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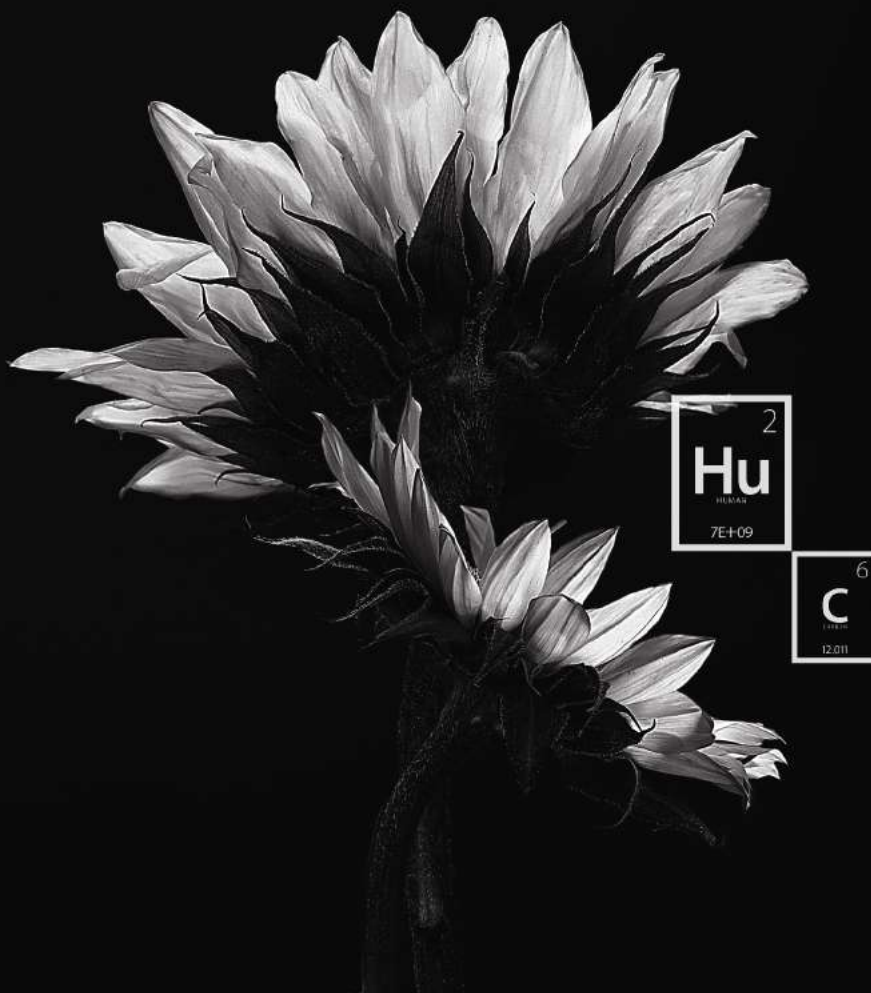
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~Dr. Patrick Adu-Peasah

Agriculture Sciences





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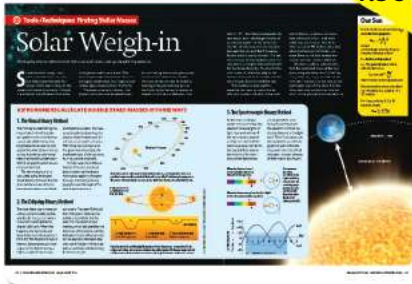
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“Suspended in clouds, fossilized inside ancient rocks, hidden in the lint in your pants pockets—pollen is everywhere.”

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Scientists pinpoint disease-fighting compounds released during exercise.



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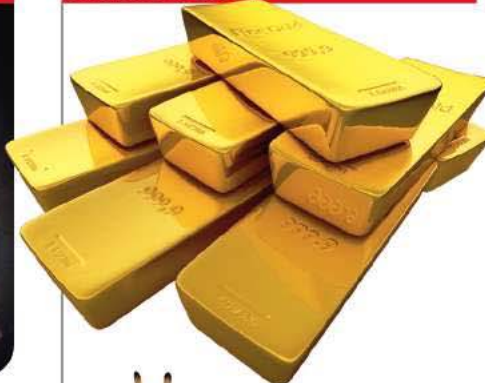
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Good news for giraffes, long-lost cityscapes, better-fitting dentures, sailing into space, Stone Age cannibals and a robot fish.

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You asked, we answered: What's a galactic collision like? How do birds get their colors? What's the biggest predatory land mammal?

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A look at gold's vital statistics.

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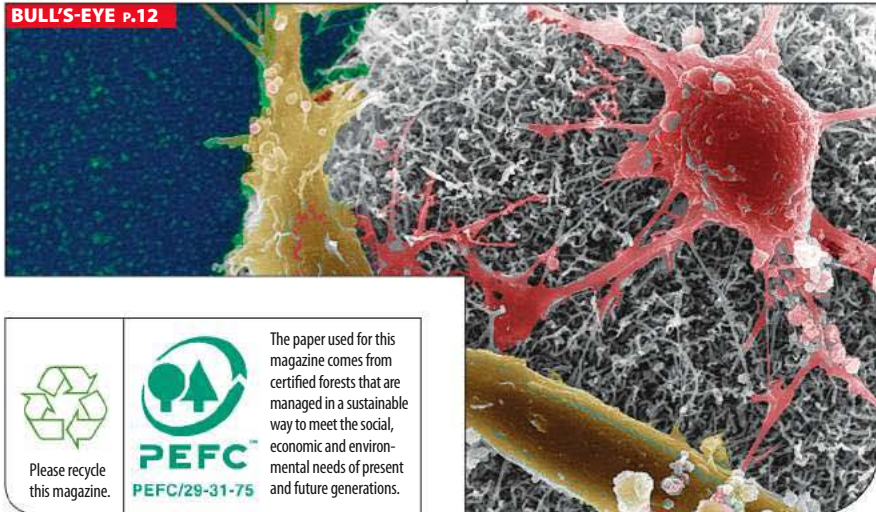
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Heated Debate

In "Reengineering Earth" [May/June], you discuss biochar production, a process I research, in which decaying plant material, which produces CO₂, is partially burned and the remains plowed back into the soil. Contrary to your story, there is enormous potential for biochar carbon sequestration without any need to produce additional crops that compete with food production.

Christoph Steiner Via e-mail
University of Georgia

Tricky Figures

You state that humans emit 600 million tons of CO₂ into the air every week ["Reengineering Earth"]. This is equal to 31.2 billion tons a year, which is four times the actual amount.

Ruben Behnke Via e-mail

EDITORS: Our statistic was based on figures published by the U.S. Department of Energy's Energy Information

Administration and the Intergovernmental Panel on Climate Change, both of which use the mass of CO₂ to measure emissions. Other sources measure emissions using the mass of carbon, which gives lower numbers. If you convert the carbon figures to CO₂, the emission amounts are roughly as stated in the article.

Relatively Close

I was surprised that "Long Live the Horseshoe Crab" [May/June] didn't mention that the animals are believed to be descendants of trilobites, extinct marine invertebrates that were dominant around 540 million years ago.

David Bartolic Via e-mail

EDS: We asked John Tanacredi, a marine scientist at Dowling College, to weigh in: "Horseshoe crabs have evolved from a similar body plan as trilobites and probably shared the same marine environment as them several hundred million years ago," he explains. "Some believe they are direct descendants, but the majority of scientists think we don't know definitively."

Life As We Know It

Although bacteria are numerous in the Antarctic Dry Valleys, they are not the sole inhabitants of this region ["Contrast," March/April]. Our research team has found thousands of metazoans (i.e. nematodes, tardigrades, rotifers, springtails and mites) living in soil and water sampled from this environment.

Adam Clayton Via e-mail
Brigham Young University

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Truly Unique



Time travel at the speed of a 1935 Speedster?

The 1930s brought unprecedented innovation in machine-age technology and materials. Industrial designers from the auto industry translated the principles of aerodynamics and streamlining into everyday objects like radios and toasters. It was also a decade when an unequalled variety of watch cases and movements came into being. In lieu of hands to tell time, one such complication, called a jumping mechanism, utilized numerals on a disc viewed through a window. With its striking resemblance to the dashboard gauges and radio dials of the decade, the jump hour watch was indeed "in tune" with the times!

The Stauer 1930s Dashtronic deftly blends the modern functionality of a 21-jewel automatic movement and 3-ATM water resistance with the distinctive, retro look of a jumping display (not an actual



True to Machine Art esthetics, the sleek brushed stainless steel case is clear on the back, allowing a peek at the inner workings.

jumping complication). The stainless steel 1 1/2" case is complemented with a black alligator-embossed leather band. The band is 9 1/2" long and will fit a 7-8 1/2" wrist.

Try the Stauer 1930s Dashtronic Watch for 30 days and if you are not receiving compliments, please return the watch for a

full refund of the purchase price. If you have an appreciation for classic design with precision accuracy, the 1930s Dashtronic Watch is built for you. This watch is a limited edition, so please act quickly. Our last two limited edition watches are totally sold out!

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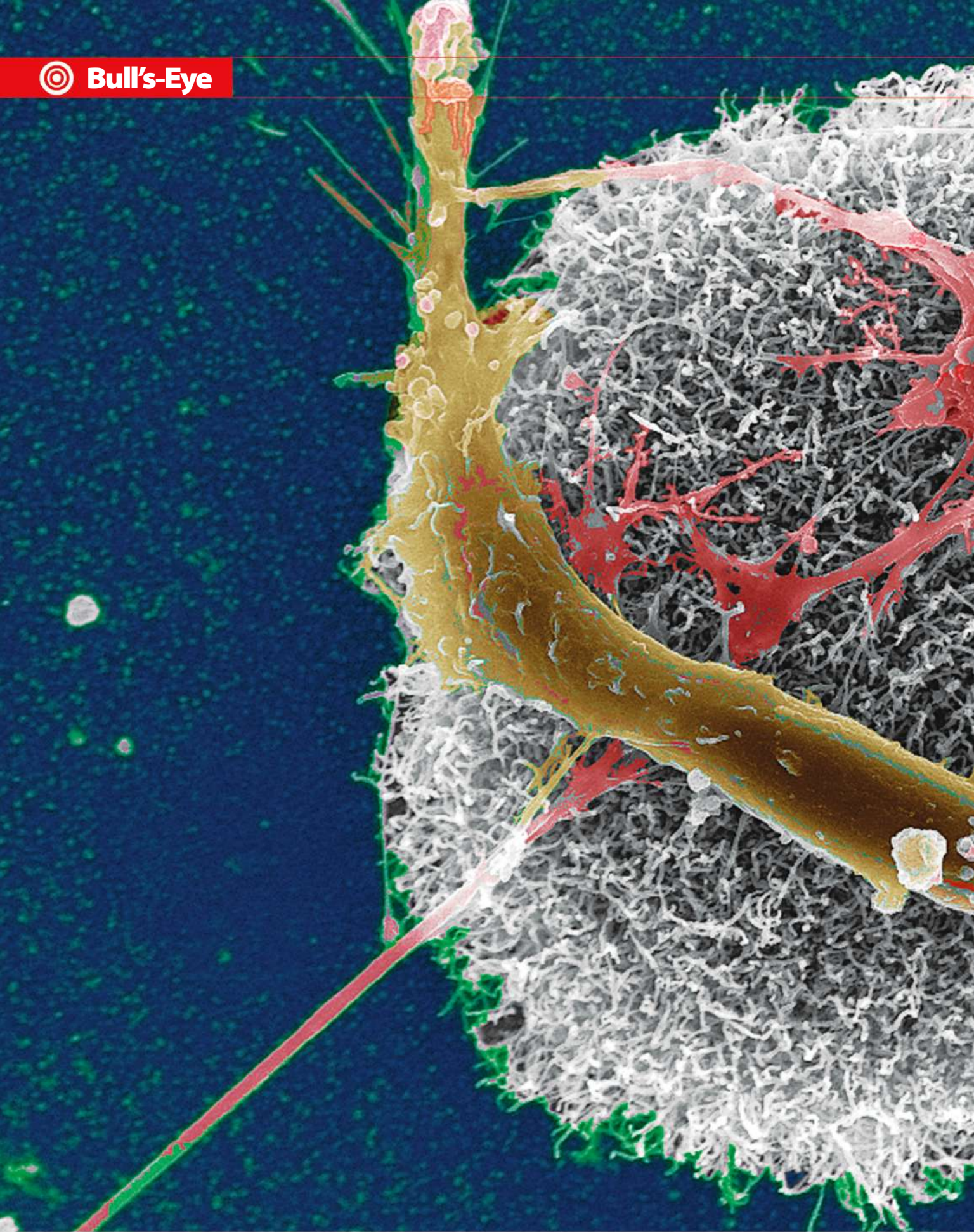
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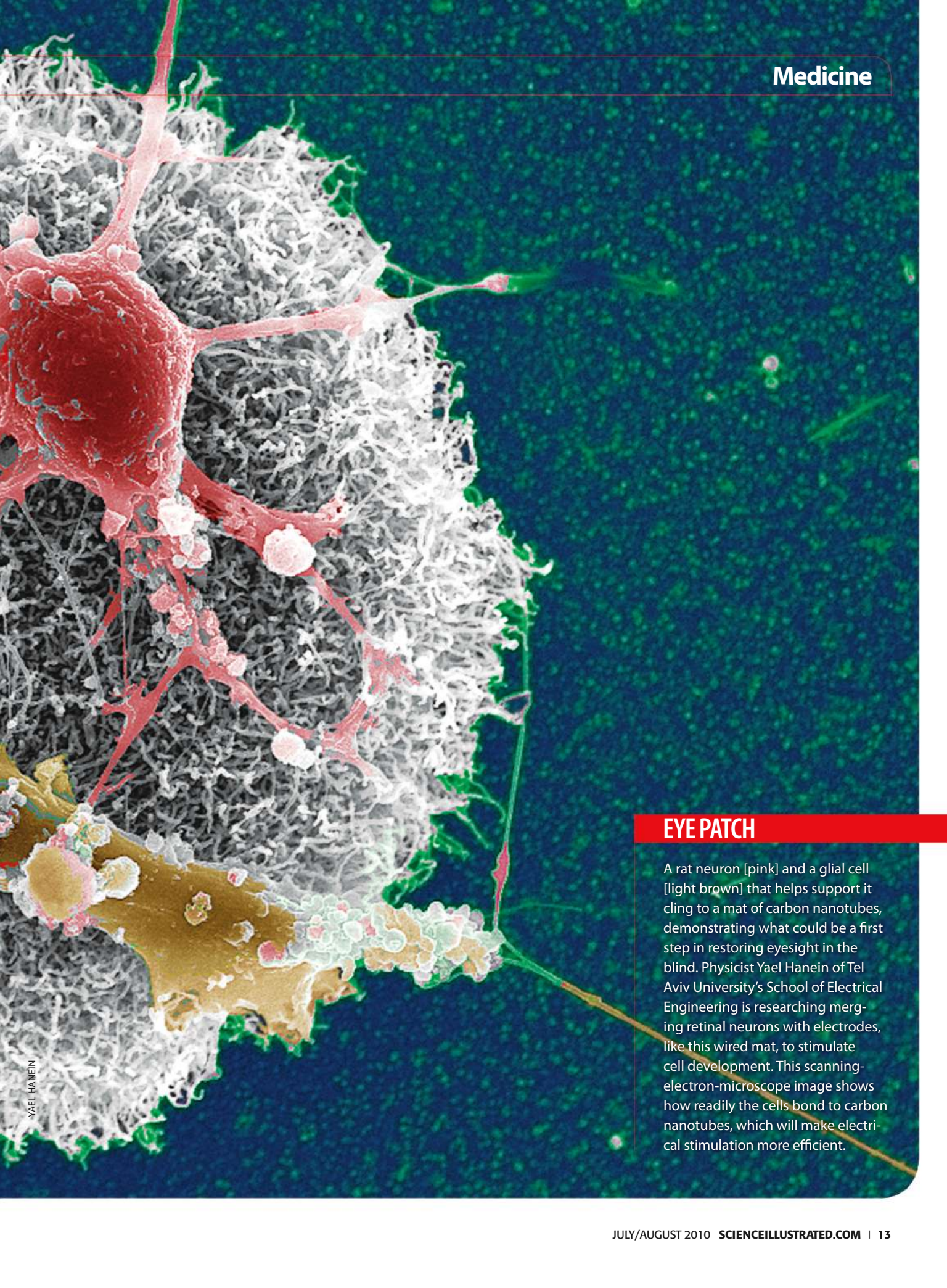
Early-morning dew glistens on a sleeping dragonfly, captured here by amateur photographer Mirosław Świątek in a forest near the town of Mikoszowa in southwestern Poland. The jewellike beads of water magnify the insect's eye facets, or ommatidia, which work together to give the bug a spherical field of vision. Dragonflies can have as many as 30,000 eye facets, the highest number yet found in nature.

GOLDEN STEED

Archaeologists in Hessen, Germany, prepare a 2,000-year-old bronze horse head for restoration. The artifact, which is covered in gold, is believed to be part of a life-size statue of the Roman emperor Augustus astride a horse. Two similar bronze equestrian statues have been found in Italy, and all date back to when the areas were occupied by the Romans. The head was discovered in an ancient well during excavations at Waldgirmes, about 30 miles north of Frankfurt, at a site now thought to have been a planned Roman city. Researchers also found what they believe is the heel of the rider and hundreds of other fragments scattered across the site. The settlement was abandoned sometime between A.D. 9 and 16.







Yael Hanein

EYE PATCH

A rat neuron [pink] and a glial cell [light brown] that helps support it cling to a mat of carbon nanotubes, demonstrating what could be a first step in restoring eyesight in the blind. Physicist Yael Hanein of Tel Aviv University's School of Electrical Engineering is researching merging retinal neurons with electrodes, like this wired mat, to stimulate cell development. This scanning-electron-microscope image shows how readily the cells bond to carbon nanotubes, which will make electrical stimulation more efficient.



BRIGHT FLIGHT

After seven years of research and development, the solar-powered HB-SIA aircraft took its premiere test flight over the Swiss countryside in April. The prototype is the first to come out of the Solar Impulse project spearheaded by Swiss adventurer Bertrand Piccard, who is aiming for completely solar-powered circumnavigation of the globe by 2013. For this 87-minute test run, which proved that the craft could fly as well as it did in simulations, the HB-SIA ran on four batteries charged by electrical-grid power. In future runs, including night flights, the craft will be powered purely by battery-stored solar energy collected from 11,000-plus photovoltaic solar cells that cover the plane's wings and the horizontal stabilizer on the tail.

Only 46 states remain in free state \$2 bill giveaway

Hotline operators can barely keep up with all of the calls because with each vault pack residents get a free state \$2 bill, so before calling the World Reserve, residents are being asked to make sure their state still appears on the list of remaining states below



NEW STATE \$2 BILLS: Each of the new state \$2 bills being overlaid and released exclusively by the World Reserve feature their state's skyline and significant state symbol with President Thomas Jefferson on the front.

NATIONAL TREASURE: The reverse of the \$2 bill features a detailed engraving of John Trumbull's famous 1820 painting "The Signing of the Declaration of Independence." The original hangs in the National Portrait Gallery in Washington D.C.

REMAINING STATES

Only residents of these states can still get their state \$2 bills free:

Alabama	Montana
Alaska	Nebraska
Arizona	Nevada
Arkansas	New Hampshire
Colorado	New Jersey
Connecticut	New Mexico
Delaware	New York
Florida	North Carolina
Georgia	North Dakota
Hawaii	Ohio
Idaho	Oklahoma
Illinois	Oregon
Indiana	Rhode Island
Iowa	South Carolina
Kansas	South Dakota
Kentucky	Tennessee
Louisiana	Texas
Maine	Utah
Maryland	Virginia
Michigan	Washington
Minnesota	West Virginia
Mississippi	Wisconsin
Missouri	Wyoming

Residents of the remaining 46 states have just 7 days to get their state's new \$2 bills free

Only existing state \$2 bills being given away free to the first 3,956 residents from the remaining states who beat the deadline to order the state \$2 bill vault packs containing 4 protective estate wallets each loaded with its own state \$2 bill

By Joan Tedeschi
Universal Media Syndicate

(UMS) - It's like a run on the banks. The phones just keep ringing off the hook.

That's because state residents are actually getting the World Reserve's exclusive state overlaid \$2 bills for free.

The only thing residents need to do to get their new state bills is call 1-866-497-6717 or one of the five Overflow Hotlines right now to get a state \$2 bill vault pack containing 4 protective estate wallets, each loaded with its own state \$2 bill for just \$12 and shipping per wallet. The first 3,956 residents from each remaining state who do are also getting their



■ **FREE PUBLIC GIVEAWAY:** Shown above are the World Reserve's state \$2 bill vault packs that residents from each state are trying to get their hands on. That's because they are the only existing state \$2 bills. But only the first 3,956 state residents who call before the 7-day deadline to order the vault packs are getting their state \$2 bill for free. So if lines are busy keep trying, all calls will be answered.

ADVERTISEMENT

state's new \$2 bill in a protective estate wallet and a Certificate of Authenticity free.

This free giveaway starts at precisely 8:00am today. But only the first 3,956 state residents who call to beat the 7-day deadline will instantly be awarded their state \$2 bills for free.

