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ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ APRIL 9, 2011

Catastrophe

Japan reels from quake, tsunami and nuclear crisis

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The Value of In-Laws

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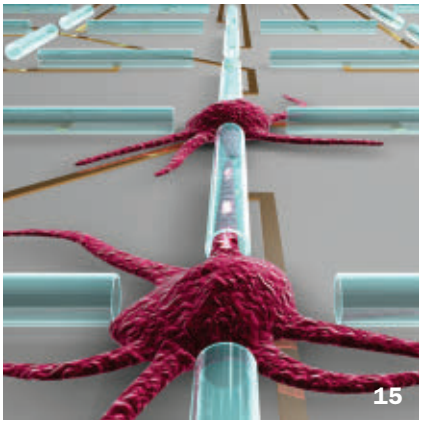

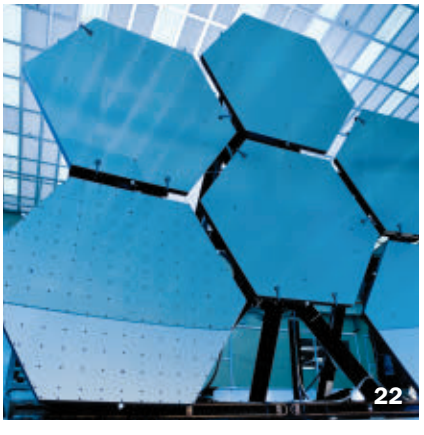

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COVER A woman walks amid the extensive ruin in Minamisanriku, Japan, one week after a quake and tsunami hit the region. *Toru Yamanaka/ AFP, Getty Images*

ScienceNews
MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC

EDITORIAL, ADVERTISING AND BUSINESS OFFICES
1719 N Street NW, Washington, DC 20036 Phone (202) 785-2255
Audit Bureau of Circulations
Subscriptions subs@sciencenews.org Editorial/Letters editors@sciencenews.org
Advertising/Business snsales@sciencenews.org
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

Disasters illustrate value of science 'stenography'

Quite a few years back now, a prominent investigative reporter for a Midwestern newspaper remarked at a journalism conference that science journalists ought to be categorized as "stenographers."

He elaborated in an essay published in *Nieman Reports*, contending that science reporters simply regurgitate what scientists tell them, hyping stories that nobody cares about on meaningless things like black holes and "tectonic plates."

At the time, that essay evoked for some reason a memory about the great Danish physicist Niels Bohr, who after reading scientific papers was known to sometimes say, "I don't mean to be critical, but how can anybody write such nonsense?" Today, memory of that essay's glib disrespect for tectonic plates has been evoked by events in Japan.

Science journalism has its shortcomings. But writing about research that seems of no practical importance (to the uninformed) is of value not just for satisfying the curiosity of people with working brains, but also for aiding everyone's ability to comprehend life's events as they unfold. Understanding science is essential, for instance, to fathom the multifaceted catastrophe playing out in Japan in the wake of one of history's most devastating earthquakes (see Page 5).

It started, of course, with the interaction of those tectonic plates, segments of the Earth's shell-like outer layer of crust and upper mantle. These plates power earthquakes and volcanoes, are responsible for building mountains, and carry deep clues to the Earth's history and inner workings (see Page 12). Knowing something about tectonic plates is prerequisite for having an intelligent grasp on the nature of the planet. And they are certainly not meaningless to the victims of their collision near Japan.

Japan's disaster expands to encompass a broad range of other examples of basic science's societal importance. From the hydrodynamics of tsunamis to the half-lives of radioactive isotopes, science illuminates the issues that public officials must face in coping with catastrophe, and aids the general public's efforts to interpret events as they are reported.

Consequently the task of telling people what's going on in science — the new things scientists are finding out about diverse realms of research — is a worthy endeavor before, during and after the events that propel basic findings into practical prominence. It's not stenography. It's a service to society. —*Tom Siegfried, Editor in Chief*

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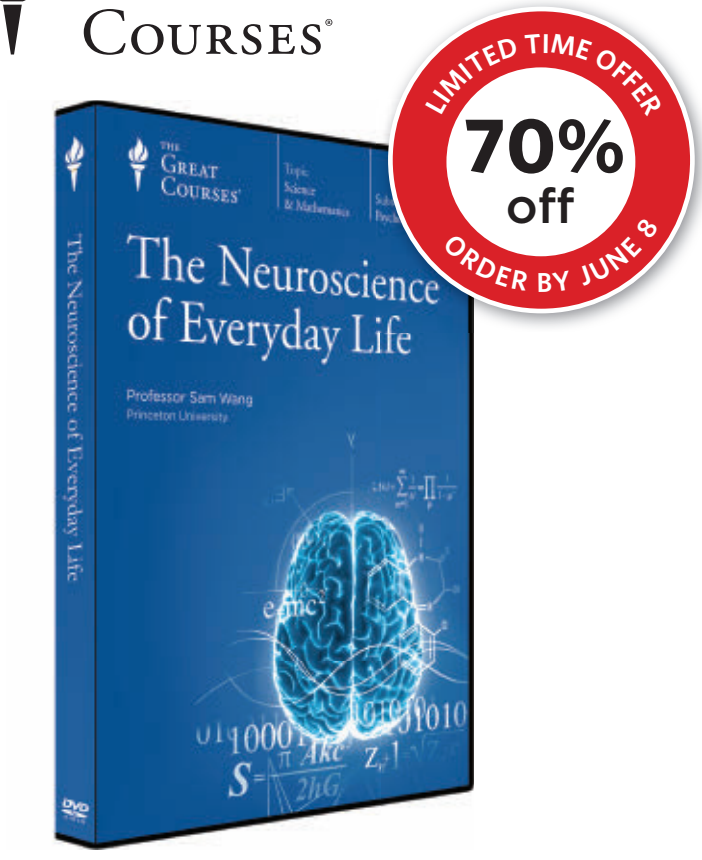

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13. Quirks of Memory
14. Learning, Studying, and Sleep
15. Willpower and Mental Work
16. Work, Play, and Stress
17. Biological Timekeepers and Jet Lag
18. The Hidden Talents of Infants
19. The Mozart Myth and Active Learning
20. Childhood and Adolescence
21. Handedness—Sports, Speech, and Presidents
22. Reaching the Top of the Mountain—Aging
23. "Brain Exercise" and Real Exercise
24. Animal and Human Personality
25. Intelligence, Genes, and Environment
26. The Weather in Your Brain—Emotions
27. Fear, Loathing, and Anger
28. From Weather to Climate—Mood
29. The Social Brain, Empathy, and Autism
30. Mars and Venus—Men's and Women's Brains
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Scientific Observations

"It is in some way a core mission of laboratories that they provide mechanisms to help ideas mature and eventually reach audiences outside the lab. Recognizing the vulnerability of unrealized ideas when separated from the passion of their creators, the most successful labs tend to move creators, along with their ideas, to new creative environments. This is as essential for the ideas as it is for those who come up with them. Creators are less original when they develop their fledgling ideas before the same small, predictably supportive groups of people. Guided in predictable ways, creators will do predictable things.... If we are not all taking a big risk together, our dependence on one another diminishes, we care less about what others do, and we cease to care all that much about our collective creative existence."

—HARVARD UNIVERSITY BIOMEDICAL ENGINEER AND WRITER DAVID EDWARDS, IN HIS 2010 BOOK *THE LAB: CREATIVITY AND CULTURE*

Science Past | FROM THE ISSUE OF APRIL 8, 1961

REMAKE VENUS 'WEATHER' — Man can land on the mystery planet Venus after making its air suitable for humans. This job could be done by dropping primitive plants into the planet's atmosphere, then waiting for results. The primitive algae would remove the carbon dioxide believed to poison the air on Venus for humans. The result would be carbon and oxygen. Dr. Carl Sagan of the University of California, Berkeley, believes the best algae to drop on Venus are the blue-green algae (primarily of the Nostocaceae family). He said many experiments on developing algae in a simulated atmosphere like that on Venus should be made ... [but] should only come after the existing conditions on Venus have been thoroughly investigated.

Science Future

April 16
The American Museum of Natural History in New York City opens an exhibit exploring the world's largest dinosaurs. Visit www.amnh.org

April 22
Learn about the planet and its ecology at events around the country. Go to www.earthday.org

April 28
Sample the science of chocolate at an evening of entertainment in Durham, N.C. See www.ncmls.org/visit/events

How Bizarre

Water confined to nanometer-sized spaces becomes quantum water, a team of U.S. and British scientists report online January 27 at arXiv.org. The tight quarters make the protons in the water's hydrogen atoms act claustrophobic — quantum mechanically speaking, anyway — and the protons become harder to pin down. Their behavior, distinct from that found in bulk water, has been hinted at by other squished experiments (*SN: 1/26/08, p. 58*) but not recognized as a direct result of the confinement. Why the quantum behavior arises the researchers don't yet know, but they note that it's also sensitive to how the bonds between the water molecules are set up inside the two types of nanotubes that have been tested. The unusual state also is present at both room and ultracold temperatures. Because water moves in similarly small spaces in cells — and in ways that befuddle researchers — understanding this new quantum state could help scientists study water's behavior in living organisms.

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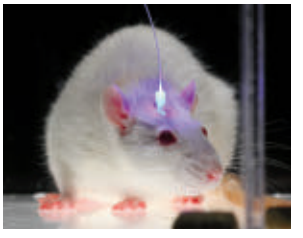
ATOM & COSMOS
Astronomers observe two closely orbiting stars merge. Read "Two stars caught fusing into one."

BODY & BRAIN
Scientists turn fretful mice fearless by tweaking a brain connection. See "Anxiety switch makes mice shy no more."



Immune cell flotsam may trigger lupus's inflammation. Read "Digging into the roots of lupus."

MATTER & ENERGY
Physicists design lasers that can pull as well as push. See "Tractor beams arrive two centuries early."

Science Stats | LIT UP

Nearly 20 percent of high school students reported current tobacco use in 2009, according to the American Heart Association. That's down from 36.4 percent in 1997.

SOURCE: AHA AND ASA 2010

CLOCKWISE FROM TOP LEFT: STEPHANIE MITCHELL/HARVARD UNIV.; DEISSEROTH LABORATORY; KK ART AND PHOTOGRAPHY/SHUTTERSTOCK

“Differences in social structures, not necessarily cognitive advances, allowed our species to cross the barrier to cumulative cultural evolution.” —JOSEPH HENRICH, PAGE 13

In the News

Science & Society Top young scientists

Life Titanic dino identified

Earth An ocean in the making

Humans The in-law revolution

Body & Brain Antibiotics impair flu defense

Genes & Cells Nerve cells grow on a chip

Atom & Cosmos Cosmic expansion refined

STORY ONE

Size of March 11 earthquake took Japan by surprise

Geologists expected a 7.5 in devastated region, not a 9.0

By Devin Powell

The magnitude 9.0 earthquake off northeastern Japan on March 11 generated a tsunami more than 7 meters high that reached the coast within 15 minutes.

Japan has been expecting and preparing for the “big one” for more than 30 years. But the magnitude 9.0 temblor that struck March 11 — the world’s fourth biggest quake since 1900 — wasn’t the catastrophe the island nation had in mind. The quake’s epicenter was about 129 kilometers east of the city of Sendai, in a strip of ocean crust previously thought unlikely to be capable of unleashing such energy.

“This area has a long history of earthquakes, but [the Sendai quake] doesn’t fit the pattern,” says Harold Tobin, a marine geophysicist at the University of Wisconsin–Madison. “The expectation was high for a 7.5, but that’s a hundred times smaller than a 9.0.”

Predicting where big earthquakes will strike is extraordinarily difficult, and nowhere more so than Japan. The northern part of the island nation sits at the intersection of four moving pieces of the Earth’s crust. Where one tectonic plate slides beneath another, forming a subduction zone, sudden slippages can unleash tremendous amounts of energy.

A map of the northern half of Japan’s main island shows the highest shaking intensity in orange.

The Sendai quake occurred at the Japan Trench, the junction of the westward-moving Pacific plate and the plate beneath northern Japan. Historical records, one of seismologists’ best tools for identifying areas at risk, suggest that this segmented fault produced several earthquakes bigger than 7.0 in the 20th century — but none bigger than 8.0.

That’s why the Japanese government has long focused on the nation’s southern coast, where the northward-moving Philippine plate has a proven ability to spawn big quakes. Quakes larger than 8.0 tend to strike the Tokai region in central Japan every 150 years or so, with the last big one in 1854. In 1976 researcher Katsuhiko Ishibashi of Kobe University warned that the Suruga trough, a subduction zone just off the coast of Tokai, was due for another big one. Since then, the Japanese government and research community have braced for such an event — deploying GPS systems to monitor the movements of islands on the Philippine plate and even generating computer simulations of how crowds in train stations might react.

Current thinking about the mechanisms governing megaquakes also favors the Philippine plate as the site of greatest risk. About 80 percent of all quakes above magnitude 8.5 occur at the edges of such geologically young tectonic plates. Kilometer-thick sediment layers carried by these plates are thought to grind smooth patches that allow long stretches of fault to rupture at once. The Pacific

FROM TOP: ASSOCIATED PRESS; USGS

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plate, some of the oldest ocean crust on the planet, doesn't fit this description.

But preliminary computer simulations at Harvard that crunched early data from the Sendai quake suggest that a long stretch of the Japan Trench — about 480 kilometers — did rupture during the event. Multiple segments that usually behave independently broke over the course of two to three minutes.

"It looks like three of the segments all slipped together," says Harvard seismologist Miaki Ishii. "There is some evidence that a fourth may have been involved as well." She doesn't know why these segments ruptured together, or why other similar segments nearby didn't join them.

