Atom & Cosmos

**13.7 billion** | Age of the universe, in years

**380 thousand** | Time in years from Big Bang to cosmic background radiation formation

## Cosmic reincarnation may be dead

### Scientists skeptical of recent evidence for series of Big Bangs

**By Ron Cowen**

A startling claim that the cosmos existed before the Big Bang is not supported by three independent analyses.

The three papers, recently posted online at arXiv.org, were responding to a widely publicized report that the cosmic microwave background — the glow left over from the explosive start of the universe believed to have occurred 13.7 billion years ago — contains echoes of previous cycles of cosmic birth and death (*SN: 12/18/10, p. 10*).

All three analyses found that Roger Penrose of Oxford University in England and Vahe Gurzadyan of the Yerevan Physics Institute and Yerevan State University in Armenia incorrectly ascribed circular patterns in the background to bursts of energy generated before the Big Bang.

Penrose and Gurzadyan failed to take into account that each small patch in a map of the temperature of the microwave background — a snapshot of the infant universe — is correlated with the temperature of adjacent patches, asserts Amir Hajian of the Canadian Institute for Theoretical Astrophysics in Toronto, who posted his analysis December 9.

Adam Moss and colleagues at the University of British Columbia in Vancouver arrived at a similar conclusion in a study posted December 7. "Gurzadyan and Penrose have not found evidence for pre–Big Bang phenomena, but have simply rediscovered that the cosmic microwave background contains structure," the team notes. Ingunn Wehus and Hans Eriksen of the University of Oslo in Norway concur in another paper posted December 7.

The three teams agree that the circular patterns do exist but are entirely consistent with the inflation model for the birth of the universe, which holds that the universe began as a subatomic entity that ballooned in size during the first tiny fraction of a second of its existence.

In a follow-up posted at arXiv.org December 8, Penrose and Gurzadyan argue that their simulations provide a better test than previous studies of whether inflation can produce the circles. They also note that the circles are bunched together rather than randomly distributed, a property that fits with the notion that the universe has undergone multiple cycles, each kicked off with a separate Big Bang.

## Body & Brain

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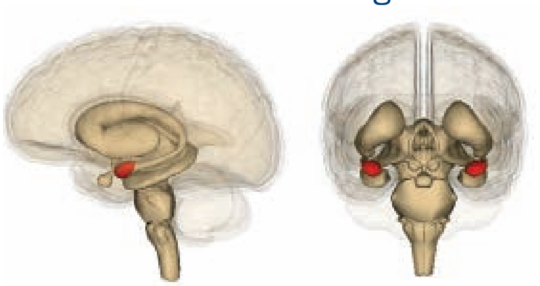
# Amygdala gone, she knows no fear

### Woman lacking basic brain structure can't be frightened

**By Laura Sanders**



**A rare genetic disease destroyed a middle-aged woman's amygdala (red), making her immune to fear even in the most traumatic circumstances.**

A middle-aged woman known as SM blithely reaches for dangerous snakes, giggles in haunted houses and once, upon escaping the clutches of a knife-wielding man, didn't run but calmly walked away. A rare kind of brain damage precludes her from feeling fear of any sort, finds a study published online December 16 in *Current Biology*.

SM has an unusual genetic disorder called Urbach-Wiethe disease. In late childhood, this disease destroyed both sides of her amygdala, which is composed of two structures the shape and size of almonds, one on each side of the brain.

Animal experiments have strongly implicated the amygdala in fear processing. "But one thing we've never known for sure, because they're animals, is whether they can consciously feel fear," says study coauthor Justin Feinstein of the University of Iowa in Iowa City. "So we said, 'Let's take a human patient who has this same sort of damage, and for the first time, actually figure out how they're feeling.'"

SM told Feinstein and his colleagues that she never felt fear, even when threatened with a knife or a gun. The researchers gave her an electronic diary that she carried for three months to record her emotional state. Fear didn't appear once. On a battery of questionnaires, SM wrote that she wasn't afraid of public speaking, death, her heart beating too fast or being judged negatively in a social setting.

The researchers showed SM clips from scary movies: She was interested, but not afraid. They took her to a haunted house. Instead of screaming, she laughed and poked one of the monsters in the head. SM claimed to dislike snakes and spiders. But during a visit to an exotic pet store she was overcome with curiosity, repeatedly asking to touch the snakes.

"Perhaps the amygdala is acting at a very instinctual, unconscious level," says Feinstein. "Without this area, instead of just losing your interest in things, you do the very thing that's opposite. She tends to approach the very things she should be avoiding."

A study of one person can't be extended to everyone, says neuroscientist Hans Markowitsch of the University of Bielefeld in Germany. And pinning a complex emotional state to a single brain structure isn't straightforward. "One could argue that the amygdala cannot act on its own — it's dependent on connections, on circuits, on other brain regions," he says.

The study's authors can't dismiss other brain regions' roles in fear. Yet SM's complete inability to experience the emotion, in a wide variety of forms, highlights the amygdala's pivotal role. ■

# Blood test can spot heart risk

### Cardiac troponin T could be added to existing indicators

**By Nathan Seppa**

A new blood test might reveal heart damage that puts some people at a hidden higher risk of cardiac failure or death, researchers report in the Dec. 8 *Journal of the American Medical Association*.

Although factors such as obesity, diabetes or high blood pressure hike heart disease risk, many people without these problems have heart attacks. Efforts to identify other warning signs have focused largely on two compounds, C-reactive protein and B-type natriuretic peptide. But only blood levels of BNP have shown predictive ability (*SN: 1/7/06, p. 13*).

Two new studies suggest that a blood compound called cardiac troponin T might outperform both as a risk indicator.

In one analysis, Christopher deFilippi of the University of Maryland School of Medicine in Baltimore and his colleagues sampled blood from more than 5,000 people nationwide who were 65 or older and had no history of heart failure. During nearly 12 years of follow-up, on average, people with the highest levels of cardiac troponin T at the study outset were at least 51 percent more likely to develop heart failure and 70 percent more apt to die from cardiovascular causes than those with the lowest levels. The researchers accounted for factors such as blood pressure, previous heart disease and smoking.

In another study, researchers evaluated blood from nearly 3,500 people without coronary heart disease, age 30 to 65, between 2000 and 2002. By 2007, people with the highest levels of troponin T at the start of the study were at least 40 percent more likely to have died of any cause compared with those with the lowest levels. That group also accounted for differences among the participants.

Combining cardiac troponin T measurements with BNP as a cardiac risk test "definitely would make sense," says cardiologist James de Lemos of the University of Texas Southwestern Medical Center at Dallas, who coauthored both papers.

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"It's clear that when you give this compound to humans, it transports them to an alternative reality." —BRYAN ROTH

# Possible clue in Alzheimer's roots

## Slowed clearance of protein by the brain may be a factor

**By Laura Sanders**

A menacing substance builds up in the brains of people with Alzheimer's disease not because they make too much of it, but rather because they can't get rid of it, a study appearing online December 9 in *Science* suggests.

Understanding how the protein, called amyloid-beta, lodges in the brain is likely to yield clues about how Alzheimer's disease inflicts its devastation.

While there's no clear consensus on the ultimate cause of Alzheimer's, many scientists think A-beta is at the core of the disease process. The protein forms deposits considered characteristic of the disease and is thought to interfere with cells in the brain, scrambling its normal operations.

In some rare forms of Alzheimer's, genetic mutations ramp up A-beta production, flooding the brain with the protein. But the cause of the accumulation is murkier for the most common form of the disease.

The new study suggests that A-beta clearance is the problem. Researchers led by Randall Bateman of the Washington University School of Medicine in St. Louis designed a way to track the flux of A-beta in people with Alzheimer's. The amino acid leucine was labeled with carbon-13, which is scarce in the body, and infused into 12 healthy volunteers and 12 volunteers with the disease.

Over the next few hours, cells used some of the labeled leucine to make proteins, including A-beta. Chemical tests on the participants' spinal fluid, which served as an indicator of conditions in the brain, revealed the levels of labeled A-beta.

Both groups produced amyloid-beta at about the same rate. Yet people with Alzheimer's cleared A-beta about 30 percent less rapidly than healthy people did.

"While I believe these data are important," says Alzheimer's researcher Paul Aisen of the University of California, San Diego, "a lot remains to be explained."

# Lab study probes psychoactive drug

## Harnessing hallucinogen could bring better pain treatments

**By Laura Sanders**

Researchers are closer to understanding exactly how a bong packed with *Salvia divinorum* recently gave "Smiley Miley" the giggles.

Although shamans in Mexico have been chewing the leaves of the hardy mint relative for centuries (and without prompting from a recent YouTube video purporting to show teen idol Miley Cyrus smoking it), little is known about what the increasingly popular recreational drug's psychoactive substance, salvinorin A, actually does.

A new study provides some data: The hallucinogen kicks off an unusually intense and short-lasting high, with no obvious ill effects, researchers report online December 4 in *Drug and Alcohol Dependence*.

Matthew W. Johnson, an experimental psychologist at Johns Hopkins University School of Medicine in Baltimore, and his colleagues recruited four volunteers who had used hallucinogens such as LSD or psilocybin in the past. Over 20 sessions, the participants inhaled various doses of highly purified salvinorin A or a placebo while researchers monitored their vital signs and queried them about their experiences.

The effects of the salvinorin A were remarkably strong, consistent and fast-acting, peaking about two minutes after inhalation, and nearly disappearing in 20 minutes.

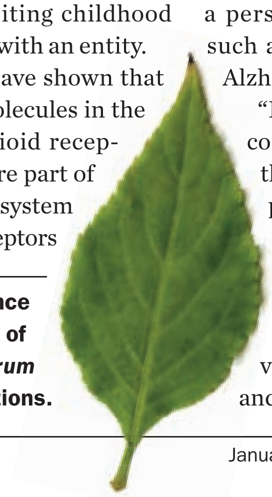
As doses increased across sessions, volunteers reported stronger and stronger hallucinations that included cartoonlike images, revisiting childhood memories and contact with an entity.

Studies in animals have shown that salvinorin A acts on molecules in the brain called kappa-opioid receptors. These receptors are part of the pain-dulling opioid system but are not the same receptors that addictive opiate drugs target.

Most of the evidence so far suggests that salvinorin A is not likely to hopelessly hook its users, Johnson says. "There's more work that needs to be done, but it's not looking like this is going to be the next cocaine or methamphetamine or heroin in the sense of a highly reinforcing, highly addicting new drug."

Scientists think the kappa-opioid receptor is important for a type of chronic pain, so understanding salvinorin A's effects on the receptor might lead to better pain treatments. Tweaking the kappa-opioid receptor with salvinorin A–like compounds might also help treat neurological disorders in which a person's view of reality is altered, such as schizophrenia, depression or Alzheimer's disease, researchers say.