Special Toll Free Hotlines have been set up because you can't get these exclusive bills at local banks, credit unions or even the Federal Reserve. They're only being released directly to state residents exclusively by the private World Reserve.

These crisp state \$2 bills featuring the exclusively designed state overlaid printing are so precious you would never even dream of carrying them around in an ordinary leather wallet.

That's why they are being released in individually loaded rich protective estate wallets. They are so impressive, everyone will swear they must have been taken right from the Governor's

desk.

"Everything in our vault may soon be gone. So residents who want to get them now had better hurry and call," said Jefferson Marshall, Executive Director of the private World Reserve Monetary Exchange.

Some collectors are always trying to snatch up all the original \$2 bills issued by the Government they can get their hands on. They know that \$2 bills are almost impossible to find in your pocket change these days.

Originally issued in 1928, the currently designed \$2 bills have largely been locked away in the bowels of the U.S. Federal Reserve vaults, rarely distributed by banks and almost never seen in circulation.

The \$2 bills issued by the Treasury Department's Bureau of Engraving and Printing, makers of all the nation's paper currency, make up less than 1% of the \$670 billion in genuine U.S. currency that circulates worldwide, according to the U.S. Department

of Treasury.

"That's why I've authorized a limited number of genuine Government issued \$2 bills to be overlaid with each state's exclusive design and released from our private vault reserve to the first 3,956 state residents who call to beat the 7-day deadline for free. For now dealers can't get the state \$2 bill vault packs to make sure residents can get what they need," Marshall said.

"These exclusive state \$2 bills will be highly sought after and are extremely popular to hand out as gifts

for friends and family. They are the perfect gift for any occasion," he said.

"That's why this announcement is being so widely advertised, to make sure the first 3,956 state residents who call from each state have a chance to get their own state \$2 bills for free," said Marshall.

They are sure to impress because most people have never even seen one of these newly enhanced state \$2 bills featuring their state's skyline and significant state symbol with President Thomas Jefferson

on the front.

"Since the World Reserve has the only existing state \$2 bills, residents who want more than 10 state \$2 bill vault packs containing 4 protective estate wallets, each loaded with its own state \$2 bill must submit requests in writing so there will be no hoarding," said Marshall.

"You better believe we will be strictly enforcing the limits so that we can guarantee there will be enough vault packs for the first 3,956 State residents who call in the next 7 days," Marshall said. ■



■ **LIMITED RELEASE BEGINS:** This is the entire 50 state \$2 Bill Collection™ shown off by the World Reserve. You can't get these exclusive state overlaid \$2 bills from local banks, credit unions or even the Federal Reserve. But getting the entire 50 State \$2 Bill Collection™ may be hard, since the release is being restricted. That's why the World Reserve Monetary Exchange has also decided to release all 50 states together in one complete collection to state residents who call 1-866-497-6717 in the next 7 days.

HOW TO GET YOUR FREE STATE \$2 BILLS RESIDENTS OF THE REMAINING 46 STATES ONLY

The special Toll Free Hotlines are open to state residents only. The first 3,956 state residents who call to beat the 7-day deadline get their state \$2 bills free beginning at 8:00am today.

The only thing residents need to do is get the state \$2 bill vault pack containing 4 protective estate wallets, each loaded with its own state \$2 bill for just \$12 per wallet and shipping. The first 3,956 residents from the remaining states who do are also getting their new state \$2 bill free.

The World Reserve Monetary Exchange is releasing the exclusive state overlaid \$2 bills free for the next 7 days. If you miss the deadline you'll be turned away and forced to wait for future announcements in this publication or others, if any. There is a strict limit of 10 state \$2 bill vault packs per household. To claim yours call the special Toll Free Hotline number below.

SPECIAL TOLL FREE HOTLINE:

1-866-497-6717

CODE: NL171

OVERFLOW HOTLINES

1-866-497-6723

1-866-545-7375

1-866-545-7705

1-866-561-3060

CODE: NL171

1-866-561-3784

WHAT TO DO IF ALL LINES ARE BUSY

If you are a resident of one of the 46 remaining states trying to get the state \$2 bills within the 7-day deadline and have not been able to reach an operator by calling the special Toll Free Hotline or any of the five Overflow Hotline numbers, follow the steps below.

- 1) Immediately call the Toll Free Hotline number below.
- 2) You will then be connected to a special operator who will ask you for the code number below and arrange delivery of your free State \$2 bill.

Call Toll Free: 1-866-584-2443 Code: NL171

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Science Update



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Details of a distant galaxy come into view



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Bones suggest Stone Age cannibalism



P. 24

The West African giraffe bounces back

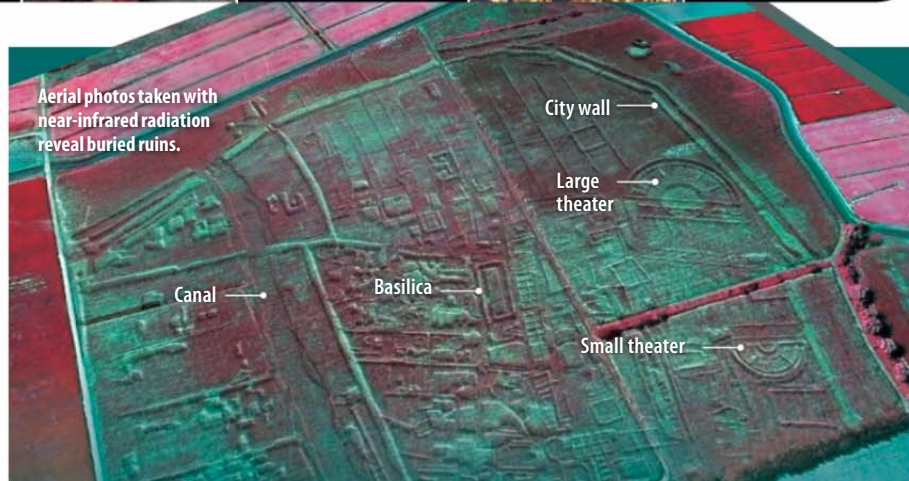


A female *Herennia multipuncta* spider [above left], can grow to be five times as large as a male [right] of the same species.

New Spider Species Has Biggest Females

BIOLOGY Golden silk orb spiders are known for their large size—around 1.3 inches long for females—and fantastic webs. *Nephila komaci*, the newest member of the group, is the biggest yet: The body of the most complete female specimen is 1.5 inches long, with a 4- to 5-inch leg span.

Matjaz Kuntner, a biologist at the Slovenian Academy of Sciences and Arts, and Jonathan Coddington, an entomologist at the Smithsonian National Museum of Natural History, believe the species might help explain why females of some animal groups are much larger than males. Like other species in the *Nephila* genus and the related genus *Herennia*, *N. komaci* females can grow to be about five times as large as the males. Being bigger might help them ward off predators and have more babies.



Aerial photos taken with near-infrared radiation reveal buried ruins.

Roman City Revealed

Plant health aboveground offers clues to ancient structures beneath the surface

ARCHAEOLOGY Italian scientists have found a way to map a city—despite the fact that it's been buried for centuries. The ancient Roman city of Altinum was abandoned between A.D. 400 and 600, when invaders drove out its inhabitants. As the city's residents moved onto the islands of a nearby lagoon, founding the city of Venice, Altinum was covered by floodwaters and soil. Although archaeologists have long known that Altinum existed just north of Venice, they haven't been able to get a good look at the remains of the city until now.

In 2007 researchers at the University of Padua took aerial photos of the area during a drought using near-infrared radiation. Healthy plants appeared as a different color than crops struggling in the dry conditions. The photos revealed the outlines of Altinum's structures, with thirsty crops growing in the shallow soil above buildings and walls, and healthy crops growing in the deeper, more hydrated soil above canals and ditches.

Now that the researchers have mapped the buried city, it could help them to select excavation sites.

Ruins Leave Clear Traces in Plant Growth

1. Moist soil in ancient ditches and canals causes crops to thrive and be green even during droughts.
2. Stone walls hold little moisture, so crops above them struggle during droughts.



Lead researcher
Peter Kühmstedt scans
a model's mouth.

New Scanner Takes 3-D Photos of Your Teeth

A technological breakthrough maps the mouth to help construct precisely fitting dentures

TECHNOLOGY Researchers at the Fraunhofer Institute for Applied Optics and Precision Engineering in Jena, Germany, have developed a 3-D imaging system that is poised to revolutionize the field of dental prosthesis.

Making dentures today is a multi-step process. Dentists take impressions of the bite, make wax or stone-material models from them, and test them in the patient's mouth for fit before sending

them to the lab for the final cast. Many dentures come back ill-fitting, requiring still more adjustments.

The 3-D system, designed for the German dental-technology company Hint Els, takes less time and improves accuracy. An optical scanner is inserted into the patient's mouth, where it takes a rapid sequence of pictures from various angles every 200 milliseconds, recording the surface and shape of

every tooth or gap. The dentist then inputs the images into 3-D software, which conducts a pixel-precise comparison to map the patient's mouth. Technicians are then able to create a dental prosthesis with a more exact fit.

Hint Els is currently working on commercial production of the optical scanner, called directScan, which could be available as soon as September. Better-fitting dentures are on the way.

The Best Look at a Faraway Galaxy

ASTRONOMY Wide Field Camera 3, installed last year on the Hubble Space Telescope, has captured the most detailed view of distant star formation yet in the galaxy M83, located 15 million light-years away in the constellation Hydra.

The images of M83 show stars at every stage of development. Young stars—less than 10 million years old—reside at the edge of the dark dust ridges spiraling

from the galaxy's core [the bright white region at right]. Their ultraviolet light ionizes lingering hydrogen gas bubbles, encasing them in a red glow. In some spots, energetic winds have been created by the young stars' charged particles and remnants from recent supernova events. These winds have blasted the hydrogen away, making the slightly older blue star clusters behind them clearly visible.



Recent images of the M83 galaxy show details of star development.

FROM TOP: FRAUNHOFER INSTITUTE; STSCI/AURA/ESA/NASA

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Clarity	"IF"	Clear
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process, but will only say that it involves the use of rare minerals heated to an incredibly high temperature of nearly 5000°F. This can only be accomplished inside some very modern and expensive laboratory equipment. After several additional steps, scientists finally created a clear marvel that looks even better than the vast majority of mined diamonds. According to the book *Jewelry and Gems—the Buying Guide*, the technique used in DiamondAura offers, "The best diamond simulation to date, and even some jewelers have mistaken these stones for mined diamonds."

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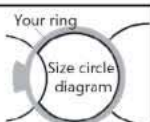
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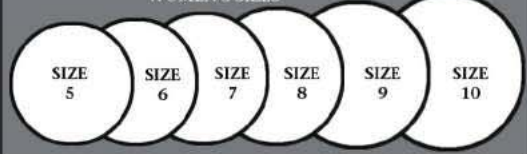
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WOMEN'S SIZES





LightSail-1 will put solar sailing to its first real test.



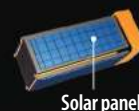
CubeSats

4. The sail will measure 350 square feet and will be about a quarter the thickness of a trash bag.

Probe to Unfurl Its Sail 500 Miles above Earth's Atmosphere

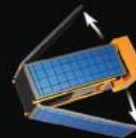
LightSail-1, slated to launch next year, will hitch a ride on a rocket to prove that solar sailing works. Later versions will study solar storms.

1. LightSail-1 will weigh less than 11 pounds. Solar panels will encase three mini-satellites called CubeSats, which house the sail.



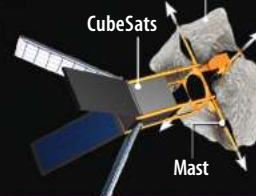
Solar panel

2. When the craft is at least 500 miles above Earth's atmosphere, the four solar panels will open, revealing the CubeSats.



Sail

3. Four 13-foot-long masts will push out from the CubeSats, unfurling the solar sail.



CubeSats

Mast

Solar Sailing Gets Ready for Liftoff

Energy from light will propel a craft on its maiden voyage, turning an idea from the 1920s into reality

SPACE TRAVEL A nearly century-old dream of space exploration is moving closer to reality as the Planetary Society in Pasadena, California, plans its second attempt to send a spacecraft sailing toward the stars powered entirely by energy from light particles.

In the 1920s, Russian scientists Fridrich Tsander and Konstantin Tsiolkovsky first contemplated solar sails. In the 1950s and '60s, a number of researchers theorized that the pressure

from light, or photons, reflecting off an ultrathin foil sheet on a spacecraft would push the craft forward. The Planetary Society attempted the world's first launch of a solar sail into space in 2005, but the Russian rocket carrying it exploded over the Barents Sea.

Shortly after the failed launch, the Society took over Nanosail, NASA's solar-sail R & D program, which was about to be shut down. The planned craft, renamed *LightSail-1*, weighs less

than 11 pounds and has a small sail, which enables it to accelerate faster and maneuver better than the Planetary Society's first, 88-pound craft. *LightSail-1* will fly 500 miles above Earth's atmosphere, where its sole mission will be to prove that solar sailing works.

The design for the craft will be finalized this year, says the Society's executive director, Louis Friedman. The group is currently seeking a rocket on which to piggyback for a 2011 launch.

Skulls from the German site



Stone Age Cannibals Uncovered?

Thousands of bone fragments and hundreds of smashed skulls found between 2005 and 2008 in Herxheim in southwestern Germany are evidence of ancient cannibalism, says French anthropologist Bruno Boulestin of the University of Bordeaux 1. Boulestin and German colleagues believe that 7,000 years ago, Stone Age people killed and consumed at least 500 human victims here, possibly during a social or political crisis raging in Europe. Other researchers, however, posit that the site was simply used for reburial purposes.

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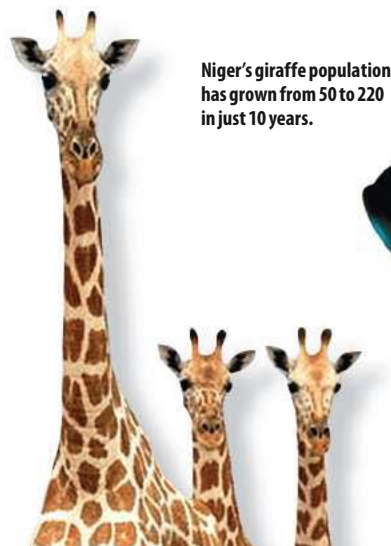


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28

The number of years naked mole rats have survived in captivity, the longest known life span of any rodent, according to research from the City College of New York



Niger's giraffe population has grown from 50 to 220 in just 10 years.



Robot Fish Slices through Water

BIOMIMICRY The most vulnerable part of any underwater robot is its propeller, which can be easily damaged on rocky terrain or get caught in submerged plants. The black ghost knifefish, a South American river species, has no such problem: An undulating fin that runs along its belly propels it through obstacles. Keri Collins, a doctoral student at the University of Bath in England, developed a robot called Gymnobot (for Gymnotiformes, a group of fish species including knifefish) using the fish as a model. The robot's flexible fin, attached to a rigid body, is tangle-proof, according to laboratory tests. When complete, Gymnobot will help scientists study marine life in coastal waters, where varying terrain and habitats are tricky to navigate.



Keri Collins is modifying the robot to swim backward and up and down.

News Flash!

Countering recent political attacks on climate researchers, the work of 255 members of the U.S. National Academy of Sciences published a statement in *Science* reaffirming evidence that "humans are changing the climate in ways that threaten our societies and the ecosystems on which we depend."

Seventy-million-year-old dinosaur bones found in Romania are the remains of an adult dwarf species, not a juvenile, say scientists at the University of Bonn in Germany. A study of the fossils' microstructure confirmed the previously dismissed theory.

Australian researchers report that adolescents with autism spectrum disorders were better able to distinguish facial expressions after receiving an inhaled dose of oxytocin, a hormone associated with love, trust and social recognition.

West African Giraffes Make Strides

One of the world's most threatened populations gets a chance at survival

CONSERVATION Sixteen years of work by the Association to Safeguard the Giraffes of Niger (ASGN) are paying off, says Jean Patrick Suraud, the group's scientific manager. In the early 20th century, West African giraffes roamed a vast area that stretched from Chad to Senegal. By the late 1990s, poaching and deforestation had decreased the population to only 50 individuals clustered 37 miles from Niger's capital, Niamey. Since 1994, ASGN has worked with the government of Niger and several international wildlife societies, banning poaching and creating conservation projects to protect the subspecies. The animals now number 220, making this one of the fastest repopulation efforts in giraffe-conservation history.



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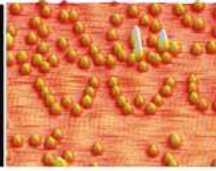
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Ask Us

You ask, we answer.



P. 28
What makes a bird's feathers so colorful?



P. 28
How do scientists see atoms?



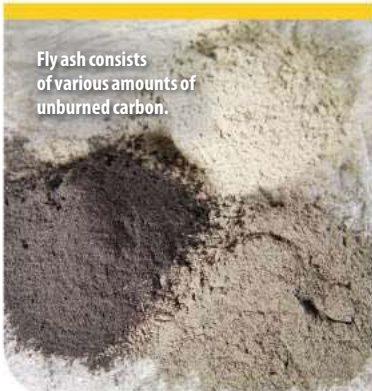
P. 30
How big can a carnivorous land mammal grow?

Q Can coal-plant waste be recycled?

A In the U.S., more than 40 percent of fly ash, a fine powder produced in coal-fired power plants, is recycled and used in the construction of highways, pavement, bridges, dams and buildings. Fly ash was a major air pollutant in the late 19th and early 20th century, when it was released directly into the air from industrial-plant chimneys, but today's incinerators mostly limit the emission of the ash into the atmosphere.

Although a large amount of the fly ash extracted from power plants is dumped (exactly how varies by state), most of what remains is made into a hard, long-lasting form of concrete. It is also useful in producing cement, asphalt and pavement. Some fly ash can even be reburned to get more energy out of it.

Fly ash consists of various amounts of unburned carbon.



Q What happens when galaxies collide?

A When mutual gravitational attraction brings two nearby galaxies together (a relatively common event), their gases collide violently. As gas and dust smash together at speeds of millions of miles an hour, they combine the raw materials for new stars in a spectacularly hot and bright display. Over millions of years, new stars and even new galaxies can form this way. Highly energetic collisions could also be the cause of rare cosmic objects called quasars, which, despite being much smaller, can be hundreds of times as bright as giant galaxies, allowing them to be observed from great distances.

Whereas some galaxies formed on their own, many others, including our

galaxy, the Milky Way, probably developed from the collisions and mergers of smaller ones. And in turn, collisions between two spiral galaxies, like ours, are thought to form still larger elliptical galaxies.

Andromeda and the Milky Way are among the largest galaxies in our galactic cluster, known as the Local Group. Andromeda, which is located about two million light-years away from our galaxy, is on track to collide with it in three to four billion years. When this occurs, many new stars will form and others will go supernova. Nearby exploding stars will probably render Earth uninhabitable. That is, if a larger, hotter sun—something our star will become—hasn't already done so.



From left: Bearded vultures bathe in red soil to get their color. Parrots get their red feathers from special pigments called psittacofulvins. The structure of hummingbird feathers creates the iridescent colors on these birds.

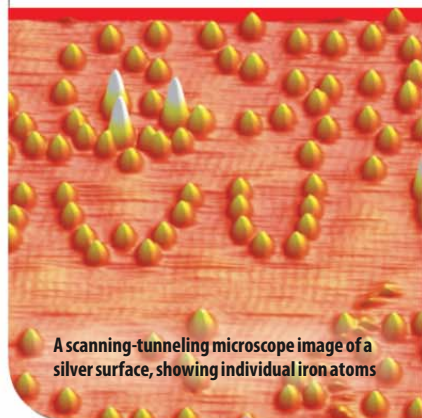
Q What gives bird feathers their colors?

Birds can see a larger spectrum of colors than most of us, and they flaunt a variety of eye-catching plumage. Pigments called melanins, carotenoids and porphyrins made in the birds' skin produce most feather colors. Melanins produce black feathers, but depending on the concentration of the pigment granules, they can also range to reddish browns and pale yellows. Bright red, yellow and orange feathers are produced by carotenoids, which birds generally get from

eating plants. These pigments can interact with melanins to produce even more colors, like olive green. The final group, porphyrins, appear as a wide range of colors, including brown, pink, red and green. Certain birds, such as parrots, get their bright colors from less-common pigments produced directly in their feathers.

In some birds, the structure of the animals' feathers produces the appearance of certain colors. The bright iridescent

hues on the throats of many hummingbird species, for example, are caused by the splitting of white light into its component colors in a phenomenon known as interference. A special kind of diffraction of light, called the Tyndall effect, can produce the blue color of many birds, including some species of tanager and blue jay. In these species, small, finely dispersed reflecting particles—often pockets of air—present in the feathers reflect blue and violet colors.



A scanning-tunneling microscope image of a silver surface, showing individual iron atoms

Q How do scientists see atoms?