What does seem clear is that the slip happened in a relatively shallow region of the subduction zone. According to initial computer simulations by geophysicist Chen Ji at the University of California, Santa Barbara, the quake originated eight to 20 kilometers below the ocean floor. The shallower an earthquake, the more easily it flexes the Earth's crust, raising a mountain of water that can turn into a tsunami. The Sendai quake lifted the seafloor several meters and generated a tsunami more than 7 meters high.

"We're learning that we can't discount any of these big subduction zones," says Tobin. "They're all capable of producing large earthquakes." The magnitude 9.1 earthquake that struck Sumatra in 2004 also broke the rules: It too happened on the edge of an old piece of crust, hurling a tsunami across the Indian Ocean deadlier than any other in recorded history.

In the United States, seismologists are eyeing the Cascadia fault zone that flanks Oregon and Washington, which last gave way in 1700 to produce the largest known earthquake in North American history.

"Perhaps the earthquake in Japan shouldn't have been as surprising as it was," says Stanford seismologist Greg Beroza.

Beroza explains that deposits of sand found kilometers from shore have revealed a large tsunami that struck the Sendai area during the Jogan earthquake of 869. Ever since this magnitude 8.0-plus quake, the Pacific plate has been moving more than 8 centimeters per year — a tectonic sprint — pushing against neighboring plates to the west and perhaps building a tremendous amount of strain.

Seismologists hope that the detailed Sendai earthquake data collected by Japan's advanced monitoring technologies — hundreds of sensors spaced an average of 20 to 30 kilometers apart across the Japanese islands — will lead to a better understanding of subduction zone quakes. Researchers will also analyze the emerging pattern of aftershocks, which include at least three bigger than 7.0 and dozens bigger than 6.0.

But being able to spot signs far in advance of a big earthquake — currently far beyond the reach of modern science — may require digging deeper. Tobin and his Japanese colleagues have for the first time embedded strain sensors directly inside a subduction zone, the Nankai trough located southwest of Tokai. Large earthquakes have struck this region every 100 to 120 years, from 686 to 1946. The researchers hope to catch the next big one in the act and find a warning sign that could provide more than a minute's notice that a monster quake is on its way. ■

Natural catastrophe begets nuclear crisis

Designed with earthquakes in mind, the Fukushima Daiichi nuclear facility on Japan's east coast was built to withstand the shaking it took on March 11.

But what came afterward — a tsunami that obliterated whole swaths of coastal infrastructure — apparently overwhelmed the plant, leading to the worst nuclear accident since the Chernobyl disaster in April 1986.

Like most nuclear plants, five of the six Fukushima Daiichi reactors used uranium as their primary fuel. The plant's other reactor — Unit 3 — used a mixture of uranium and plutonium. Pellets of enriched fuel are encased inside long, narrow tubes made of an alloy containing the metal zirconium. These tubes, known as fuel rods, are spaced in an array with water flowing between them. Several hundred of these packages are put together to create the core of a nuclear reactor.

A satellite view of the Fukushima Daiichi plant taken March 14 shows smoke rising after an explosion that may have damaged one reactor's containment vessel.

The uranium-235 isotope, which contains 92 protons and 143 neutrons, is inherently unstable, tending to split, or fission, into lighter elements. Such spontaneous fission releases stray neutrons; when one of those neutrons hits a uranium atom, it initiates another fission into lighter elements, releasing more neutrons. Those neutrons can then go on to hit other uranium atoms, causing a chain reaction. Fission generates heat, which causes water to boil, making steam to drive turbines that produce electricity.

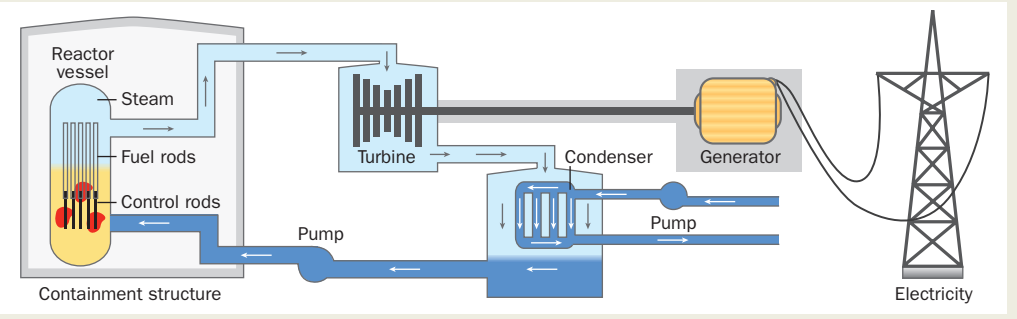
A reactor core requires constantly flowing water for cooling and to moderate the flux of neutrons. The earthquake knocked out power at the Daiichi facility, the tsunami knocked out backup generators, and the battery backups to the generators could not keep the water moving. Excess heat in several reactors caused steam to build up, which plant operators vented into the environment to relieve pressure. Hydro-

DIGITALGLOBE/GETTY IMAGES

"We can't discount any of these big subduction zones." —HAROLD TOBIN

Electricity from the atom

Boiling-water reactors like the ones at the Fukushima Daiichi plant use heat from nuclear fission to make steam, which powers a turbine to generate electricity. The steam is then condensed back into liquid water for another trip through the reactor. The design uses water both as a coolant and to absorb neutrons, keeping the nuclear reaction under control.



gen gas, formed in reactions of water with the hot zirconium rods, also built up and exploded at two of the reactor buildings, releasing radioactive by-products of fission like iodine-131 and cesium-137.

The reactors weren't the only potential source of radiation emitted by the crippled plant. Spent fuel—depleted in uranium but containing highly radioactive fission by-products—is stored in pools of water in the same buildings that house the Fukushima Daiichi reactors. The flow of water through those pools was vulnerable to the same power-supply problems that plagued the reactors, and the tanks began heating up. In at least one case, the spent fuel appears to have caught fire.

As plant workers and emergency responders fought to bring the plant under control, radiation spread. At first, the Japanese government reassured the public that no radiation had spread beyond the plant itself, and cautioned people living nearby to stay indoors. But by the evening of March 12 the government had evacuated a 12-mile radius around the site, and within a week of the earthquake monitoring had revealed contamination of local food and water.

On March 18 the U.S. Environmental Protection Agency and the Department of Energy announced that a federal radiation monitoring station in Sacramento, Calif., had "detected minuscule quantities of the radioactive isotope xenon-133," a substance that could have come only from nuclear fission. It posed no health threat; plant emissions reaching California were so slight they caused no radiation increase above natural background levels.

Though the accident's full health impact won't be known for decades, the plant workers and emergency responders who struggled to bring the plant under control are at greatest risk. Radiation levels around Unit 3 reached 400 millisieverts per hour on March 15. Health effects depend on how long someone is exposed to such levels, says Kelly Classic, a medical health physicist at the Mayo Clinic in Rochester, Minn. For comparison, 400 millisieverts is about the dose people would receive from 40 CT scans of the abdomen. Natural background rates of radiation average about 3 millisieverts per year. In the long term, exposures above even 10 millisieverts might somewhat elevate an individual's risk of developing cancer. — *Janet Raloff and Alexandra Witze*

The magnitude 9.2 earthquake that hit Alaska on March 28, 1964 (March 27 local time) devastated downtown Anchorage.

FROM TOP: AXYSE /SHUTTERSTOCK, ADAPTED BY T. DUBÉ; © BETTMANN/CORBIS

Back Story | SCALE OF 1 TO 10

At magnitude 9.0, the March 11 earthquake in Japan was the fourth largest since 1900. Though there is no theoretical limit to an earthquake's size, it is extremely unlikely that motion along a known tectonic fault could produce an event of magnitude 10.0 or larger.

May 22, 1960
Valdivia, Chile
Magnitude 9.5
1,886 killed*

December 26, 2004
Sumatra, Indonesia
Magnitude 9.1
228,000 killed*

March 28, 1964
Prince William Sound, Alaska
Magnitude 9.2
128 killed*

March 11, 2011
Sendai, Japan
Magnitude 9.0
At least 9,000 killed*

*Combines deaths due to earthquake and tsunami

Science & Society

To learn more about the Intel Science Talent Search, visit **www.societyforscience.org/sts**

Honors for young star researchers

Intel Science Talent Search recognizes 40 prizewinners

By Laura Sanders

Evan Michael O'Dorney (right) won the top award in the 2011 Intel Science Talent Search. Top spots also went to Michelle Abi Hackman (center) and Matthew Miller.

LAURENCE GENON/INTEL

WASHINGTON — The high-wattage glitz and glamour at the 2011 Intel Science Talent Search gala couldn't outshine America's best young scientists, mathematicians and engineers. You could do the math — perhaps with help from first-prize winner Evan Michael O'Dorney, 17, of Danville, Calif. He garnered the top award of $100,000 from the Intel Foundation for his insights on how to best estimate a number's square root. O'Dorney and the other winners of the science competition were named March 15 at the National Building Museum.

Guided by his deep, lifelong fascination with patterns of numbers, O'Dorney discovered an unexpectedly simple formula that clears up a mysterious link between two methods that approximate square roots. His work was rated first by Intel Science Talent Search judges, who have spent an average of 30 years as working scientists. His project beat out 39 other finalists chosen from more than 1,700 proposals. The competition has been administered by Society for Science & the Public, publisher of *Science News*, since 1942.

Second place and $75,000 went to Michelle Abi Hackman, 17, of Great Neck, N.Y., for her project on what happens when teenagers are separated from their cell phones. Students without phones weren't more anxious, Hackman found in her study of 150 high school students. But phoneless teens did appear more bored.

Matthew Miller, 18, of Elon, N.C., won third place and $50,000 for engineering energy-boosting bumps on wind turbine blades. Miller's design, first tested in a wind tunnel in his family's garage, changes the sound produced by the turbine to a more pleasant buzz without increasing the noisiness of the blades.

"It is innovation and creativity that powers society," said Society for Science & the Public president Elizabeth Marincola. "Society for Science & the Public and Intel could not be prouder of our 40 Intel STS finalists of 2011."

Fourth place and $40,000 went to Madeleine Amanda Ball, 18, of Dallas, Texas, for discovering that freshwater crustaceans known as copepods can harbor cholera-causing bacteria. Selena Shi-Yao Li, 17, of Fair Oaks, Calif., won fifth place and a $30,000 award for her studies on a new way to treat liver cancer. Sixth place and $25,000 went to Keenan Monks, 17, of Hazleton, Pa., for research on the mathematics of elliptical curves, which has applications in cryptography. Seventh place was awarded to Benjamin Mathias Clark, 15, of Lancaster, Pa., for his studies of binary star systems.

Eighth through 10th places, each of which comes with a $20,000 award, went to Xiaoyu Cao, 17, of San Diego, Calif., for designing a better way to make biosensors; Jenny Jiaqi Liu, 18, of Orange, Conn., who found that people respond better to robots that exhibit emotions; and Scott Paul Boisvert, 17, of Chandler, Ariz., for finding a link between water contaminants and a dangerous fungus.

The rest of the finalists will each receive $7,500. All the students spent the week before the gala touring Washington, presenting their research to the public and their congressional representatives, and meeting with President Obama.

"We celebrate you. You are our role models," Intel president and CEO Paul Otellini told the honorees.

This year's winners don't excel just at academics (five of the 40 finalists did record perfect SAT scores). Over half of the finalists are musicians, 17 are varsity athletes and eight are writers or editors for their school publications.

The finalists join a distinguished list of STS alumni, including seven Nobel laureates, four National Medal of Science winners and 11 MacArthur Fellows.

Finalist Shubhro Saha, 17, of Avon, Conn., was elected by his peers to receive the Glenn T. Seaborg award, named for the late Nobel Prize–winning chemist and longtime Science Talent Search judge. In an address, Saha thanked all of the mentors, teachers and parents who had believed in him and his fellow finalists.

"We may be young scientists," Saha said, "but we were able to accomplish so much because of this belief."

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Life

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Proposed dino species is titanic

Titanoceratops may be an older relative of *Triceratops*

By Susan Milius

An oddball fossil skull in an Oklahoma museum may represent the earliest giant horned dinosaur species yet found.

The 1.2-meter-long partial skull, unearthed from 74-million-year-old rock in northwestern New Mexico 70 years ago along with some other bones, deserves to be recognized as belonging to its own species, says Nick Longrich of Yale University.

This beast probably weighed 6,550 kilograms, rivaling *Triceratops* and modern-day elephants. Paleontologists, including those who reconstructed the fossil for the Sam Noble Oklahoma Museum of Natural History in Norman, have until now treated the find as a weirdly huge specimen of the *Pentaceratops* dinosaurs known from the U.S. Southwest.

But in the June *Cretaceous Research*, Longrich christens the dino *Titanoceratops ouranos*. The species would add another branch of giants to the horned-dino family tree and would mean that huge size evolved in the lineage some 5 million years earlier than thought.

The head, among the biggest of any known land animal, was an estimated 2.6 meters long. Longrich found that the skull's outsized nostrils, the position of its nose, some of the cavities inside it and other features resemble not *Pentaceratops* but those of the *Triceratops* and *Torosaurus* giants. It looks like an early relative of those species, he says.

A museum display of an early horned dinosaur is labeled *Pentaceratops* but may deserve to be considered a new species, *Titanoceratops*.

"It would suggest there are a lot of undiscovered horned dinosaurs sitting around out there," says Andrew Farke of the Raymond M. Alf Museum of Paleontology in Claremont, Calif. "Right now, I'm skeptical but convincible on the validity of *Titanoceratops*."