"It's clear that when you give this compound to humans, it transports them to an alternative reality," says psychiatrist and pharmacologist Bryan Roth of the University of North Carolina at Chapel Hill. "So what that suggests to me and to others is that this receptor is very important for consciousness and how we view reality."



**A psychoactive substance contained in the leaves of the plant *Salvia divinorum* causes vivid hallucinations.**

TED KINSMAN/PHOTO RESEARCHERS, INC.

# Life

**2.5** metric tons | Weight of adult male African forest elephant

**6** metric tons | Weight of adult male African savanna elephant

**5.4** metric tons | Weight of adult male Asian elephant

## Female chimps play with dolls

### Youngsters mimic mothering by treating sticks as babies

**By Bruce Bower**

Deep in a Ugandan forest, Betsy Wetsy has gone wild. Young females in one African chimpanzee group use sticks as dolls more than males do, often treating pieces of wood the way a mother chimp would care for an infant, a new study finds.

The ape observations, collected over 14 years of fieldwork with the Kanyawara chimp community in Kibale National Park, provide the first evidence of a wild nonhuman animal exhibiting sex differences in play, two primatologists report in the Dec. 21 *Current Biology*. This finding supports a controversial view that biology as well as society underlies human boys' and girls' contrasting toy preferences.

Young male Kanyawara chimps occasionally used sticks to mimic child care. But far more often they fought with sticks, an infrequent behavior among females, say Sonya Kahlenberg of Bates College in Lewiston, Maine, and Richard Wrangham of Harvard University.

"Although play choices of young chimps showed no evidence of being directly influenced by older chimps, young females tended to carry sticks in a manner suggestive of doll use and play-mothering," Wrangham says.

Consistent with reported cultural traditions among adult chimps (*SN: 11/21/09, p. 24*), Kanyawara youngsters learn from each other to play with sticks as if caring for infants, the researchers propose. Childbearing females never played with sticks and thus didn't model such behavior for younger chimps.

"These new data suggest that sex differences in how children play may go way back in our evolutionary lineage and predate socialization in human cultures," says Elizabeth Lonsdorf, director of the Lester E. Fisher Center for the Study and Conservation of Apes at Lincoln Park Zoo in Chicago.

**A young chimp cradles a piece of bark. In one group, females used objects as dolls more frequently than males did.**

## African elephants are two species

### Forest and savanna dwellers prove distinct in gene analysis

**By Tina Hesman Saey**

Forest-dwelling African elephants are a separate species from Africa's savanna elephants, a genetic analysis shows. The research, published December 21 in *PLoS Biology*, "does a very thorough job of nailing shut the coffin on some of the more heretical theories" about elephant evolution, says Stephen O'Brien, a geneticist at the National Cancer Institute in Frederick, Md., who was not involved in the research.

**A study shows that Africa's forest (left) and savanna elephants (right) are two species. Forest elephants are smaller, with more rounded ears and straighter tusks.**

Forest and savanna elephants evolved into different species from a common ancestor between 2.6 million and 5.6 million years ago, the new analysis reveals.

In the study, researchers compared nuclear DNA from living elephants as well as from a 43,000-year-old woolly mammoth bone from Siberia and from a 50,000- to 130,000-year-old North American mastodon tooth. The African forest and savanna groups are at least as different as Asian elephants and mammoths, the researchers say.

"I've always argued that they are very different, but that level of difference surprised me," says study coauthor Alfred Roca, a conservation geneticist at the University of Illinois at Urbana-Champaign.

People have debated for a long time whether the big savanna elephants and smaller forest elephants belong to one or two species. "This has been an ongoing debate since before genetics began," Roca says.

The two pachyderms look different but sometimes come together and breed, producing hybrids. Hybrid males are sterile, but females can breed.

The study may not be the final word on the number of elephant species, but many researchers say it is convincing. "It's hard not to agree with this overwhelming amount of genetic data that gives such clear-cut answers," comments Sergios-Orestis Kolokotronis, a conservation geneticist at the American Museum of Natural History in New York City.

CLOCKWISE FROM TOP: SUZI ESZTERHAS; A. SCHAEFER; NICHOLAS GEORGIADIS

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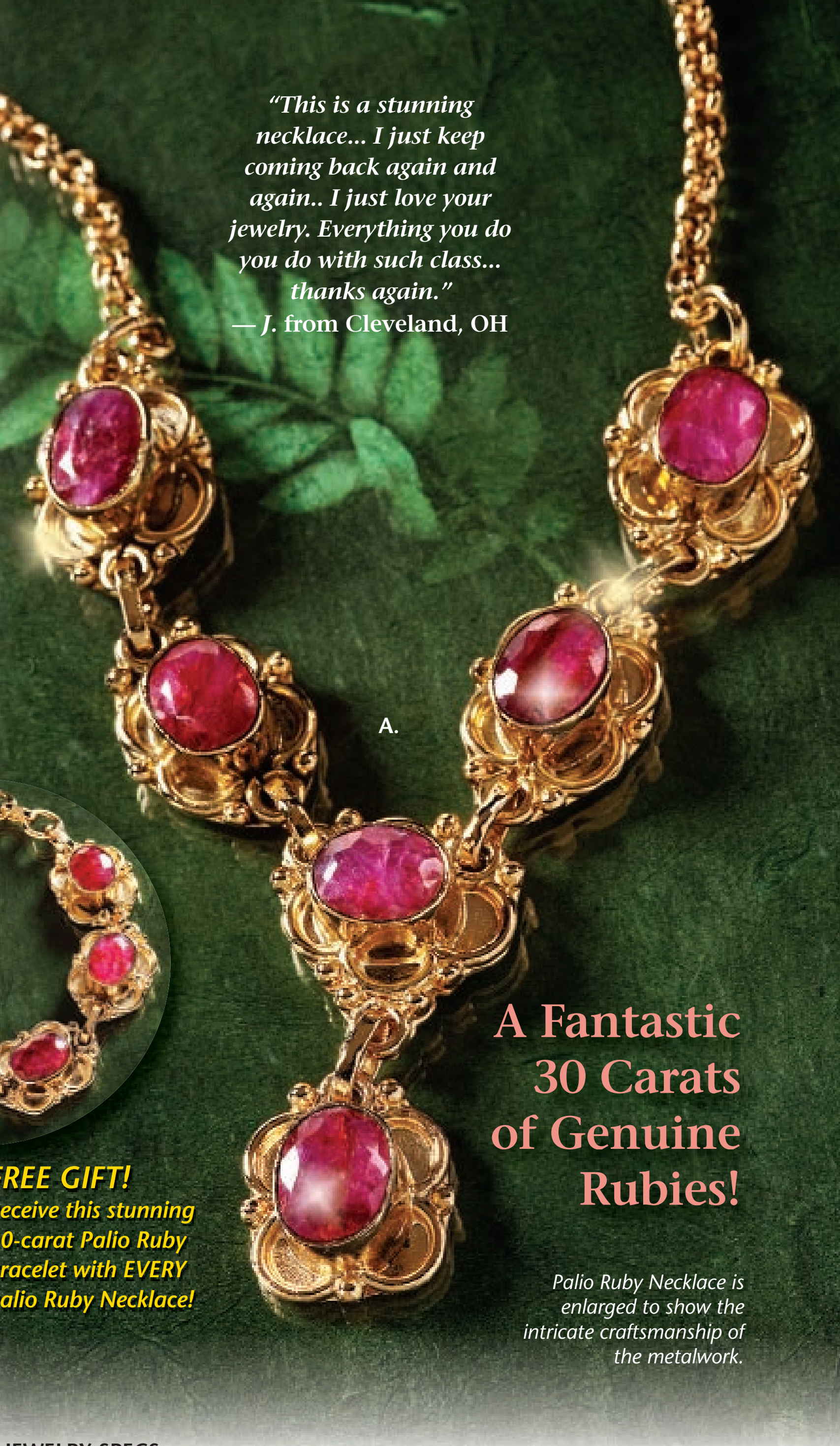


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# Young'uns adrift on the sea

## Scientists try to identify and track elusive larvae in a boundless ocean

**By Susan Milius**

Steve Simpson is gearing up his lab for research he dismissed as loony just two years ago: studying how coral larvae, mere squiggles of still-developing tissue, respond to sound.

He hadn't expected corals — that is, the simple, tiny animals that build coral skeletons — to even have a way of detecting noises. "They're kind of lecture two in invertebrate biology," says Simpson, of the University of Bristol in England.

Most of his earlier work had focused on larval reef fishes, which unlike corals grow up to have ear bones and brains. But a few years ago when he deployed students to Australia's Great Barrier Reef to study the fish, a minor mutiny gave him a new perspective.

His fish team fell in with a crew of coral biologists and developed an urge to broadcast sounds to corals so young they still bobbed along in open water. Perhaps the sounds of a reef would clue in larvae about where to settle down, the biologists speculated. "You guys have got to be crazy," Simpson remembers telling them.

In May 2010, however, Simpson and his colleagues reported in *PLoS ONE* the first evidence that coral larvae (and larvae of any cnidarian, the group that includes corals, sea anemones and jellyfish) respond to sound. He has thus joined a growing circle of biologists who are rethinking the capabilities of elusive marine larvae.

Plenty of sea species, including many shellfish, crabs and worms, as well as corals and fish, go through a larval stage as they develop from fertilized eggs to full-grown adults. Instead of immediately settling down where mom and dad live, the very young sea creatures venture off. They're tiny; the oceans are vast.

Where larvae go, whether they control their travels or just wash along with the currents, and how much the specks of life sense their environment remain largely open questions for most species. Conservationists, fisheries managers, marine ecologists and evolutionary biologists would dearly love to find the answers, and they are beginning to develop the tools to do so.

Researchers have observed that juveniles eventually settle down to replenish populations on rocks, sand or reefs and the waters around them. Whether these are the offspring spawned in those spots days or weeks before, or are counterparts swept in from elsewhere, has perplexed generations of biologists. As answers start to emerge, though, biologists are discovering that treating these larvae as helpless blobs floating in the water would indeed be lunacy.

### The whatsit phase

To try to convey the challenges of studying marine larvae, Tracey Sutton stares at the computer in his shipshape office at the Virginia Institute of Marine Science in Gloucester Point and clicks through baby pictures.

These very young fish, mostly days or weeks old, are of interest to fishing fleets, ecologists and aquatic enthusiasts, but are fiendishly hard to identify. The larvae often look nothing like their parents, Sutton explains.

Many fish eggs hatch into similar, pale, simplified larvae that don't carry a lot of diagnostic characteristics. Sutton calls them nondescript, with much the same intonation that a polite person might use to admit that looking at a dozen cell phone photos from a friend's recent marathon got a little repetitive. Other larvae have distinct traits, but look more like cartoon aliens than adult fish.