With high-powered microscopes. Most of our early knowledge of atomic structure was based on indirect experimental observations, but in 1955, Erwin Muller and Kanwar Bahadur of Penn State University imaged individual atoms using field-ion microscopy. Fifteen years later, scanning-transmission electron microscopy produced atomic-resolution images from a stream of electrons scanning across an object's surface. Since the 1980s, scanning-tunneling microscopes have been used to image individual atoms. These microscopes detect electrons as they tunnel across the distance between the microscope's probe and a surface. By observing this process, scientists can see the surface with atomic resolution.

CLOCKWISE FROM TOP LEFT: NATURE PL; K.W. FINK/ARDEA; COURTESY PDPHOTO.ORG; ANDREAS RIEMANN/WESTERN WASHINGTON UNIVERSITY



Yellow carotenoid pigments secreted by a special gland give great Indian hornbills their color.

BIRDS GET THEIR COLORS IN THREE DISTINCT WAYS

- **Pigments:** Chemical compounds produce color.
- **Structure:** Physical characteristics create colors.
- **Cosmetics:** Birds add colors to themselves.

Often, structural colors combine with pigments to produce the colors seen in feathers. For example, the green color of some parrots is the result of the interplay between structural blue-reflecting feathers and yellow pigments.

Some animals “paint” themselves with so-called cosmetic colors from resources available in their surroundings or from their own secretions. Birds such as hornbills and pelicans change the color of their plumage by coating it with yellow or red pigments secreted from a special gland. And some feather colors aren’t produced by birds at all. The bearded vulture, for instance, splashes itself with red soil to get its characteristic hue. There are varied reasons some birds paint themselves and others have evolved fanciful displays of color, the most important of which may be to attract mates during courtship or to signal status.

Who ... ?

Who first tried to sail around Africa?

A Greek explorer, Eudoxus of Cyzicus, made the first known attempt to sail the entire perimeter of Africa in the 2nd century B.C. His first boat ran ashore, and his second expedition was lost. No one tried again until the late 1400s.

Who first used the word “computer”?

The word comes from the verb “compute,” meaning to determine, especially by mathematical means. That word comes from the Latin *computare*. “Computer” was first written in 1646 by English author Thomas Browne to describe a person who computes.

Who invented the pocket watch?

Peter Henlein, a German locksmith, is thought to have invented the first watches in the early 1500s. Unlike clocks, these used springs instead of drive weights, allowing them to be small and portable.



Q Is swallowing gum bad for you?

A “It’s generally not a problem,” says pediatric gastroenterologist Esther Israel of the North American Society for Pediatric Gastroenterology, Hepatology and Nutrition. Gum will almost always pass through your gut within three days. But in rare cases, swallowing gum—specifically, the additives in some brands—can have surprising repercussions. Large amounts of sorbitol, a sweetener in many sugar-free varieties, can cause diarrhea, gas and abdominal pain; cinnamon flavoring has been linked to ulcers; and a licorice flavoring has been associated with high blood pressure. An even rarer complication observed mainly in young children involves a large wad of gum blocking the gastrointestinal tract.



The extinct bear *Arctodus simus*, shown to scale next to a polar bear and an average-sized human was once the largest mammalian carnivore on land.

Polar bear
Weight = 900–1,800 pounds

Arctodus simus
Weight = 1,700–2,200 pounds

Q How big can carnivorous land mammals grow?

A **Theoretically, around 2,425** pounds for terrestrial mammals, according to models developed by researchers at the Institute of Zoology in London. That number takes into account the fact that larger animals need to eat more, and that carnivores spend much more time and energy looking for (and killing) food than herbivores do.

Carnivores face energy-based challenges related to their size: The larger a predator becomes, the more difficult it becomes to take in enough calories. Once mammals

exceed about 44 pounds, they can generally meet their energy needs only by eating prey of their own size or larger. Large prey provides significant food and energy but also takes more energy to hunt, and this imposes a limit on the maximum size of carnivores. The very largest mammalian predators must modify their behaviors to conserve energy. For example, lions lie around more than 90 percent of the time, and many bears become dormant [for more on dormancy and hibernation, turn to “The Superstarvers,” page 60]. Polar bears, which weigh 900 to 1,800 pounds, are the largest living carnivorous land mammals. The extinct bear species *Arctodus simus*, estimated to have weighed as much as 2,220 pounds, holds the all-time record.

Reptiles have much lower metabolic rates—the rate at which the body consumes energy—than mammals, which might be how some carnivorous dinosaurs reached weights of more than 26,000 pounds. Mammalian herbivores, like the 30,000-pound *Indricotherium*, a type of extinct hornless rhinoceros, can get even bigger because of the relative ease with which they find their food.

Putting animals in the water changes the equation. Aquatic mammals, like sperm whales and elephant seals, can become much larger than terrestrial ones because their fat helps them float and also provides insulation, thus decreasing the energy they expend while swimming and regulating their body temperature.

Gigantic Carnivores

Among the largest predators to have ever lived on land were the dinosaurs *Spinosaurus aegyptiacus* and *Tyrannosaurus rex*. Biologists believe these reptiles were able to reach much larger sizes than carnivorous mammals because their metabolic rates were relatively low.

Spinosaurus aegyptiacus
Weight: 26,455 pounds
Length: 47 feet
Height: 16 feet

Tyrannosaurus rex
Weight: 22,046 pounds
Length: 39 feet
Height: 13 feet



How ... ?

How do electric eels generate electricity?

These fish contain special cells called electroplaques that produce electricity through the excitation of nerves. Large numbers of electroplaques in the tail region of the eels form the electric organs, which the animals use to stun their prey. The organs can discharge up to 650 volts, nearly four times the peak voltage produced by a household outlet.

How was the speed of light first measured?

English astronomer James Bradley calculated the speed of light in 1725 by measuring changes in the position of stars. He correctly concluded that the movement of the Earth along its orbit, and the fact that light had a finite speed, caused the stars' apparent orbital movement.

How do squirrels choose which acorns to store for winter?

Squirrels favor acorns from red oaks because they last through the winter without sprouting. Once they sprout, the acorns are less valuable as food.



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Does anyone read “how to” books to learn to walk, run, or ride a bicycle? Is anyone taught that it is by conforming to natural laws that one learns to perform those feats? No, of course not! *Whoever or whatever created natural laws* had to wait centuries on end for people to identify natural laws by studying the environment and nature’s phenomena.



Richard W. Wetherill
1906-1989

There is a natural law of behavior that was not identified until the past century. It was identified by Richard W. Wetherill and requires *mankind’s behavior to be rational and honest*, according to natural law—not according to man-made law.

Wetherill spent decades trying to explain that the social, health, and economic woes of mankind were being caused by everybody’s ignorance of nature’s behavioral law: a law he called the *law of absolute right*.

His talks and writings were rejected by leaders of the educational, religious, and scientific communities, although one psychologist built a wide reputation on Wetherill’s command phrase technique for releasing wrong, unconscious thoughts.

In general, people resent being told what they can and cannot think, say, and do. Their reason seems to be that it is “their business”: a mistake made by those who overlook where the gift of life originates. *Whoever or whatever is the creator* arranged all the details, thereby enabling people to procreate.

Introduction to the *law of absolute right* and its influence on behavior is vital information desperately needed by every member of society.

Strange as it might seem, it could be said that the only choice people have is whether they will live in accord with the requirements of natural laws or die for ignoring them. People willingly adhere to the laws of physics, telling them what to think, say, and do. Scientific researchers eagerly seek to understand how natural laws function and the penalties for ignoring them. But to date, their failure to acknowledge nature’s *law of absolute right* and its impact on human affairs is perpetuating countless human miseries.

The behavioral law is nature’s way to create a community of survivors that having resolved their formerly unsolved problems and trouble are enjoying a new life. A common comment of those persons is, “*It works.*”

For example, one person reported that he had made friendly overtures to a long-time estranged, close relative and introduced him to the *law of absolute right*. Later this person reported a phone call from his formerly estranged relative who said, “It works.”

We invite readers to face all future situations with *sincere intent* to respond rationally and honestly, no matter what past reactions might have been. In that moment you will have yielded to yet another natural law created by *whoever or whatever is the creator*, and you will discover that it works.

By conforming to the behavioral law, you join others who are already benefiting from adhering to it with rational and honest thoughts, words, and action.

Visit our colorful Website www.alphapub.com where essays and books describe the changes called for by whoever or whatever created nature’s law of absolute right. The material can be read, downloaded, and/or printed free. Also press a button to listen to each Website page being read aloud with the exception of the texts of the seven books.

This public-service message is from a self-financed, nonprofit group of former students of the late Richard W. Wetherill. We are putting this information where it is available worldwide, and we invite your help to direct others to our Website so that they, too, can learn that conforming to this natural law creates a life that truly is well worth living.

An underwater photograph showing two divers swimming in clear blue water. One diver in the foreground is wearing a striped shirt and fins, holding a light. Another diver is further back. A large whale shark is visible at the bottom of the frame. The title 'MAN MEETS GIANT' is overlaid on the image.

MAN MEETS

GIANT

The world's largest living fish is also one of its most mysterious. Now one team—a marine conservationist, a technical writer and a NASA research scientist—is looking at whale sharks in an entirely new way

Brad Norman affixes a "daily diary" to a whale shark's 5.5-inch-thick skin. The device tracks the animal's speed and depth.



Brad Norman has loved the ocean since he was a little boy, but after a surreal encounter with a feeding whale shark, he decided to dedicate his life to protecting the species. The Australian marine conservationist encountered the massive fish in 1995 while conducting master's-degree research at Murdoch University in Australia. As it passed, the whale shark ignored Norman completely. "I was laughing into my snorkel," he says, recalling "a mix of excitement and relief." Soon he was diving with the species regularly, intrigued by how little researchers knew. These gentle giants, which can grow to 60 feet long during their lifetime, sport glowing white spots on their skin. Norman thought the markings might be used to identify individuals just as fingerprints identify humans.

Before a 1986 review, Norman soon discovered, there were only 320 recorded observations of whale sharks. He realized that no one had any clue how many individuals there were in the world. And so, in 1999, Norman founded Ecocean, a database where he and other divers could pool their photos of the whale sharks and their markings. The idea was to find a way to identify individual sharks and to

raise public awareness of the species.

Whale sharks are classified as vulnerable on the International Union for Conservation of Nature Red List because of past unregulated harpooning in Taiwan, India and the Philippines. The animals are now protected in the latter two countries, and protective regulations are pending in Taiwan. But conservation is hampered by how little scientists understand about the animals. For instance, whale-shark reproduction is a mystery. They have never been seen mating because they spend most of their lives in waters too deep for observation. A rare insight surfaced in 1995, when a fisherman

harpooned a pregnant female off the coast of Taiwan. Around 300 embryos of various sizes were found in her two uteruses, leading to suspicions that the species is ovoviviparous, meaning eggs hatch inside the female.

The Team Forms

In 2002, while diving in the Red Sea off the coast of Djibouti in northeastern Africa, Jason Holmberg, a technical writer, also fell in love. "As we were about to leave, someone said 'whale shark,' so I dove back in," he recalls. The object of his affection was an eight-foot juvenile. He was particularly fascinated by the glowing spots



Brad Norman's Ecocean database can identify individual sharks from photos by comparing the pattern of spots with more than 26,000 other pictures in the database.

The increased popularity of diving and snorkeling has helped researchers keep better track of sharks, with amateur photos.

Empirical Evidence: Travel



A whale shark and divers at the Georgia Aquarium

How to Get Close to Whale Sharks

Georgia Aquarium, the world's largest, is home to the biggest indoor aquatic exhibit, Ocean Voyager. Here you will find four whale sharks that you can observe behind glass, swim with, or dive alongside. The aquarium also offers a special whale-shark diving certificate program, available to certified divers.

WHERE: Atlanta

WHEN: All year

COST: Adult admission, \$26; children, \$19.50; seniors, \$21.50; swim, \$225; dive, \$325; certificate program, \$75
georgiaaquarium.org

San Diego Shark Diving offers a five-day trip into the Gulf of Mexico, which includes three mornings of guided warm-water snorkeling. You can expect to swim with massive whale sharks in their natural habitat during the height of the season.

WHERE: Isla Holbox, Mexico

WHEN: June through August

COST: \$1,500 (includes transportation from Cancun airport to Chiquila, ferry from Chiquila to Isla Holbox, and a double-occupancy hotel room at Isla Holbox)
sdsharkdiving.com



Whale sharks swim with their mouths open and expel the water through gill slits to filter their prey.

"daily diaries" to individual sharks. These devices record the speed, depth and location of the animals, allowing Norman to track their activity. Through these recordings, he has learned that whale sharks, which swim slowly in shallow depths, climb and dive repeatedly and quickly while feeding at depths of up to 4,220 feet.

Because getting an exact count on the whale-shark population is so difficult, Norman is still collecting data, and he hopes to gain a better understanding of the species' health. Researchers speculate that whale sharks' extensive migrations follow food pulses, or mass spawning of corals and other animals in tropical reefs near Australia, the Philippines, Mozambique, the Gulf of Mexico and the Galápagos (as filter feeders, their diet consists of zooplankton, small fish and mollusks). If whale sharks stop visiting a particular area, it could be an important indicator of the health of their environment there, which could also affect other species. "I like to think of whale sharks as a canary in a coal mine for how our ecosystems are faring," Norman says. In the end, it seems, falling in love with these giant fish means falling in love with the entire ocean. ■

on the shark's skin. Holmberg wondered, like Norman had, if he could use the spots to identify individual fish. "It was just an afterthought," he says. "But the more I thought about it, the more curious I became." He approached Zaven Arzoumanian, a research scientist at NASA Goddard Space Flight Center, about adapting the Groth algorithm—used to map stars observed from the Hubble Space Telescope and other facilities—to identify spot patterns on whale sharks. To test the algorithm, the pair needed photos of the animals, and that's how Holmberg and Arzoumanian found Norman and Ecocean. In 2005, the trio

published proof that such an algorithm could, in fact, identify sharks.

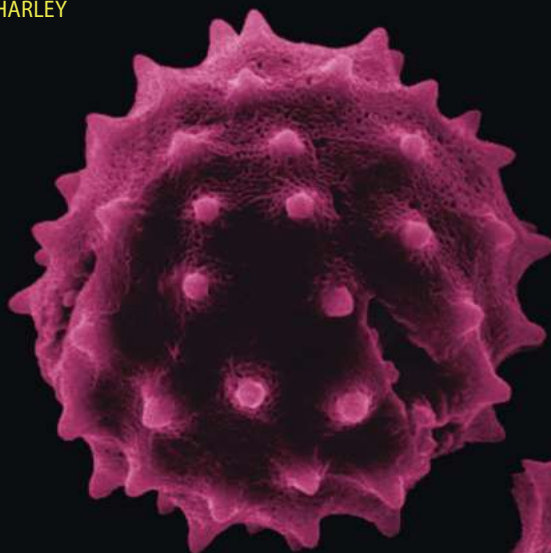
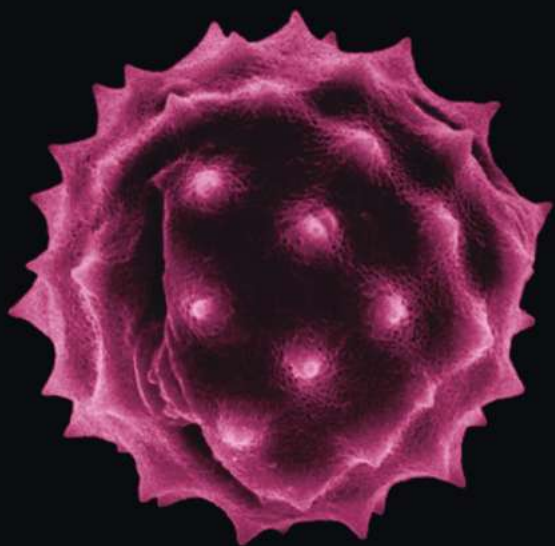
Today Ecocean contains more than 26,000 photos of over 2,100 whale sharks identified by the algorithm. These contributions, coming from a mix of researchers and amateur divers, have become essential to whale-shark research. "By taking these photos, anyone can become a citizen scientist," Norman says. Using Ecocean, which won Norman a National Geographic Emerging Explorers Award in 2008, people have recorded whale sharks off the coasts of 43 countries.

In addition to Ecocean, Norman has also been able to attach digital

Grains of Truth

Fingerprints? DNA? That's ancient history for a handful of dogged forensic scientists around the globe. They're catching bad guys with the unlikelyst of evidence: pollen

PHOTOGRAPHS BY ROB KESSELER AND MADELINE HARLEY

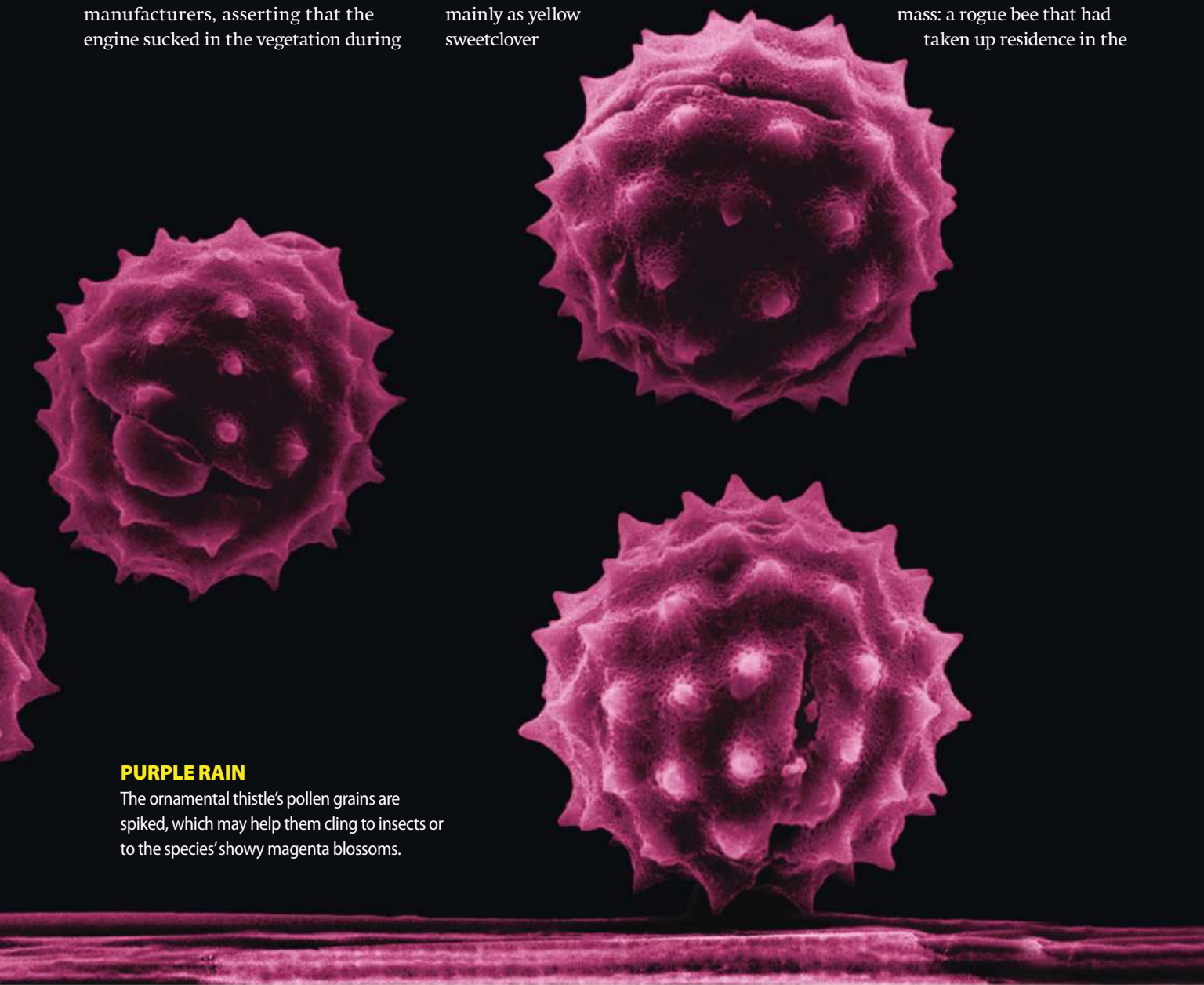


On December 2, 1989, a private twin-engine plane traveling from San Diego crashed near a regional airport in Ruidoso, New Mexico, killing the pilot and his wife. Investigators found no defects in the engines and attributed the crash to pilot error before storing the wreckage in a yard outside the airport. Attorneys for the children of the couple later salvaged some of the plane parts and conducted their own investigation, turning up a small mass of plant matter in one engine's fuel lines. They sued the plane's manufacturers, asserting that the engine sucked in the vegetation during

the aircraft's flight or approach, clogging the fuel line and causing power loss. Filters, they claimed, would have prevented the crash.