Don't trust any elephant under 60

Older matriarchs are better judges of danger to their clans

By Susan Milius

In a test of a particular leadership skill among elephants, age and experience have trumped youth and beauty.

Elephant matriarchs 60 years of age or older tended to assess threats in a simulated crisis more accurately than younger matriarchs did, says Karen McComb of the University of Sussex in Brighton, England. When researchers played recordings of various lion roars, elephant groups led by older matriarchs grew especially defensive at the sound of male cats. Younger matriarchs' families underreacted, McComb and her colleagues report in an upcoming *Proceedings of the Royal Society B*.

Elephant groups in Kenya with older matriarchs responded more appropriately to lion roars as potential threats.

The older females have it right, McComb says. Male lions rarely attack an elephant, but when they do they can be especially deadly: Even a single male can bring down an elephant calf.

The new study supports the idea that older individuals show more leadership in tasks involving specialized knowledge and extends that notion to threats.

"There is an interesting trade-off here, which certainly applies to humans and maybe elephants as well," says psychologist Mark van Vugt of VU University Amsterdam, who studies the evolution of leadership. "The group might want a young, fit and aggressive leader to defend the group ... but at the same time might want an older, more experienced leader ... to make an accurate assessment of the dangers in the situation."

McComb and her colleagues played lion calls to 39 elephant families in Kenya's Amboseli National Park. Researchers compared reactions to roars from one lion versus three lions. All the matriarchs correctly perceived that three was more worrisome than one. "It was quite a revelation," says coauthor Graeme Shannon, also of Sussex. Before this test, evidence had been unclear about how widespread numerical threat assessment capabilities would be. But the older matriarchs also managed an additional layer of awareness, judging male lions as more threatening than females.

"If you remove these older individuals, you're going to have a much bigger impact than you realize because they're repositories of ecological knowledge and also of social knowledge," McComb says. Poachers, targeting the big old elephants, pose a particular menace to the species.

FROM TOP: SANFORD MAULDIN, © SAM NOBLE MUSEUM/ UNIV. OF OKLAHOMA; K. MCCOMB

"If you remove these older individuals, you're going to have a much bigger impact than you realize."—KAREN MCCOMB

NEWS BRIEFS

Apes show handedness

Contrary to earlier reports, apes show humanlike hand preferences when manipulating objects. Chimpanzees, bonobos and gorillas favored the right hand and orangutans the left hand, a team led by psychologist William Hopkins of Agnes Scott College in Decatur, Ga., found in a study to appear in the *Journal of Human Evolution*. Hopkins and colleagues observed which hand 777 captive apes used to reach peanut butter smeared inside a long tube. Roughly twice as many animals in each ape category employed their species' dominant hand, whereas about 90 percent of humans are right-handed. Hopkins wants to explore reasons for orangutans' left-handedness. —*Bruce Bower*

Mouse songs

Mice can sing (sort of), but a baby-swapping lab experiment finds no evidence that lab mice learn to sing by listening to adults around them. Male mouse pups reared by foster parents of a different mouse strain grew up sounding more like their biological dads than like their foster dads. In an ongoing debate, that negative finding may dampen hopes that the high-pitched, songlike mouse vocalizations could join human speech and the sounds of songbirds, certain marine mammals and a few other creatures as examples of vocal learning through imitation. Yet innate, unlearned mouse song could have value for genetic studies of behavior, researchers in Japan suggest online March 9 in *PLoS ONE*. —*Susan Milius*

Invader that can't go home

Fish called red shiners don't seem able to recolonize certain waterways where they once lived as natives, even though the shiners readily invade new territory. The fish had disappeared from six Oklahoma tributaries of Lake Texoma by 2006, but a few showed up again after a flood. Their return offered an unusual opportunity to study early stages of possible colonization. Yet observations in the wild and studies in naturalistic outdoor enclosures suggest that even shiners arriving in relatively high numbers weren't able to recolonize. Increasing habitat for predators may be foiling the shiners' return, University of Oklahoma researchers report in an upcoming *Biological Invasions*. —*Susan Milius*

Earth

"We might be getting into an ozone hole situation." — FRANCIS SCHMIDLIN

The 2010 Erta Ale eruption in Ethiopia (shown) is the latest sign that a rift there will one day form a new ocean.

Continent prepares to do the splits

Thinning East Africa crust shows how land gives way to ocean

By Alexandra Witze

Breaking up is easy to do, if you're East Africa. Researchers have discovered new details of how the Earth's continental crust is tearing apart in Ethiopia, a split that will one day give birth to a new ocean.

In the final throes of breakup, it turns out, the crust thins dramatically, allowing a flood of magma to rise from deep in the Earth and erupt onto the surface, the scientists report online March 13 in *Nature Geoscience*.

"It shows that we're starting to understand some of the processes of how we go from continental to oceanic crust," says James Hammond, a seismologist at the University of Bristol in England who was not involved in the research.

Earth's surface is broken into more than a dozen large tectonic plates, which drift around, collide and create geological phenomena such as earthquakes and volcanoes. The plates are driven by magma that wells up from within the planet, then cools and solidifies to form fresh oceanic crust. Older, lighter crust makes up the continents.

In East Africa, continental crust is tugged by tectonic forces from either side and is destined to eventually rip apart, creating a new ocean like the neighboring Red Sea and Gulf of Aden.

"Ethiopia is an ideal natural laboratory because we can see all these things happening," says study coauthor Ian Bastow of the University of Bristol.

Bastow and Derek Keir, a geologist at the University of Southampton in England, reanalyzed data collected by scientists in the 1970s who set off explosive charges and watched how the resulting vibrations traveled through the ground. The speed of those waves allows researchers to determine how thick the crust is.

In northernmost Ethiopia, the crust is so thin that much of the ground has dropped below sea level. Earthquakes shake the ground constantly, and volcanoes pour out lava across the hot, flat landscape. The new analysis shows that this lava erupts because of the recent stretching and thinning of the crust.

Arctic ozone may post record loss

Depletion could boost UV exposure for midlatitudes

By Janet Raloff

The annual thinning of ozone over the Arctic is shaping up to be especially severe this spring, an international team of scientists announced March 14. During the six weeks preceding the announcement, a large portion of the region's stratosphere had lost at least half of the layer that normally filters out much of the sun's harmful ultraviolet rays.

The new data "are kind of a warning that we might be getting into an ozone hole situation," says Francis Schmidlin of NASA's Wallops Flight Facility in Virginia, who was not involved in the study.

Data radioed back from sensors aboard high-altitude weather balloons show that the ozone-depleted region spans about 15 million square kilometers — an area about 22 times the size of Texas. The region is centered roughly over the North Pole but at times can wander as far south as Italy.

Polar stratospheric clouds that formed this winter over the Arctic could signal growing losses of protective ozone.

People throughout Europe, Canada and much of the northern United States could briefly face higher than normal exposures to UV radiation this spring. Ground-level UV would still be lower than in the tropics but high enough to cause a sunburn within 20 minutes in some areas, says team member Markus Rex of the Alfred Wegener Institute for Polar and Marine Research in Potsdam, Germany.

Ozone destruction occurs in low-pressure rings of winds, known as polar vortices, that form over the poles each winter. Ozone loss in the Arctic vortex could worsen through mid-April, Rex says.

Though stratospheric ozone thins annually in the Arctic, Rex says, this year's loss appears headed for a record.

FROM TOP: LORRAINE FIELD/UNIV. OF BRISTOL; ROSS J. SALAWITCH/UNIV. OF MARYLAND

Humans

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In-laws vital to early human society

Relations by marriage sparked cultural exchange, study says

By Bruce Bower

Give it up for in-laws. Those much-maligned meddlers helped spur an ancient social revolution that propelled human groups from savannas to cities, a new study suggests.

That conclusion stems from an analysis of genealogical and marital data showing that, among modern hunter-gatherers, monogamous sexual unions between men and women from neighboring groups create networks of in-laws that spawn widespread cooperation and cultural learning, says a team led by anthropologist Kim Hill of Arizona State University in Tempe. Social groups organized in this way distinguish humans from other primates, Hill and his colleagues propose in the March 11 *Science*.

The Agta in the Philippines have social networks like those that may have ignited cultural learning among ancient human ancestors.

BION GRIFFIN

"Alliances between foraging groups are facilitated because unrelated males all associate with the same female, who may be their daughter, sister, wife, mother or daughter-in-law," Hill says. "By friendly association with her, males begin to associate with each other."

A social system of this type, which encourages collaboration among genetically unrelated individuals, originated about 2 million years ago as human ancestors began to hunt and gather foods that youngsters could not obtain for themselves, Hill hypothesizes. In this situation, females would have had an incentive to seek mates willing to stick around and provide food for offspring.

Monogamy began even earlier, some scientists suspect, perhaps more than 3 million years ago (*SN: 6/11/05, p. 379*).

"Differences in social structures, not necessarily cognitive advances, allowed our species to cross the barrier to cumulative cultural evolution," says Joseph Henrich, an anthropologist at the University of British Columbia in Vancouver.

Based on limited observations, researchers have thought that modern foraging communities, and by inference prehistoric groups, consist of many male relatives with women migrating into groups as marriage partners. Hill's analysis of a range of hunter-gatherer populations shatters that assumption, in Henrich's view.

Hill and colleagues analyzed previously collected data on more than 5,000 individuals from 32 modern hunter-gatherer societies worldwide. Each society consists of two or more bands of people that live together while moving about the landscape. Bands range in size from five to 64 individuals.

Three social features characterize hunter-gatherer societies and are unique to humans, the researchers conclude. First, both men and women are as likely to stay in the bands they were born into as to move to new bands to find marriage partners. Second, adult brothers and sisters frequently reside together, along with lots of in-laws. Third, a majority of band members are genetically unrelated.

In a comment published in the same issue of *Science*, anthropologist Bernard Chapais of the University of Montreal argues that this monogamy-based social structure encourages males to circulate freely among bands in which they have kin and in-laws. Cultural innovations and traditions thus spread rapidly and unite bands into larger tribal units, Chapais proposes.

NEWS BRIEFS

Time twists morality

Moral judgments may be time sensitive. In experiments conducted by psychologists Renata Suter and Ralph Hertwig, both of the University of Basel in Switzerland, volunteers less frequently said that they would kill one person in order to save the lives of many others if the decision had to be made quickly, as opposed to after deliberation. Time affected moral judgments in this way when hypothetical scenarios involved harming someone as a means to an end, Suter and Hertwig report in an upcoming *Cognition*. Emotional impulses against killing others can be overridden if a person is given time to ponder the merits of sacrificing one to save many, the researchers suggest. —*Bruce Bower*

Miscarriages of mood linger for years after lost pregnancy

Women who have lost pregnancies to miscarriage and stillbirth experience unusually high levels of depression and anxiety during new pregnancies and for nearly three years after they deliver healthy infants, finds a study published online March 7 in the *British Journal of Psychiatry*. Many women become depressed and anxious after losing a baby during pregnancy, and these reactions often persist even after carrying another child to term, propose psychiatrist Emma Robertson Blackmore of the University of Rochester Medical Center in New York and her colleagues. The researchers interviewed 13,133 women twice during pregnancy and up to 33 months after those women delivered healthy babies. —*Bruce Bower*

Body & Brain

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Antibiotics may weaken flu fight

Drugs hit beneficial bacteria that boost immune system

By Tina Hesman Saey

Taking unnecessary antibiotics could make the flu or other viral infections worse, a new study suggests.

Mice on antibiotics can't fight the flu as well as mice that haven't taken the drugs, a team from Yale says. Antibiotics quash the immune system's infection-fighting power by killing friendly bacteria living in the intestines, the researchers report online March 14 in the *Proceedings of the National Academy of Sciences*. These friendly, or "commensal," bacteria help defend against viruses by keeping the immune system on alert for viral invaders, the team discovered.

"There's a lot of beneficial effects of having commensal bacteria," says Akiko Iwasaki, a Yale University immunologist who led the study. "This is one that was unexpected, but makes sense."

Scientists knew that friendly bacteria in the intestines could help stop disease-causing bacteria from setting up shop in the gut. And previous experiments hinted that gut microbes could influence how well the immune system works, but researchers thought the effect was mainly confined to the digestive system and wouldn't show up in far-away tissues such as the lungs. "What's fascinating about [the new study] is that there's a distant regulation of resistance to viruses by gut microbiota," says Alexander Chervonsky, an immunologist at the University of Chicago.

Lungs are normally sterile, so it was a bit of a surprise that killing bacteria in the colon would have an effect on how well the respiratory system could fight viruses.

Iwasaki and her colleagues treated mice for a month with four antibiotics commonly given to people with bacterial infections, then infected the rodents with the flu. Antibiotic treatment impaired the mice's ability to make an important flu-fighting molecule called interleukin-1 beta or IL-1 beta, the researchers found. IL-1 beta is necessary to combat influenza and other viruses.

Treating mice with antibiotics didn't appear to generally weaken their immune systems, though. Antibiotic-treated mice were still able to fight off herpes, because the immune system fights that and some other viruses using a different molecular weapon.

The researchers aren't sure yet which bacteria in the gut are responsible for the virus-defense mechanism. "We know for sure that there are certain bacteria that can't do it," Iwasaki says. *Sphingomonas* bacteria, for instance, don't stimulate the virus-fighting response.

Some *Lactobacillus* bacteria, on the other hand, are known as "friendly" gut bacteria and may play a role in virus defense. Mice treated with the antibiotic neomycin, which wipes out most types of *Lactobacillus* bacteria while leaving *Sphingomonas* bacteria alone, have a hard time fighting the flu. If researchers can figure out which bacteria are responsible, it may be possible to make probiotic compounds that boost virus-fighting capabilities. ■

'Diabetes Belt' cinches the South

Highest rates in areas with greatest obesity and stroke risk

By Nathan Seppa

Two swaths spanning the Deep South and Appalachia have emerged as the U.S. Diabetes Belt.

