AMAZING MANTA RAYS P.44

UNDER THE HOOD: F1 RACERS P.50

SCIENCE ILLUSTRATED

Alien Earth

Inside the Most Powerful Effort Yet to Find Earthlike Planets Beyond Our Solar System P.40



P.54

ANCIENT ANTS



P.34

Your Ancestors Ate Dinosaurs

Surprising Discoveries about Early Mammals

P.76

Hunting a Tropical Killer

Virologists Tackle Dengue Fever

P.68

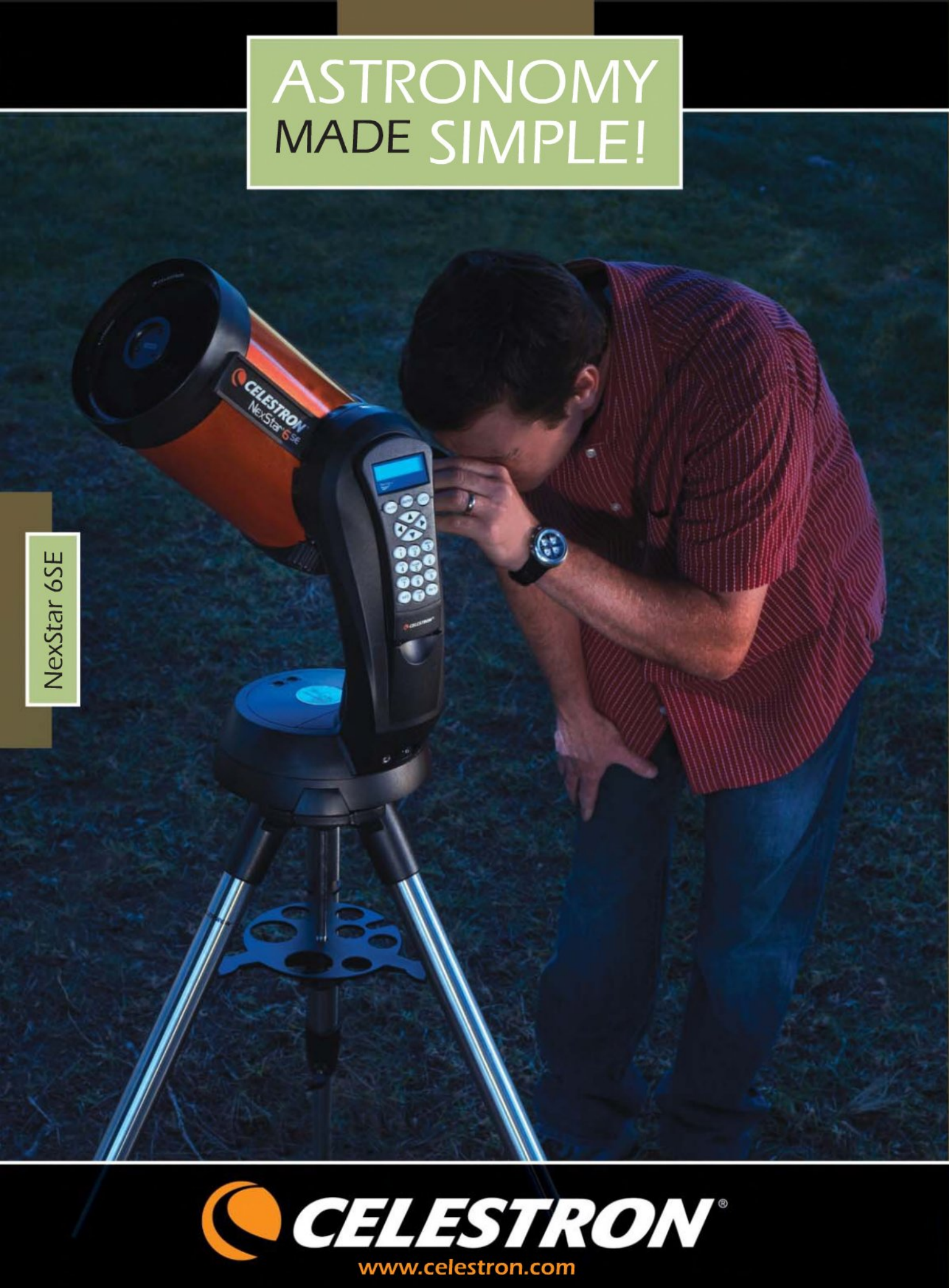
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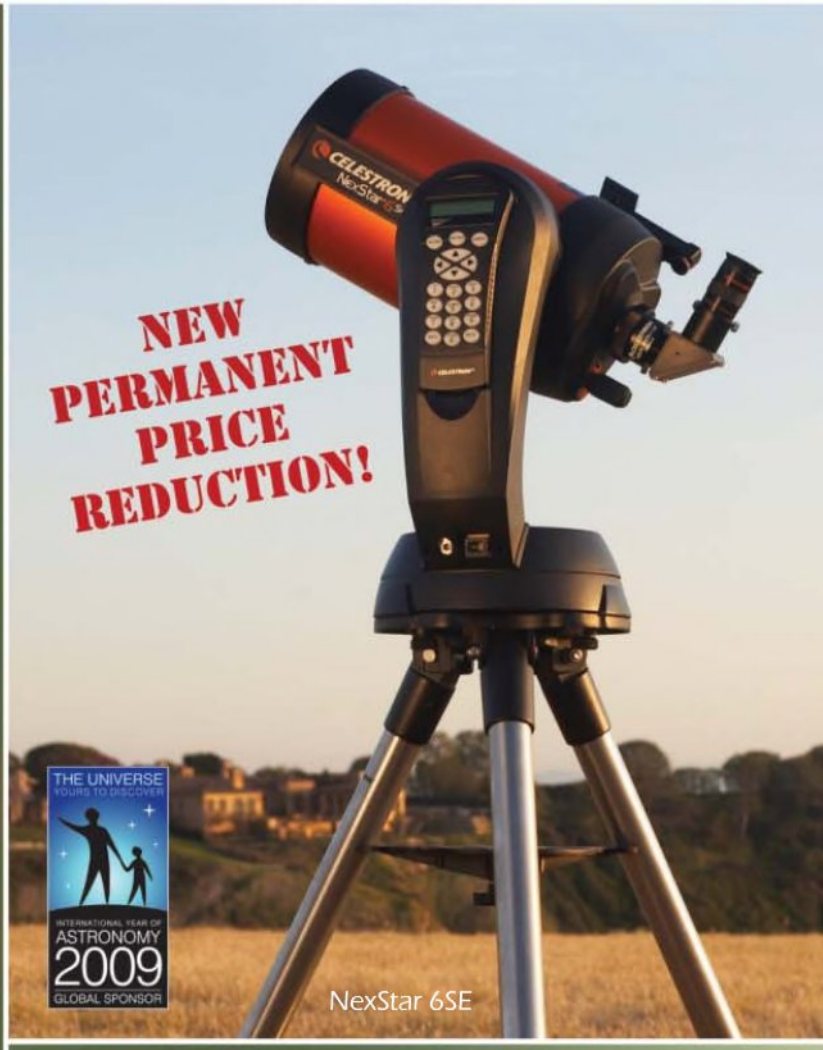
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Contents