In an unusual move, the defense attorneys called in palynologists—experts on pollen and spores—to pinpoint the origin of the mass, which included plant leaves and hairs and a small pellet of pollen grains. Did the vegetation enter the fuel line when the plane was airborne, or later, when the wreckage was stored outside? The experts analyzed the grains under high magnification and identified them mainly as yellow sweetclover

and curlycup gumweed, two insect-pollinated flowers that grew in the yard where the plane parts had been stored. Hardly any pollen would have been in the air during the winter when the crash took place, let alone insect-dispersed pollen, which is heavier than grains carried by the wind and is scarce at high altitudes. Plus, the pollen was fresh and intact, showing no signs of being burned in a fiery crash. The possibility that the matter had entered the motor in-flight was ruled out, and the defendants were exonerated. The source of the plant mass: a rogue bee that had taken up residence in the



PURPLE RAIN

The ornamental thistle's pollen grains are spiked, which may help them cling to insects or to the species' showy magenta blossoms.



engine after the crash, leaving a tell-tale hair embedded in the pollen.

Suspended in clouds, fossilized inside ancient rocks, hidden in the lint in your pants pockets—pollen is everywhere. Some 240,000 described species of flowering and coniferous plants produce the fine dust—many in huge quantities—yet single grains are invisible to the naked eye. Their diverse beauty is revealed best in scanning-electron-microscope images like those on these pages, magnified thousands of times and hand-colored. Pollen's shapes and adornments fulfill a practical purpose, researchers theorize: Each grain is designed to help the male reproductive cells inside it find their way, whether on wind, water or animals, to female parts of the same species, and stay there. Yet lately pollen has begun to play a very different role—as a sophisticated form of forensic evidence.

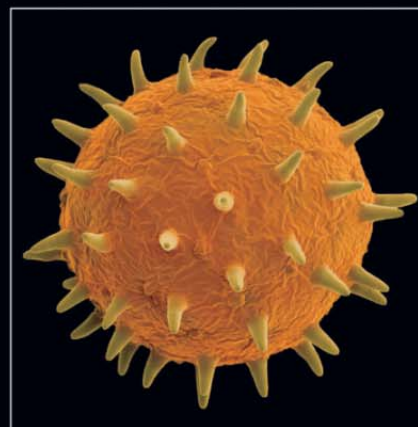
The Pollen Print

French forensics pioneer Edmond Locard famously stated that every contact leaves a trace. This is a defining principle of forensics. Trace evidence may be clothing fibers, a fingerprint or DNA from blood or hair. Or it could be pollen.

Bees, like other animal pollinators, pick up the grains as they travel from flower to flower, collecting nectar

CATCHING A RIDE ▲

Two pollen grains of a high mallow flower are attached to a bumblebee's leg. Animal-dispersed pollen is usually bigger, heavier and more adorned than wind-dispersed varieties.



◀◀ **OPEN WIDE**

Most pollen, like that of the pinang palm, has one or more apertures, openings covered by membranes that burst under pressure from its pollen tube [not shown]. Reproductive cells travel down the tube to the ovule of a receptive flower.

◀ **PRETTY PRICKLY**

The apertures are closed on this ginger-bush grain and appear as small bumps between spines.

POLLEN PARACHUTES

The wind-dispersed grains of the Douglas fir, commonly used for Christmas trees, rely on air-filled sacs [yellow] to stay afloat.





CONNECTED FOR LIFE

Long, sticky threads link fireweed's triangular grains.

and pollen for food and nest building. Pollen grains that travel on animals tend to be relatively large (up to 200 microns, or 0.008 inch, across) and can be elaborately adorned. These adornments may have evolved to help the grains attach to animals or to the stigma, the female receptive organ on a flower. Wind-dispersed pollen is usually smaller (five microns at its tiniest), smoother and more plentiful, but it's no less striking. A glance at the grains in a scanning electron microscope explains why palynologists refer to pollen's artful topography as "sculpture."

Surprisingly, not all pollen is spherical. Some is disc-like, some football-shaped and some triangular. The pollen of a particular species even differs from that of its closest relatives. Spores, the reproductive cells of the planet's roughly 26,000 described ferns, mosses and other primitive, asexual plants, also vary from one another. All this diversity of shape and size means there's a different "fingerprint" for every plant in the world. These fingerprints are the domain of forensic palynologists, a small group of experts who use pollen and spores to link objects and people to crime scenes.

And just as every plant has its own fingerprint, every location too has a distinct "pollen print," the assemblage

of different types of pollen and spores present on the scene. Matching the pollen print from a crime scene to samples found on a suspect's belongings may place the person at the scene. If a suspect denies having been there, pollen may show that he's lying. And if a victim and suspect have the same pollen profile on them, it can often be concluded that both were at the same place at the same time. "Pollen is one of the most powerful techniques in trace and contact evidence," says Patricia Wiltshire, a forensic ecologist, botanist and palynologist at the University of Gloucestershire in England, which leads the world in the use of forensic palynology.

Beautiful Tool

Last year, Wiltshire used pollen to convict three drug dealers for murdering a drug runner. "It was a spectacular case," she says. "One of the gang hid behind an oak tree within a cypress hedge. We showed that the palynological assemblage in samples from the crime scene—from leaf litter, soil, washings from the oak tree trunk and from foliage on the cypress hedge—was very similar to that on the clothes, shoes and vehicles retrieved from the suspects. There were a number of rare plant pollens that were in the soils at the scene that matched

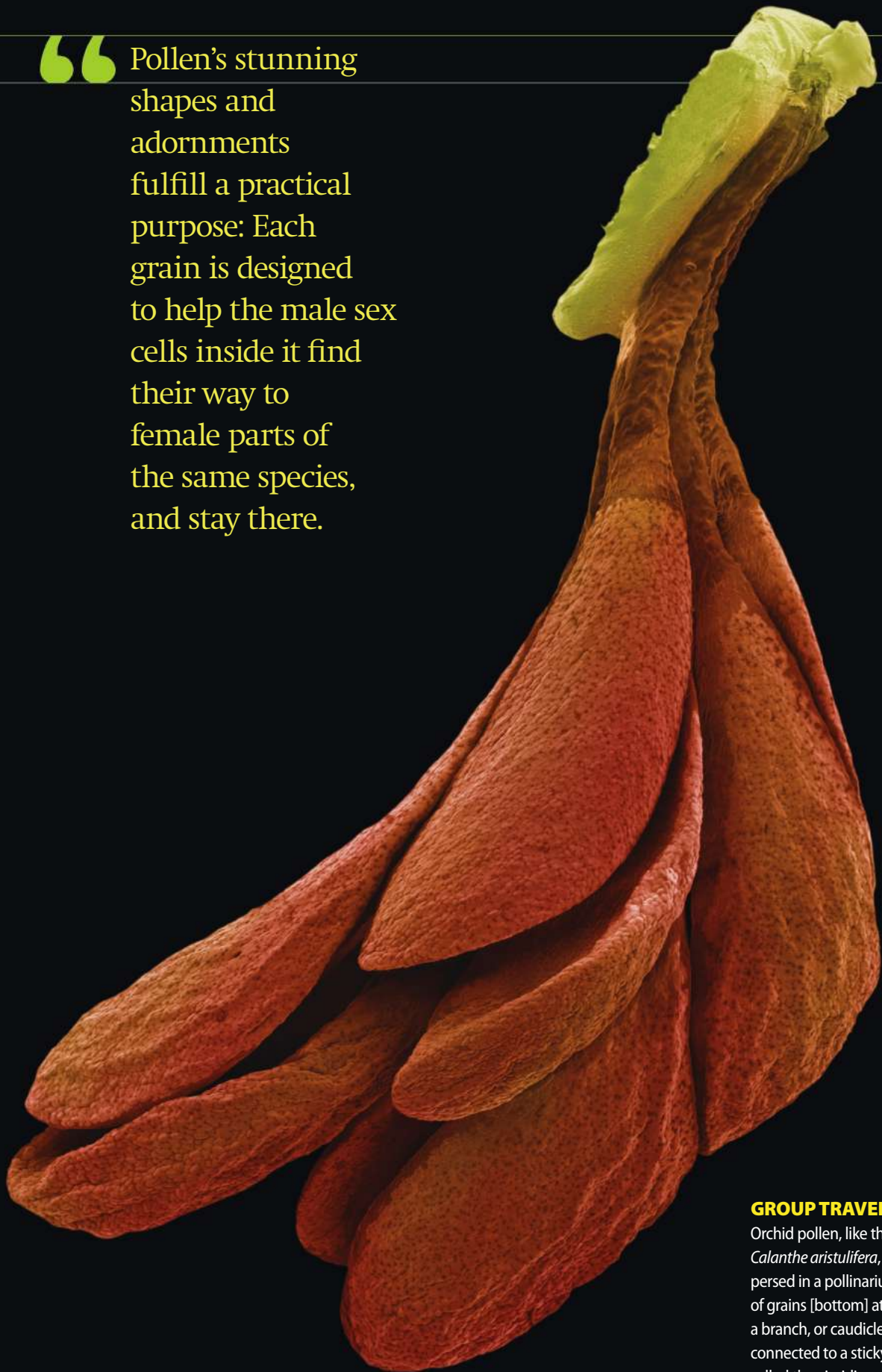
some on the exhibits." All three of the suspects were found guilty, thanks in large part to Wiltshire's pollen analysis, and sentenced to life in prison.

DNA, the current darling of forensics, is faster to process than a pollen assemblage, which must go through a painstaking chemical treatment to remove the material surrounding it and the cytoplasm and sex cells inside it and then be carefully analyzed through a microscope to identify each individual species. Palynologists can determine a plant group—spruce trees, for example—using a standard light microscope at up to 1,500 times magnification. More time-consuming and expensive is the higher-resolution scanning-electron- or transmission-electron-microscope analysis that's sometimes needed to identify a plant species. So why bother with pollen? "The problem with a single hair is, how did it get there?" explains Dallas Mildenhall, a principal scientist at the forensics lab GNS Science in New Zealand. "Couldn't it have blown in from the window? But when you're dealing with a large number of pollen grains, the chances are highly likely that they were transferred at a precise time."

"For a while, DNA was God," adds Lynne Milne, Australia's leading forensic palynologist at Curtin University of Technology. "It almost seemed



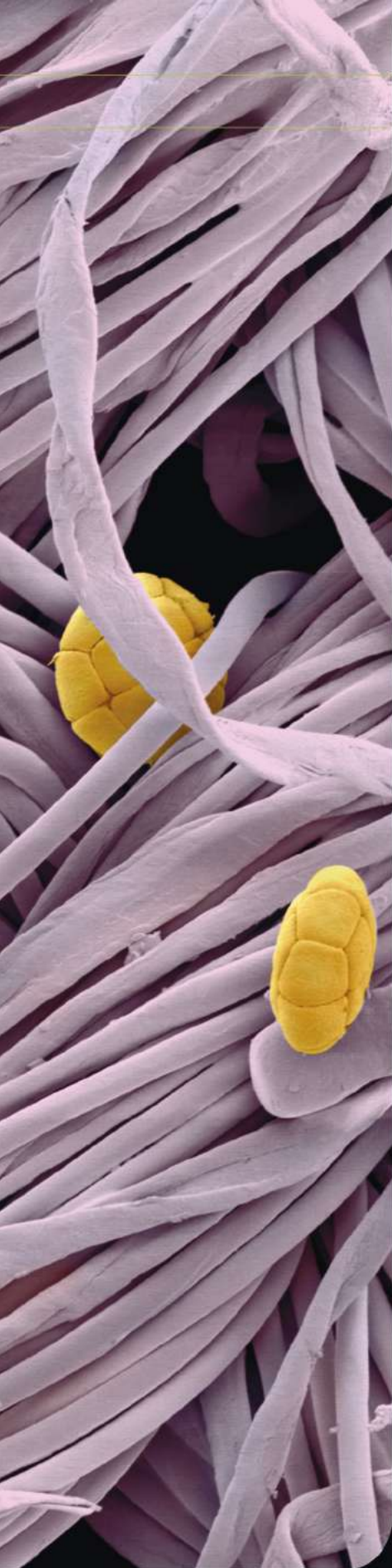
Pollen's stunning shapes and adornments fulfill a practical purpose: Each grain is designed to help the male sex cells inside it find their way to female parts of the same species, and stay there.



GROUP TRAVEL

Orchid pollen, like that of *Calanthe aristulifera*, is dispersed in a pollinarium, a group of grains [bottom] attached to a branch, or caudicle [middle], connected to a sticky structure called the viscidium [top].





like if there was no DNA, there was no evidence. But now people are looking at it differently.” One of pollen’s greatest advantages for forensics is its microscopic size. Criminals don’t realize they’ve taken it with them or left it behind. In Milne’s first case, in 1997, a man washed his clothes after murdering his estranged wife. Laundering the clothes didn’t succeed in eliminating the trace evidence on it. Milne still found an uncommon type of acacia-shrub pollen on his shirt clearly linking him to the woods where he had dumped his wife’s body and to the car that had been used to get there.

The Coldest Cases

Pollen’s cell walls are very durable, so the grains can survive for millions of years. In one case in Wales, pollen from a walnut tree that had been cut down 80 years prior linked suspects to the scene of a crime where the tree had once stood. The pollen had persisted in the soil and made its way into the suspects’ vehicle. Pollen’s longevity makes it especially useful for investigating cold cases, like the mysterious identity of a teenage girl murdered in a cornfield in upstate New York in 1979. Twenty-seven years later, in 2006, palynologist Vaughn Bryant, the director of the palynology lab at

TAKING FLIGHT

Pollen is produced in anthers, the sacs on the tips of the stamens, the male organ of flowers.



◀ SHIRT TALES

Pollen on clothing, like these silk-tree grains trapped on the fibers of a cotton shirt, can link people to crime scenes. This species sheds polyad pollen, in which grains are packaged in groups of four or more.

CASE CLOSED

Grains of pollen from the acacia, or wattle, family of shrubs helped solve a 1996 murder in Australia.



Texas A&M University, analyzed her clothing and found pollen that occurs only in the southwestern U.S., possibly around San Diego. This supported the local police's belief, based on other evidence, that she was from the southwest, not the northeast. "Pollen is an incredible tool and resource," says Livingston County sheriff John York, who is still searching for the girl's identity. "We can always suspect where a person came from, but to have definitive proof is another thing."

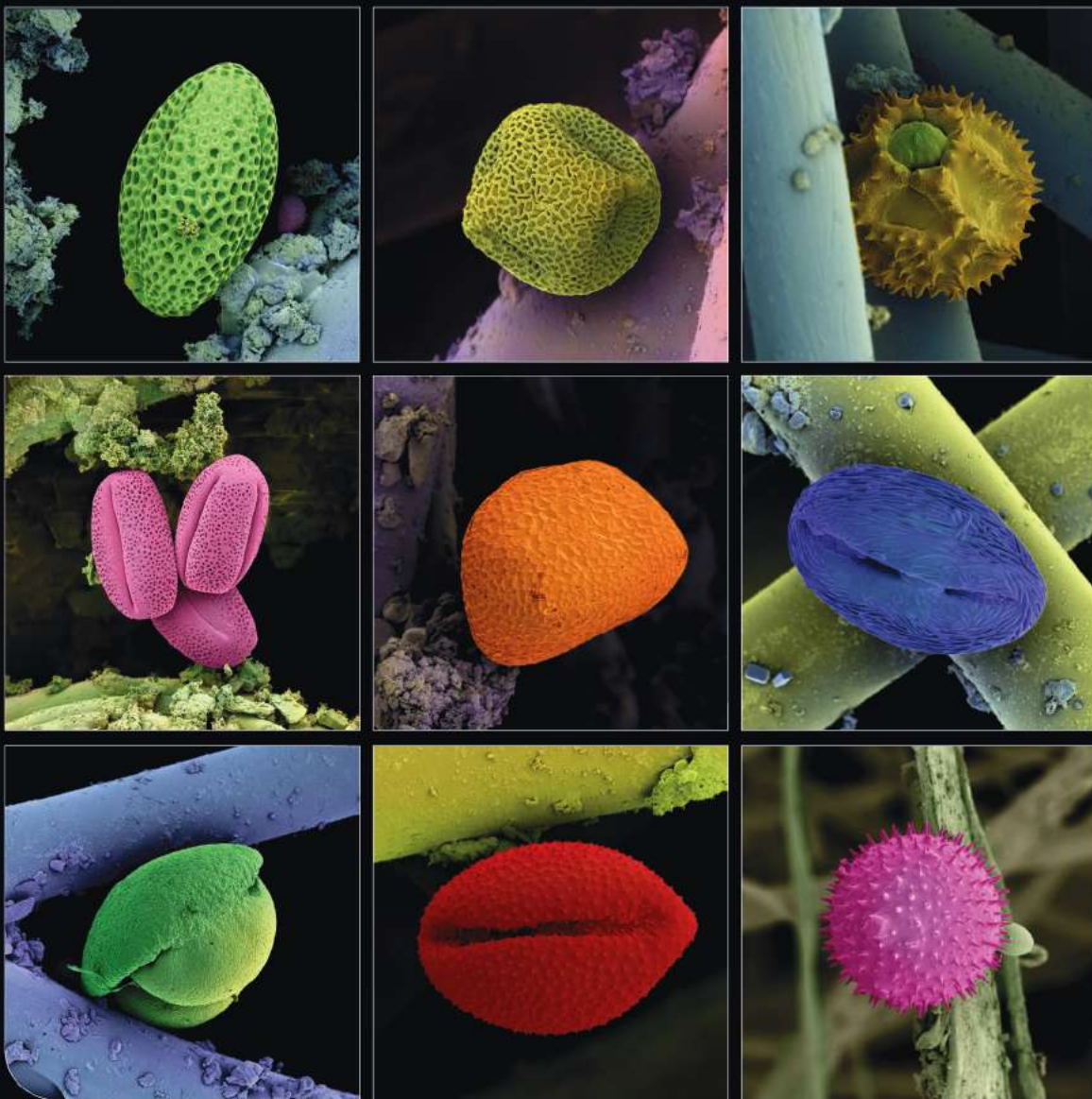
The U.S., with its huge diversity of flora and extensive pollen records, is ideal for forensic palynology. The field debuted here in the mid-1970s, when the Department of Agriculture first used pollen to ensure that beekeepers receiving domestic subsidies were actually making their honey in the U.S. But it's only been used in a handful of criminal cases here since then. "Local law-enforcement agencies don't know about it or don't believe it's useful," Bryant says.

"Or they don't want to pay for it."

Interest has grown at the federal level since 2001. "After 9/11, Bryant says, "the U.S. government was eager to do anything to find out who had committed the attacks and to prevent it from happening again." Pollen has since been used in several terrorism investigations. Although he couldn't comment on the cases, Bryant hinted at their nature: "Pollen is a very good telltale for where things come from." The burned clothing of suicide bombers, for example, may retain pollen that could hold clues to their origin. Pollen has also been used to investigate war crimes. In the late 1990s, forensics experts working with the United Nations in Bosnia found pollen evidence indicating that more than 2,000 Bosnian Muslim men and boys executed over five days in 1995 during the Bosnian war had later been moved from five large mass graves to several smaller ones scattered across the countryside to cover up the massacre.

Yet pollen's purview extends far beyond violent crimes. Around the world, it has been used to break up a cocaine ring, authenticate antiques, find counterfeit Viagra and antimalarial drugs, and even track down stolen sheep and a lawn mower. Pollen's seemingly limitless versatility is one more reason why it's a crucial addition to the forensics toolbox.