"This one has eyes on stalks," Sutton says. On the screen he shows a long, pale Y-shaped thingy with a plump bulge of an eye atop each of the Y's arms. Whatever this creature looks like, a mutant ninja gummy worm or a doodle from the dawn of slingshot design, it does not resemble the dragonfish it will grow up to be.

Marine biologists thus struggle with problems comparable to that of a mammal biologist finding some newborn feline but not knowing whether it's a house cat or a tiger. In some cases, it's as bad as not knowing whether a mewling little cutie is a kitten, a puppy or a bear cub. And any worry over identification assumes that scientists can find the creatures in the first place. Larvae don't nestle under a cozy rock outcropping but are more like dandelion fluff blowing, or maybe flying, in the wind.

During a research cruise sampling life in deep water, Sutton managed to spot an elusive youngster that resolved a long-standing muddle of the kitten-puppy-bear type. The youngster was developed enough to be recognized as a whalefish but hadn't lost all of its baby features yet.

The transitional youngster allowed Sutton and colleagues, including G. David Johnson of the Smithsonian Institution in Washington, D.C., to outline the whole sequence from larva to adult for the species in 2009. Once called tapetails, the larvae drag a long tattered streamer behind them as if they've just emerged from a tangle of seaweed. The larval form, the adult female and the adult male had previously each been identified not only as separate species, but also as species in different families.

Some of the misclassifications are

**Like many other marine youngsters, this larval *Chaetodon* butterfly fish starts life by drifting off into open water.**

**Bulging eyes on two long stalks give the larval *Idiacanthus* dragonfish (top) a very different look from adults of the same family (bottom, *Bathophilus*).**

side effects of the power of evolutionary adaptation to environments. Larvae have to survive as bite-sized nuggets in open water, coping with perils different from those faced by bigger adults flitting around reefs or nudging along the seafloor. Outrageously long spines and prickles on larvae may poke and choke a predator. Johnson speculates that larval streamers like those on the tapetails may create a helpful ambiguity about whether a larva is edible.

To human eyes, ambiguous characteristics can bedevil the study of even some common fish. Sutton says that the 300-plus known species of rattails mature from larvae that basically look alike. Rattails may not be familiar menu items, and probably never will be under that name, but the elongated, slinky fish nicknamed for a stretched-out anal fin play an important role on the abyssal plains of the seas. "Drop some dead meat down there, and they're usually the first things that show up," Sutton says. By volume, the deep sea amounts to a lot of habitat on a blue planet. Thus, he points out, biologists can't yet distinguish reliably among the larval forms of species of one of the most dominant fish families on Earth.

## Building boundaries

As difficult as larvae are to identify, their actions are of interest for conservation as well as basic biology.

A recent surge of larval research addresses the challenges of drawing borders for protected areas in the seas. Declaring a teeming stretch of coastal waters off-limits to fishing, for example, may not do much good if the new reserve's residents start out as larvae somewhere with no protection. To complicate matters, the politics of protection often play out differently at sea than they do on land.

For instance, people protect Yellowstone and Yosemite to preserve gems of terrestrial wilderness. But a marine reserve where people aren't allowed to fish often has a lot to do with saving the livelihood of people fishing nearby, says marine ecologist Robin Pelc of the Monterey Bay Aquarium in California.

"Fisheries are in crisis," she says. One big hope for rebuilding and sustaining them is to create fishing-free sanctuaries with marine populations that grow large enough to spill over the boundaries and replenish fisheries beyond. Designing such a reserve requires tricky balancing acts, Pelc says. Borders have to embrace enough area for populations to thrive, yet the area can't be so big that the riot of life inside the borders stays within those lines.

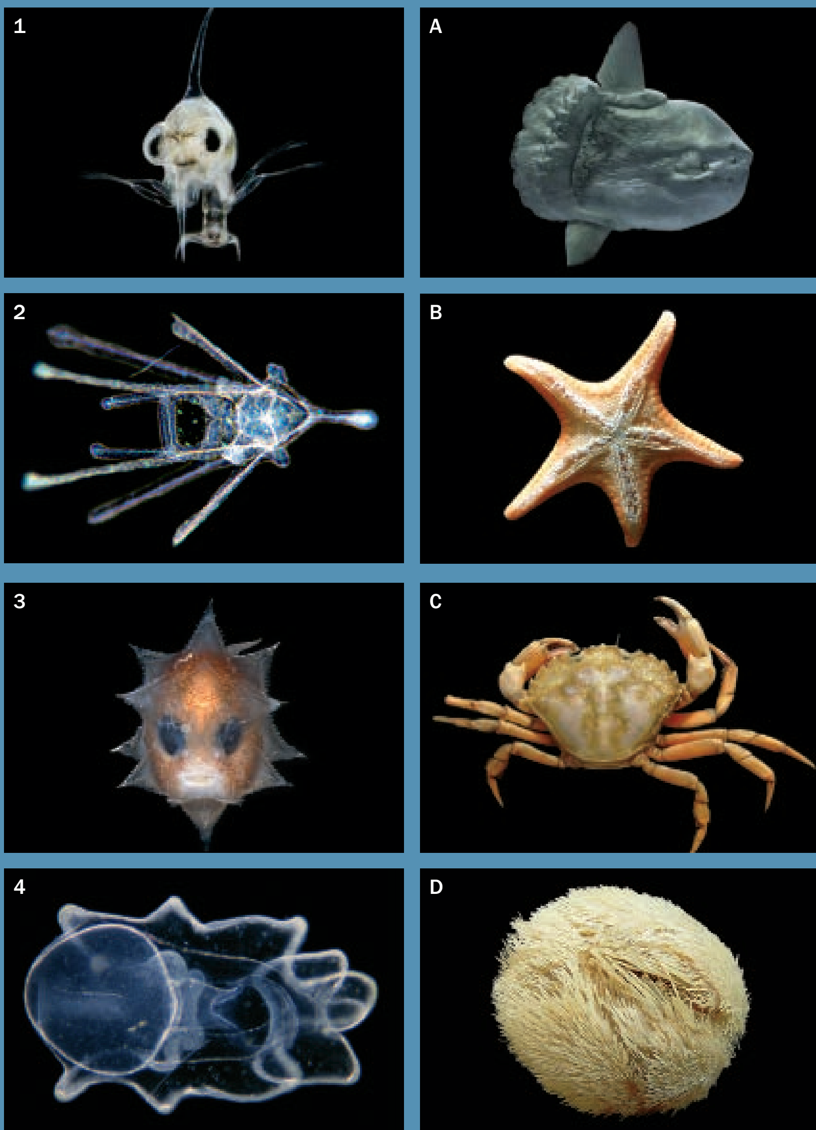
A modeling analysis confirms the idea that reserves designed to enhance fisheries should be no larger than roughly twice the target species' larval dispersal scale, Pelc and her colleagues report in the Oct. 26 *Proceedings of the National Academy of Sciences*. Proving that the sacrifices made for a reserve really have generated spillover has been tricky, though. Most of the success stories feature shellfish, Pelc says. That trend may reflect the tendency of shellfish larvae not to travel particularly far and thus to show up readily during monitoring just beyond park borders.

In contrast, larvae that disperse widely may indeed spill over the borders of the park but continue on to scatter over a broad swath of ocean. Far-flung

FACING PAGE: FISH: G. DAVID JOHNSON; WATER: PESHKOV DANIIL/SHUTTERSTOCK; THIS PAGE, FROM TOP: G. DAVID JOHNSON; JULIAN FINN/MUSEUM VICTORIA

## Matching game: Then and now

Many marine youths look nothing like their adult forms, which makes it difficult for scientists to identify the larvae. In some cases, larvae of different but related species look so much alike that few, if any, biologists can tell them apart. Try your hand at matching the larval creatures below (on the left) with their adult counterparts (on the right). Answers can be found below the images, upside down.




Answers: 1C, green crab; 2D, heart urchin; 3A, sunfish; 4B, starfish

CLOCKWISE FROM TOP LEFT: WIM VAN EGMOND/VISUALS UNLIMITED/CORBIS; FRED HSU/WIKIMEDIA COMMONS; MIKEMURPHY/WIKIMEDIA COMMONS; © HANS HILLEWAERT/ WIKIMEDIA COMMONS; © HANS HILLEWAERT/WIKIMEDIA COMMONS; WIM VAN EGMOND/VISUALS UNLIMITED; G. DAVID JOHNSON; OTTO LARINK/WIKIMEDIA COMMONS

larvae may fulfill the dreams for going forth and replenishing, but they may end up so thinly distributed that typical monitoring programs won't notice any uptick against naturally hiccuping population changes.

It's the catastrophic natural variations that interest Lauren Mullineaux of the Woods Hole Oceanographic Institution in Massachusetts, who studies larvae at deep-ocean vents.

As underwater volcanoes, these vents offer a nutrient-rich but precarious home, where thriving communities often disappear in a Pompeii minute. They're great spots for ecologists to study how ecosystems rebuild after a disaster, a process that all depends on those traveling larvae.

In late 2005 or early 2006, a catastrophic eruption occurred along the East Pacific Rise off the coast of Central America, eradicating a swath of the tube worms and mussels and other vent dwellers that Mullineaux and her team had been studying for a decade or more. Though the interruption was bad in some ways, Mullineaux says, "most of us knew it was going to happen eventually and were pretty excited at the chance to take advantage of a natural experiment."

After four years of monitoring the new settlers at the site, she and her colleagues say the emerging vent community seems to be on a trajectory different from that of the previous community. Species are mixing in a different blend, the researchers report in the April 27 *Proceedings of the National Academy of Sciences*.

"The most astonishing thing about this discovery is that we found a species recolonizing our site that appears to have come from over 300 kilometers away," Mullineaux says. Larvae of the limpet *Ctenopelta porifera* have arrived. The adults, shaped roughly like a lima bean with rows of prominent bumps, are thriving even though Mullineaux has never seen them at the site before. Another small limpet, predicted to survive only during the earliest days of rebuilding, remains a dominant player at the site.

### Where, oh where have they gone?

Despite the importance of larval travel, researchers are still figuring out where in the world the youngsters go. Tracking has proved difficult, and researchers have often made do with rules of thumb for estimating travels.

In a heroic research effort about a decade ago, scientists combined information about water movements around deep-sea vents with studies of larval development done in chambers pressurized at 250 atmospheres to simulate the deep ocean. The study's conclusion: The larvae of an iconic *Riftia* tube worm probably settle within 100 kilometers of their parents.

For shallower species, molecular tagging has yielded more direct evidence. The results are shaking up a long-standing assumption that since many species occur widely, their larvae must also travel widely. Some larval damselfish dosed with tetracycline, which leaves a mark on their ear bones, later set up housekeeping in their native home reef off of Australia's Lizard Island. And a bunch of clownfish settling in a stretch of Kimbe Bay in Papua New Guinea were identified as local kids.