SEPTEMBER/OCTOBER 2009

BIOLOGY P.44



From their infamous defenses to their perilous status, a look at the lives of rays.

ASTRONOMY P.40



An Earthlike planet could harbor life. Will NASA's Kepler satellite be the first to find one?

PALEOZOOLOGY P.34



New fossils and DNA dating revise the history of mammals during the time of the dinosaurs.

IMMUNOLOGY P.76



Scientists race to develop vaccines to protect against the deadly dengue virus.

AUTOMOTIVE TECH P.50



Racecar technology comes to consumer cars, saving fuel and slashing CO_2 emissions.

PALEONTOLOGY P.54



High-resolution imaging reveals prehistoric creatures preserved in ancient tree sap.

METHODOLOGY P.68



Decades ago, nuclear tests left a signature in our cells that's furthering medical research.

PHYSICS P.70



How a fundamental force of nature came to be understood, and what we still don't know.

OCEANOGRAPHY P.60



Fifty nations team up to create the best map yet of ocean currents around the world.



"The hunt for exoplanets is a dramatic endeavor that has become one of the most popular enterprises in astronomy." P.40

ON THE COVER: MAIN: COURTESY ESO; INSETS, CLOCKWISE FROM TOP: PASCAL GOETCHELUCK/SPL/FOCI; CM STUDIO AND R. MICKEN/AMNH AND CLAUS LUNAU

Contents

SCIENCE UPDATE P.18



ASK US P.27



BULL'S-EYE P.14



Departments

Bull's-Eye P.8
This month's gallery of amazing images: colorful cell fusion, a solar racecar, mini golf that teaches physics, and the whitest bugs.

Science Update P.17
Woolly-mammoth adaptations, offshore wind-farm improvements, how stars are born, missile-seeking lasers and an icy surprise on Mars.

Ask Us P.27
Do fish drink? Is there dinosaur DNA? What is spontaneous combustion? Why does the full moon look so big? Why do ice cubes crack?

World of Science P.81
The most athletic fleas, the solar system's longest day, a toy tank, venomous mammals, and other nuggets of scientific knowledge.

Letters P.6

Trivia Countdown P.84

Brain Trainers P.88



SCIENCE UPDATE P.20



WORLD OF SCIENCE P.82

PROFESSOR PET VUKUSIC/UNIVERSITY OF EXETER; *GAOH-OFFSHORE.COM*; G. GUIDA/NATURAL VISIONS

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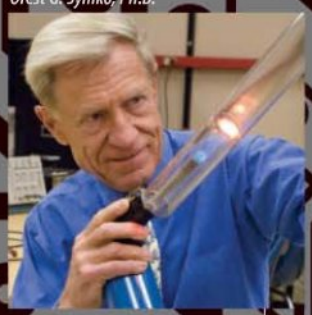
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Orest G. Symko, Ph.D.



PHYSICS

2007 Nobel Laureate Mario R. Capecchi, Ph.D.



BIOLOGY

- Utah Center of Excellence for Acoustic Cooling Technology
- Utah's only major degree program in astronomy
- Eccles astronomical observatory includes 32-inch telescope

- "Knockout mouse" gene-targeting technology
- Stable Isotope Ratio Facility for Environmental Research
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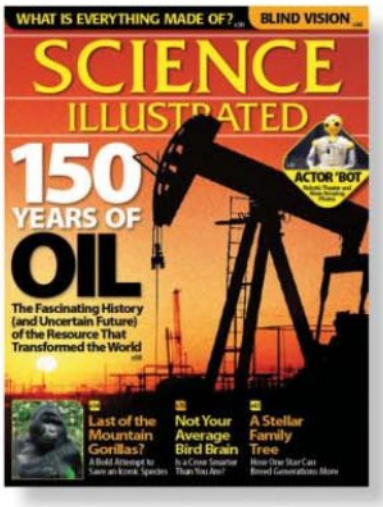
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Nifty Number Nine

Like the number 999, which you highlight in "Tricky Number" ["World of Science," July/August], the number nine itself is also curious. Start with any number containing only nines, such as 999. If you add up all the digits until you are left with a single digit, that digit will be nine (9 + 9 + 9 = 27 → 2 + 7 = 9). And any number times any multiple of nine will also ultimately come to nine when you repeatedly sum the digits: 5,683 x (9 x 3) = 5,683 x 27 = 153,441 → 1 + 5 + 3 + 4 + 4 +1 = 18 → 1 + 8 = 9.

John Irvine Via e-mail

Beyond 1969

As noted in "The Next Moonrace" [May/June], NASA marked the 40th anniversary of the *Apollo 11* lunar landing in July. For one shining moment in history, the Earth stood still and humanity took one giant leap into the unknown! Exploration of the moon, Mars and beyond would restore national pride and bring purpose to our space program.