County-by-county mapping shows that the belt also touches parts of North Carolina, Virginia, Florida, Texas, Arkansas, Ohio and Pennsylvania, researchers at the Centers for Disease Control and Prevention report in the April *American Journal of Preventive Medicine*. High-diabetes pockets also crop up in Oklahoma, Michigan, Arizona, the Dakotas and elsewhere. The data do not distinguish between types of diabetes, but nationally more than 90 percent of diabetes cases are type 2, or adult-onset diabetes.

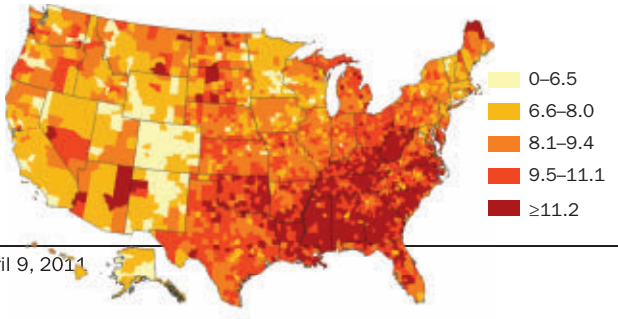
The new map overlaps considerably with the "stroke belt"; the conditions have similar risk factors. Obesity, a sedentary lifestyle and the proportion of the population that is African-American are all higher than average in the Diabetes Belt, says study coauthor Lawrence Barker of the CDC. The area also has below-average education levels.

"It's really important from a public health perspective for counties and regions to recognize the health problems for which they are at particular risk," says endocrinologist Judith Fradkin of the National Institute of Diabetes and Digestive and Kidney Diseases in Bethesda, Md. Mapping the belt will help public health officials target communities for programs to curb the disease.

Diabetes Belt

Dark red portions of this county-by-county map show that high rates of diabetes are common in the South and in Appalachia. Researchers hope that a defined diabetes belt will help public health officials target areas for intervention.

Percentage of adults diagnosed with diabetes, 2007



CDC

Genes & Cells

510 segments — DNA in macaques, mice and chimps but missing in humans

210 segments — Duplicated DNA in humans compared with other primates

Computer chips wired with wetware

Experiments could lead to ways of melding mind and machine

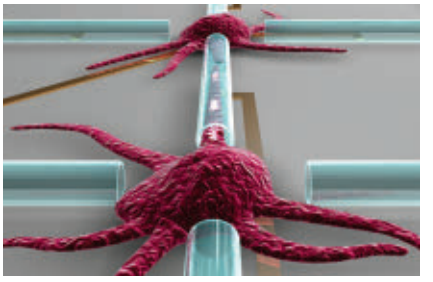
By Rachel Ehrenberg

Nerve cell tendrils readily thread their way through tiny semiconductor tubes, forming a crisscrossed network like vines twining toward the sun, scientists have found. Understanding how offshoots from nascent mouse nerve cells explore the specially designed tubes could lead to tricks for studying nervous system diseases or testing the effects of potential drugs. Such a system may even bring researchers closer to brain-computer interfaces that seamlessly integrate artificial limbs or other prosthetic devices.

"This is quite innovative and interesting," says nanomaterials expert Nicholas Kotov of the University of Michigan in Ann Arbor. "There is a great need for interfaces between electronic and neuronal tissues."

To lay the groundwork for a nerve-electronic hybrid, graduate student Minrui Yu of the University of Wisconsin–Madison and his colleagues created tubes of layered silicon and germanium, materials that can insulate a nerve cell's electric signals. The tubes were various sizes and shapes and were big enough for a nerve cell's extensions to crawl through, but too small for the cell's main body to get inside.

When the team seeded areas outside the tubes with mouse nerve cells, the cells sent threadlike projections into the tubes, even curving along the inner edge of the tunnel entrance, the researchers report in an upcoming *ACS Nano*.



Mouse nerve cells (purple) extend projections through specially designed semiconductor tubes in this illustration.

M. YU

At this stage, the team has established that nerve cells are game for exploring the tiny tubes, which seem to be biologically friendly, and that the cell extensions will follow the network to link up physically. But it isn't clear if the nerves are talking to each other, sending signals the way they do in the body. Future work aims to get voltage sensors and other devices into the tubes so researchers can eavesdrop on the cells.

Defining humans by what's lacking

DNA lost to evolution created some traits in the naked ape

By Tina Hesman Saey

In evolution as on reality TV, sometimes the biggest loser is a winner.

Losing chunks of DNA may have enabled humans to develop bigger brains and other distinctive traits, Stanford researchers David Kingsley, Gill Bejerano and their colleagues report in the March 10 *Nature*. The study is the latest attempt to find genetic factors that make humans human. Previous work focused on searching for genes unique to humans, but the new study turns that approach on its head by looking for pages redacted from the human genetic instruction book.

Humans lack at least 510 chunks of DNA that chimps, macaques and mice all seem to share. Most are also missing from Neandertals, suggesting that the pieces were lost sometime between 500,000 and 6 million years ago.

Only one of the missing bits contained an actual gene. The rest of the absent genetic instructions may be important switches for turning on genes. Such switches, known as enhancers, can be located far from a gene but still govern when and where the gene is flipped on during development.

Humans and chimps have roughly the same set of genes, yet have clear physical and behavioral differences. Some scientists have reasoned that changing the way genes are used — by turning a gene on or off in a particular tissue or during a phase of development — may be a way to evolve new characteristics, such as the bigger brains possessed by people.

Because most of the missing chunks of DNA don't contain genes, it is difficult to say exactly what the pieces are supposed to do. The Stanford team used "a very clever computational analysis" to tease out a couple of pieces of DNA that might have clear-cut functions, says David Haussler, a Howard Hughes Medical Institute investigator at the University of California, Santa Cruz.

One piece enhances the activity of a gene that controls production of facial sensory whiskers and small spines on the penises of both chimps and mice. Since humans don't have the enhancer, the gene is not turned on, and sensory whiskers and penile spines fail to develop.

In some mammals, penile spines are prominent and may help males achieve ejaculation quickly. "The key to reproductive success is impregnation, and the faster you can achieve that, the better," says Owen Lovejoy, a biological anthropologist at Kent State University in Ohio. But even though the loss of the spines makes copulation last longer, it hasn't hurt the reproductive success of humans, he says. Longer copulation times may help cement bonds between mating partners — a possible key to humans' evolutionary success, Lovejoy says.

Atom & Cosmos

"The Hubble constant is the first and most important number in cosmology." —MICHAEL TURNER

Further evidence for dark energy

More precise measurements rule out alternative proposal

By Ron Cowen

New evidence bolsters the case for a bizarre form of energy that is uniformly accelerating the expansion of the universe. The new study, which measures the present-day expansion of the universe to unprecedented accuracy, refutes one alternative to the idea of dark energy. The work also suggests that the cosmos may be slightly older than previously calculated.

A team of astronomers used the Hubble Space Telescope's new infrared camera to refine the Hubble constant — a number that indicates the current rate at which galaxies are receding from one another due to cosmic expansion. By precisely measuring the distance to various celestial objects and then gauging the speed at which they are receding from each other, the team derived a Hubble constant of 73.8 kilometers per second per megaparsec. That means that for every million parsecs (3.26 million light-years) separating two distant galaxies, they move apart 73.8 kilometers per second faster.

Precisely measuring the distance to the galaxy NGC 5584 helped astronomers refine the universe's expansion rate.

The value has an uncertainty of only 3.3 percent, Adam Riess of Johns Hopkins University and the Space Telescope Science Institute in Baltimore and his colleagues report in the April 1 *Astrophysical Journal* — about 30 percent better than the team's previous estimate (*SN Online: 5/5/08*).

"The Hubble constant is the first and most important number in cosmology," says Michael Turner of the University of Chicago. "It is hard to measure accurately. Any improvement — and this is a real improvement — has broad implications."

Although the Hubble constant measures only the current rate of cosmic expansion, given certain assumptions the new value implies that the universe is about 75 million years older than the previous estimate of 13.75 billion years.

Obtaining a precise value of the Hubble constant also places new restrictions on one alternative to "dark energy" as the driving force behind accelerated cosmic expansion, Riess says. In the alternative scenario, Earth and its environs would sit at the center of a vast void a few billion light-years across (*SN: 6/7/08, p. 12*). That configuration would produce an optical illusion making it appear as if the universe's expansion is accelerating.

But such a setup would require a significantly lower Hubble constant than the one Riess and his colleagues have now measured to high precision. Previous measurements of the constant were already at odds with the void model, but the added precision refutes the model conclusively, Riess says.

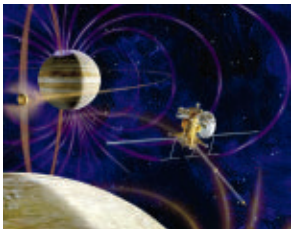
NASA's planetary science to-do list

Panel identifies Mars life probe as top mission for funding

By Ron Cowen

The search for life in the solar system tops the wish list of a panel of space scientists convened by the National Research Council. Mindful of shrinking budgets, the panel has issued hard-nosed recommendations that identify which planetary science missions NASA should fly in the decade that begins in 2013. Even some top-rated missions should be either deferred or canceled outright if their estimated costs can't be significantly cut, the panel says in a report released March 7.

Among big missions, the panel says, NASA should give highest priority to the Mars Astrobiology Explorer-Cacher. The project would be the first of three missions designed to collect and return martian samples for analysis of any evidence of life. But the panel recommends that the mission go forward only if NASA's cost can be limited to $2.5 billion — $1 billion less than the project's estimated price tag in fiscal year 2015 dollars (adjusted for inflation). The European Space Agency and NASA, which would jointly run the mission, should work together to reduce the high cost, the report suggests.



The Jupiter Europa Orbiter, illustrated here, should be funded only if costs can be cut, a panel recommends.

NASA's Jupiter Europa Orbiter also received a nod from the panel, which ranked the mission as the second-highest priority among large projects. The craft would carry a suite of instruments to determine if Jupiter's moon Europa has an ocean — a possible haven for life — buried beneath its icy surface, as many scientists suspect. But the panel says the mission should fly only if the project's current estimated cost of $4.7 billion is reduced and if NASA increases its planetary science budget.

FROM TOP: NASA, ESA, A. RIESS/STSCI AND JHU, L. MACRI/TEXAS A&M UNIV., HUBBLE HERITAGE TEAM/STSCI/AURA; JPL/NASA

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Backup bees

Luring and taming wild pollinators for help on the farm

By Susan Milius

Farms of the future could offer some strange sights, and California isn't a bad place to go searching for them. On the edge of a yet-to-be-planted field northwest of Bakersfield, for example, stands what looks like a white clothes closet that has run away from home.

It's a bee lock. Instead of keeping air from escaping, the way an air lock on a submarine or space station does, this box will prevent bees from zipping out of a five-acre mesh tent, explained pollination biologist Gordon Wardell of Paramount Farming during a tour last winter.

At the time of the tour, the tent was under construction, with rows of sturdy poles marching away from the bee lock under swoops of fine gray mesh. But by springtime, mesh will enclose the entire field. Red, yellow and blue nesting boxes will dangle from the poles in an experiment in raising bees that may one day pollinate some of Paramount's thousands of acres of almond trees.

Wardell will not be rearing honeybees, the mainstay of farmers for centuries. Instead, he hopes to create a workforce of tens of thousands of blue orchard bees, species *Osmia lignaria*. These small, dark, mild-mannered creatures with a vest of white fuzz have no interest in making honey or joining in colonies the way honeybees do. But blue orchard bees do visit almond trees, and as a female collects pollen for her eggs, she inadvertently transfers some of it from flower to flower. Wardell hopes the blue orchard bees will serve as a backup, or maybe a

An experiment in California aims to see if blue orchard bees can become commercial almond pollinators. The bees, which don't form hives like honeybees, may live in nesting boxes (one shown).

COURTESY OF PARAMOUNT FARMING

partner, to the increasingly expensive and beleaguered honeybee pollinator. The blue orchard bees, he says, could be the farm's "insurance."

In days when honeybees face increasing threats from diseases and pesticide-intensive farming, interest is growing in such "insurance" pollinators. The blue orchard bees are just one example of an alternative to honeybee pollination on the buzzing edge of research.

Biologists are finding that free-ranging wild pollinators dropping by certain farms for lunch can deliver enough pollen to render honeybees there unnecessary. Other pollination researchers, including Wardell, are bee-deep in devising new ways to domesticate wild insects for managed pollination on farms. Rearing a new kind of six-legged worker requires pioneering on all levels, from basic physiology to nest decoration.

But Wardell and other hard-core optimists are getting to work. Standing in his partly unpacked lab across from the future tent, he points to a whiteboard with a list of problems he needs to solve before blue orchard bees can become regular farming participants. "There's no doubt in my mind it can be done," he says.

Bees in one basket

California's almonds have good-news, bad-news pollination. The remarkable honeybee is able to sustain a vast industry, but that means a vast industry has come to rest on a single insect.

While some of the world's most important food plants — such as corn — can fertilize themselves, most almond flowers can't. And while corn also gets delivery help from wind, the pollen of the almond flower isn't wind-friendly.

So the United States' whole $2-billion-plus-a-year almond-growing enterprise depends on animal couriers. And almonds are not alone. Crops that account for 35 percent of food production worldwide, including apples, cherries, coffee, mangoes, tomatoes, on down to zucchini, rely to various degrees on animals. Not only do such plants need insects, but they are needed in mind-boggling numbers.