Considering human impacts on the ocean, one important question is what larvae can and can't travel through. Larvae of a common starfish can't readily disperse around water outflows from river mouths or water-treatment plants, says Jonathan Puritz of the University of Hawaii's Hawaii Institute of Marine Biology in Kaneohe Bay. He and Robert Toonen, also of HIMB, used genetic markers to see where starfish larvae settled in the waters off southern California's coast. The populations on either side of water outflows differed more than populations from opposite ends of the United States' Pacific coast, he reported at the Evolution 2010 meeting in June in Portland, Ore.

Water movements also play a role in larval dispersal, Lisa Levin of the Scripps Institution of Oceanography in La Jolla, Calif., and colleagues report in the Nov. 9 *Current Biology*. Two closely related mussel species growing in roughly the same place along the California coast tend to send larvae off in opposite directions, the scientists found, because one spawns during the spring and the other spawns in fall, when nearshore currents move in a different direction.

## Masters of their fate

But current isn't everything. Certain species are turning out to have some say in where they end up.

The fastest fish larvae of the tropical reef can challenge a human scientist fitted with fins and swimming earnestly, says Jeff Leis of the Australian Museum in Sydney. Even larvae that don't swim much at all can still change their fate by moving into another layer of water that's flowing in a different direction.

Considering larvae as possible captains of their fate, or at least contributors to it, opens the question of how the youngsters might choose that fate. Experiments offering various water samples to larval clownfish at the settlement stage have found that water collected near an island, for example, holds more appeal than a sample from the open ocean, and water that has flowed over vegetation proves more attractive than water that has not.

Now it turns out that corals may have their preferences too. Simpson's wayward fish team set up three underwater speakers to broadcast sounds recorded on reefs outward in different directions. In front of each of the speakers, the researchers positioned a long tube holding coral larvae, with mesh ends to keep the larvae inside.

Each tube was positioned at a different angle relative to possible environmental cues such as water currents and the reef itself. Regardless of the orientation, though, the majority of larvae crowded into the end near the sound. In a tougher test, the researchers repeated the experiment with speakers raised above the tubes of larvae. Even though tiny corals normally sink downward to settle, the majority of larvae in tubes reversed the normal preference and clustered on the tube's ceiling. Sound appears to be an overlooked cue for determining where corals settle, Simpson and his colleagues report.

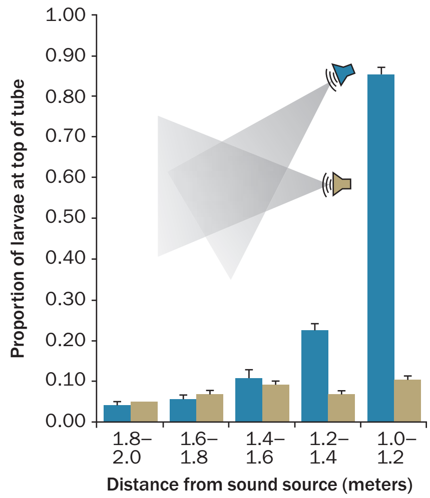
Coral researcher Valerie Paul says she doesn't know about sound, but she has seen that coral larvae show strong preferences for, or against, certain surfaces. Paul, of the Smithsonian Marine Station at Fort Pierce in Florida, and her colleagues offered larvae of staghorn and elkhorn coral what looked like swatches of pink paint (actually four species of crustose coralline algae) as possible landing pads. Biologists have known that corals often settle on such algae. But as the researchers reported in the March 2010 issue of *Coral Reefs*, larvae responded differently to the algal species.

In the emerging view of larvae, marine youngsters are not only elusive. As Paul puts it, "they're very picky." ■

### Sounds like home

Some larvae may settle down in response to external cues. Coral larvae housed in a plastic tube, for example, were more likely to settle on or near the tube's ceiling when reef sounds were nearby and played from above (blue) than when sounds were played from the side (tan), suggesting an attraction to the cue.

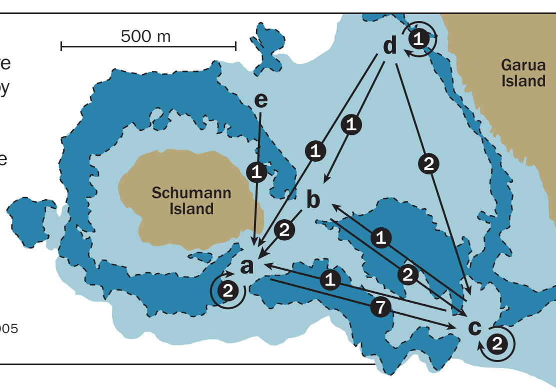
**Larval settlement in response to sound**




SOURCE: M.J.A. VERMEIJ *ET AL/PLOS ONE* 2010

### Stay-at-home clownfish

Tiny as they are, very young fish are not just washed around willy-nilly by currents. Scientists labeled panda clownfish eggs off the coast of Papua New Guinea and tracked the larvae from five spots (lettered). The number of larvae tracked is shown on arrows indicating movement direction. Circular arrows show that a surprising number settle very close to home.




SOURCE: G. JONES *ET AL/CURRENT BIOLOGY* 2005

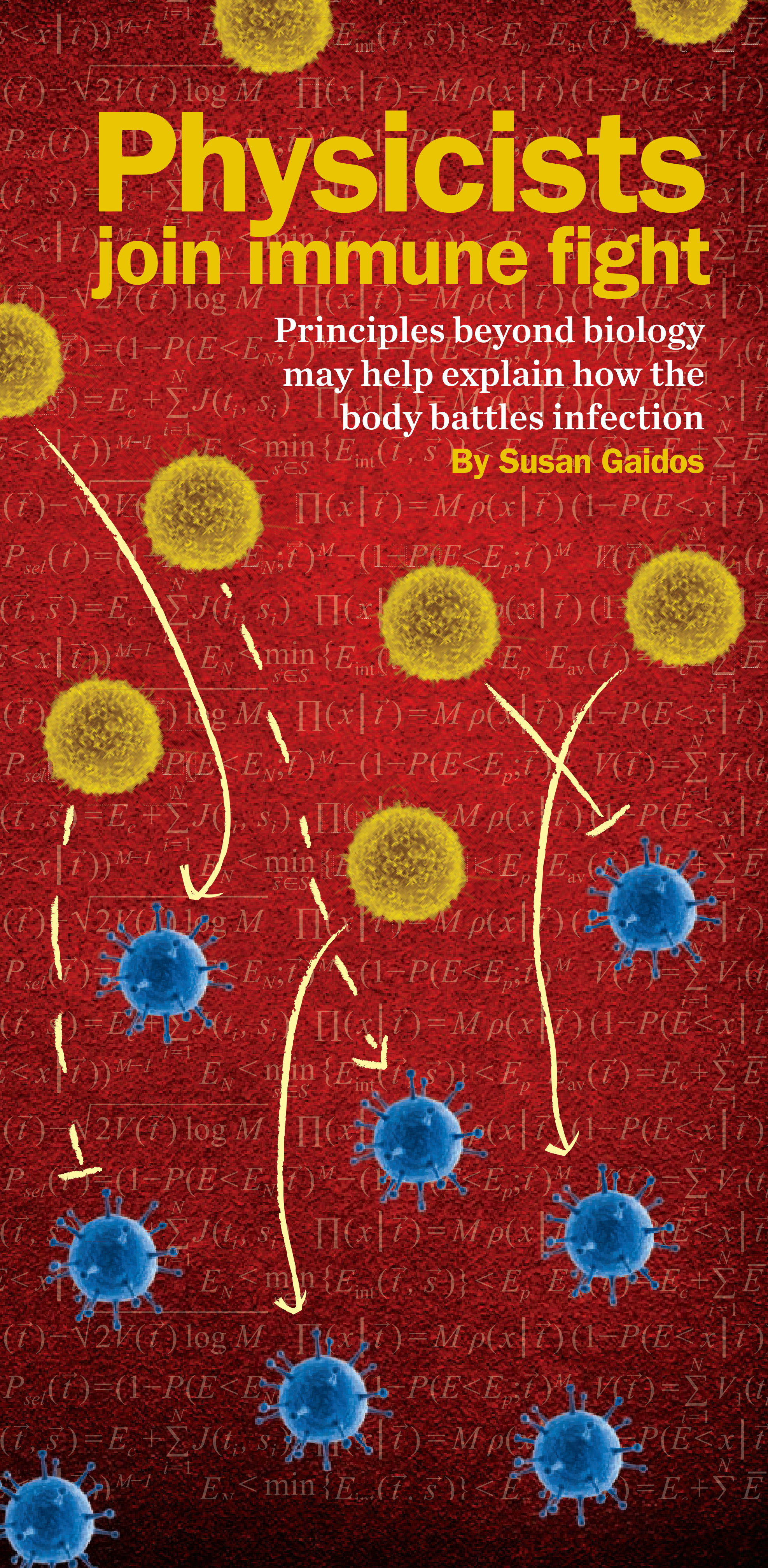
### Explore more:

- For more on moving larvae: J. Leis. "Ontogeny of behaviour in larvae of marine demersal fishes." *Ichthyological Research*. September 3, 2010.

# Physicists join immune fight

## Principles beyond biology may help explain how the body battles infection

**By Susan Gaidos**



A runny nose, sore throat and fever may send you running to your doctor — a perfectly satisfactory strategy if all you are seeking is relief. Applying their knowledge of biology, doctors can analyze your symptoms and then prescribe the best drugs to alleviate them. But if you want to know what's really going on inside your body, consider asking a physicist.

Through the years, biologists have identified and described the various cells that orchestrate the immune system's response to infection, leading to effective vaccines and treatments for many diseases. Mathematical experts have helped to get a handle on the numbers, revealing how many cellular players there are and where they go, as well as showing how quickly the body clears an infection or how long it takes to acquire resistance to a drug. But these approaches haven't yet revealed the full playbook directing the coordinated activities of all involved.

Fighting an infection requires scores of players, each with a job to do. Some cells patrol the body, seeking out and devouring invaders. Others send signals, receive messages or destroy infected or mutated body cells. As the various components in the immune system carry out their work, they interact over multiple levels and time periods, says Arup Chakraborty, a chemical engineer at MIT.

Such complexities make it difficult to intuit the underlying mechanistic principles involved through experiments or simple calculations alone, he says. So now physicists are being called into the game, applying laws governing movement and matter to explain the complex goings-on. Using approaches from statistical physics — a field that employs probabilities to predict and describe the outcomes of events that arise from the interactions of many linked variables — scientists are developing new models to study the play-by-play maneuvers that occur during a full-blown immune response.