Rick Schreiner San Marino, Calif.

Neutrally Buoyant

Regarding the cargo-carrying airship you mention in "Blimps to Deliver the Goods" ["Science Update," May/June], I wonder if it could be possible to fuel the ship with solar power by covering the skin of the craft with photovoltaic film. The long arctic summer that occurs where the craft traveled would be an advantage, and reducing the need for liquid fuel might offset the weight difference.

Eddie McConway Arverne, N.Y.

The Real Loch Ness

Some say we know more about the landscape of the moon than we do about our own oceans, and your very interesting article "Monsters of the Deep" [May/June] proves that. I truly believe that the oarfish is the source of our sea-serpent legends.

Paul Dale Roberts Elk Grove, Calif.

Corrections

Crude oil was sold as medicine in the mid-1800s, not the mid-1900s ["Oil: From the First Drop to the Last," July/Aug.].

In "Trivia Countdown" [July/Aug.], we stated that the tongue has up to 150 sense receptors. In fact, each of the tongue's thousands of taste buds have that many receptors.

We wrote in "Metamorphosis" [May/June] that swallowtail caterpillars give off an odor from their antennae. Actually, the odor is excreted from a pair of glands behind their head.

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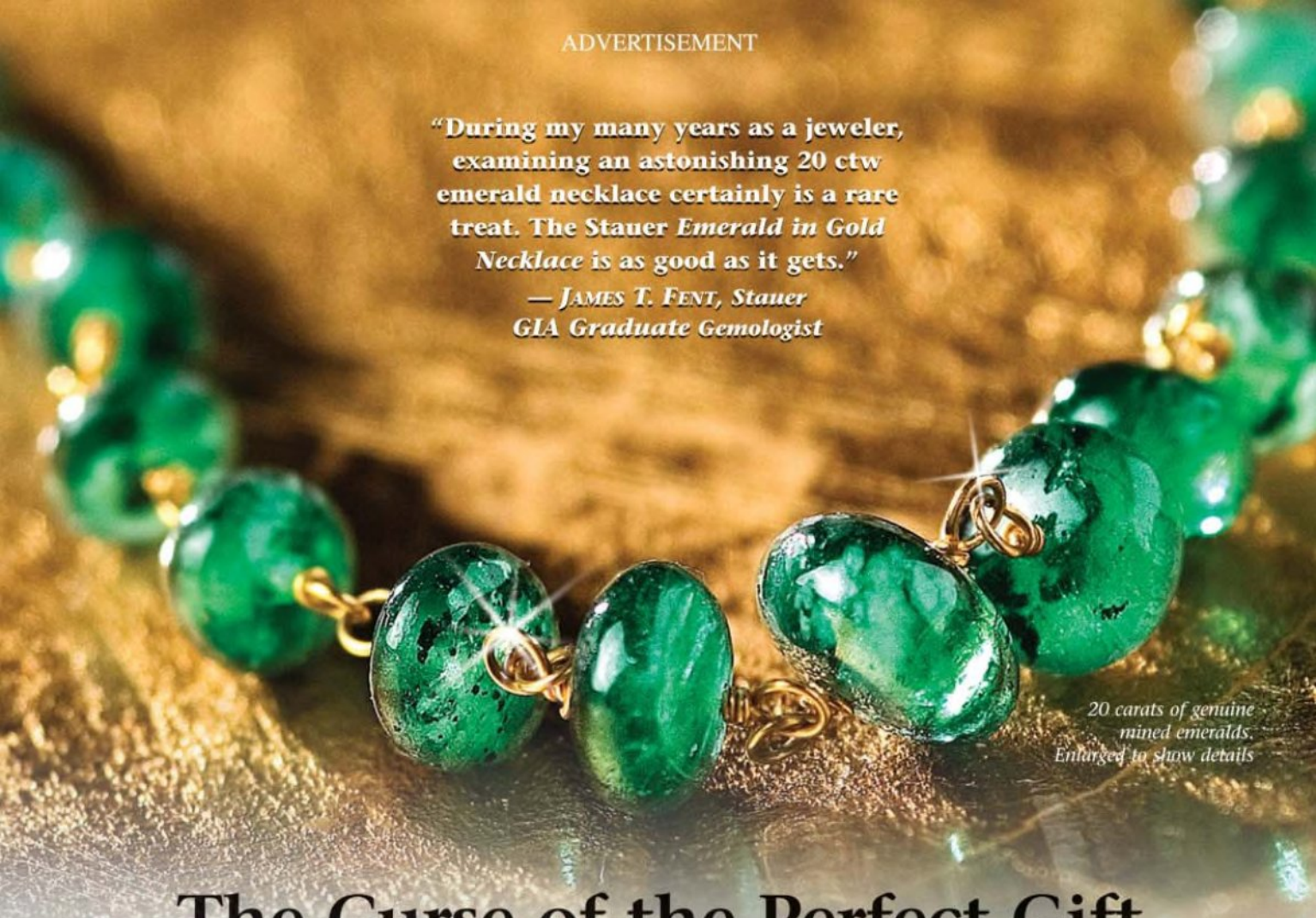
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But there was no mistake. And after returning home, I had 20 carats of these exquisite emeralds strung up in 14k gold and wrapped as a gift for my wife's birthday. That's when my trouble began. She loved it. Absolutely adored it. In fact, she rarely goes anywhere without the necklace and has basked in compliments from total strangers for months now.