Wardell started his winter tour of the almond world by driving away from Bakersfield through blue-gray fog. Trees lined the highway in eerie, repetitive ranks. Each row flicked by the truck window with the same spacing and same height. After miles, a sibling domain of trees planted at a different time and thus of a different height abruptly took over. The new trees repeated and repeated.

In spring, the almond trees among these orchard regiments will fluff into clouds of blossoms with just a few weeks to attract insect go-betweens. As the pollination czar for Paramount Farming, Wardell contracts with commercial beekeepers to rent 90,000 honeybee hives, which are deployed one or two per acre.

About 1.5 million bee colonies, mostly from out of state, will converge on California's almond fields. And after the almond petals fall, beekeepers will send their colonies on to the next assignment, as another crop's season begins.

But honeybees are beset by an increasing number of menaces. *Varroa destructor* mites and *Nosema ceranae* gut parasites can weaken and kill colonies. Since 2006 the still-unexplained colony collapse disorder has been striking otherwise healthy hives and causing most of the workers to vanish over the course of a few weeks (*SN: 6/19/10, p. 15*). And like other migrant farmworkers, honeybees face risks from exposure to pesticides as well as from the stress of a nomadic life. With all these troubles, a new generation of large-scale beekeepers hasn't replaced all the retirees in this increasingly uncertain industry.

Today's nationwide supply of movable honeybee hives, at 2 million hives or somewhat more, is only half what it was in the mid-1940s, says Eric Mader of the Xerces Society, an insect-focused wildlife conservation group in Portland, Ore. Yet the U.S. acreage needing pollination roughly doubled during the same time.

"The honeybee is not about to go extinct," Mader says, "but we are well positioned to see rising food prices."

Relying on just one species for the majority of crop pollination is risky, warns Rachael Winfree of Rutgers University in New Brunswick, N.J. Though worldwide production of pollinated crops hasn't yet declined, some emerging pest or disease that slams honeybees could put a lot of beloved foods at risk. "We're putting all our eggs in one basket," she says.

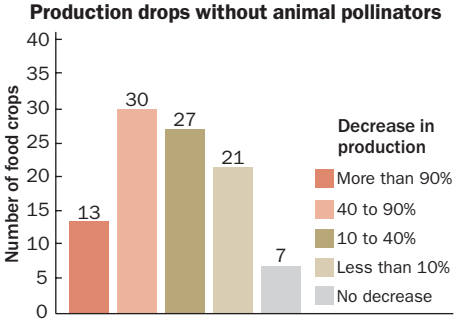
Wild side

Thankfully, honeybees are hardly the only pollinators on the planet. Many of the world's 18,000 or so types of non-honeybee bees visit crops. And creatures other than bees stop by farm fields too, including little flying midges that pollinate the species of *Theobroma* that provides the world with chocolate. So as concern over honeybees grows, so does

Animals wanted A recent worldwide analysis of crops showed that the absence of animal pollinators — mostly bees, but also birds and flies — could greatly reduce the production of a number of valuable foods. SOURCE: A.-M. KLEIN *ET AL/PROC. OF THE ROYAL SOCIETY B* 2007

Decreases in production for certain crops in the absence of animal pollinators

More than 90%	40 to 90%	10 to 40%	Less than 10%	No decrease
Cantaloupe	Apple	Eggplant	Lemon	Chickpeas
Cocoa	Almond	Coffee	Papaya	Grapes
Pumpkin	Buckwheat	Soybean	Peanut	Lentils
Macadamia	Cucumber	Coconut	Safflower	Olives
Watermelon	Mango	Strawberry	String bean	Pepper (seasoning)



Backup nominees

As the honeybee faces increasing threats, researchers are looking for other insects that may share some of the pollination burden. The species below are some of the potential pollinators.

Alfalfa leafcutting bee Introduced from Europe and the Middle East, this bee (*Megachile rotundata*) has been managed longest in the United States after the honeybee. Beyond alfalfa, farmers use it to pollinate blueberries, cranberries and some veggies.

Blue orchard bee Native to North America, this solitary bee (*Osmia lignaria*) has a similar life cycle and nesting style to the alfalfa leafcutting bee. Blue orchard bees have been used commercially in the United States since the 1990s for cherries, almonds and other crops.

Hornfaced bee A relative of the blue orchard bee, the hornfaced bee (*Osmia cornifrons*) was imported from Japan in the 1970s. Though used mostly for fruiting trees, it has shown promise as a blueberry pollinator.

Syrphid flies Often mistaken for bees, flies in this group visit wild flowers to get nectar. Though not commercialized, syrphid flies may contribute to crop pollination during their typical wild wanderings.

Bluebottle fly These flies (*Calliphora vomitoria*) resemble the housefly and are sold commercially for pollination of crops including carrots, broccoli, lettuce and canola. Bluebottle flies adapt well to caged life.

interest in what wildlings are dropping in, with no rental charges.

"Most growers don't know whether they need honeybees or not," Winfree says. A pitiful crop could result not just from a lack of honeybees, but from mistimed pesticide or fertilizer application or a myriad other mishaps of agriculture.

While checking the need for honeybees in watermelon fields in New Jersey and Pennsylvania, Winfree and her colleagues found 46 native bee species visiting the fruit's flowers. Using a computer simulation to analyze bee visitors and the pollen grains they delivered, Winfree found that wild bees could have fully pollinated the crop by themselves in 21 out of 23 farms.

Her study doesn't mean that honeybees aren't necessary, she says. "They're very necessary. They're just not necessary for all types of farm systems." These watermelon farms were small compared with California agriculture, and they may have gotten a boost from shrubby refuges where wild species abound.

In the search for wild pollinators, pumpkin and squash growers have the advantage of their own private bee species. Females of *Peponapis* and *Xenoglossa* species, nicknamed squash bees, collect pollen as baby food only from squashes and their closest relatives, explains pollination biologist T'ai Roulston of the University of Virginia's Blandy Experimental Farm in Boyce.

Out of 20 farms growing pumpkins in Virginia and Maryland, at least 13 received full-service wild pollination, Roulston and a colleague reported in 2009. And in an ongoing study in Pennsylvania, nine out of 11 farms had enough hardworking squash bees in 2010 to make renting honeybees unnecessary, says horticulturist Alex Surcică of the Penn State Cooperative Extension in Franklin County.

To help farmers determine if they have enough squash bees, Surcică wants to develop a census technique that takes advantage of a squash bee's nighttime habits. Before squash or pumpkin flowers close up around midday, bees settle into a floral sleeping bag for the night. Surcică thinks farmers could estimate the bee population at the beginning of the season by collecting spent blooms at night and seeing how many of the bees emerge in the morning. Too few, and it's time to scramble for honeybee rentals.

A taming task

Growers who really do need an alternative honeybee — a pollinator species they can summon in vast numbers or deploy in a predictable way — are tackling the domestication of wild insects.

Steve Hanlin and Sharon McClurg have no choice but to rely on domesticated pollinators. As entomologists at the U.S. Department of Agriculture's North Central Regional Plant Introduction Station in Ames, Iowa, the researchers have learned some practical lessons about honeybee alternatives.

The station maintains breeding lines of important plants from corn to medicinal *Echinacea*. And when scientists need fresh seed from a particular line, Hanlin and McClurg step in to provide pollinators. Mingling pollen across breeding lines would defeat the purpose of preservation, so the rule is pollination in a cage; no wild wanderers here. The researchers work not just with honeybees but also with five other pollinators, and are looking for more. Bonus points go to insects that don't sting the people who have to work caged too.

Flies don't sting, but their place in the farming world is one with an asterisk. Hanlin and McClurg have found that houseflies and bluebottle flies do quite well on broad, simple flower heads, such as carrot flowers, but not as well with complex blooms.

Also there's the rearing. Bluebottle larvae normally feast on rotting meat, and even a special meatless diet made the building stink. "Like a bad diaper pail," McClurg says.

When Hanlin had to collect the young flies from their broth, he wore a face mask and chewed peppermint gum for olfactory distraction. He has concluded that raising the flies in-house is not financially worthwhile, at least not at a small scale. His most important

FROM TOP: PEGGY GREB; COURTESY OF PARAMOUNT FARMING; BEATRIZ MOISSET/WIKIMEDIA COMMONS; WHITNEY CRANSHAW/COLORADO STATE UNIV., BUGWOOD.ORG; SUSAN ELLIS/BUGWOOD.ORG

discovery: a company in Idaho that raises bluebottle flies to sell.

Raising bees isn't so hard on the nose but has its tough moments too. The alfalfa leafcutting bee, one of the most intensively managed among alternative pollinators, for example, refuses to stick out its tongue when its antennae are tickled with sweets. And that quirk may force a change in the way researchers study how farmers could make nesting sites more alluring.

Unlike honeybees, many alternative pollinators don't nest in colonies, so farmers can't haul an existing hive into a field and be done with nest location. Each solitary bee arrives in a field nestless and chooses a home, possibly where the farmer wants the bee but quite possibly not. To keep alfalfa leafcutting bees and other helpers near a crop, a farmer needs to lure them to a prefab home, so the farmer has to know what the bees like.

A standard test for honeybee preferences relies on the bees' reflexive response when a bit of sucrose is touched to their antennae. But when Cory Stanley of Utah State University in Logan and Theresa Pitts-Singer of the Department of Agriculture's bee lab in Logan tried to design a similar test for alfalfa bees, the insects' tongues wouldn't budge.

A previously unrecognized feature of at least some solitary bees is this difference in the proboscis reflex, the researchers reported last year in the *Journal of the Kansas Entomological Society*. Now researchers are developing other tests that might reveal the types of odors that could attract bees to a farmer's housing offerings.

Another challenge of domesticating pollinators also comes from their non-honeybee biology. Individual honeybees may not live long as adults, but new workers grow into tasks as older bees falter. With the right conditions, the pollination fleet can keep flying most of the year. For alfalfa leafcutting bees, blue orchard bees and other non-colony-dwelling species, however, six weeks or so of flight-worthy adult life means just six weeks or so of pollination, for the whole year. The farmer needs to get bees in the air when a crop is in bloom. The rest of the year, bees hunker in their nests.

During their short flying period, female blue orchard bees need to mate with males and then lay a series of eggs, packing enough pollen into a nest to sustain the youngsters until the next year. Eggs hatch, larvae grow into adults, and adults lower their metabolism for a long winter's wait. Yet despite that slowdown, blue orchard bees lose substantial weight, Jordi Bosch of the Autonomous University of Barcelona and his colleagues reported in December in the *Journal of Insect Physiology*. Farmers have to make sure the time-pressured females can get enough pollen to adequately provision their nests. Too few flowers for the number of bees loose on the farm may leave youngsters underfed.

Back at Paramount, Wardell already knows his blue orchard bees like a purple wildflower called *Phacelia*, and he'll provide a waving field of it in his rearing tent, and a twin rearing tent nearby. For nests, the red, yellow and blue boxes will hold bundles of strawlike tubes, open end out, as well as blocks with rows of bee-diameter tunnels. Wardell is even experimenting with marks on the faces of the nesting boxes to see if bees find their nests faster with a landmark.

To test whether raising blue orchard bees would even be worthwhile for Paramount, though, Wardell is going to test the bees outside the tents, in the actual almond groves. He'll set the insects out to see whether pollination improves and how they get along with honeybees during the frenzy of pollen collecting in an ocean of almond flowers.

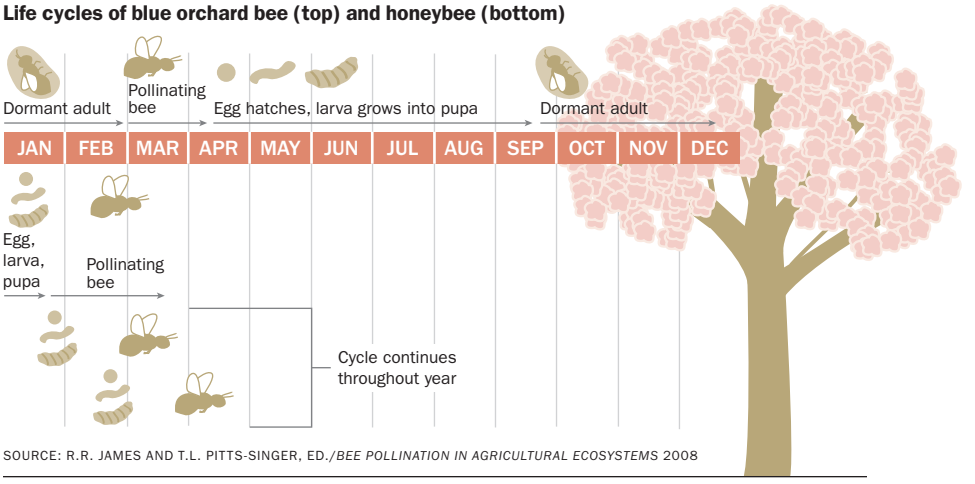
After envisioning a field abuzz, it's time for an almond tourist to meet the blue orchard bees. Wardell leads the way into a roomy warehouse, where in the far corner stands what looks like a big, silvery food cooler behind the scenes in some restaurant. It *is* a big food cooler, he says.

As the heavy door eases open, Wardell points out a container of what from a distance look like miniature misshapen peanuts. Actually they're blue orchard bees still robed in their protective winter covering, a netting as delicate as a silk stocking. Wardell peels the covering off one little bee, who stirs groggily in protest. "A male," Wardell says. "Look at the mustache."