And it won't be the last. A few years ago, a fungus expert, or mycologist, named David Hawksworth advanced Wiltshire's work by sharing his knowledge of fungi, whose spores, like those of plants, can link objects and people to crime scenes. Mold can also be used to determine time of death when other clues, like flies swarming a corpse, aren't present. Hawksworth and Wiltshire later married, and today the two are championing the use of ecological evidence in forensics. Pollen and fungi evidence have bolstered each other in some cases, Wiltshire says. Fungus, it seems, is the next frontier. ■

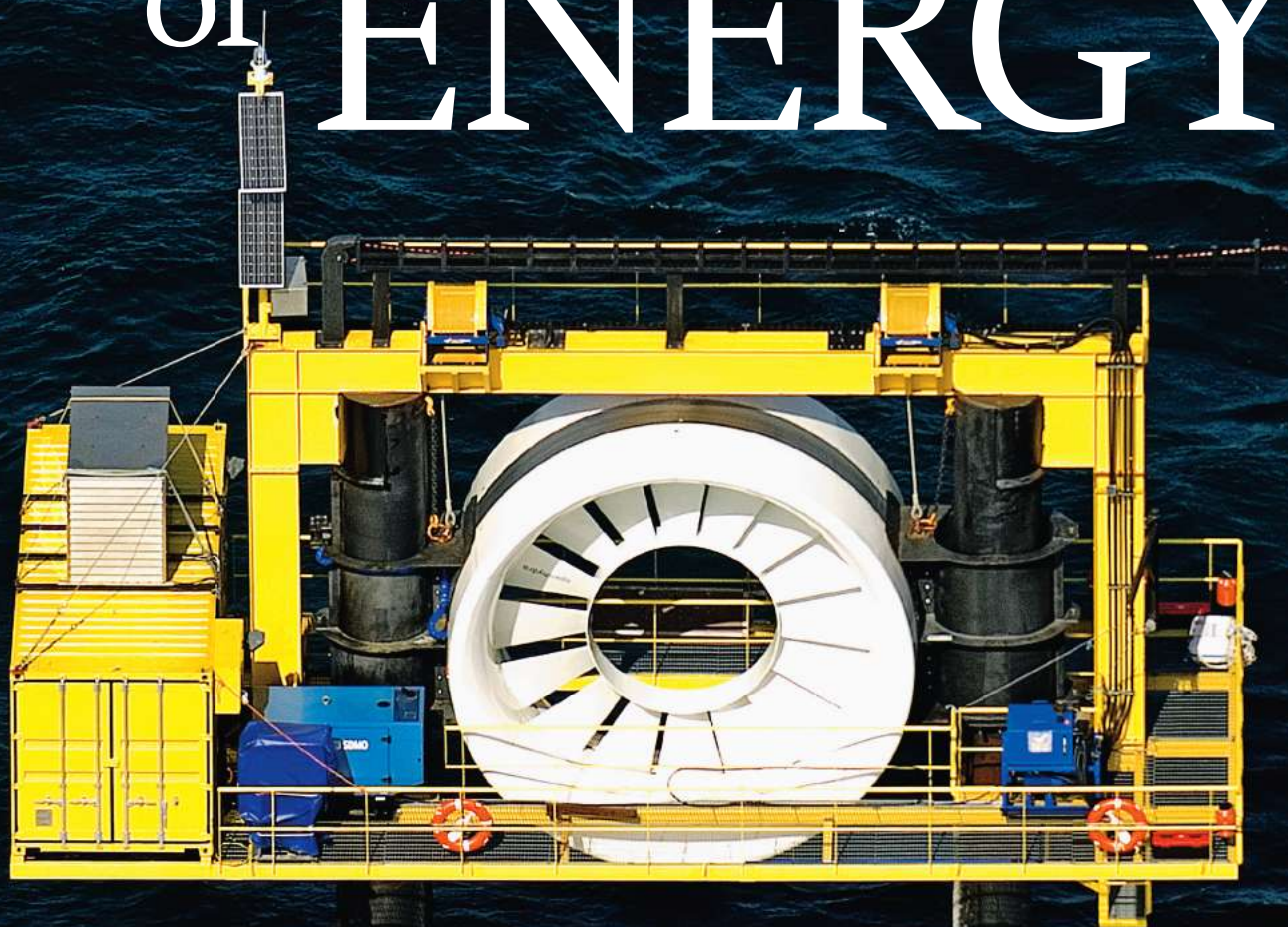


BEHIND THE SCENES

The scanning electron micrographs in this story were captured by visual artist Rob Kessler, a former fellow at the Royal Botanic Gardens, Kew, in England, and Madeline Harley, the former head of the palynology unit at Kew and a current research fellow there. Kessler colored the black-and-white images—including the group on this page, from his car's air filter—by hand. "My coloration is based on the flower

color and adjusted to give the form a stronger feeling of three-dimensionality while also indicating different functional characteristics of the pollen grain," he explains. "I spend a lot of time building up subtle layers of color to create the final image. Although I use a graphic pen and drawing tablet, the artistic sensibilities are in many ways no different than when I draw with pastels or paint with watercolors."

Oceans of ENERGY



Waves and tidal currents are two of nature's most renewable resources. The U.S. and European nations are finally taking notice, with prototype power plants springing up in their coastal waters

A tidal turbine is installed off the coast of the Orkney island of Eday.

Water crashes against the steep, rocky cliffs on the western coast of Mainland, the largest of the Orkney Islands north of Scotland. The waves rolling in from the Atlantic are typically 6 to 10 feet high in the summer. In winter, they can reach 30 feet. It's a perfect home for the European Marine

Energy Center (EMEC), a testing ground for wave- and tidal-power installations.

Ocean-power generators are simple in theory. Like conventional hydroelectric power plants, which are often located in river dams, marine plants rely on moving water—either from strong tidal currents or big waves—to turn a mechanism such as the blades

in a turbine, driving a generator to produce electricity. But ocean-power stations must be able to withstand the heavy currents and unpredictable weather of the open seas.

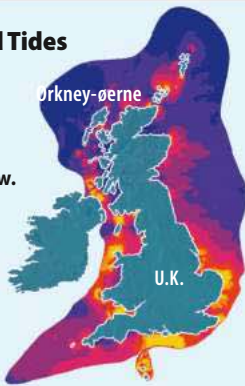
EMEC will need to ensure the reliability and safety of ocean installations under such harsh conditions and prove that the projects won't harm

High-Powered Tides

The areas around the British Isles with the most potential for tidal power are in yellow.

Map courtesy of Sustainable Development Commission, Scotland

Tidal Activity
High Low



The Earth's Tides Explained

The tides are controlled by the gravitational pull of the moon and the sun. The moon is the major player, causing water to collect at the points on the Earth that are closest to it and opposite it. This results in high and low tides approximately two times a day.

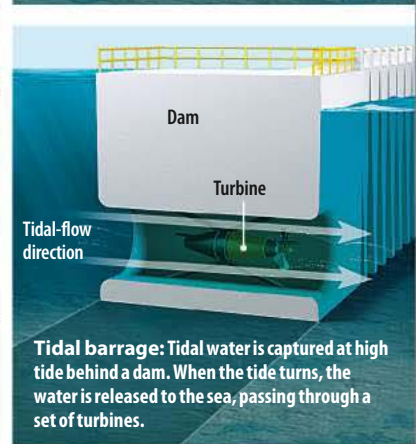
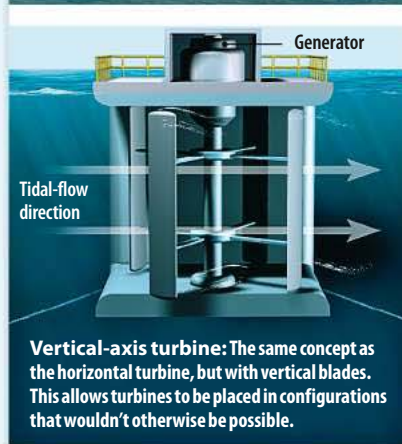
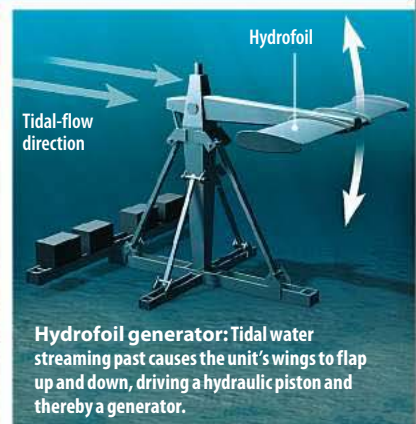
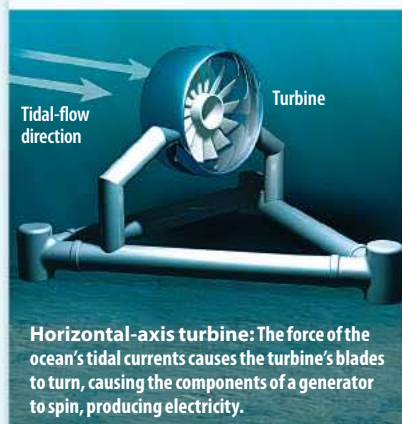
Features on the Earth's surface can affect the height and speed of the tides as well. The tides flow over an uneven ocean floor and around uneven landmasses, sometimes spreading out over an especially deep or wide body of water and sometimes funneling into especially shallow or constricted areas such as bays, inlets or even rivers.

This funneling often causes choppy waves, whirlpools and fast-moving currents—like the nearly 9mph stream at the European Marine Energy Center's Eday test site in the Orkney Islands—as water travels between two landmasses or

STATUS
The first commercial tidal-power plant is operating off the coast of Northern Ireland, with a waiting list for several more designs to be tested at the European Marine Energy Center's test site in the waters around the Orkney Islands.

Exploiting the Power of the Tides to Create Energy

Energy can be harvested from tidal currents in various ways, from very simple underwater turbines to enormous damlike projects. Here are four designs:



over a shallow area of the ocean floor. It can also cause a phenomenon known as a tidal bore, in which the incoming high tide creates a wave that travels up and against the usual current of a river or inlet.

Tidal bores can speed along two or three times as fast as the tidal current in open

water, sometimes accompanied by high, powerful waves. On the Amazon River, for example, the waves of the tidal bore can reach 12 feet high and are strong enough to dislodge logs along the river's edge. And on China's Fuchun River, waves crest as high as 15 feet, and the current travels up to 15 mph when the tidal bore rolls in.

the marine ecosystem. To do so, it has started laying down infrastructure for test projects from companies around the world in the waters near Orkney. Undersea electric cables connect equipment just off the coast of the island of Eday to a substation onshore. The cables carry power from underwater installations that will attempt to use

the area's almost 9mph tidal streams—among the fastest in Europe—to generate electricity. Likewise, cables have been laid from the open waters off Mainland to test harnessing waves.

Others Dive In

The U.S. lags behind the U.K. in wave- and tidal-power technology, with most

projects still in the planning stage. To help America catch up, last year the Department of Energy invested more than \$17 million to support research on the technologies. Part of that money established the Hawaii National Marine Renewable Energy Center at the University of Hawaii and the Northwest National Marine Energy Center, run

Waves of the Future

Wave power has always lagged behind tidal power, which takes advantage of the slightly more predictable nature of currents and has more similarities to wind power.

Wave power suffered a setback in 2008, when a principal investor in a wave farm off the coast of Portugal—

the first ever to deliver power to the grid—went bankrupt, forcing the farm to shut down after just a few months at sea. But supporters of wave power haven't been discouraged. "We learned a huge amount from the Portugal project," says Max Carcas of Pelamis Wave Power, the Scottish company responsible for the design and manufacture of the equipment used at the Portugal farm. "We're keen to move forward," he says.

The company is partnering with the English energy supplier E.ON UK to install and

test Pelamis's attenuator-style machines [see Attenuator, facing page] at the European Marine Energy Center's Orkney site later this year. And in March, Pelamis announced another energy-company partnership with plans to manufacture and test a second machine at Orkney. Each test-site installation will produce enough electricity to power 500 homes. If all goes well there, the company will deploy larger wave farms at other sites around Scotland, ultimately generating enough electricity for 100,000 homes.

STATUS

The first wave farm failed financially, but new installations connected to the grid (each with the capability to power 500 homes) are in the works in the U.K., and full-scale wave farms could eventually provide enough electricity to power 100,000 homes.

Pelamis's wave-power installation resembles a sea serpent and will soon be installed at the European Marine Energy Center's test site.

PELAMIS WAVE POWER; PRECEDING PAGES: FROM LEFT, MIKE BROOKES/ROPER, CLAUDI LUNAU

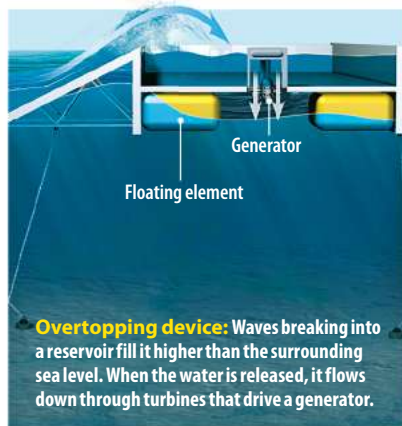
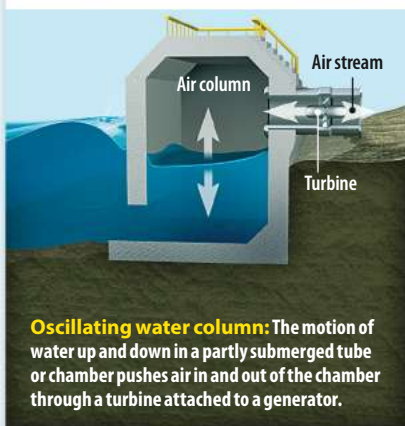
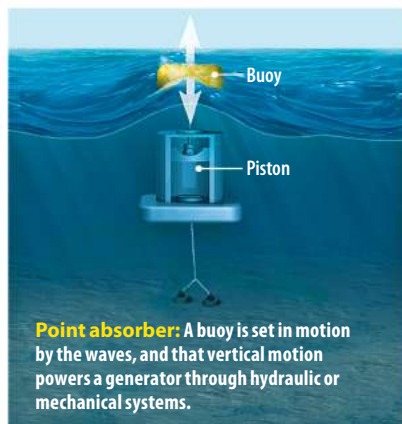
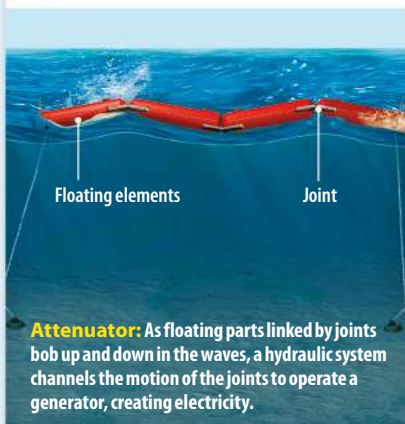
jointly by Oregon State University and the University of Washington. Much like EMEC, the centers will host ocean-power prototypes and allow researchers to study the performance and environmental effects of their designs. The DOE is also keeping track of some 70 other wave and tide projects being tested in U.S. waters.

Across the pond, the first commercial tidal-power plant, owned by Marine Current Turbines, is already operating in Northern Ireland. With the U.S. increasingly focused on eco-friendly energy and the European Union committed to drawing 20 percent of its energy from renewable sources by 2020, ocean-based

power plants have the potential to be the next big thing in alternative energy. And although there's still a long way to go—wave and tidal power lags about 20 years behind wind, and no one is quite sure which of the proposed designs will prevail—researchers are working hard to help ocean power enter the playing field. ■

Rugged Installations Generate Power on the High Seas

Powerful wave conditions demand strong materials such as giant plants built into coastal cliffs and resilient equipment that can move with the force of the water. Here are four designs:



More Ways to Harness the Ocean's Energy

In the future, tides and waves will probably be the most important sources of energy from the seas, but not the only ones. Even though the major oceanic currents usually move far more slowly than tidal currents, they could provide energy. Researchers in Florida are studying whether the energy in the Gulf Stream, which flows along the East Coast, could be tapped.

A method known as ocean thermal energy conversion (OTEC) takes advantage of the substantial temperature difference between cold deep-sea water and warm surface water, using both in a process that generates electricity. OTEC systems are being researched at the National Energy Laboratory of Hawaii Authority facility in Kailua.

And last November, the European energy company Statkraft opened its prototype osmotic power plant in Tofte, Norway, which harnesses the pressure of saltwater and freshwater mixing through a semipermeable membrane to drive a turbine.

Where the Waves Are

Not all the world's seacoasts have useful wave energy. Some seas are placid; others have powerful waves rolling in year-round. Here, the red lines show the areas with the most potential.

Average wave strength
(in kilowatts/meter of wave crest)



The Strength to Live

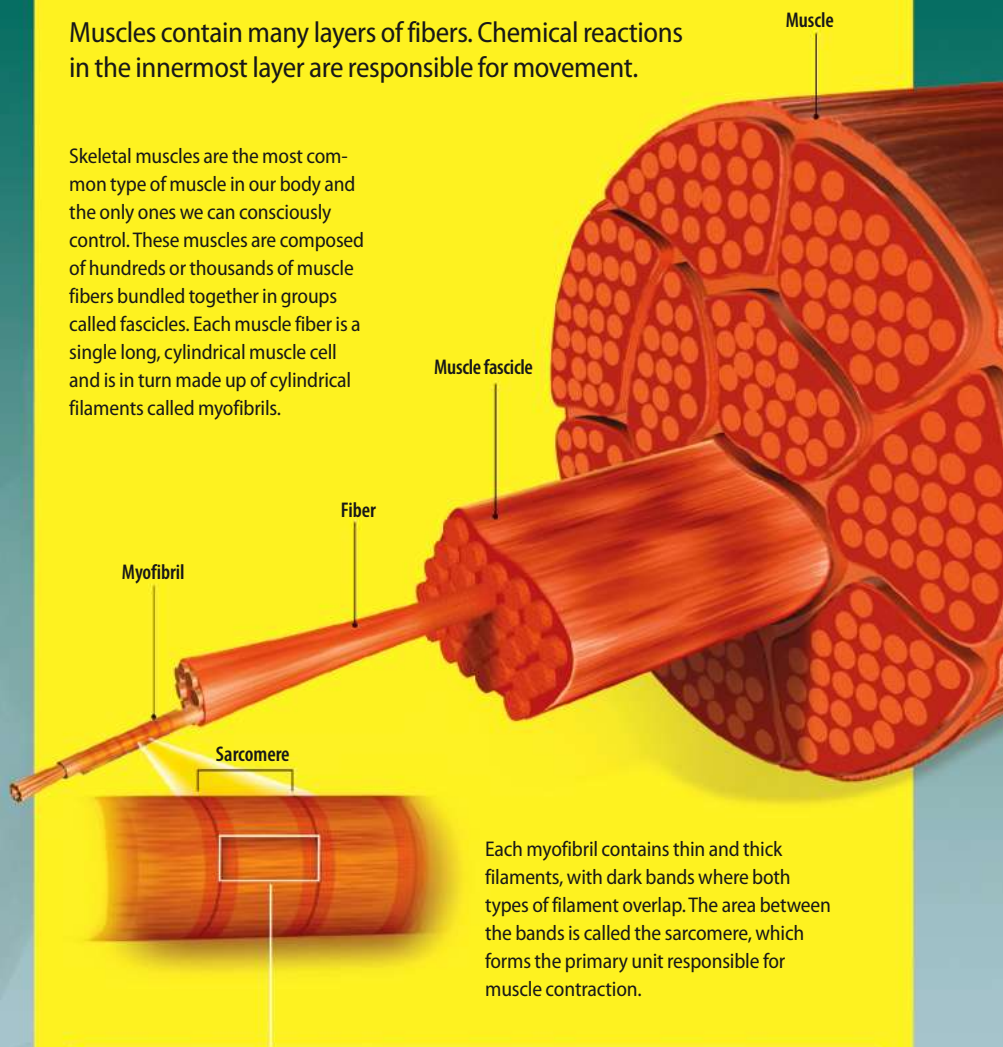
Exercise causes the body to secrete many compounds that keep us disease-free, which could help explain why a lack of activity can lead to diabetes, cardiovascular disease, depression and cancer. Here's how movement sustains us

BACKGROUND

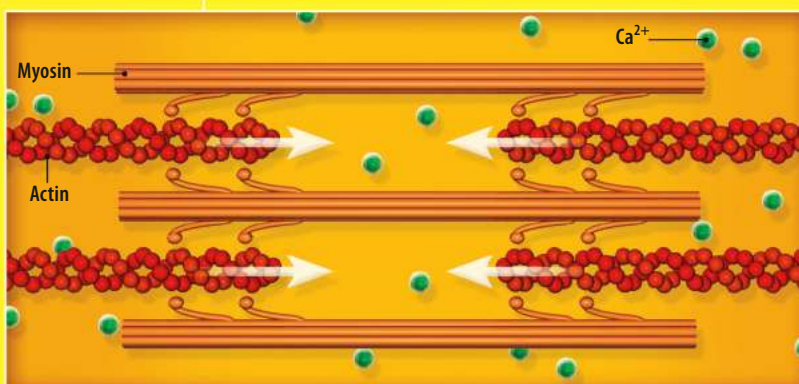
Calcium Ions Make Us Move

Muscles contain many layers of fibers. Chemical reactions in the innermost layer are responsible for movement.

Skeletal muscles are the most common type of muscle in our body and the only ones we can consciously control. These muscles are composed of hundreds or thousands of muscle fibers bundled together in groups called fascicles. Each muscle fiber is a single long, cylindrical muscle cell and is in turn made up of cylindrical filaments called myofibrils.



Each myofibril contains thin and thick filaments, with dark bands where both types of filament overlap. The area between the bands is called the sarcomere, which forms the primary unit responsible for muscle contraction.



When a nerve impulse activates a muscle, calcium ions (Ca^{2+}) stream out into the muscle cell. The calcium allows actin (thin) and myosin (thick) filaments within the myofibril to bind, pulling the filaments toward each other. The sliding filaments cause each sarcomere to contract a bit. This process occurs simultaneously across all the sarcomeres, so that the entire fiber contracts at once.



of the muscle secretome will set a new agenda for the scientific community which is likely to dominate the coming decade.”

—Bente Klarlund Pedersen

Centre of Inflammation and Metabolism at Rigshospitalet, Copenhagen

Exercise is the cornerstone of good health—it strengthens the heart and lungs and helps us keep our weight under control. Staying active also benefits the body in more-subtle ways, reducing the risk of obesity, diabetes and cardiovascular disease. For example, physical activity seems to ward off insulin resistance, which occurs when cells become less sensitive to the ability of the hormone insulin to decrease blood glucose levels. This resistance can cause a buildup of blood sugar, which may lead to several illnesses, including cardiovascular disease. Sedentary adults are more likely to suffer insulin resistance, a condition that could eventually lead to Type 2 diabetes. And people who don't exercise are more likely to suffer atherosclerosis, a condition in which plaques form on the walls of arteries. The deposits can become so thick that blood cannot flow through.

A common factor in all diseases associated with a lack of exercise is constant, low-level inflammation in the body. This inflammation manifests as a slight increase in the number of immune-signaling molecules, called cytokines, circulating in the blood. But although researchers have known about the interplay between exercise and inflammation for some time, it is

only in the past decade that they have begun to understand the biological underpinnings of the phenomenon.