So what's the problem? I'm never going to find an emerald deal this good again. In giving her such a perfect gift, I've made it impossible to top myself.

To make matters worse, my wife's become obsessed with emeralds. She can't stop sharing stories about how Cleopatra cherished the green gem above all others and how emeralds were worshiped by the Incas and Mayans and prized by Spanish conquistadors and Indian maharajahs. She's even buying into ancient beliefs that emeralds bring intelligence, well-being and good luck to anyone who wears them. I don't have the heart to tell her that I'm never going to find another deal this lucky.



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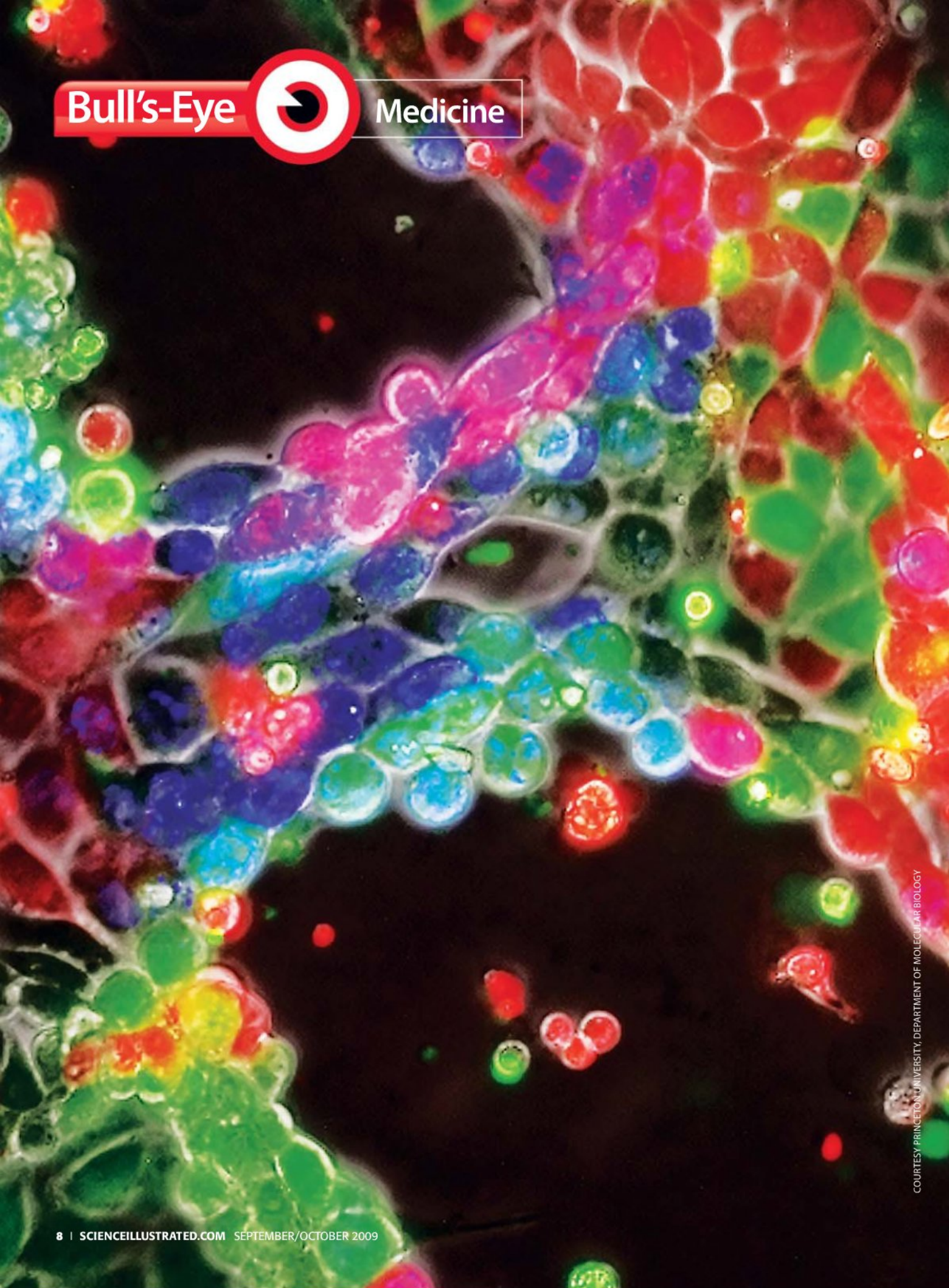
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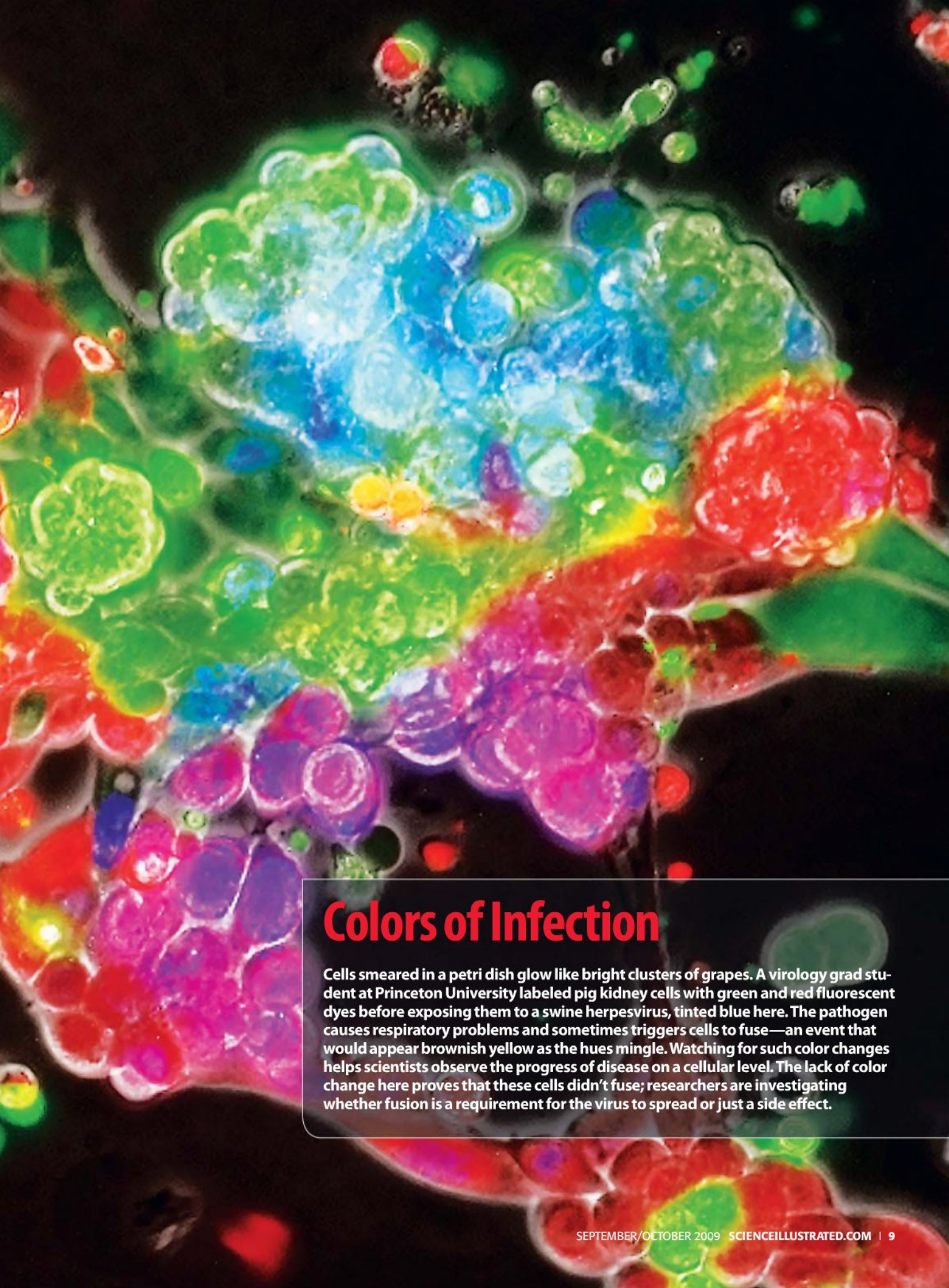
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Colors of Infection