As well as the fuzzy vest, the little fellow has a tiny wisp of white fuzz on his face. If his is the face of tomorrow, then the future of pollination is pretty cute. ■

A tale of two bees A blue orchard bee typically pollinates for only about six weeks, after developing and hunkering down in its nest. Each honeybee doesn't have a long pollination period either, but bees in a colony reach adulthood at different times, meaning new pollinators replace old ones and pollination can continue throughout the year. Farmers who hope to rely on blue orchard bees need to stir the bees from dormancy just as the crop is blooming—or miss a crucial window.

Life cycles of blue orchard bee (top) and honeybee (bottom)



SOURCE: R.R. JAMES AND T.L. PITTS-SINGER, ED./*BEE POLLINATION IN AGRICULTURAL ECOSYSTEMS* 2008

E. FELICIANO

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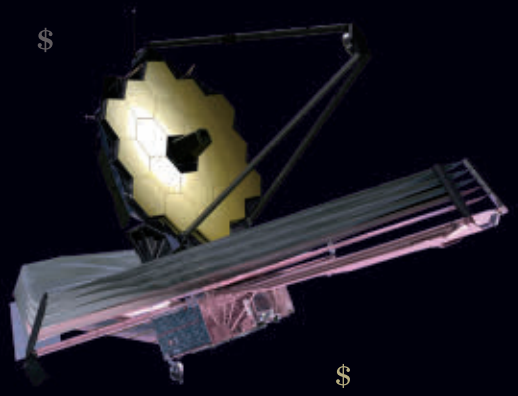
■ For a guide to managing alternative pollinators, visit http://bit.ly/hdT3vn



Star cents

How the cost of NASA's next big space telescope skyrocketed

By Ron Cowen

It will be the largest telescope ever launched into space, with a mirror that has about six times the light collecting area of Hubble's. When the James Webb Space Telescope flies later this decade, its unparalleled infrared vision will record the flickers of the first stars and galaxies to light up the universe, in a mission that promises to rewrite astronomy textbooks. But for now, the 6.5-ton observatory has become a financial albatross for NASA.

An independent investigative panel reported in November that the telescope, known by the acronym JWST, is running a minimum of $1.4 billion over budget (*SN Online: 11/11/10*). That overrun, which would bring the total cost of building the telescope to at least $6.5 billion, may lead to the cancellation of another highly touted NASA mission to probe the nature of dark energy and extrasolar planets.

Convened at the request of U.S. Senator Barbara Mikulski, the panel found that managers for the James Webb project, based at NASA's Goddard Space Flight Center in Greenbelt, Md., consistently underestimated the cost of the telescope. Lack of money in one year forced scheduled work to be deferred to the next, a practice that kept contractors on the payroll longer and ended up doubling or tripling the cost of their labor. Poor cost management and reporting practices went unchallenged by NASA staff in Washington, D.C., reflecting "the lack of an effective cost and programmatic analysis capability at headquarters," the panel concluded.

But the problem appears to go beyond mismanagement. Interviews with current and recently retired NASA officials, astronomers and the Government Accountability Office reveal a culture of deception when it comes to estimating the cost of large NASA missions. Given the limited supply of money for new projects, those with proposals are encouraged to underestimate the true price tag, and those who question the estimates are ignored or reprimanded.

"It's a game of you lie and I'll swear to it," says Michael Griffin, NASA's administrator from April 2005 to January 2009. "The whole community talks itself into unrealistic cost estimates.... Everyone knows it's wrong. Every engineer knows it's utterly without foundation, but engineers aren't making the decisions."

Big agencies such as NASA, says Griffin, need to find a way to carry out major new endeavors without disrupting the whole system: "How can an executive branch of a democratic government do a bold new thing like JWST when the competition for the dollar is so intense that people with otherwise good will and good character will basically lie to get what they want?"

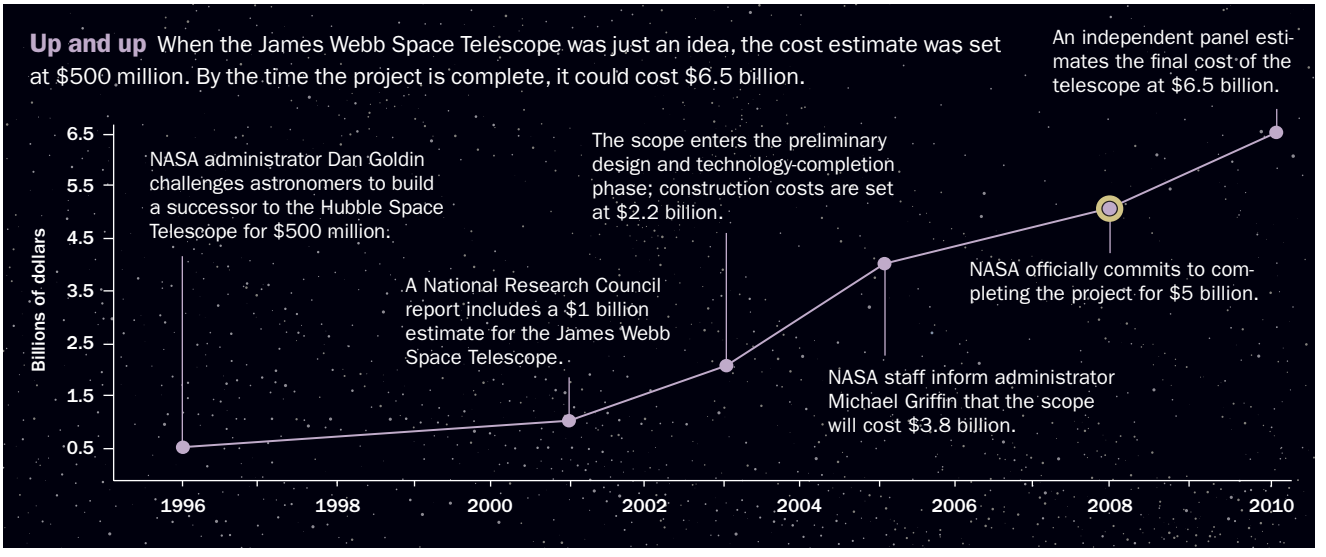
Jon Morse, director of NASA's astrophysics division, based in Washington, D.C., which until recently oversaw the telescope, says that the problems are not about any one person or individual. "This was an agency failure in cost performance and government and contractor coordination," he says. "NASA is disappointed to have not maintained the level of cost control the agency has been striving to achieve on all of its projects."

Genesis of a problem

Some of the lowballing on JWST costs goes back more than a decade, when the project was still just an idea.

In the mid-1990s, Alan Dressler of the Carnegie Observatories in Pasadena, Calif., chaired a committee charged with recommending a successor to the Hubble Space Telescope. He and his colleagues settled on a 4-meter infrared space observatory that could look further back in time and space than Hubble's 2.4-meter mirror, perhaps to find the most distant galaxies in the universe and trace their origins. Dressler's panel believed that a 4-meter telescope was the biggest that could be constructed on a budget limited to about $500 million.

In the fall of 1995, Dressler briefed NASA's administrator at the time, Dan Goldin, about the report. In January 1996, Goldin gave a speech in San Antonio at a meeting of the American Astronomical Society, exhorting astronomers to dream bigger. He mentioned Dressler by name, who was in the front row of the audience, and challenged him to make Hubble's successor twice



Up and up When the James Webb Space Telescope was just an idea, the cost estimate was set at $500 million. By the time the project is complete, it could cost $6.5 billion.

OPPOSITE PAGE: NASA; THIS PAGE: JANEL KILEY; STAR BACKGROUND: TIMOPH/ISTOCKPHOTO

as big — an 8-meter mirror instead of a 4-meter one. At that time, the project was still in its infancy, so no hard-and-fast cost estimate was set. But Goldin claimed that the cost could still be capped at about $500 million. For comparison, Hubble cost about $3 billion in 1996 dollars to build, says Craig Tupper, director of NASA's resources management division, which formulates the space agency's science budget.

To many experienced telescope builders Goldin's suggested price tag seemed a fantasy. "No sophisticated person would walk away believing that estimate," says Jerry Nelson of the University of California, Santa Cruz, who designed the twin 10-meter Keck telescopes atop Hawaii's Mauna Kea.

But the remarks delivered by Goldin, who declined to comment for this story, received a standing ovation.

"That was a pretty strong vote of confidence that the astronomy community really wanted us to do that project," says Nobel laureate and JWST project scientist John Mather of Goddard. NASA started allocating study funds through Goddard, which became the designated center for overseeing design and construction of the telescope and testing its components.

Goldin's challenge to build a bigger telescope on the cheap, combined with the astronomy community's eager acceptance, led to the current funding dilemma, says astronomer Charles Beichman of the California Institute of Technology and NASA's Jet Propulsion Laboratory in Pasadena. "Our eyes and stomachs were so big and our wallets were so small that we now have the biggest subprime mortgage loan crisis, the biggest stomachache that the community can have."

Rising costs

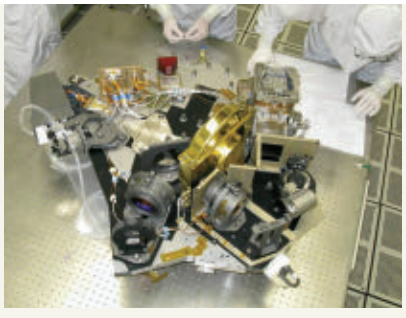
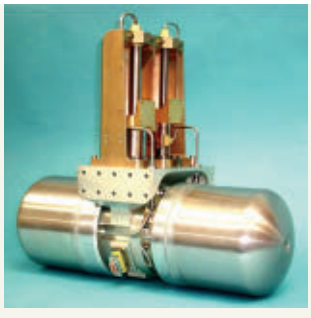
In 2001, a price of $1 billion was quoted in a National Research Council report. Though it's not clear where the value came from, many within the astronomy community came to think of it as an official cost estimate.

"NASA gave us a cost for it that no one in the community believed," says cosmologist Michael Turner of the University of Chicago, who served on the panel that prepared the council's report. No other budget estimate existed, he says.

Around that time several astronomers told NASA officials that the project's cost may have been seriously underestimated. "I got whacked on the head," for questioning the cost of JWST a decade ago, recalls one astronomer, who asked to remain anonymous. "They do punish you for questioning this sort of thing."

Mather acknowledges that "a lot of people from outside the project looked at us and said that this can't possibly be right." But the team at Goddard had a strategy for keeping the price down, he says. The team had been working well in advance on the novel technologies needed for the telescope, including a 22-meter-long sun shield, a segmented gold-coated beryllium mirror that would unfurl in space and a cryogenic system.

The hope was that those early


FROM LEFT: MIRROR: DAVID HIGGINBOTHAM, EMMETT GIVEN, MSFC/NASA; NIRCAM: LOCKHEED MARTIN; CRYOCOOLER: NORTHROP GRUMMAN; SUN SHIELD: NORTHROP GRUMMAN; ISIM: CHRIS GUNN, GSFC/NASA

In the details

Long before the proposed James Webb Space Telescope got the go-ahead, researchers began developing new technology needed to carry out the mission.

Mirror, mirror The James Webb Space Telescope's primary mirror, totaling 6.5 meters across, will have about six times the collecting area of the Hubble Space Telescope's mirror, allowing for improved sensitivity. Because it is so large, the mirror had to be designed as 18 segments (six shown above). This design allows the mirror to fold, so it can be carried to space in a rocket about 5 meters wide. Made of beryllium, a strong yet lightweight element, the mirror's segments are coated in a thin gold film to maximize reflectivity. The mirror will unfurl once in space and actuators will adjust the segments to achieve the ideal focus for recording distant galaxies at infrared wavelengths.

Webb spies The telescope's Near-Infrared Camera (second from left) will use arrays made of mercury-cadmium-telluride to detect light in the 0.6- to 5-micrometer wavelength range, which includes yellow light, red light and a range beyond what the human eye can see. These wavelengths should reveal early star and galaxy formation, star populations in nearby galaxies and, astronomers hope, signs of dark matter. The camera also helps sense when the primary mirror needs adjustment to correct for aberrations in the optical system. The Mid-Infrared Instrument will detect wavelengths of light from 5 to more than 28 micrometers.

So cool Anything hot — including a telescope itself — can give off infrared light, so scientists need to keep the telescope and its scientific instruments cool. The mirrors will be kept at an average of –228° Celsius. A special cryocooler (middle), which achieves cooling by circulating certain gases, was designed by Northrop Grumman specifically for the telescope's Mid-Infrared Instrument, which will operate close to –266° Celsius, 7 degrees above absolute zero.

Blocking the sun In order to block any heat coming from the sun, a tennis-court–sized parasol will unfurl to shade the telescope once it gets to space. This "sun shield" (second from right) is made of five layers, each less than a millimeter thick, of

expenditures would reduce the overall cost of building the telescope, because the cost of labor and materials increases over time. But in the end, the early investment in new technology didn't overcome the size and complexity of the project, Mather says. Costs kept rising — even though NASA decided to reduce the mirror diameter from 8 meters to 6.5 meters.

"The project went through a billion dollars at the speed of sound," Turner says.

By the end of 2001, Goldin had departed as administrator, and in the following years, the Space Shuttle Columbia disaster turned the agency's attention away from missions like JWST, Turner notes. In 2003, the project had entered what the agency calls "Phase B" — the preliminary design and technology-completion phase. NASA's estimate for construction was set at $2.2 billion.

Griffin says that the week he became administrator, in April 2005, NASA staff informed him that the $2.2 billion estimate had been lowballed and that the scope was going to cost an additional $1.6 billion. The extra money was supposed to take the telescope through launch, set for 2011, and the first six months of operation. The additional dollars would come from shifting money internally, among projects in the agency's astrophysics division.

"I'll tell you straight out, I knew that wasn't enough," he says. "We all knew it wasn't enough."