How Exercise Bestows Its Benefits

Scientists had been looking for half a century for a conclusive link between exercise and the changes it induces. The skeletal muscles that help us move our limbs were obvious targets for studying exercise-related physiological and biochemical changes. Many of the effects muscles have on metabolism and systemic inflammation were thought to be indirect—somehow muscle movement affected the nervous system, researchers believed, which in turn reduced inflammation in the body. But experiments in patients with spinal-cord injuries, who could no

longer voluntarily move their muscles, suggested that muscles reduced inflammation directly, rather than being mediated solely by the nervous system. When these patients' paralyzed muscles were electrically stimulated, the researchers noticed metabolic and hormonal responses despite no involvement of the nervous system.

As a result, scientists hunted for an “exercise factor,” the exact process or chemical released by contracting skeletal muscles that might account for some of the exercise-induced changes in other parts of the body. “It was while looking for a mechanistic explanation for exercise-induced immune changes that I came across interleukin (IL)-6,” says Bente Klarlund Pedersen, the director of the Centre



When mice are fed a high-fat diet, they typically accumulate large amounts of abdominal fat [1, 3]. But mice that were genetically modified to secrete more myokines were leaner and stronger despite being on the same diet [2, 4].

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of Inflammation and Metabolism at Rigshospitalet in Copenhagen. “Our identification of muscle as a cytokine-producing organ was a breakthrough.”

In 2000, Pedersen found that contracting muscles released significant amounts of IL-6 into the circulation during prolonged exercise. Such muscle-secreted cytokines and hormones were dubbed myokines. Further experiments also showed that this muscle-derived IL-6 has played an important role in metabolism.

The First Piece of the Puzzle

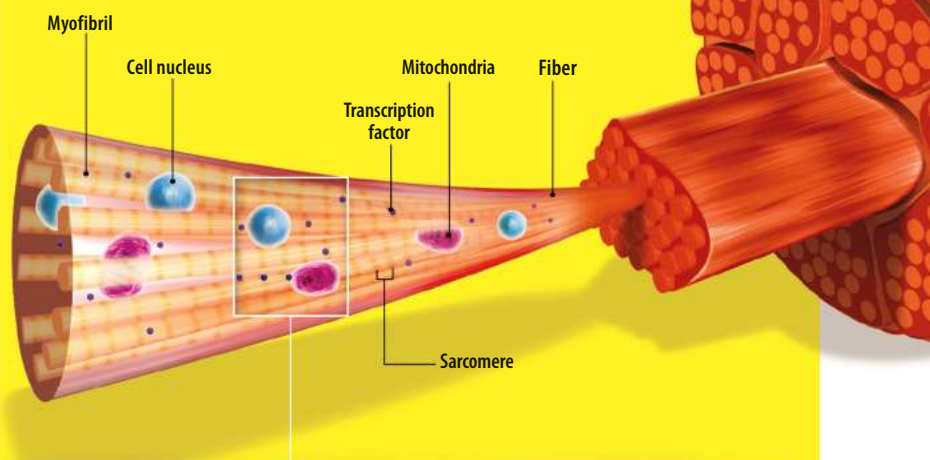
IL-6 is a classic pro-inflammatory cytokine, normally secreted as a signaling molecule to cause inflammation that helps the body fight off infection by microorganisms. IL-6 is also the first and most abundant myokine produced during exercise, and its concentration increases exponentially during strenuous activity, peaking at the end before falling back shortly after. Pedersen and her colleagues initially thought that muscle damage from exercise induced immune cells to secrete IL-6. One of Pedersen’s key discoveries was that contracting muscles produce IL-6 themselves and secrete it into the blood. She also found that exercise-induced IL-6 actually reduces inflammation rather than causing it.

Because IL-6 is mainly produced in immune cells, researchers tried to figure out why muscles released it during moderate exercise. One explanation is that calcium secreted within muscle cells during a contraction could cause intermediate proteins, known as transcription factors, to stimulate IL-6 production. Another theory is that reactive oxygen species (ROS)—chemical waste products created in muscles during exercise that react with and alter other compounds in the cell—could act on other transcription factors to raise levels of IL-6.

“Some of the benefits of regular exercise may be due to its anti-inflammatory effects, which may be mediated in part by IL-6,” says

Contracting Muscles Produce Myokines

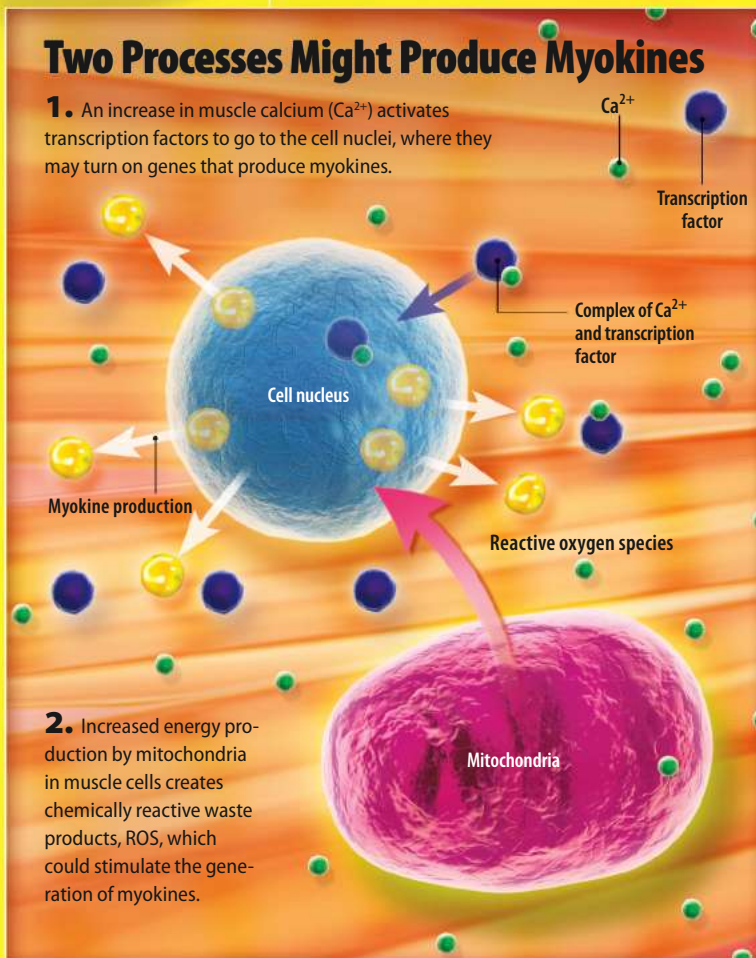
When a nerve signal causes a muscle to contract, it begins to produce chemicals called myokines, such as IL-6, which have many beneficial effects on the body.



Two Processes Might Produce Myokines

1. An increase in muscle calcium (Ca^{2+}) activates transcription factors to go to the cell nuclei, where they may turn on genes that produce myokines.

2. Increased energy production by mitochondria in muscle cells creates chemically reactive waste products, ROS, which could stimulate the generation of myokines.



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A Sedentary Lifestyle Causes Disease

Part of the benefit of exercise stems from the anti-inflammatory effects of myokines. Without them, abdominal fat promotes mild inflammation in the body, which is associated with a number of chronic diseases

Dementia and depression: Exercise helps guard against depression, possibly by increasing production of a myokine, BDNF. This myokine helps the cells of our nervous system grow and survive, and reduced levels have been associated with depression and impaired memory and cognition.

Cardiovascular disease: Chronic inflammation can activate immune cells, and these cells can influence plaque formation in arteries. These deposits cause a narrowing of the arteries, leading to high blood pressure and increasing the risk of blood clots, heart attacks and strokes.

Breast and colon cancer: Inflammation can cause the pancreas to secrete more insulin, which can increase cell growth, especially in the colon, and may ultimately lead to cancer. It is also possible that lack of exercise could prevent the secretion of a myokine with anticancer properties, but such a myokine hasn't yet been identified.

Type 2 diabetes and obesity: Low-grade inflammation and insulin resistance are also known to lead to Type 2 diabetes. In addition, without exercise-induced secretion of IL-15, we accumulate abdominal fat, which can contribute to obesity.

Pedersen. This finding was initially confusing, since IL-6 causes inflammation when secreted by immune cells. The key to this conundrum seems to be other pro-inflammatory molecules, such as tumor necrosis factor alpha (TNF-alpha), which determines whether IL-6 will increase or decrease inflammation. When TNF-alpha is present, IL-6 promotes inflammation. But exercise appears to inhibit TNF-alpha, and the IL-6 molecules suppress inflammation instead. Whether IL-6 has a pro- or anti-inflammatory role thus depends on when, in which cells and with which other molecules it's released.

Using Myokines to Boost Metabolism and Prevent Diseases

After IL-6, other myokines were discovered, each with a specific effect on body composition and physiology. A myokine expressed in skeletal muscle called IL-15 promotes muscle formation and may also reduce accumulation of fat, especially in the abdomen. Belly fat is particularly harmful because it is associated with insulin resistance and diabetes. Mice that expressed high levels of IL-15 have significantly reduced body fat; and the results are similar in people. Humans with higher IL-15 gene expression levels, which can be achieved through strength training, also tend to have lower levels of body fat. Further, researchers believe that IL-15 promotes muscle growth both

CLAUS LUNAU

PERSPECTIVES

Exercise Pills

Chronic inflammation is associated with aging and long-term medical conditions, but exercise can alleviate the inflammation because of the secretion of anti-inflammatory myokines during physical activity. To mimic the effects of exercise in those who cannot

by increasing protein production and inhibiting protein breakdown. Another kind of myokine, IL-8, helps the body form new blood vessels.

The brain is not immune to the effects of myokines, either. One myokine, brain-derived neurotrophic factor (BDNF), helps regulate the survival, growth and maintenance of nerve cells. Decreased levels of this protein are associated with major depression, impaired memory and cognitive function, and Alzheimer's disease. Although this protein increases in muscles after exercise, it is not released into the bloodstream, so BDNF's direct effect may be only on fat metabolism in the muscle. Its other effects may be indirect.

To understand myokine regulation and its effects on body composition, biologist Kenneth Walsh of Boston University bred mice that expressed a protein that increases the secretion of fibroblast growth factor-21 (FGF21), another myokine. These mice became leaner and stronger than others despite being fed the same diet and getting less physical activity.

Myokines' influence on inflammation, obesity and insulin resistance has implications for cardiovascular diseases and even cancer. Low-grade inflammation and insulin resistance can lead to hypertension, stroke and heart disease, partly through atherosclerosis. The increased insulin secretion that occurs as a result of insulin resistance can also promote



Researchers analyze a patient's metabolism to try to understand the beneficial effects of exercise.

cell proliferation that could result in cancer. Pedersen speculates that some myokines may have anticancer properties, and her efforts to find more myokines will undoubtedly uncover more of these proteins' positive effects.

Next Step: Put It in a Pill

Exercise plays a central part in regulating metabolism and protecting us from chronic diseases, but just how it improves our health involves a complex interaction between cells and signaling molecules, such as myokines. As the roster of known myokines increases, it has opened up the study of

muscles as hormone-secreting organs, like any other gland. This knowledge should provide rich territory for scientists to mine and could lead to drugs that could alter myokines' activity. For people who are bedridden because of illness or infirmity, drugs that mimic beneficial myokines could help reduce the incidence of chronic-inflammation-related disease. "Our identification of the muscle secretome [the entire map of all the proteins that muscles secrete]," Pedersen says, "will set a new agenda for the scientific community which is likely to dominate the coming decade." ■

FROM TOP: CENTRE OF INFLAMMATION AND METABOLISM; CLAUD LUNAU



physically do it, researchers are investigating whether these myokines could be given as a supplement. This could prove particularly beneficial for those with limited mobility.

Both aging and getting too little exercise also result in muscle wasting, which leads to a vicious cycle of further inactivity and insufficient myokine secretion. In this situation,

treatment with IL-15 could help ameliorate Type 2 diabetes and build muscle, and IL-6 supplements may protect healthy individuals against insulin resistance.

Anti-inflammatory drugs could also restore protein synthesis and thus prevent muscle wasting. Researchers treated age-related muscle atrophy in mice with ibupro-

fen, an anti-inflammatory agent. Unfortunately, high doses of these medications can cause serious side effects in humans. But some drugs, like salsalate, have shown promising results against inflammation-induced insulin resistance, and similar treatments could one day be used to protect against chronic diseases and muscle loss.



Solar Weigh-in

Astrophysicists determine the mass of stars using simple equations

Scientists can't weigh a star on a scale, but they can, with the help of gravitational formulas, find a star's mass, or the amount of matter it contains. (Weight is a different measurement: the force

that gravity exerts on a mass.) This knowledge helps astronomers and cosmologists understand how bright a star shines, plus when and how it will die.

The mass of celestial objects, like planets and stars, can be determined

by calculating how much gravity one exerts on the other. For example, the mass of the sun can be found by looking at its gravitational pull on the Earth using Newton's version of Kepler's Third Law of Planetary Mo-

ASTRONOMERS CALCULATE DOUBLE STARS' MASSES IN THREE WAYS

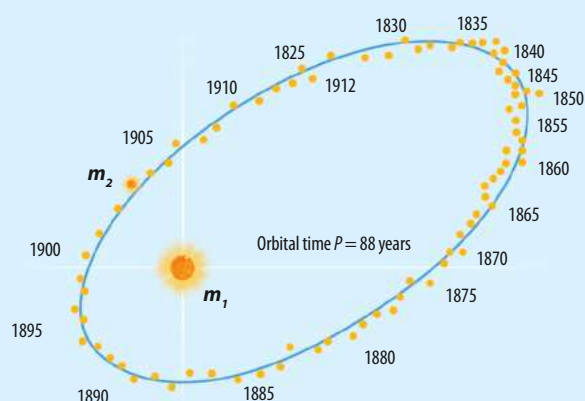
1. The Visual Binary Method

The first step to determining the mass of stars in far-off double-star systems starts in the observatory, visually determining how long it takes for one star to orbit around the other. Some orbits are so long that this can take many years of painstaking observation, which hampers its usefulness as a measurement tool.

The semimajor axis (a) is calculated using the largest visual distance between the two stars and the known distance between the observer on Earth

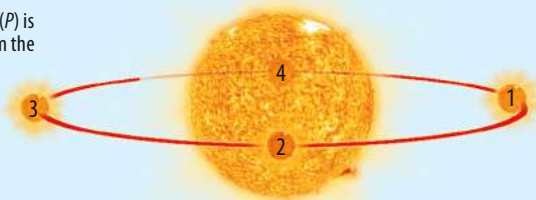
and the binary system. P is measured directly by observing the amount of time that it takes for the stars to complete one orbit. With these two numbers and the gravitational constant, the combined mass of the two stars, $m_1 + m_2$, can be calculated.

In most cases, the individual masses of the stars in a visual binary system can't be found without also applying the spectroscopic method [see facing page] because the angle of the stars' orbits is unknown.



When both stars in orbit around each other, m_1 and m_2 , can be seen from Earth, it is possible to measure the periods of their orbits, quantity P , which may be many years. The value of the semimajor axis (a) requires that their distance from Earth is known.

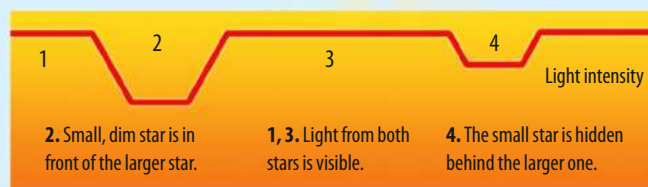
Orbital period (P) is calculated from the four positions.



2. The Eclipsing Binary Method

The most direct way to measure a binary system's orbital period, and thus its mass, occurs when the system's orbit is perfectly aligned with Earth. When that happens, one star blocks our view of the second as it passes in front of it. This happens at regular intervals. Astronomers can draw a graph of the light intensity, a "light curve," from the double-

star system. The rate of "blinking" from this system indicates the orbital period. Add to this the data from the spectroscopic method, which tells scientists the total mass of the system, and the individual masses of the two stars can be precisely calculated. Alas, only a small fraction of binary star pairs are perfectly oriented along Earth's line of sight.



Based on the timing of the light fluctuations when binary stars, as seen from Earth, eclipse each other, astronomers calculate the orbital period (P), the semimajor axis (a) and the relative distance between the two, which gives the ratio of the stars' masses.

tion: $a^3 / P^2 = Gm$. Here a represents the semimajor axis—the longest radius of an elliptical orbit—of the Earth and the sun. In this case, a is the distance between the sun and Earth because Earth's orbit is nearly circular. P is the time it takes for the planet to orbit the sun, and G is the gravitational constant for the force of gravity. To solve for the sun's mass, m , scientists plug in the distance from Earth to the sun and the time it takes Earth to orbit the sun.

This method is also used to measure the mass of stars outside our solar system, but only if the stars

are in binary systems—two stars that orbit each other—and their orbit sizes are known. The Milky Way has some 400 billion stars, and about half are part of binary systems. Even so, reliable masses are known for only around 200 stars.

In binary systems, astronomers find the combined mass of the two stars using the formula $a^3 / P^2 = G(m_1 + m_2)$. Here $m_1 + m_2$ is the sum of the two stars' masses, a is the sum of the semimajor axes of the stars, P is the time they take to orbit one another, and G is the gravitational constant. ■

3. The Spectroscopic Binary Method

As two stars in a binary system orbit each other, the spectrum (wavelengths of light) they emit will vary if the star is moving toward or away from Earth. When stars move away from Earth, the spectral lines skew to the red end of the spectrum, where light waves

are longer; when a star moves toward the Earth, the spectrum shifts to the shorter, blue end of the light scale. These fluctuations can be translated into a velocity graph for each of the two stars, and if the ratio of their velocities is known, the ratio of their mass is also known.

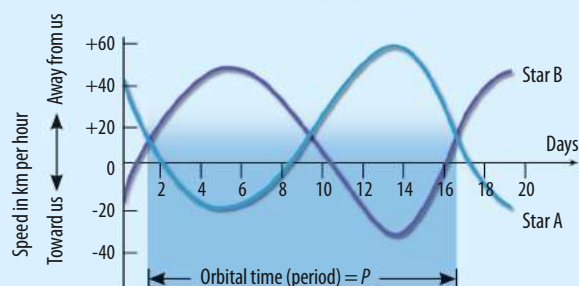
When star A moves toward Earth, the light shifts to the blue end of the spectrum.



When star A moves away from Earth, its light shifts to the red end of the spectrum.



Astronomers translate variations in the light emitted by binary stars into a velocity graph for the two stars, and from this they determine the binary's orbital period (P).



Our Sun

To determine the mass of our own sun (m_{sun}), we use the following equation:

$$m_{\text{sun}} = \frac{4 \cdot \pi^2 \cdot a^3}{P^2 \cdot G}$$

Where

a = Semimajor axis: the distance between the sun and Earth

P = Earth's orbital period

G = The gravitational constant, which is defined as

$$G = 6.67 \times 10^{-11} \frac{\text{Nm}^2}{\text{kg}^3}$$

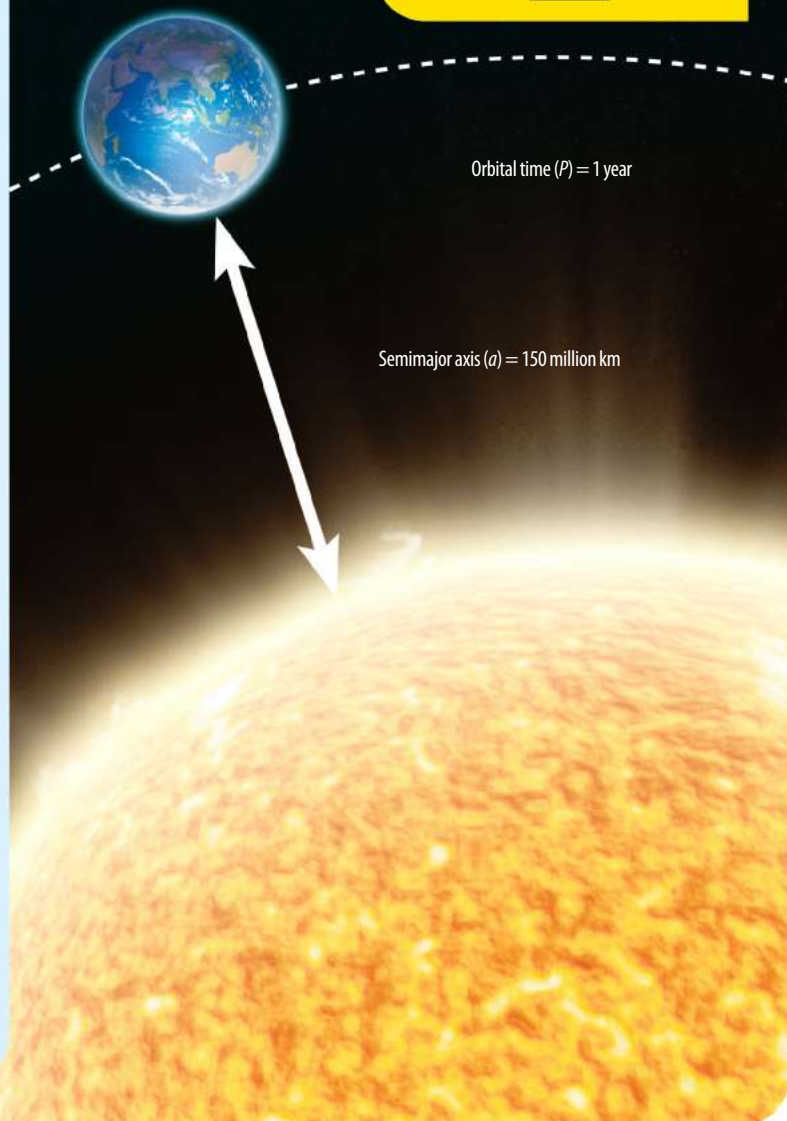
(where N , newton, is the unit kilograms times m/s^2)

If we insert these measured values:

a = 150 million km, which is 1.5×10^{11} meters

P = 1 year, which is 3.15×10^7 seconds, we get:

$$m_{\text{sun}} = 2 \cdot 10^{30} \text{ kg}$$



The Superstarvers

During scarcity, drought or winter, hunger becomes part of an animal's life. But there are many ways to survive famine, and certain species have learned to soldier on without food

Eastern Pygmy Possum

Gets fat, then dormant

Australia's Eastern pygmy possum [below] survives an unpredictable climate and irregular food supply by having the longest known period of body-fat-fueled hibernation among mammals—up to 310 days on average. Biologists think a related species, the little pygmy possum [right], hibernates for up to six months. Both species eat insects, pollen and nectar. When food is readily available they eat until they're fat, accumulating reserves to get them through lean times.