By coupling laboratory experiments

**Physicists are mapping out how T cells (yellow) and other immune players respond to threats like viruses (blue).**

T. DUBÉ, BACKGROUND: EKY STUDIO/SHUTTERSTOCK, T CELL: © DENNIS KUNKEL MICROSCOPY, INC./VISUALS UNLIMITED/CORBIS, VIRUS: ERAXION/ISTOCKPHOTO with this new approach, researchers are beginning to uncover some of the key events in immune signaling. Chakraborty and his team have studied how some immune cells operate in an on-or-off digital manner and have explored how the cells learn to distinguish invaders from the body's own tissues. Current studies using the statistical physics approach are looking at how immune cells create and keep memories of past infections. Others are developing new theoretical models to explain how immunity adapts to keep up with ever-changing pathogens.

Understanding how immunity works as a single system may help scientists find new ways to manipulate and control it, leading to more effective vaccines or improved treatments for persistent autoimmune disorders.

## By the numbers

The immune system's first line of defense is to prevent bacteria, parasites, viruses and other infectious agents from entering the body. Skin and the cells that line the nose and stomach serve as a front line, keeping out and wafting away dirt, dust and germs. Specialized cells also patrol the bloodstream, attacking and devouring any germs that get through.

If a bug manages to outwit this system and infect a cell, the adaptive immune system kicks in. This special team serves as a backup defense, designed to identify offenders and produce legions of cells ready for combat. The process starts when white blood cells swoop in to capture and kill the invaders, taking their remains to the lymph nodes. There, protein fragments of the invading pathogen are displayed on the surface of antigen-presenting cells. Serving as a red flag, the fragments identify the bug and signal the immune system to attack cells infected by that agent. Leading this attack are the T cells, white blood cells that work to neutralize infectious agents.

Generally, the various immune cell types exist in small numbers. But under threat, cell numbers can quickly expand into the millions. These cells use chemicals to talk and coordinate an attack.

"It's a game of numbers as much as it is a game of molecular and cellular biology," says biologist Rustom Antia of Emory University in Atlanta.

Alan Perelson, a theoretical immunologist at the Los Alamos National Laboratory in New Mexico, was one of the first to show how mathematical models could be used to study immune changes occurring during infection. In the early 1990s, his team developed models to track how the number of T cells shifts in response to HIV, the virus that causes AIDS.

At the time, many scientists considered AIDS to be a slow-acting viral infection because it takes many years — on average a decade — for symptoms to appear.

Using models to analyze the amount of virus in the body, Perelson's group showed that the virus is, in fact, quite active during this seemingly latent period. The findings revealed that once a person is infected, the virus is cleared from the body quickly. But, in the absence of drug therapy, it multiplies just rapidly enough to keep up with this clearance.

Since Perelson's work, advances in instrumentation have made it possible to collect much more quantitative data. "I think people are starting to recognize the value of having quantitative information," Perelson says.

While simple mathematical models that rely on a limited amount of data can track the movements and actions of large numbers of players, explaining the play-by-play actions of smaller teams within the team is much harder. In the same way that football has special teams that are called in only during a punt or a field goal attempt, the immune system has special units — made up of molecular players — that get called in for certain situations.

Chakraborty says such orchestration creates a "hierarchy" of organized cooperative processes. With so many interacting components, calculating the behavior of any particular individual is not straightforward.

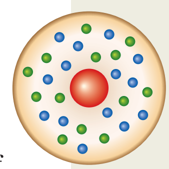
This is where statistical physics can help. By using equations that take all the interactions into account, researchers can estimate the likelihood that a certain result will occur.

## Sending out an SOS

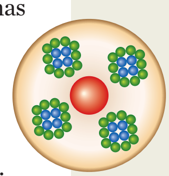
Chakraborty, a chemical engineer and biochemist by training, became interested in immunology after hearing about a paper on the immunological synapse, a crucial communications point for T cells and antigen-presenting cells. Studies had shown that when the two cells meet, various receptors and molecules bind across the synapse, organizing into a doughnut-shaped pattern. But researchers couldn't figure out what function the structure served.

After thinking about its possible signaling function, Chakraborty developed a series of computer simulations to look at all the possible biochemical events that the synapse might influence. The simulations showed that the synapse acts as an adaptive control device, ramping up to enhance T cells' sensitivity to an antigen, but backing off so as not to overstimulate or kill the T cell.

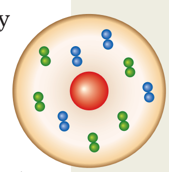
**Signal sums** Different mathematical approaches can be used to understand T cell signaling depending on the complexity of the system.



**Uniform** Ordinary differential equations can be used when signaling components in the cell are uniformly distributed, intrinsic chance events don't play a role and average concentration is what researchers are after.



**Dynamic** When signaling molecules are organized in a specific way and that organization can change over time, calculations using partial differential equations can supplement those that use ordinary differential equations.



**Scarce** If there are fewer copies of signaling molecules within a cell, then chance events become important. In this case, researchers turn to more complex calculations, conducting what are called Monte Carlo simulations.

Increased complexity and computational time

SOURCE: A. CHAKRABORTY AND J. DAS/*NATURE REVIEWS IMMUNOLOGY* 2010

T. DUBÉ

Once in the immunology game, Chakraborty got hooked. He is now bringing his engineering background to another question: How do T cells determine their course of action?

T cells aren't fickle. As they go about their activities and respond to the environment, the cells make friend-or-foe distinctions on the fly. A timid T cell could invite all kinds of germs and misery, while an overzealous one could cause allergic reactions and harm the body's own tissues. The deliberations start when T cells and antigen-presenting cells meet in the lymph nodes, causing a series of molecular events leading to the activation of a protein called Ras.

Arthur Weiss, an immunologist at the University of California, San Francisco, and his colleagues had done a lot of work identifying the pieces of the signaling machinery, but the intricate regulation of the T cells' decisions to mobilize was a puzzle. T cells contain two types of Ras activators: a molecule called SOS and another called Ras guanyl nucleotide-releasing protein, or RasGRP. The scientists hypothesized that SOS worked to amplify T cell receptor signaling while RasGRP played a priming role for SOS.

When Weiss described the complex signaling system at a scientific meeting in 2006, Chakraborty was in the audience. He approached Weiss after the presentation to suggest a way the system might work, based on a physical phenomenon called hysteresis. In hysteresis, a system's response is determined by the last action exerted on it. Iron, for example, remains magnetized for a brief period of time even after the magnet is removed — and responds according to that magnetization.

Chakraborty proposed that the chain of events that led a T cell to go forth and conquer involved a type of hysteresis; the response to signals from antigen-presenting cells was based on recent encounters with other antigen-presenting cells. His group then developed simulations to mimic this type of interaction. The simulations showed that the interplay of Ras and SOS creates a positive feedback loop — a condition in which a little bit of Ras activation by SOS makes a future, more robust activation more probable.

**The model showed how small tweaks in the signaling process could give rise to large effects.**

In further experimental studies, Chakraborty, Weiss, Jeroen Roose of UCSF and colleagues showed how the second Ras activator, RasGRP, can prime SOS, amplifying its signal. Through this mechanism, the T cells not only exhibit hysteresis, but also work in an on-or-off fashion, much like a digital circuit in a computer, the team reported in 2009 in *Cell*.

Weiss says Chakraborty's insights and understanding of physical systems allowed the team to extend its understanding of the immune signaling system.

"He was able to take experimental observations that largely already existed and provide a computational model that could explain how different quantitative parameters in signaling could give qualitatively different outcomes," Weiss says.

The model also showed how small tweaks in the signaling process could give rise to large effects, Weiss says. "That's something that I think we biologists don't understand because it's not the kind of training that we generally have."

## Dealing with frustration

Recently, Chakraborty and his team developed another type of model to study the education process that T cells go through when learning to tell the body's cells from those of invaders.

The model, first described in 2009 in *Physical Review Letters* and later in May 2010 in *Proceedings of the National Academy of Sciences*, is based on an idea from statistical physics called "frustration."

A frustrated system in physics — much like any of life's trying circumstances — occurs when a system has to make many players happy simultaneously, but has no power to change itself or its conditions in order to make that happen.

Such is the case when T cells learn to distinguish between fragments of foreign proteins and bits of the body's own proteins, or self-peptides. T cells that bind too tightly to self-peptides die off. Those that bind weakly come out as winners, and move out into the bloodstream to perform their killer duties.

The frustration enters because the T cell's receptor can't change its configuration, yet it has to learn to bind weakly to a variety of different self-peptides. "It's sort of like you have to make friends with diverse people who are very different," Chakraborty says. "It's very hard. It takes a certain personality to do that."

### T cells remember

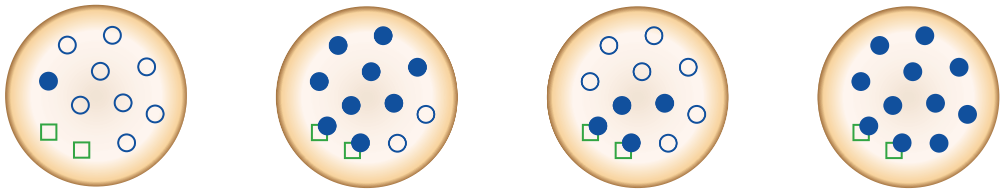
T cells exhibit a property well known in physics called hysteresis, in which a system's response is determined by a previous action.

□ SOS protein

○ Ras protein

● Activated Ras

**First weak signal** | **Strong signal** | **Deactivation** | **Second weak signal**



First weak signal: Following a weak signal, not enough of the Ras protein is activated, so the T cell won't take any action.

Strong signal: A strong signal, on the other hand, prompts a protein called SOS to activate a lot of Ras, leading to a robust T cell response.

Deactivation: Following the response, some of the Ras is deactivated, but some maintains its activated state.

Second weak signal: The next time a weak signal comes around, SOS can rebound quickly and activate enough Ras for a strong T cell response.

SOURCE: A. CHAKRABORTY/ *THE SCIENTIST* MARCH 2010

T. DUBÉ

Last May in *Nature*, Chakraborty and colleagues described how this learning process could be a contributing factor to how people with certain genes can control HIV better.

While learning to make friends, T cells also remember past enemies. Emory's Antia is working with Rafi Ahmed, head of Emory's vaccine center, to model ways in which long-term memories of opponents are stored so they can be recognized the second time around. Antia describes the model as a bucket filled with memory cells against different pathogens.

"When the immune system encounters a new pathogen, there are one of two things it might do," he explains. "One, it can expand the size of the bucket, or two, it can throw away things that were in the bucket already to make room for the new memories."