After an investigation of rising costs, the Government Accountability Office issued a report in July 2006 warning that the project did not have sufficient funds for dealing with the inevitable problems that crop up as technologies are developed. The underfunding, the report said, could put the telescope "at risk of further cost growth and schedule slippage."

In an attempt to prevent future funding crises, Griffin announced in March 2006 that major projects like JWST would have additional contingency money added to their budgets to cushion unexpected expenses.

But Griffin says that his associate administrator for science at the time, Alan Stern, did not put that extra money in JWST's proposed budget for fiscal year 2009, the first time the funds could have been added. Griffin adds that he did not become aware that the money wasn't requested until after Stern departed in March 2008. Scott Pace, who was then NASA's associate administrator for program analysis and evaluation, confirms that the money was not put in the proposed budget.

Stern says he gave the Goddard team all the money it asked for and strongly denies holding any money back from the JWST project.

Uncovering a gap

In July 2008, NASA formally confirmed the James Webb Space Telescope as a project mature enough to have a firm budget for completing construction. Whatever underestimates happened before that time can be wiped clean from the slate, says John Casani of NASA's JPL, who led the investigative panel commissioned by Senator Mikulski. But at confirmation, he notes, the telescope's budget is no longer an estimate but a detailed blueprint — and a clear commitment from NASA — for completing the device at a designated cost.

The Goddard team "went into confirmation with a badly flawed budget; the reserves were inadequate," Casani says. "The first mistake was the wrong budget; the second mistake was that nobody caught it."

At the confirmation in 2008, the team estimated that the project, through its first five years of operation, would cost a total of $4.96 billion. (A further revision between fiscal years 2010 and 2011 added $100 million more to the project, bringing the total cost to just about $5.1 billion.)

The team also said it would spend $450 million on the telescope in 2008, Tupper says. And the money needed in future years, closer to the launch date, was supposed to decline, contrary to the trend for other large space missions. But when the books closed on 2008, the actual expenditures were about $63 million more, Tupper says. By the end of September 2011, the current fiscal year, NASA will have spent about $3.5 billion in total on the telescope, he says.

Casani's panel found that the project had tried to stay within budget by consistently deferring work that was supposed to be done in one fiscal year to the next. People had to be kept on payroll, and inflation made postponed work more costly. The deferred work ended up costing millions more than had it been done on time, the Casani panel concluded.

In 2008, NASA management thought that there was a 70 percent probability that the telescope would launch in June 2014 for a total cost of around $5 billion, Casani and colleagues noted. "In fact, the project had no chance of meeting either the schedule or the budget profile," they wrote in the report.

Panel member Garth Illingworth of the University of California, Santa Cruz says that two committee findings were particularly unsettling. First, although JWST managers at Goddard did a full accounting of potential risks in 2008,

a heat-resistant material called Kapton. The layers are designed and connected so that a small hole in one layer shouldn't affect the other layers. As the telescope orbits about 1.5 million kilometers from Earth, the sun, Earth and moon will remain on one side, blocked by the shield.

Blinded by science
Beyond the Near-Infrared Camera and the Mid-Infrared Instrument, two other science instruments will operate throughout the life of the telescope, which, unlike Hubble, will be too far away to be serviced. The Near-Infrared Spectroscope, which disperses light into its component colors, will allow scientists to simultaneously observe 100 objects. The Tunable Filter Imager can select very specific wavelengths to focus on. All four instruments are housed in the Integrated Science Instrument Module (right).

they failed to ask for funds to deal with those potential problems in the budget presented at confirmation.

"The other thing that really astonished us was the lack of insight from headquarters about the project and what it was doing," Illingworth says. No one was monitoring what was being done or asking why project deadlines hadn't been met and how this might drive up the overall cost, he says.

The Casani panel estimated that the telescope would cost, at minimum, an additional $1.4 billion over NASA's official $5.1 billion estimate — and that assumes launch by 2015 and that it gets $500 million more than currently budgeted between now and the end of next year.

The $1.4 billion overrun "is really the criminal part," Dressler says. He thinks it's reasonable to expect that building JWST would end up costing about $5 billion. But the extra $1.4 billion has accrued because people on the project weren't acknowledging that the work deferred each year was going to add significant costs, Dressler notes.

Lessons for the future

Following the findings and recommendations from the Casani report, NASA has taken the project out of the astrophysics division and appointed Rick Howard as the new senior manager for the telescope. Howard reports directly to the NASA administrator.

During a February 14 press briefing about the president's proposed budget for fiscal year 2012, Howard said it seems unlikely that the telescope will launch before 2016. (And it is unclear where the extra $1.4 billion will come from.)

As of March 16, nine of the 18 mirror segments had been polished, coated and readied for flight, and the other nine will be ready by the end of the year, says Mark Clampin of Goddard. Three of four science instruments will also be ready, but engineers have not yet begun assembling JWST's pieces.

To figure out for itself exactly how much money is required, NASA is conducting a bottom-up review, separate from the Casani panel's estimate.

Regardless of the exact dollar value, astronomers are worried that future astrophysics projects, both on the ground and in space, won't get their start for years because the James Webb telescope has devoured some 40 percent of the astrophysics division's 2010 and 2011 money. The most vulnerable mission appears to be the space-based Wide-Field Infrared Survey Telescope, WFIRST, which would seek the origins of dark energy, the mysterious stuff that is accelerating the expansion of the universe, and hunt for exoplanets. A recent National Research Council report (*SN: 9/11/10, p. 10*) recommended that WFIRST be given highest priority for this decade. Though costs were initially estimated at about $1.6 billion, scientists are trying to modify plans to make WFIRST a $1 billion mission.

"WFIRST is the question mark," says Alan Boss of the Carnegie Institution for Science in Washington, D.C. During a meeting at NASA headquarters in February, he and the rest of the NASA advisory committee on astronomy projects were told that only funding for WFIRST was uncertain. All other projects requested in the council's recent report could be accommodated.

Saul Perlmutter of the University of California, Berkeley, a member of the WFIRST planning team, says no one at NASA has given him guidance on how much he needs to cut the mission's cost, and he is worried that it might not fly.

The same problems encountered with JWST are bound to come up again, says Griffin, unless NASA holds individuals accountable. "As long as nothing bad happens to the people who misrepresent the data, then it's not going to change."

Cristina Chaplain, director of acquisition and sourcing management at the Government Accountability Office in Washington, D.C., agrees, but says people also need to feel free to speak up, without being punished, when there's a problem.

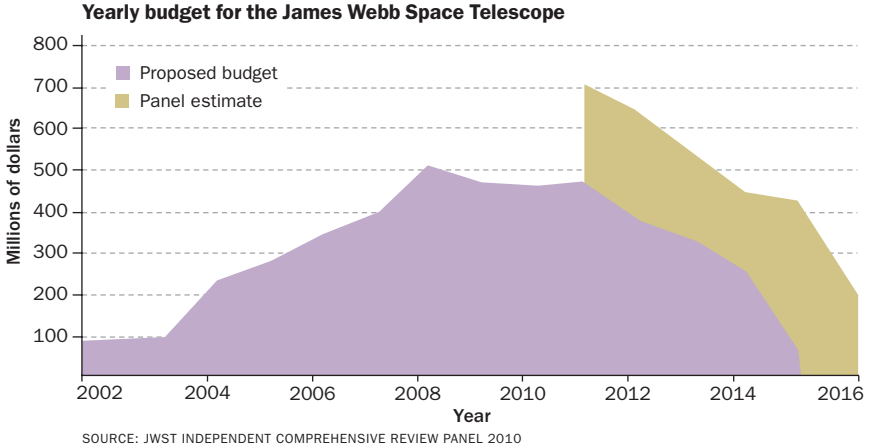
Then again, amnesia about overruns often prevails after a successful launch.

"If you get away with it, everyone praises you as a genius," says Beichman of Caltech. "You won't be remembered as the person who had all the overruns; you'll be remembered as the person who created the successor to Hubble that went on to be the greatest scientific machine of the coming decade."

Hubble had a history of overruns too, but the telescope's astounding images and discoveries are its legacy, not the dollars spent nor its flawed mirror.

"It's like childbirth," Beichman says. "So long as your children turn out well, you're happy as a clam. The pregnancy and the birthing process are simply forgotten." ■

Funding gap An independent panel commissioned by U.S. Senator Barbara Mikulski found in 2010 that the James Webb Space Telescope can't launch before 2015 and will need $1.4 billion more in funding. Work deferred from year to year has driven up the cost, the panel reported.



SOURCE: JWST INDEPENDENT COMPREHENSIVE REVIEW PANEL 2010

Explore more

■ To read the full Casani report: http://1.usa.gov/cMhzJ8

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BBB ACCREDITED BUSINESS

Big fishing yields small fish

Researchers map predator loss and predict unstable oceans

By Janet Raloff

Sharks, billfish, cod, tuna and other fish-eating fish — the sea's equivalents to lions on the Serengeti — dominated the marine world as recently as four decades ago. They culled sick, lame and old animals and kept populations of marine herbivores in check, preventing marine analogs of antelopes from overgrazing their environment.

But the reign of large predators now appears over — probably forever.

Two new studies, presented in February in Washington, D.C., at the annual meeting of the American Association for the Advancement of Science, suggest that the ecologically valuable marine lions are rapidly disappearing. Another pair of related analyses point to physical and chemical changes, driven by Earth's warming climate, that threaten to diminish the maximum size that any species — predator or prey — can attain.

For decades, fisheries biologists have been chronicling the overfishing of large predatory fish by species or region (*SN: 6/4/05, p. 360*). Villy Christensen of the University of British Columbia in Vancouver and his colleagues have now offered the first worldwide analysis of predator loss.

The team identified more than 200 separate snapshots of the marine food web taken from 1880 to 2007, studies that describe and quantify all the constituents of a local or regional marine ecosystem. Together, the research points to a steady, slow loss of roughly 10 percent of the top predator fish in the world's oceans between 1910 and 1970, Christensen reported at the meeting. At that point, fishing fleets began adopting more efficient gear and the loss of predators skyrocketed, he said.

Today, predatory fish exist at one-third of their 1910 abundance. "We see no indication that things are improving," Christensen said. "It's a pretty bleak situation." By midcentury, he predicts, predators will be rare.

But the ocean won't be empty. The loss of big fish has been largely offset, at least in biomass, by an explosion in the abundance of small, prey fish, including everything from anchovies to blennies.

The trend is disturbing, Christensen said, because the species that are disappearing are the ones that people most prefer to eat and the ones that can pre-

A net of herring are pulled from Sitka Sound in Alaska. Researchers report that global fishing efforts have become more intense but yield has stagnated.

vent smaller fish from overrunning and potentially destroying their ecosystems.

Such changes, Christensen said, could have been predicted based on what's known about how ecosystems respond to the culling of predators. But until now "we just haven't had the numbers to show that — certainly not at the global level."

Upping the effort

Fisheries biologist Reg Watson, also of the University of British Columbia, has been acquiring numbers of a different but complementary type. His team has quantified how aggressively fishing has increased since the 1950s.

A steep escalation in the effort that fleets employ, he reported at the AAAS meeting, has allowed them to continue supplying consumers' large and growing demand for predator species against a backdrop of declining stocks.

During the mid-20th century, global harvests totaled about 16 million metric tons per year and came from fishing almost exclusively along coasts. Maps Watson showed at the meeting illustrated that by the 1980s, intensive fishing had exploded into most of the open oceans. Reliance on more efficient gear such as trawlers or helicopter-guided purse seines, which can mine the water of almost all fish within their reach, has boosted the intensity of the effort. By the 1990s, the total global harvest had climbed to roughly 80 million tons per year. Despite steadily increasing effort, Watson says, the catch stagnated in the 1990s — and has yet to improve.

Watson cited 2006 figures indicating that the commercial industry hauled in 76 million tons of seafood, about 7 trillion individuals. This leveling off alongside rising efforts is further evidence that predatory fish are becoming scarcer, he concluded.

Feeling the heat

The real wild card in predicting the future of fisheries is climate change.

Predatory fish eat smaller ones, which in turn feed on tinier ones. Further down this food web are fish that feed on plankton — tiny floating animals and plantlike organisms. These plankton, the base of the living marine world, derive much of their nutrition from organic matter that wells up from the ocean's cold depths.

On the menu Many species that face threats from overfishing are types that people like to eat. As predators disappear, smaller prey species are becoming more common.
SOURCE: V. CHRISTENSEN

Predator species decreasing	Prey species increasing
Cod	Bearded gobies
Grouper	Jellyfish
Swordfish	Sand lances
Atlantic and other halibut	Anchovies
Bluefin and other tuna	Menhaden
	Blennies

In a warmer world, water will become less dense. Heavier rains, projected in and near the tropics, could lead to a freshening of the upper seas. Together, such changes should foster a stratification of ocean layers, with a less salty layer stably topping a saltier one, geochemist Jorge Sarmiento of Princeton University noted at the AAAS meeting. This stratification would make it harder for nutrients to reach the surface, he said.

He compared various projections by five computer programs that attempt to predict ocean features in a changing climate, including a new program under development by his team. When ocean surface temperatures 2 degrees Celsius warmer than today's were fed into the programs, every simulation showed a fall in the production of large plankton, the size that fish eat. Globally, the drop will average 1 or 2 percent, Sarmiento said, although regionally it could hit 16 percent. Fewer large plankton will mean less food for fish, thus limiting their size.

William Cheung of the University of East Anglia in Norwich, England, has fed certain chemical and other features projected by Sarmiento's team into another computer program. It probes global warming's potential impact on more than 5,000 commercial fish stocks, covering 1,060 species.

Cheung's model projects that the ultimate size of most fish might fall by about 10 percent, he reported at the meeting.

Until, that is, he factored in ocean acidification.