FAST LENGTH:
310 DAYS



The little pygmy possum may fast for up to six months in its dormant state.



For most animals, life is a balance between periods in which food exists in surplus and periods of scarcity. The better a species is at dealing with the hungry times, the better its chances of survival. Some animals are hunger artists, so superbly adapted that they can last months or even years without food. Others are at risk of death after just a few days without eating.

Efficient energy conservation is the key to surviving long periods of hunger. In order to preserve vital energy, some animals reduce their body temperature. Many of them also cut back on the blood supply to their organs and put their digestive tract and immune system on standby.

The tiny Arctic ground squirrel takes energy savings especially seriously. It allows its body temperature to fall to about 27°F during its 8- to 10-month-long hibernation. The black bear, on the other hand, enters a so-called dormant state, in which its body temperature remains at an almost normal level, and shivers to keep warm. And the Australian striped burrowing frog can live in its arid environment without food or water by remaining dormant for periods of four or five years. It survives the fasting period by bur-

rowing underground and changing its metabolism so that it uses its energy reserves more efficiently.

Consuming the Body's Stores

Most animals have a predictable cycle of starving and eating and plan accordingly. Storm petrel chicks accumulate large stores of fat, for example. It is thought that these reserves provide energy during the intervals between feeding, which can last for several days.

A TYPICAL HUMAN ADULT can survive without food for as long as 70 days, after which the body will have exhausted its energy stores.

HOW LONG WE CAN SURVIVE WITHOUT:

OXYGEN: 2–4 minutes

SLEEP: Unknown

WATER: 1–10 days

FOOD: 70 days

Many migratory birds subject themselves to extreme physical exertion when they make nonstop journeys over deserts or oceans, where there are limited opportunities to eat or drink. On the way, these birds almost entirely consume the stored resources in their bodies. When a garden warbler migrates from Tanzania to Ethiopia over the Sahara, for instance, its liver, spleen, kidneys and digestive system shrink to just half their normal

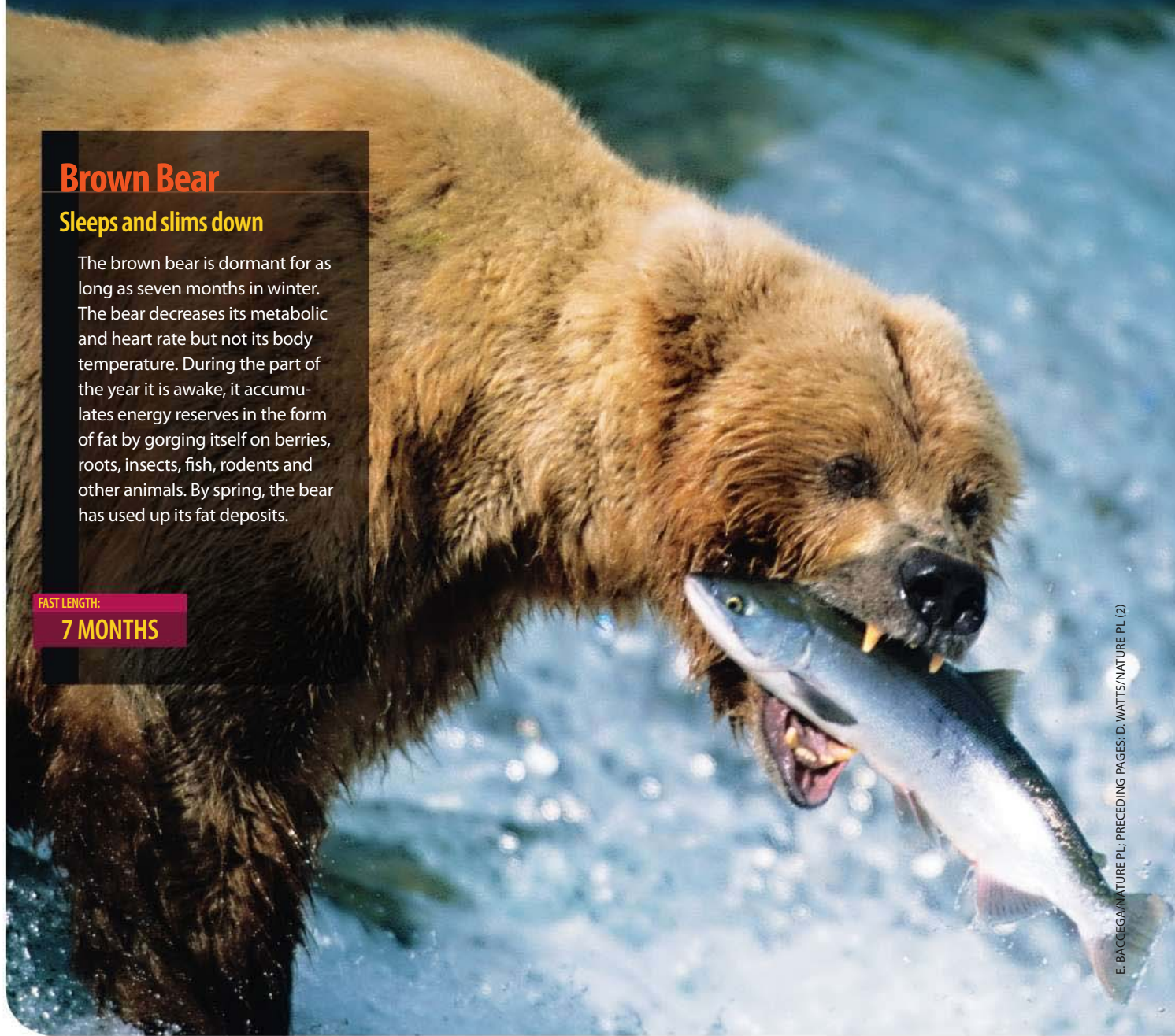
Brown Bear

Sleeps and slims down

The brown bear is dormant for as long as seven months in winter. The bear decreases its metabolic and heart rate but not its body temperature. During the part of the year it is awake, it accumulates energy reserves in the form of fat by gorging itself on berries, roots, insects, fish, rodents and other animals. By spring, the bear has used up its fat deposits.

FAST LENGTH:

7 MONTHS



E. BACCAGA/NATURE PL; PRECEDING PAGES: D. WATTS/NATURE PL (2)

FAST LENGTH:

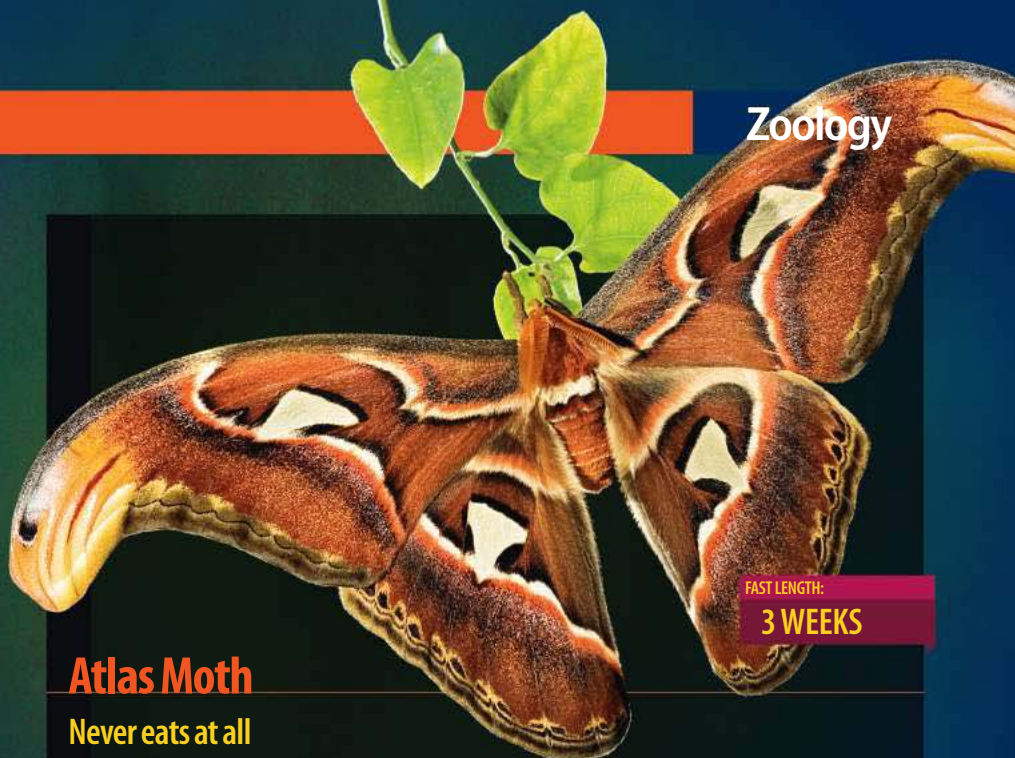
7 MONTHS



Fat-Tailed Dwarf Lemur

Acts reptilian

This native of Madagascar becomes dormant every winter for up to seven months. It curls up in holes in trees, surviving on fat deposits in its body and tail. The lemur saves energy by letting its body assume the ambient temperature, like a reptile. In a poorly insulated tree hole, its body temperature fluctuates with the weather, but in a well-insulated hole, the temperature stays relatively constant.



FAST LENGTH:

3 WEEKS

Atlas Moth

Never eats at all

Although caterpillars eat a great deal, once they become adult moths they may never feed again. The mouthparts of many adult moths, including the Atlas, do not develop completely. These adults have to rely entirely on fat deposits accumulated in the larval stage. But these energy reserves don't have to last long: Atlas moths die within two or three weeks.

FAST LENGTH:

5 YEARS



Australian Burrowing Frog

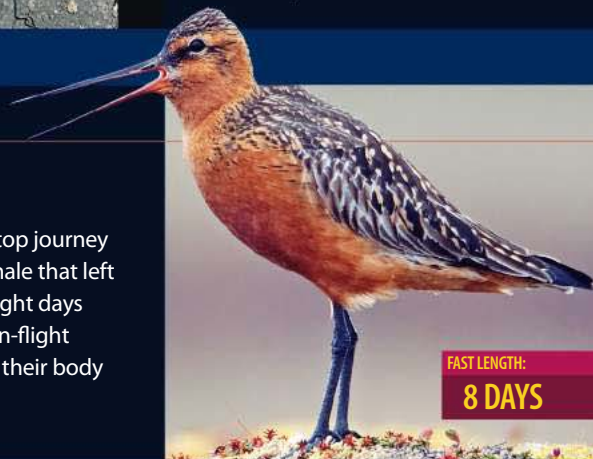
Goes underground

The Australian burrowing frog buries itself to survive long droughts and can live for about five years on its fat reserves. It lies cocooned in a layer of shed skin. When the rains return, the frogs quickly surface to reproduce and to feed. They then begin a feeding frenzy, consuming animals up to half their body size.

Bar-Tailed Godwit

Flies 7,000 miles on one tank

The Alaskan variety of these waterfowl undertakes an amazing nonstop journey every year and eats nothing along the way. One study followed a female that left her nesting grounds in western Alaska and landed in New Zealand eight days later, after a migratory flight covering 7,257 miles—without a single in-flight snack. Before godwits take off, their digestive organs shrink, and half their body weight consists of fat for energy storage.



FAST LENGTH:

8 DAYS

FAST LENGTH:

MANY WEEKS

Land Snail

Locks itself inside

During periods of prolonged drought or cold weather, Europe's land snails can shut themselves in for days or weeks. They withdraw into their shells and secrete a mucus membrane that closes the opening. This slows the loss of water by evaporation, and the snails also conserve energy by reducing their metabolic rates. When water is available again or the temperature increases, the snails wake up and come out of their shells.

Python

Lets its gut shrivel

Pythons can go more than a year without a meal, but when they do eat, they can consume animals of more than one and a half times their size. Unlike humans and other animals, a python's digestive system doesn't operate between feedings. It restarts once a python eats, and within 24 hours of eating large prey, the snake's intestines can double in size.



FAST LENGTH:

1.5 YEARS

FAST LENGTH:

2 YEARS



Lungfish

Slows down to survive

The African lungfish, so named because it has both gills and air-breathing lungs, burrows into the floor of a river or lake and secretes a mucus coating that protects it when water levels fall. The fish slows down its metabolism to save energy.

Tardigrade

Returns from the dead

Tardigrades can survive without eating for almost a decade. These microscopic animals go into a dormant state called cryptobiosis. With their metabolism completely arrested, they can withstand extreme conditions, including temperatures ranging from near absolute zero (-459.67°F) to around 200°. They have also been found to survive pressure of up to 6,000 atmospheres.

FAST LENGTH:

8 YEARS



CLOCKWISE FROM TOP LEFT: R. MAIER/ANIMALS ANIMALS; W. BOLLMANN/PHOTOLIBRARY; PHILLIP COLLA/SEAPICS.COM; SPL/FOCI

STORY CONTINUES ►►

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BONNIER

weight—and even the birds' heart and flight muscles lose part of their mass.

Learning from Superstarvers

Lack of food is dangerous, but lack of water is the real killer. Although energy from food is the body's fuel, think of water as its motor oil—a necessity for the body to function. Water enables countless chemical reactions and transports nutrients around the body, while helping dispose of harmful waste products. Humans begin to suffer detrimental effects after losing just 2 percent of their body weight from fluid loss, and losing more brings on even more serious symptoms. But for

microscopic terrestrial animals called tardigrades, losing almost all their water is no big deal. Found virtually everywhere on Earth, these unusual creatures can survive for around a decade in the most extreme dormancy in the animal kingdom—cryptobiosis, in which metabolic activity appears to come to a standstill. This allows them to handle extreme atmospheric pressures and temperatures ranging from close to absolute zero to around 200°. They resume their metabolic activities upon rehydration.

Biologists and physicians are eager to understand how such superstarvers survive. Humans cannot withstand a

shutdown of metabolic activity, and after long-term starvation, people often suffer from gastrointestinal problems when they eat again. Not so with burrowing frogs, which are able to successfully switch from starvation to consumption as soon as food or water becomes available. By studying how superstarvers regulate their metabolism to get through long periods of dormancy under extreme conditions, we might someday create therapies that could allow us to turn our metabolism up and down like thermostats, control weight gain and loss, and survive extremes of temperature. ■



Emperor Penguin

Starves for love

FAST LENGTH:

4 MONTHS

Emperor penguins breed during the Antarctic winter, and their chicks are welcomed into the world by temperatures that can reach as low as -76° , accompanied by fierce winds. After laying her egg, the female abandons incubation to her mate and goes off to the ocean to feed and refresh her fat deposits. The dutiful male fasts while incubating the egg under a fold in his skin for about four months. When the female returns, she relieves him of his duties.

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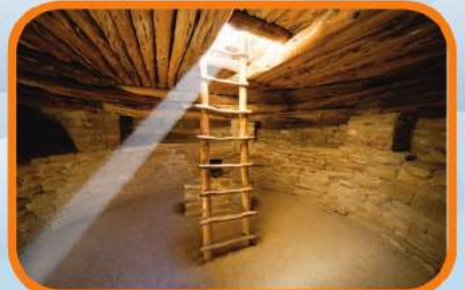
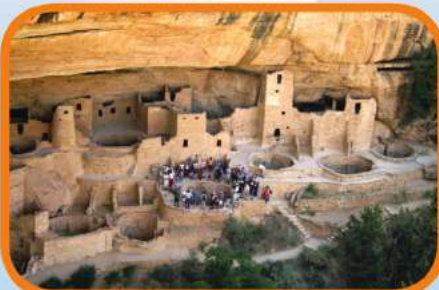
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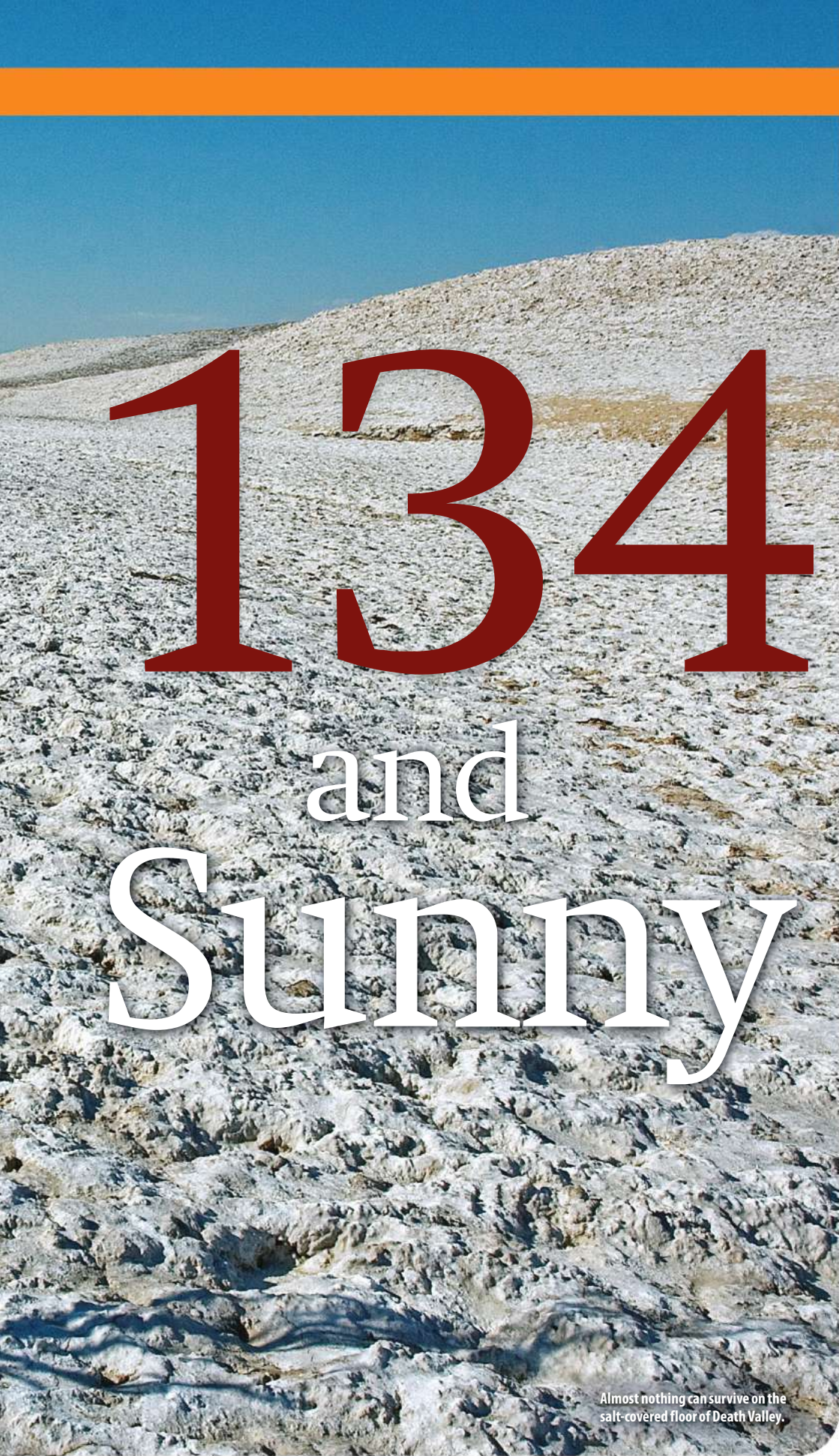




California's Death Valley is an extreme environment—one of the hottest, driest and lowest spots on Earth. It takes a convergence of dangerous geological forces to drive temperatures here above 120°F

DEATH
VALLEY

U.S.