Because people are a finite size, researchers first theorized that the bucket was limited in size as well. Indeed, models showed that once the bucket is filled, the immune system begins tossing some of the preexisting cells. Rather than tossing the earliest memories first, the models suggest that the rule for discarding is to reach into the bucket and choose cells at random.

The scientists then developed a model to see if the bucket could grow. The simulations called for adding huge numbers of new immune memory cells to see how the preexisting memory would decline.

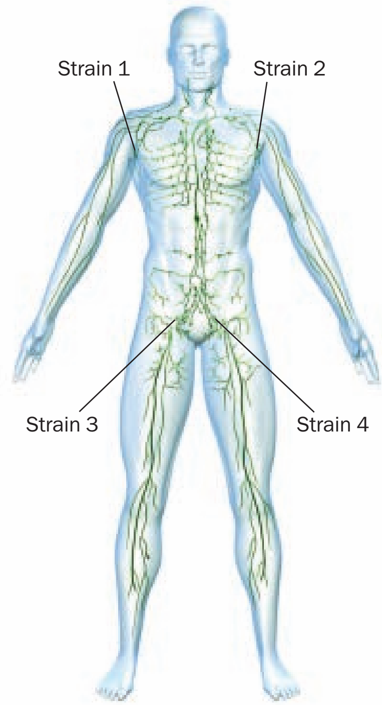
"We actually thought the test would be trivial," Antia says. "We thought it would just test our previous model."

But the second model, published in *Nature* in early 2009, showed that the immune system's repertoire has the ability to expand. Antia is now working with experimental biologists to find ways to test the predictions in animals.

## Back to the body

While statistical physics can inform basic biology, it also has something to say about preventing disease.

Biomathematician Michael Deem of Rice University in Houston became interested in studying the immune system 15 years ago when he rolled up his sleeve




SEBASTIAN KAULITZKI/SHUTTERSTOCK

**Vaccination four ways** Typically, a vaccine for only one or two strains of a virus can be given at a time because the immune system will ignore any additional strains. Using mathematical models, though, one team has found that injecting the different strains into different parts of the body (as shown above) generates responses from different lymph nodes and helps eliminate this problem.

to get his annual flu shot. While administering the shot, the nurse told Deem that getting a flu shot in any given year could, in certain circumstances, make you more susceptible to the flu the following year. Viruses such as the flu are constantly evolving into new variations. A minor change in a strain that the body has learned to recognize can allow the new bug to slip right past.

The incident pushed Deem to develop theoretical models that could more accurately predict which vaccines work best against ever-evolving flu strains. In 2006 his group introduced a model to look at variations in amino acids in the regions of a virus that the immune system recognizes, called epitopes. The model is based on random energy models from physics that are used to study complex systems with many "metastable" points, or states in which the system can get stuck.

Using information from the virus, vaccine and antibody structures, scientists can predict tendencies for amino acid evolution in the epitopes, and develop new vaccines accordingly. Deem says his new model, detailed in February 2010 in the *Annual Review of Chemical and Biomolecular Engineering*, may better predict the effectiveness of a vaccine than do the animal models currently used.

Deem is also using his model to find ways to counter diseases caused by viruses that have multiple strains. Dengue fever, for example, can be caused by any one of four strains of the virus. People who are infected with one strain are more likely to get dengue hemorrhagic fever if infected by one of the other three strains. Vaccinating for all four strains in a single vaccine doesn't work, though, because the immune system will focus on only one or two dominant strains.

While simulating how such dominance occurs, Deem's team came up with an idea: Because the immune system does its looking in lymph nodes located throughout the body, why not inject different variations of the virus into different areas of the body? The process would eliminate the competition for the immune system's attention because each of the four different strains would go to a different lymph node, Deem says.

Recent experiments in animals suggest that the multivaccination approach works. In one experiment, monkeys were immunized with four different strains of dengue virus in four different injections, one in each leg and each arm.

For a short period of time, a few days or so, the antibodies and T cells produced in response to each strain remain localized at a lymph node near the injection site. Eventually, though, the T cells from each lymph node circulate throughout the body, giving protection to all four strains.

If Deem has his way, future vaccinations may take advantage of such principles, nudging physics a little further into the doctor's office. ■

## Explore more

■ NIH's immune system basics: www.niaid.nih.gov/topics/immunesystem

# Liquid Acquisition

Two new scenarios ramp up debate over how Earth got its water **By Ron Cowen**

Water is the life of the party on Earth. From shallow creeks to cascading waterfalls and raging rivers, it's the primal heartbeat of the planet, nurturing a wealth of biological systems from the very simple to the amazingly complex. But no one knows for sure how Earth got this most precious of fluids.

Some researchers contend that the Earth was born wet. Others assert that the planet only later acquired the liquid, ferried in from distant reaches of the solar system. That long-simmering debate has now reached the boiling point.

Two new ideas for supplying water to the early Earth have come to the forefront in the past few months. In thrashing out which scenario is more likely, researchers hope to develop a guide for finding water-rich and possibly habitable planets beyond the solar system.

During the Earth's formation, 4.5 billion years ago, temperatures in the inner solar system exceeded 400° Celsius — hot enough to melt lead. So scientists had assumed that any water would vaporize: Earth would have been born bone-dry and would have acquired its water from elsewhere. For a while, icy comets seemed a suitable delivery source, but during the last decade scientists have found that comet water doesn't chemically match the recipe for Earth's oceans. Most researchers have turned to asteroids because these space rocks have water with a better chemical match, although they too have problems.

One of the new proposals circumvents the need for asteroids, offering not only new ideas about the origin of terrestrial water but also about the early days of the inner solar system. Alessandro Morbidelli of the Côte d'Azur Observatory in Nice, France, and collaborators suggest that the formation of the inner, terrestrial planets was accompanied by a rowdy encounter with the solar system's big bully, Jupiter. In the process of barreling into the inner solar system and then getting slung back out, Jupiter may have kicked ice-rich bodies from the outer solar system into new orbits, some headed toward Earth.

But another team argues that Earth didn't need a special delivery at all. The group, including Michael Drake of the University of Arizona in Tucson, has performed simulations indicating that Earth's building blocks — cosmic dust grains — managed to grab water molecules so tightly that even the high temperatures of the early inner solar system couldn't break the bonds.

Understanding whether Earth got its water locally or from the colder outer reaches of the solar system has implications that go far beyond Earth and its planetary neighbors. If water was plentiful in Earth's building blocks, many extrasolar terrestrial planets could also have been born wet.

The controversy over the origin of Earth's water may have bearing on the diversity of extrasolar terrestrial planets, including how common an ingredient water may be in these bodies, says Philip Armitage of the University of Colorado at Boulder.

## A new model, by Jove

Only four years ago, Morbidelli and his colleagues were satisfied that they had a working model of Earth's water acquisition. They had proposed that the material came in as a veneer delivered by denizens of the outer part of the asteroid belt, which lies just inside Jupiter's orbit. The asteroids would have pummeled Earth after the planet had finished forming.

It wouldn't take much. Although water covers 70 percent of Earth's surface, that water accounts for only about 0.02 percent of the planet's mass. (There also may have been, and still may be, 1.3 to 60 times all the oceans' worth of water present in the planet's interior.) Meteorite measurements indicate that outer-belt asteroids have a water content of about 10 percent, so even if only a relatively few asteroids ferried water to Earth, it might have been enough to account for the planet's water.

And unlike comets, which orbit the sun farther out than asteroids and must get past Jupiter — no mean feat — to reach Earth, it's comparatively easy for asteroids to escape their birth region and head inward. Still, something had to jump-start their departure. In Morbidelli's 2006 model, the researchers envisioned that moon-sized to Mars-sized chunks of material took shape in the youthful asteroid belt. Those embryos scattered some of the rocky material out of the belt, and some of it headed Earth's way.

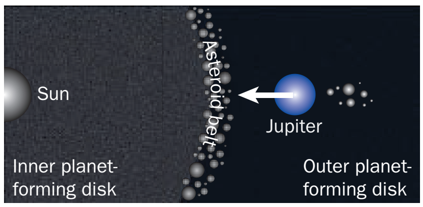
But Morbidelli and collaborators soon uncovered problems with their model. Such scattering would have left the asteroids that remained in the belt on tilted orbits, more highly inclined than observed. More significantly, notes Morbidelli, material piling onto the terrestrial planets would have made Mars, the inner solar system planet closest to the asteroid belt, as massive as Earth. In reality, the Red Planet has only about one-tenth Earth's mass.

Over the last few years "alarm bells started going off," Morbidelli recalls, prompting the researchers to consider a new model. Their latest proposal provides a sweeping new view about planet formation in the inner solar system as well as a new solution to the puzzle of how Earth got its water.

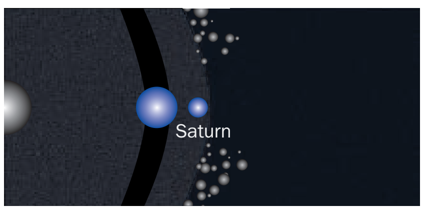
The stage was set when Brad Hansen of the University of California, Los Angeles began exploring a scenario in which the inner solar system's planets coalesced from material confined to a width 0.7 to 1.0 times Earth's distance from the sun, a much narrower disk than normally considered. His simulations with that narrowed disk produced a set of planets similar to the terrestrial orbs, including a properly lightweight Mars, he reported in 2009 in the *Astrophysical Journal*.

Hansen didn't know why the planet-forming disk would be so narrow. But Morbidelli and his collaborators, including Kevin Walsh of the Southwest Research Institute in Boulder, Colo., David O'Brien of the Planetary Science Institute in Tucson, and Sean Raymond

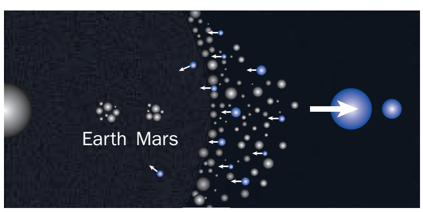
**Fluid delivery** A proposed scenario suggests that Jupiter, the largest planet in the solar system, could be responsible for water on Earth.



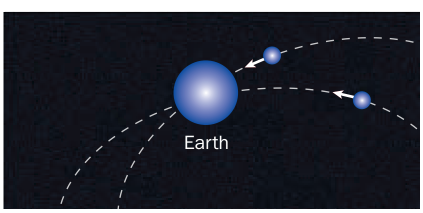

**1.** A few million years after the birth of the solar system, Jupiter was pulled inward by the swirl of gas and dust falling toward the sun.




**2.** With Saturn at its heels, Jupiter cleared the asteroid belt as it moved inward and opened a gap in the inner planet-forming disk.




**3.** Then Jupiter and Saturn boomeranged outward, sending icy debris back into the asteroid belt and inner solar system.