Ocean surface waters are already experiencing some acidification, because of increased air concentrations of carbon dioxide (*SN: 3/15/08, p. 170*), a prevalent greenhouse gas. At least some sensitive fish will have to expend substantial energy clearing acid from their bodies, Cheung said, meaning that energy can no longer be devoted to growth. When his analyses accounted for this, predicted drops in fish growth in many regions reached 30 or 40 percent.

"In our model, more than 75 percent of commercial stocks would experience some reduction in body size," Cheung said. And the effects could be widespread, he reported, hitting fish in what are currently some of the ocean's most productive areas.

Warming could stress fish even if levels of chemicals in surface water don't change. In warmer waters, fish move more and breathe faster, which increases their oxygen demand. But owing to the gills' fixed surface area, Sarmiento said, there is a limit to how much extra oxygen the swimmers can take in. He predicts, for this reason and others, that warming will propel some fish to find cooler neighborhoods.

Cheung reported that if waters warm an average of 2 degrees Celsius, more than 50 percent of stocks could be expected to move — by up to 40 kilometers per decade. Some fish may become more costly for fishers to get, while others may shift from one country's territory to another.

Clearly, Christensen said, climate change is going to radically alter the oceans. They'll become less stable chemically even as overfishing is making them less stable ecologically.

Watson agreed. When it comes to fisheries health, "many alarm bells are ringing." ■

Explore more

- For a recent report on the state of the world's fisheries, go to www.fao.org/fishery/sofia/en

FACING PAGE: ALASKA STOCK; THIS PAGE: FISH: ENJOYNZ/ISTOCKPHOTO

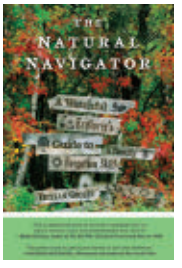
The Natural Navigator: A Watchful Explorer's Guide to a Nearly Forgotten Skill

Tristan Gooley

Before navigation was a science, it was an art — a craft that relied on observing nature's subtle clues and then deducing one's location or the best route to reach a destination. Besides obvious directional clues such as the rising sun or Polaris, the North Star, there are innumerable more subtle signposts. In the Northern Hemisphere, for example, branches of many types of trees, seeking to maximize their exposure to light, grow more horizontally on the sunny southern side than on the shade-soaked northern side.

Gooley, a longtime adventurer who teaches what he calls "natural navigation," has compiled an intriguing trove of tips and tricks from cultures such as the Inuit and Aborigines. As he explains each technique, Gooley reveals the scientific rationale for why it works. For instance, the complex interactions between sun and shade, surface texture, slope, prevailing winds and moisture mean that moss often — but not always — grows on the north side of a tree.

A natural navigator can use all the senses. A whiff of salt breeze can guide a landlubber to the sea as surely as an earthy smell can lead a transoceanic yachtsman to the nearest landmass. And the techniques can be more accurate than modern instruments. While someone using Polaris can determine a path north within 1 degree, compasses point to magnetic north, not true north. GPS equipment is notoriously inaccurate when it comes to finding direction rather than position.



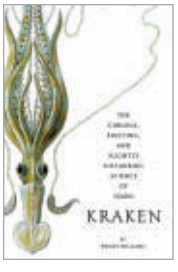
Even for readers who never intend to rely on these tips to find their way through the wilderness, *The Natural Navigator* is a great primer on how the forces of nature affect the landscapes and seascapes that everyone travels through. — *Sid Perkins*

The Experiment, 2011, 304 p., $16.95.

Kraken

Wendy Williams

The great sea beast, with slimy tentacles and a penchant for dragging sailors down into the inky depths, is a common literary figure. And Williams isn't shy about diving into those myths. She launches her survey of cephalopods, a group that includes squid, octopuses and cuttlefish, with a quote from *Pirates of the Caribbean* and a true story — maybe — of squid attack. Williams, though, argues that these strange creatures are much more. They're important to medicine and ecosystems, and apparently quite clever to boot.



Tales of friendly and problem-solving octopuses with names like Truman and Lucky Sucker may help to dispel some of the eerie aura surrounding these sea invertebrates. But Williams also brings readers up to date on modern cephalopod science, including an exploration of the ongoing Humboldt squid invasion of California's Monterey Bay. And how octopuses change color so quickly — that's a topic too fascinating to pass up (hint: It works like a cellular peekaboo game). Most important, perhaps, these animals have also taught humankind a lot about itself. Much of what scientists know today about brain and spinal cells, for instance, came from studies of rice noodle–like neurons that run down the bodies of small squids.

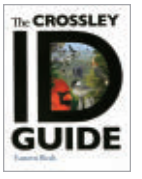
If that sounds like a bit of a hodgepodge, it is. Taken as a whole, *Kraken* amounts to an episodic argument for the coolness of cephalopods. Luckily, Williams' anecdotes and historical forays are fun, and her writing style is ideal for general-interest readers of many ages. — *Daniel Strain*

Abrams Image, 2011, 223 p., $21.95.

Craving Earth

Sera L. Young

Human biology and culture are interwoven in this exploration of pica, the craving to eat clay, dirt, starch and other nonfood substances. *Columbia Univ. Press, 2011, 228 p., $29.50.*



The Crossley ID Guide: Eastern Birds

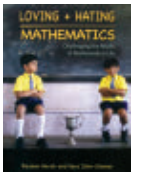
Richard Crossley

This illustrated field guide shows each bird in lifelike scenes using the author's photos. *Princeton Univ. Press, 2011, 529 p., $35.*

Fast Car Physics

Chuck Edmondson

Fans of fast wheels and science alike will get a charge from this look at motor sports by a physicist and amateur race car driver. *Johns Hopkins Univ. Press, 2011, 229 p., $29.95.*



Loving + Hating Mathematics

Reuben Hersh and Vera John-Steiner

Tales of mathematicians' engagement with their subject bring to life this examination of the human and cultural aspects of math. *Princeton Univ. Press, 2011, 416 p., $29.95.*

The Most Human Human

Brian Christian

The Turing test competition, an annual search for the most "human" computer, is the thread in this tour through the makings of human intelligence. *Doubleday, 2011, 303 p., $27.95.*

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Water at the start, and later

"Liquid acquisition" (*SN: 1/15/11, p. 26*) discusses two new models about how Earth got its water. But the two models are not mutually exclusive. Indeed, I wonder if perhaps two (or more) sources of water may be the only way to match all of the observed isotopic abundances. Is anybody working along these lines?

Stanley Friesen, Frederick, Md.

A combination of the two proposed scenarios — some of Earth's water coming from the planet's immediate surroundings at its formation, some delivered later from space — is definitely possible. Some researchers believe that this may in fact be the best solution to the puzzle. — Ron Cowen

Arsenic-eating microbes

I was glad to see the article ("Microbe swaps arsenic for key ingredient of life," *SN: 1/1/11, p. 5*) on arsenic incorporation by microbes. The news media implied that the arsenic incorporation was natural.

In the 1970s, Richard L. Raymond Sr. started an industry using bacteria present well below the ground surface (where there's an absence of light) to degrade hydrocarbon contamination. The hydrocarbons are the electron donors and energy source for the microbes. Over the years, we have learned to use chlorinated solvents as the electron acceptors. Oxygen, nitrate and sulfate all play roles in the process. The use of microbes for soil and groundwater remediation is now a large industry.

Bob Norris, Longmont, Colo.

When tales of the arsenic-consuming bacteria from Mono Lake first appeared in the news, it was indeed a big deal, oversetting all our experience with biochemistry. I was just itching to know how the organism GFAJ-1 managed to do the metabolism. But no such luck; the news coverage just degenerated into shrill accusations, devoid of scientific details. Thank you for reporting the science behind the discovery. You have kept alive my faith in *Science News*.

Tom Kimmel, Tucson, Ariz.

Correction

The brief item "You spin me right round" (*SN: 3/12/11, p. 19*) erroneously reported the first "spin-orbit coupling" between the motion of a particle and its spin. Spin-orbit coupling has been achieved before in other systems, such as electrons in gallium arsenide crystals. The new work is the first to accomplish it in the much-desired system of atoms in an ultracold gas.

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Marketplace

Michael Levi

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Japan crisis may have little effect on U.S. energy policy

Whatever the ultimate repercussions of the Fukushima Daiichi nuclear plant accident in Japan (see Page 6), the crisis raises questions over the role nuclear power should play as an energy source. Michael Levi, head of the energy security and climate change program at the Council on Foreign Relations in New York City, spoke to reporters on March 14 about the accident's potential implications for U.S. nuclear policy. Science News *contributing editor Alexandra Witze excerpted his comments.*

How will this event affect public opinion on nuclear power in the United States?
Most people will have their previous biases reconfirmed. The one place where I see a potential shift is in the group of environmental advocates who may have been willing in the past to compromise on nuclear energy as part of a broader deal on climate change, just like many of them were willing to do on offshore drilling. This sort of event will make them a lot less comfortable doing that.

Ultimately, the way this affects the future of U.S. nuclear power is through regulatory uncertainty and the sort of public opposition that ultimately drives up the cost of financing, and thus the cost, of nuclear power. But a warning I would give anyone trying to interpret this is that it is extremely early. If you go back and look at people's conclusions on the consequences of last year's oil spill for the future of energy policy a couple of days after the spill, you'll find that most of them bear little resemblance to the reality that unfolded. And it's worth having a similar level of caution right now.

How does this compare with last year's Gulf of Mexico oil spill?
Again, people had their views confirmed. If you were antidrilling, you looked at it and you saw a horrible environmental disaster. If you were pro-drilling, you looked at it and you saw that there was still limited physical impact on the shores.... Less than a year after the Gulf disaster, we're back to the same old debate over offshore drilling. So it's important not to overstate the consequences of a particular event for U.S. policy until you really wait to see how all the details play out and how the context evolves.

What about the nuclear reactors currently applying for relicensing, or those located in earthquake-prone zones?
The particular contours of public opinion in areas with nuclear reactors vary enormously from site to site. In some places, like in Westchester, N.Y., people hate nuclear.... In other places, they see it as a source of employment.

Do you anticipate increased regulation?
It's not like U.S. regulators don't look at things like earthquake risk already. I'm sure people will be taking a careful look over their regulatory schemes and trying to understand exactly what the vulnerabilities are that they may not have understood previously, and if that leads to changes in how they regulate, then there will be changes. And regulators are constantly reassessing their understanding for a variety of different reasons.

The other thing that will come into play is there's been a lot of discussion about how next-generation reactors are — the technical term is "passively cooled" — so that they can still cool themselves even if they have a complete power shutoff. This situation would certainly tilt things that way, but the lesson is not just that there's a particular failure mode associated with earthquakes. It's that things happen that you don't predict when you have very complex systems, and you need to be prepared not only to prevent bad situations from happening but you need to be prepared to mitigate the consequences.

It's important not to overstate the consequences of a particular event for U.S. policy until you really wait to see how all the details play out.

How important is nuclear to U.S. energy policy?
The nuclear component is hugely consequential for U.S. negotiations on energy policy. There is no question that when it comes to alternatives to fossil fuels, those on the right are far more enthusiastic about nuclear than about anything else. It's also true that many of those on the left have become more open to nuclear as part of a package. And you saw, for example, the president in his State of the Union speech pushing for a clean electricity standard, rather than a renewable electricity standard — one of the two key differences being that it would include nuclear power under its remit. So certainly it's a big piece of energy policy negotiations. Now, let's not overplay this. Energy policy negotiations are not in great shape, period, so it's not like nuclear will be decisive. Right now nothing big is happening, and this only makes things somewhat harder. But over the longer term, I find it very difficult to see a political compromise on clean energy — and on clean electricity in particular — that doesn't say something serious for nuclear. ■

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Technology Breakthrough | **Safe, comfortable bathing** | By John Fleming

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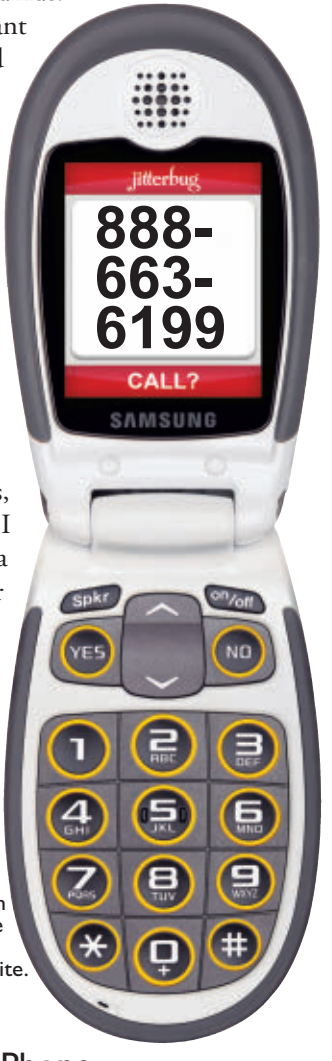
The people at the store weren't much help. They couldn't understand why someone wouldn't want a phone the size of a postage stamp. And the rate plans! They were complicated, confusing, and expensive… and the contract lasted for two years! I'd almost given up when a friend told me about her new Jitterbug phone. Now, I have the convenience and safety of being able to stay in touch… with a phone I can actually use."



The cell phone that's right for me. Sometimes I think the people who designed this phone and the rate plans had me in mind. The phone fits easily in my pocket, but it flips open and reaches from my mouth to my ear. The display is large and backlit, so I can actually see who is calling. With a push of a button I can amplify the volume, and if I don't know a number, I can simply push one for a friendly, helpful operator that will look it up and even dial it for me. The Jitterbug also reduces background noise, making the sound loud and clear. There's even a dial tone, so I know the phone is ready to use.

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