134° and Sunny

Almost nothing can survive on the salt-covered floor of Death Valley.

July of 1913 was not an especially hot month in California, but one day, in a little valley hidden behind tall mountains, the mercury climbed to an incredible 134°F—the highest air temperature that had ever been recorded anywhere in the world. That blast furnace of a place is called Death Valley, now part of a national park. (The record has since been eclipsed, but just barely: The Libyan desert once reached 136°.) Because of Death Valley's very special geological conditions, it remains one of the hottest, driest and lowest pieces of land on Earth. On average, temperatures soar above 90° for seven

months of the year. Some years are even hotter. In the summer of 2001, there were 154 consecutive days of 100° or higher, and 1996 saw a stretch of 105 days that were at least 110°.

Death Valley is one of numerous valleys in the western U.S. that formed along active faults as the Earth's crust extended under North America, or was stretched apart, by tens or hundreds of miles over the past 35 million years. The faults caused large chunks of the crust to tilt downward in some places, forming valleys, and upward in others, to make intervening mountain ranges. Valleys in the vicinity of Death Valley started to take shape as early as 13 million years ago, but its current topography emerged more recently.

The many mountains west of Death Valley account for its dryness. When moisture-laden winds blow off the Pacific onto the continent, they hit the mountain ranges and rise. This cools the air, condensing water vapor and turning it into rain or snow, which then falls on the ranges' western slopes before the wind passes over the highest mountains. Every time the winds encounter another range, they lose moisture. To reach Death Valley, they must cross several major ranges, among them the Sierra Nevada, which includes Mount Whitney, the highest peak in the lower 48 states,

at 14,494 feet. By the time this air is over Death Valley, it very rarely has enough moisture for precipitation. Less than two inches of rain typically fall here in a year, and in 1929 and 1953, no rain fell at all. The wettest years on record are 1923 and 1983, which each saw around four and a half inches.

What Fuels the Furnace

The lack of precipitation is not the decisive factor in making the valley so hot, however. Instead, the deadly heat results from the relation between elevation and air temperature.

The higher you go into the atmosphere, the lower the air pressure. This thinner air is cooler. Generally, for every 1,000 feet of altitude, the temperature will fall by about four degrees up to elevations of 5,000 feet, and at a slightly higher rate at higher elevations. Large parts of the deserts in the American West lie at altitudes of roughly between 2,000 and 5,000 feet.

Death Valley's situation is very different. Here, crustal extension has pulled apart the ground so that the valley dropped downward, and Death Valley's lowest point, Badwater Basin—just about 90 miles east of Mount Whitney—lies 282 feet below sea level. This makes the valley the lowest-lying area in the Western Hemisphere. In addition, the tall mountains around

The mysterious tracks in Racetrack Valley are thought to be the result of stones blown across slippery terrain by strong winds after rainstorms.



FROM TOP: EBBE RASCH/ILLUSTRATED; OMENS VALLEY HISTORY; CLAUD LUNAU; PRECEDING PAGES: FROM TOP LEFT: CLAUD LUNAU; EBBE RASCH/ILLUSTRATED; VIDENS4B

Mountains Make Death Valley Bone-Dry

Death Valley is so dry and hot because it lies hidden behind long ranges of high mountains. When moist air from the Pacific rises to cross a mountain range, it loses moisture, and by the time the air reaches the skies over Death Valley, it has almost no water left.

Sierra Nevada/Mount Whitney: 14,494 ft.

Owens Valley: Approx. 4,100 ft.

Argus Range: 7,490 ft.

(Not to scale)

Mule-drawn wagons in the late 1880s hauled borax from the valley to a rail line. This photo of a wagon train was taken in 1949.



Stones That Leave Ghostly Trails in the Dust

A unique geological phenomenon occurs in a long desert valley at the northwestern end of Death Valley. In this oval-shaped dry lakebed, or playa, known as the Racetrack, rocks as big as oil drums appear to have moved around under their own power, leaving long, snaking tracks in the hard dirt.

The stones certainly do not move themselves. According to one theory, they are pushed around by the wind. This could occur because the floor of the playa is practically flat. The Racetrack is more than three miles long, and its northern end is just one and a half inches higher than the southern end. When it rains, its dry, hard-packed surface becomes an extremely slippery layer of mud, and if strong winds blow through the valley right after a rain, the rocks are set into motion, leaving their mysterious wakes. No one has, in fact, ever witnessed one in motion. But the evidence of their movement has been studied by many groups of scientists. In an experiment conducted from 1968 to 1975, geologists marked about 30 stones and tracked their movements. They found that the rocks sometimes moved more than 200 feet in one winter. The rocks typically move only during this wetter season, and even then, a stone moves only once every two or three years.



Death Valley Was a Mecca for Miners

In the 1800s, thousands of fortune-seekers defied the heat to look for minerals in Death Valley. At first it was stories of silver and gold that led miners here, and although these heavy metals were mined in the area, less-glamorous minerals like talc and borax were the most profitable. Borax was first found

here in 1881 and was mined heavily until 1928, when a large-scale discovery of the mineral in Boron, a nearby mining complex, rendered the Death Valley operations nearly obsolete. The valley is still peppered with mineshafts and the ruins of ghost towns to remind tourists of that short boom time.

Panamint Range: 11,049 ft.

Panamint Valley: Approx. 1,840 ft.

Death Valley: 282 ft. below sea level

Black Mountains: 6,384 ft.



How to Survive Death Valley

GETTING THERE

The easiest way to reach the valley is by flying to McCarran International Airport in Las Vegas and renting a car. Taking NV-160 W from the airport should get you there in just over two hours.

WHERE TO STAY

There are plenty of camping sites in the area, but if you prefer the great indoors, check out Furnace Creek (furnacecreekresort.com) or Stovepipe Wells (stovepipewells.com), the valley's only lodgings.

HOW TO STAY ALIVE

Hydrate: On average, at least one person dies of heat exhaustion every summer in Death Valley, so stock up on water. Death Valley public information officer Terry Baldino recommends at least a gallon per person per day, plus an extra gallon in the car. And don't forget moisturizer and lip balm.

Stay Cool: Light-colored clothes and protective gear like hats, sunglasses and sunblock will keep you from sweltering and burning. If you want to hike or cycle, Baldino suggests you do it in the early morning or at night, or in the fall and winter when daytime temperatures drop to the 60s and 70s.

Stay in the Car: If you get lost or stuck, do not try to hoof it. Rescue parties can find a vehicle more easily than a wandering hiker. This is when that extra water you stashed in the trunk could come in handy.

Plan Ahead: Decide what you want to do and see in advance, and let family or friends know your exact itinerary. If you don't return by a certain time, they should report it immediately. A rescue team will thereby have clues as to where exactly you might be. Go to nps.gov/deva for help in planning your trip.

Not Your Typical Desert

Contrary to popular belief, not all deserts are covered in wide expanses of sand. In fact, less than 1 percent of Death Valley National Park is composed of sand dunes, which formed when particles that eroded from nearby canyons were blown by the wind and trapped by the surrounding mountains. The park's Eureka dunes, at around 680 feet high, are the tallest in California and some of the tallest in North America.

Although sand dunes are a symbol of barren deserts, living conditions are reasonably

good beneath the dunes' surface. Water from rainfall is trapped in the tiny interstices between grains of sand. When the top layers dry out, they insulate the lower areas, keeping them moist. This enables plants such as creosote and mesquite to find water by extending their roots deep into the dunes.

Despite the typical image of a cactus-strewn desert, cacti are relatively rare throughout Death Valley. The arid heat, as well as saline soil, make it habitable to only about 15 cactus species.

The dunes on Mesquite Flats flow across Death Valley.

Death Valley hold in the hot air. As a result, temperatures in the valley are often 10 to 20 degrees higher than in the surrounding deserts.

A Watery Past

About a million years ago, enormous quantities of water stemming from melting glaciers in the Sierra Nevadas filled huge lakes that covered all low-lying areas. In fact, most of today's Death Valley was covered by Lake Manly—a giant body of water that was once 100 miles long and 600 feet deep—until about 10,000 years ago, when climate changes caused the lake to dry up. The area flooded again between 2,000 and 5,000 years ago, but the more recent lake was just 30 feet deep and has since evaporated, leaving a thick layer of salt called a salt pan, along with brackish, chemical-laden pools, on the valley's floor.

The present salt pan includes three large interconnected basins, the largest

and deepest of which is Badwater. It is one to six feet deep in places and contains sulfate and carbonate salts, as well as sodium chloride. The high chemical concentration makes the water undrinkable but also makes for a fascinating landscape, which includes small crystal-rimmed blue-green pools and giant saucers made of salt.

Despite its inhospitable climate, people have, over the years, settled the valley. Native Americans occupied the region on and off starting around 12,000 years ago. The most recent group, the Tumpisa Shoshone, lived here until settlers, including many European immigrants, flooded the valley in the 1800s. Gold was discovered in California in 1848, and some fortune-seekers on their way west crossed the valley. One group almost died of hunger, thirst and exhaustion, and before escaping, one member turned to cry out: "Good-bye, Death Valley!" That's been its name ever since. ■

Animal Life Defies High Temperatures

Although unprotected extended exposure to Death Valley's extreme combination of heat, sun and lack of water will kill any human, a wide variety of hardy animals all manage to live here. Fifty-one species of mammal, 307 birds, 36 reptiles, three types of amphibians, five fish species and one fish subspecies call the valley home. How do they survive in a place that is otherwise so deadly?

At about 150 pounds, the Nelson bighorn sheep is the largest wild mammal species living in Death Valley. The sheep are well adapted to the extreme temperatures and get most of the water they need by eating desert plants.

The North American desert tortoise, which is designated as vulnerable on the International Union for Conservation of Nature Red List, survives the heat by excreting waste as a white paste, instead of urine, to slow its rate of water loss. Adult tortoises can live for about a year without taking a drink.

Bighorn sheep and desert tortoises are among the animals inhabiting Death Valley.





By the Numbers: Gold



ATOMIC NUMBER: 79

DENSITY: 316.3 grams/cubic inch

MELTING POINT: 1,947.5°F

BOILING POINT: 5,172.8°



42.5 lbs.

The weight of a one-liter milk carton filled with gold. That's around the weight of the average five-year-old.



0.0004 ounce

of gold may be found in the body of an average adult male—presumably from dietary intake.

Gold mine



\$1,215.70

At press time, the record high price for gold per ounce, set on December 2, 2009

Elevator

158 lbs.

The weight of the Welcome Stranger, the world's largest gold nugget

Transport level

2/3

The fraction of the gold supply between 2003 and 2008 that was newly mined. Much of the remaining third was recovered from scrap, such as connectors in circuit boards.

Transport level

Digging Deep for Gold

The world's deepest gold mine, at 2.4 miles below the surface, is TauTona in South Africa.

4,600 people work in the mine.

52.5 feet/second The mine's fastest elevator's speed

497 miles of tunnels have been excavated.

140° The temperature of "virgin rock" at the mine's deepest point

Production level:
2.4 miles deep

2,485 tons

of gold are produced from 400 mines worldwide every year.

0.000000000004

ounce of gold is in each cubic foot of seawater.

Golden Empires

China led the world in gold mining in 2007.



CLOCKWISE FROM TOP LEFT: D. NUNUK/SPU/FOCI; KENNETH BO DRABAEK; ALAMY/IMAGESELECT; CLAUDE LUNAU

70 tons

of gold are used every year in dental bridges and crowns.



6 grams go into an Olympic gold medal. For the Vancouver Olympics, each gold medal contained 550 grams of silver, plated with six grams of gold.

24 karat denotes pure gold; 14-karat-gold jewelry is 58 percent pure.

1 ton of ore must be processed to make **1 pure-gold wedding band.**



Gold Jewelry

Top 5 Consumers around the World

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1. INDIA

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2. CHINA

347.1 tons

3. U.S.

150.3 tons

4. SAUDI ARABIA

82.3 tons

5. TURKEY

75.2 tons



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The percentage of gold in Canada's Gold Maple Leaf bullion coin—higher than any other coin in the world

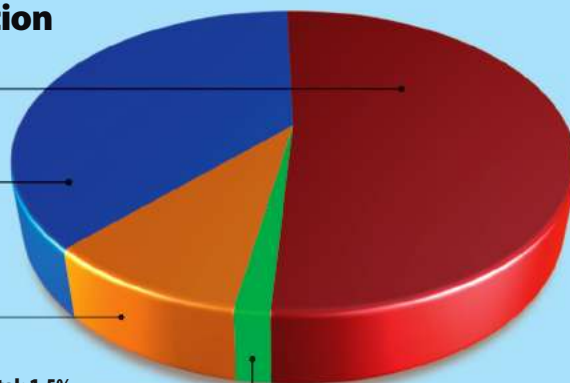
Almost **243 lbs.** of solid gold were worked into the innermost of Tutankhamen's three sarcophagi.



1 ton of personal computing scrap contains more gold than **17 tons of gold ore.**

Gold Consumption in 2009

Jewelry: 51.6%
Investment: 37.6%
Industrial: 9.3%
Dental: 1.5%



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Trivia Countdown

Earn more points by using fewer clues to answer each question.		5 points	4 points	3 points	2 points	1 point
BOTANY	Name this tree	Twenty species of deciduous trees in the genus <i>Juglans</i> go by this name.	One species common to the eastern U.S., <i>J. nigra</i> , has blackish bark and produces edible nuts.	This tree's nuts are encased in hairy, yellow-green husks, which are sometimes used to make dye.	Its dark, fine-grained wood is used for furniture, paneling and rifle stocks.	Its name comes from the Old English <i>walhnutu</i> , or "foreign nut."
CHEMISTRY	Name this reaction	Humans didn't reliably "produce" it until around 7,000 B.C.	Its original source on Earth was probably lightning.	In Greek myth, Prometheus stole this from the gods to help mankind.	This reaction can often be stopped with water or gases such as carbon dioxide.	It requires fuel, oxygen and heat to occur.
GEOGRAPHY	Name this city	A Dutchman, Jan van Riebeeck, arrived here on April 6, 1652, and set up a provisioning station for passing ships.	This capital is sometimes called its country's "mother city."	Rising over the city is the picturesque backdrop of the famous Table Mountain.	In Xhosa, a Bantu language spoken here, the city is called iKapa, and in Afrikaans it is Kaapstad.	The local government opposed its country's policy of apartheid, which was legally abolished in the early 1990s.
PERSONALITIES	Name this person	This Serbian-American inventor emigrated to the U.S. in 1884.	Thomas Edison was his first employer in America, but they did not work together long.	He is well known for his alternating-current inventions—and his fantastic claims, like communicating with other planets.	An all-electric car, which debuted in 2006, bears his name.	The standard unit for magnetic induction is named after him.
INVENTIONS	Name this device	Erik Rotheim, a Norwegian, first patented this invention in 1927.	In 1941, American chemist Lyle Goodhue developed it further to help American soldiers ward off mosquitoes during World War II.	The 1989 Montreal Protocol banned versions that used ozone-harming chlorofluorocarbons.	Its manufacturers today use hydrocarbons or carbon dioxide as propellants.	The first half of its name is a combination of the Greek word for "air" and the English word "solution."

What year was it?

March 27, Bikini Atoll

On a barge moored nearby, the U.S. military detonates a hydrogen bomb [right] in a test called Castle Romeo. The bomb has a yield of 11 megatons.

May 7, Vietnam

Viet Minh forces capture Dien Bien Phu, defeating French troops and ending the first Indochina War.

December 2, Washington, D.C.

The U.S. Senate strongly censures Senator Joseph McCarthy for his anti-Communist witch hunt.

Your guess Points

Correct year

± 2 years

± 4 years

± 6 years

± 8 years

5

4

3

2

1



CORBIS/POLFO

Your score:

24-30

Genius

17-23

Top of the class

9-16

Passing grade

0-8

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Answers appear on page 79

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Answer Key

TRIVIA

Botany: Walnut
Chemistry: Fire
Geography: Cape Town
Personalities: Nikola Tesla
Inventions: Aerosol can
History: 1954

BRAIN TRAINERS

1. 26. The numbers increase by 5, 1, 5, 1, 5, 1 and 5. The next increase should be 1, yielding 26.
2. D. Figures A, B and C are duplicates that have simply been rotated, while D is the mirror image of the other three.
3. 4. In the first figure, the product of the top three numbers is 625, or 5⁴, the fourth power of the bottom number. In the second figure, the product of the top three numbers is 1,296, or 6⁴, the fourth power of the bottom number. In the third figure, the product of the top three numbers is 58 + 63 + 61 + y, and 4 is also y. Now the sum of the four column sums is 58 + 63 + 61 + y, and y be the sum of row 2. Since row 2 and y be the sum of row 4
1. 34. The numbers in row 1 match the numbers in column 2, so the first-row sum is 63. Let x be the sum of row 4

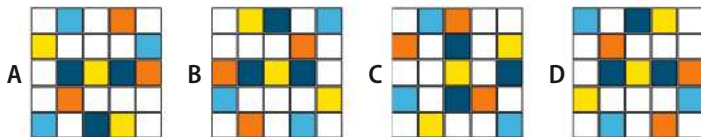
HEADBREAKERS

5. 2,730. In the first column, the numbers after the first number are obtained by multiplying by 3, then 4, then 5. In the second column, they are obtained by multiplying by 4, then 5, then 6. In the third column, we multiply by 5 and then 6. To continue the pattern, multiply by 7 to get the missing number.
6. The numbers in row 1 match the numbers in column 2, so the first-row sum is 63. Let x be the sum of row 4 and y be the sum of row 2. Since row 2 and y be the sum of row 4
4. A, B and D.
3. Since this is the fourth power of 4, we can continue the pattern by putting 4 at the bottom. 58 + 63 + 61 + y = 63 + y + 85 + x. Subtracting 63 + y from both sides yields 58 + 61 = 85 + x, and thus x = 34.
2. B. Each full row contains five dark green dots, so the missing square should have just one dark dot in its middle row; this eliminates A. The numbers in each complete row total 10, so the middle row of the missing piece must total 6; this eliminates C and D.
3. 6. The blue team can't all be lying: if 2 is lying, then 3 must be telling the truth. Thus, they are all telling the truth. 5 says "yes," so the cat must be under 4 or 6; but 3 says "no," so it is under 6.
4. 8,008. All the numbers in this increasing sequence are unchanged if they are rotated 180 degrees. The next number that fits this property is 8,008.

1 What number comes next in this sequence?

2 7 8 13 14 19 20 25 ?

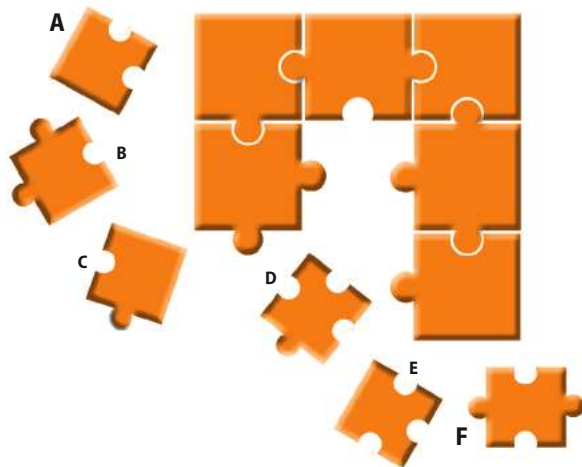
2 Which one of these mosaics is different from the other four?



3 What number goes into the empty space?



4 Which three pieces complete the jigsaw puzzle?

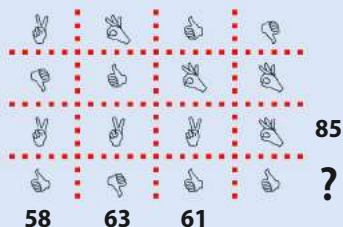


5 What number completes the grid?

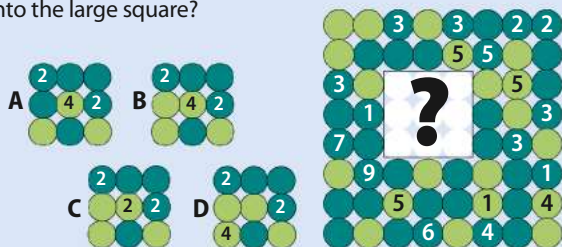
7	2	13
21	8	65
84	40	390
420	240	?

Headbreakers

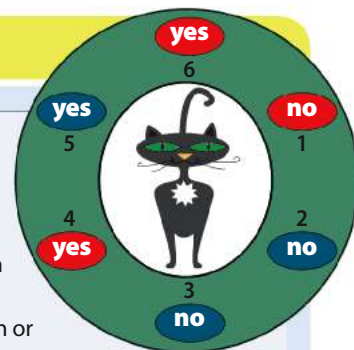
1 Each of the hand signals represents a number. The sum of the numbers in each of the first three columns and the third row is shown. Find the sum of the numbers in the fourth row.



2 Which of the small squares fits into the large square?



3 Three players from the red team and three from the blue sit around a table playing cards, and a cat sits under one of their chairs. On each of the teams, either all of the members tell the truth or all of the members lie. When each player is asked if the cat is under one of the two chairs next to him, they answer as shown in the diagram. Where is the cat?



4 What number comes next in this pattern?

6009 6119 6699
6889 6969 ?

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