**4.** Some icy bodies acquired elongated orbits that could intersect with a fully formed Earth and provide the fledgling planet with water.

FACING PAGE: NASA/GSFC IMAGE BY RETO STÖCKLI; THIS PAGE: B. RAKOUSKAS of the Laboratoire d'Astrophysique de Bordeaux in France, thought Jupiter's movement could be the culprit.

The team's new model begins after the gaseous Jupiter was fully formed, a scant few million years after the birth of the solar system. The inner planets — Mercury, Venus, Earth and Mars — had just started to coalesce from bits of cosmic dust. The asteroid belt, which now lies between the orbits of Mars and Jupiter and marks the transition to the outer solar system, was a much denser jumble of rocks and dust than it is today, and Jupiter's outlying sister planet, Saturn, had yet to reach full size.

**"Our old ideas weren't working, so maybe we do have to start over to some degree."**
**FRED CIESLA**

As the gas from the planet-forming disk spiraled into the sun, the researchers propose, Jupiter was dragged along, plowing through and emptying the asteroid belt and entering the inner solar system. The combination of Jupiter's heft and motion opened up a gap in the inner part of the planet-forming disk, effectively narrowing it just as Hansen required to make a svelte Mars, Walsh reported in October in Pasadena, Calif., at a meeting of the American Astronomical Society's Division for Planetary Sciences (*SN Online: 10/4/10*).

Jupiter's proposed motion may also have played a crucial role in delivering water to Earth, O'Brien noted at the meeting. In the new scheme, gravitational interactions with Saturn, which trailed its big brother in migrating inward, caused Jupiter to stop in its tracks about where Mars now resides and then reverse direction.

As Jupiter and Saturn traveled outward, they moved farther than ever into the frigid outer region of the solar system (though not as far out as the reservoirs of bodies that would become comets). There Jupiter and Saturn encountered an icier, water-rich population of bodies. The duo would have scattered some of this icy material into the outer part of the asteroid belt. More important for Earth, Jupiter and Saturn's foray would have placed icy outer solar system material on elongated orbits aimed into the inner solar system. Some of the material headed inward would have bashed into Earth, baptizing the planet with water.

So as Morbidelli and colleagues now envision it, Earth's water didn't come from the asteroid belt. Instead, water-rich objects that smacked into Earth and the objects now in the outer part of the belt came from denizens of the outer solar system flung inward by gravitational encounters with Jupiter and Saturn.

Two recent findings may dovetail with this new model. Until about a year ago, no one had found evidence of ice on an asteroid's surface. At the Pasadena meeting, Humberto Campins of the University of Central Florida in Orlando announced the discovery of frozen water on the surface of outer asteroid 65 Cybele. His team and others had previously reported the detection of ice on another outer-belt rock called 24 Themis, the first discovery of ice on one of these space rocks (*SN: 11/7/09, p. 9*).

Those discoveries can be consistent with the new model by Morbidelli and his collaborators, Campins says. Water would be delivered to such asteroids just as it was delivered to Earth.

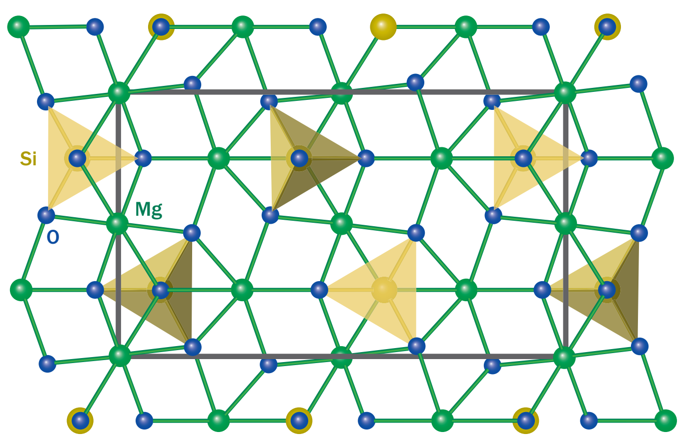
"Work like this is overdue, and I'm excited to see where these ideas lead," says Fred Ciesla, a theorist at the University of Chicago. The migrating Jupiter model "makes our lives more difficult," he says, because it may force scientists to rethink their ideas on the possible sources of water for the inner solar system and the conditions that the fledgling planets were exposed to. "However, as the authors state, our old ideas weren't working, so maybe we do have to start over to some degree," Ciesla notes.

### A watery birth

But for other researchers, starting over means that Earth got its water from the very start. "For 30-odd years, I taught my students that Earth got its water from comets or wet asteroids," says the University of Arizona's Drake. He stopped being a true believer a decade ago.

That's when studies began revealing that comets contain too much deuterium, a heavy form of hydrogen, relative to the amount of ordinary hydrogen. Comets have about twice the ratio of deuterium to hydrogen found in terrestrial oceans. And asteroids, Drake and some others argue, don't have the right isotopic abundances of certain noble gases, such as xenon, to match Earth's waters.

So Drake began considering a model in which, despite the hot early temperatures, Earth could have acquired its water as it formed. In recent simulations Drake, Nora de Leeuw of University College London and their collaborators examined the interactions of individual water molecules and grains of olivine, a dry mineral common on Earth and in planet-forming disks around other stars. The team found that magnesium on the surface of olivine grains grabs hold of the oxygen in water molecules so




**Some researchers think that the Earth could have been born wet. Magnesium (green) in grains of the mineral olivine (molecular structure shown) could have held tight to water despite searing temperatures.**

PERDITAX/WIKIMEDIA COMMONS

tightly that the water remains bound at temperatures over 600° C. The researchers describe their study in the Dec. 21 *Chemical Communications*.

It's likely that at least some and perhaps most of Earth's water came from the cosmic dust from which the planet arose, Drake says.

And for any rocky, terrestrial planet whose building blocks do contain water, it should be relatively easy to transform that interior fluid into a surface ocean, says Linda Elkins-Tanton of MIT. Her new simulations show that as Earth, which formed molten, began to cool, minerals within its magma skin would solidify and crystallize. Those crystallized minerals leave most of the water behind in the magma fluid. Eventually, the water in the magma becomes so concentrated that it bubbles out of the molten material, creating a steam-rich atmosphere that ultimately condenses on the surface as oceans.

Even super-Earths — planets two to 10 times as massive as Earth — would commonly produce an ocean within tens to hundreds of millions of years after formation. That could bode well for supporting the onset of life, says Elkins-Tanton, who describes her work in a paper posted online November 16 in *Astrophysics and Space Science*.

But there's one catch in Drake's scenario, notes Raymond. Studies suggest that the young sun and the dust around it had a deuterium-to-hydrogen ratio that's only one-sixth the amount in Earth's oceans.

Drake acknowledges the mismatch and says his team has begun computer simulations to determine if the deuterium-to-hydrogen ratio might somehow have increased as the dust coalesced to make Earth.

Drake and his colleagues give further support to the idea that water could be adsorbed onto the olivine grains that later aggregated to form the building blocks of the Earth, Ciesla says. But it remains unclear how much of that water would have been retained during planet formation, when dust particles bashed into each other, he adds.

## Beyond the solar system

If Drake's model holds up, it could paint a rosier picture for the prevalence of water in extrasolar terrestrial planets, Armitage says. Observations with infrared telescopes over the last decade have revealed there's no dearth of water in the planet-forming regions around other stars. And water molecules would probably stick to dust particles in those systems, too.

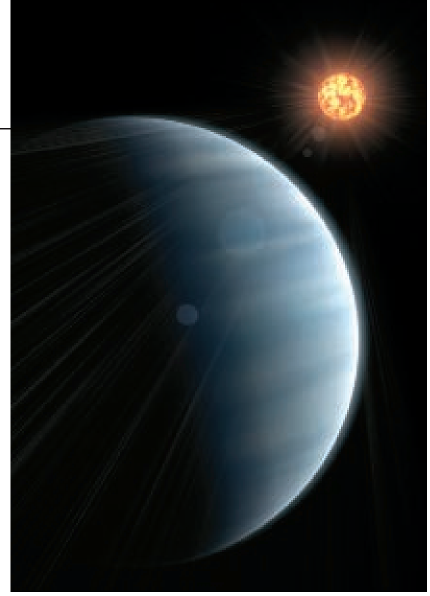
Alternatively, says Armitage, if the rocks that coalesced to form terrestrial planets are truly dry, "then we have to rely on water delivery from the extrasolar analogs of the solar system's asteroid belt."

To acquire fluid, the planets would have to depend on a host of other factors, including the architecture of those systems. For instance, systems that have an analog to Earth's asteroid belt or a reservoir of comets might be more likely to deliver water to inner, Earthlike planets, some researchers speculate. Or if the new model by Morbidelli and collaborators is correct, water delivery might require some highly specialized choreography from a Jupiter-like planet journeying in and out of the terrestrial zone to help ferry the fluid.

While a migrating Jupiter may bode well for the presence of water-rich rocky planets, a hot Jupiter could be the kiss of death. These planets orbit in the hot zone, much closer to their parent star.

Only two years ago, hot Jupiters were assumed to migrate gently inward from the outskirts of their planetary system and quickly settle into sedate, circular orbits that would keep them well away from the zone in which terrestrial planets could form. But beginning in 2009, studies revealed that several hot Jupiters either orbit backward or at a tilt relative to the direction in which their parent star is spinning (*SN: 5/8/10, p. 11*; *SN: 9/12/09, p. 12*). Such unruly orbits indicate that hot Jupiters don't settle down for millions of years. And until they do, they rampage through the inner solar system, destroying or expelling any water and the other building blocks of Earthlike planets, Raymond says.

Clues from Earth's neighborhood and beyond may prove to be invaluable in looking for habitable planets in the flood of new data from missions like NASA's Kepler spacecraft. In February, Kepler researchers are expected to announce a trove of new planets, possibly dozens, including several super-Earths. Kepler finds planets by detecting the tiny amount of light that they block each time they pass in front of their parent stars. Follow-up studies with other telescopes can reveal the mass of a planet and whether its parent star harbors other planets as well.



PAUL A. KEMPTON

**The super-Earth GJ 1214b (artist's illustration) may either host a water-rich steamy atmosphere or a thick haze that masks its atmospheric composition.**

Recent observations suggest water-rich planets may indeed await discovery beyond the solar system. In the Dec. 2 *Nature*, researchers reported that a recently found super-Earth called GJ 1214b has an atmosphere containing either steam or large clouds that mask its true composition. Additional observations at several more wavelengths are likely to distinguish between the two possibilities.

Before too long, new observations of extrasolar planetary systems may even help settle the debate about water on Earth. ■

### Explore more

- For archived talks from a conference on the delivery of volatiles and organics to Earth and exoplanets, visit http://bit.ly/fskkaf

### Here is a Human Being: At the Dawn of Personal Genomics

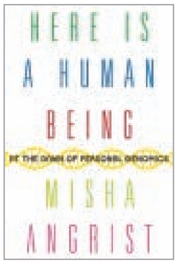
*Misha Angrist*

Genetics isn't just a dry, academic pursuit — it's getting personal. In *Here is a Human Being*, Angrist, a geneticist, introduces people who have already started living in what he calls the DNA Age. They include Angrist himself, who is one of 10 volunteers in a Harvard project that will publicly post participants' DNA blueprints online along with personal information such as medical records, personality traits and pictures.

The title suggests an exploration of Angrist's genome, but in fact, the book is just as much about the pioneers of personal genomics. Angrist covers the rise and decline of genetic-testing companies and the technology that makes knowing your own genetic makeup possible. He also explores the privacy concerns and other ethical questions that arise whenever DNA comes into the equation.

The book's tone is conversational. Angrist is funny, irreverent, sometimes profane, and right on the money, such as when he discusses the impolitic remarks of James Watson, codiscoverer of the structure of DNA. "One wants to kick him under the table or pull him aside and say, 'Dude. Stop.' "

Although Angrist is dedicated to sharing his DNA openly so that people




will realize that "we are not our genes," he admits feeling angst when he first saw his genetic information. He was relieved that he does not carry a potent risk factor for Alzheimer's disease, but a bit disconcerted by his higher-than-average risk for obesity and type 2 diabetes.

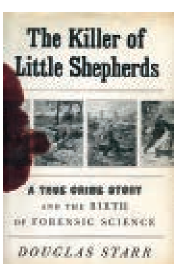
Since this book was finished, hundreds more complete genomes have been announced. As the DNA Age comes fully mature, the rest of humankind will have Angrist and his fellow pioneers to thank for helping make sense of it all. *— Tina Hesman Saey*

*Harper, 2010, 352 p., $26.99.*

### The Killer of Little Shepherds

*Douglas Starr*

Imagine the investigators on *CSI* working without the modern tools of forensics: no DNA, no ballistics lab, not even a basic knowledge of putrefaction to establish time of death. Until just over a century ago, there was no organized study of forensic science and autopsies were likely to happen on a victim's kitchen table, if they happened at all. In



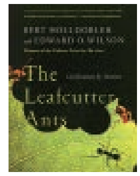

his latest book, Starr, a veteran journalist, traces the beginnings of criminal science, a fascinating history made all the more compelling by the interwoven story of 19th century French serial murderer Joseph Vacher, known as the Killer of Little Shepherds.

The tale of Vacher's crime spree is written with the dramatic tension of a good novel and the impeccable detail of a well-researched history. Starr traveled to France and pored through case files and letters that Vacher wrote from jail, and the quotations that enliven the story are drawn from these records.

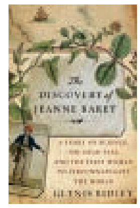
Starr tracks Vacher as he kills dozens of shepherds and other lone victims of opportunity, and the author alternates across chapters to the work of forensics pioneer Alexandre Lacassagne, who eventually testified at Vacher's trial. The French doctor invented many basic forensic techniques, such as calculating how long a body has been decaying, matching a bullet to the gun that fired it and using chemicals to reveal footprints.

The reader roots for Lacassagne to figure out a *CSI*-style trick and catch the killer. In the end, Vacher was caught the old-fashioned way — red-handed — but the thrill of the chase is no less for it.
*— Erika Engelhaupt*

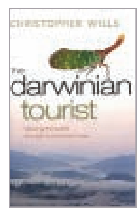
*Knopf, 2010, 300 p., $26.95.*



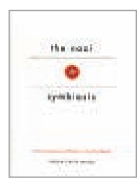
**The Leafcutter Ants**
*Bert Hölldobler and E.O. Wilson*
Two Pulitzer Prize–winning biologists team up to describe ants that farm their own food and form colonies that can be considered advanced civilizations. *W.W. Norton, 2010, 160 p., $19.95.*



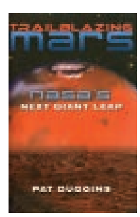
**The Discovery of Jeanne Baret**
*Glynis Ridley*
The story of the first woman to sail around the globe — as "Jean Baret" — details her unheralded accomplishments as a botanist and explorer. *Crown, 2010, 288 p., $25.*




**The Darwinian Tourist**
*Christopher Wills*
A globe-trotting biologist explores how evolution has shaped today's world, from Indonesian corals to Mongolian wolves. Includes more than 100 original photos. *Oxford Univ. Press, 2010, 345 p., $34.95.*



**The Nazi Symbiosis**
*Sheila Faith Weiss*
A historian offers a detailed account of genetics research and its ethical ramifications under the Third Reich. *Univ. of Chicago Press, 2010, 383 p., $45.*




**Trailblazing Mars**
*Pat Duggins*
A veteran space reporter examines hurdles to human exploration of the Red Planet. *Univ. Press of Florida, 2010, 242 p., $24.95.*

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### Another cell phone annoyance

In response to "Why cell phone talkers are annoying" (*SN: 10/9/10, p. 13*), I contend that these researchers are only addressing half of the problem with their "halfalogue" hypothesis. Years ago, I was struck by how irritating it was to walk near people talking on cell phones and wondered if I was simply biased against this new technology. I concluded that, no, they really are far more annoying than people talking face-to-face because cell phone users speak so much more loudly. A halfalogue delivered at twice the volume of a face-to-face conversation is doubly annoying to other people and downright dangerous to a driver. Drivers on cell phones are distracted not only by the content of their conversations, but also by the difficulty of hearing their caller over traffic noise, and by their need to speak more loudly and clearly than usual.

**Teresa Audesirk,** Steamboat Springs, Colo.

### Defining Neandertals

Please clarify the terminology now employed to distinguish between modern humans and Neandertals. Not long ago one spoke of *Homo sapiens sapiens* and *Homo sapiens neandertalis*, clearly indicating that Neandertals were viewed as human beings. Yet Bruce Bower ("Neandertals taken out by volcanoes," *SN: 10/23/10, p. 12*) refers to Neandertals as "these humanlike hominids," continuing the recent trend to distinguish not between modern humans and Neandertals but between humans and Neandertals. Are Neandertals no longer viewed as human beings by the scientific community?

**Bill Sugrue,** Falls Church, Va.

*Many paleoanthropologists regard Neandertals as a separate species,* Homo neandertalensis*, that nonetheless shared many anatomical and cognitive features with* Homo sapiens. *Others take a "Neandertals are us" stance, classifying these Stone Age hominids as a subspecies of* H. sapiens *or simply as illustrations of the anatomical variation that existed within ancient* H. sapiens. *The popularity of these views has waxed and waned for more than a century. —Bruce Bower*

### Correction

In the "Predicted April snow depth, 2045–2050" maps on Page 27 of "The final climate frontiers" (*SN: 12/4/10, p. 24*), the elevation scale bar is mislabeled. The elevation shown is actually in feet, not meters. The elevations in feet don't seem as high as real-world elevations because the map has only a 12-kilometer resolution, meaning mountain peaks tend to be smoothed out.

**Send communications to:** Editor, Science News, 1719 N Street, NW, Washington, D.C. 20036 or **editors@sciencenews.org**. Letters subject to editing.

## John Holdren

For more Comment, visit Columns at **www.sciencenews.org**

# White House science adviser discusses next two years

*Just over a month after the midterm elections, President Obama's science adviser took the podium in San Francisco at the American Geophysical Union meeting. John Holdren, a physicist and climate scientist, said the White House is making strides in improving the nation's science and technology policies. Later that week, Holdren's Office of Science and Technology Policy released long-overdue federal guidelines for scientific integrity.* Science News *contributing editor Alexandra Witze excerpted his comments from a lecture and later press briefing at the AGU meeting.*

**How do you respond to criticism that the federal government was slow to request and use outside expertise after the *Deepwater Horizon* oil spill?**

In the first few days of the spill, I made a number of calls to leaders of major marine science organizations in the country to see what resources and insights and scientific capabilities they could bring to bear. Within the first few days, the White House was convening meetings. Very quickly task forces were set up that reached out into the academic community and the private sector community.

It was a huge challenge. I'm not saying we got everything right at every moment. Certainly there were disagreements about priorities, about approaches, about specific resources. That's inevitable in any problem of this scale and complexity and with a wide variety of different people. But overall, this actually was handled remarkably well given the magnitude of the mess and its complexity.

**How will the White House go about working with the new, more Republican Congress on science issues?**

It will be a big challenge working with the new Congress, whose composition is obviously somewhat less favorable to Democrats than the last one. My view is that science, technology and innovation are not fundamentally partisan issues. My hope is therefore we will be able to keep much of this out of the domain of poisonous partisan politics and get quite a lot done. But only time will tell.

There has been a fair amount of talk about congressional hearings looking into climate science. I personally will welcome such hearings because I think what they will reveal is that the science of climate change is robust, that the core conclusions of climate science are sound — namely that the climate is changing in ways that are unusual against the backdrop of natural variability and that humans are responsible for a large part of that. A variety of forms of harm, in a variety of places, are already associated with climate change, and we know that that harm will grow unless and until we significantly reduce the emissions of greenhouse gases and other heat-trapping substances. Any set of hearings into the climate science issue are simply going to underscore the reality of those propositions. I think most policy makers will eventually reach the conclusion that betting on mainstream science being wrong is gambling with the public's welfare against very long odds.

There has been a fair amount of talk about congressional hearings looking into climate science. I personally will welcome such hearings.

There will be other discussions with the Congress that will be less contentious, because investments in science and technology accelerate the pace of innovation that we need to maintain economic competitiveness, to increase American exports and to create high-quality jobs. That should not be the slightest bit controversial across party lines.

**How does the administration intend to move ahead with the control of greenhouse gas emissions?**

Investments that we make in clean energy, in more efficient energy systems, in a smart grid are all investments that are valuable, important and productive even if you don't believe that climate is changing and we need to reduce our greenhouse gas emissions.

There are a lot of executive authorities that can be used without the Congress to tackle pieces of the problem. We already saw in the first two years of the Obama administration an agreement between the Environmental Protection Agency and Department of Transportation to issue the first set of combined … tailpipe standards that address greenhouse gas emissions as well as fuel economy and conventional pollutants. We have an interagency task force on adaptation now in the executive branch. That's something I think is unlikely to be challenged … because measures you take to increase resilience against storms, shoreline erosion, floods, droughts, heat waves — these are things that one should be interested in doing even if you don't believe climate is changing. There is enough that we can do without legislation. I think we can get on the emissions trajectory that would ultimately take us to President Obama's goals for 2020 in the next two years. ■

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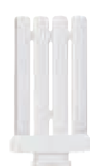

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