Cells smeared in a petri dish glow like bright clusters of grapes. A virology grad student at Princeton University labeled pig kidney cells with green and red fluorescent dyes before exposing them to a swine herpesvirus, tinted blue here. The pathogen causes respiratory problems and sometimes triggers cells to fuse—an event that would appear brownish yellow as the hues mingle. Watching for such color changes helps scientists observe the progress of disease on a cellular level. The lack of color change here proves that these cells didn't fuse; researchers are investigating whether fusion is a requirement for the virus to spread or just a side effect.



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The Speed of Light

Behold the *Infinium*, a sleek 10th-generation solar racecar constructed by students at the University of Michigan. The same kind of supersensitive solar cells used on satellites plaster its three-wheeled carbon-fiber frame, and a backup lithium-ion battery ensures power on cloudy days. This October, the school's solar-car team will race *Infinium* 1,800 miles across the heart of Australia at the Global Green Challenge, a six-day trek that showcases dramatic advances in sustainable engineering. Michigan has claimed five North American titles and placed third several times at international competitions. An early pileup at the last world event derailed the team, and they're seeking redemption this year.



Rockets on the Green

It's hard not to get excited about space when you're playing putt-putt with 100-foot-tall 1960s-era rockets in the background. Rocket Park Mini Golf, a permanent exhibit and nine-hole course, opened in June at the New York Hall of Science in Queens to introduce families to the physics of spaceflight. The Hall's director, Eric Siegel, says, "The challenges of the old, familiar mini-golf course—force and vectors, friction, gravity, logistics and planning—are precisely the same fundamental challenges of spaceflight."



DAVID HANDSCHUH/NY HALL OF SCIENCE


8
9

Biomimicry Bugs

A white appearance isn't caused by pigment but by the scattering of light. In this regard, the scarab-like *Cyphochilus* beetle is unmatched. The insect is covered with snow-white scales, each of which is one tenth the width of a human hair. The scales' irregular internal networks of filaments efficiently scatter light waves, making the beetle look white, an adaptation probably developed to mimic white fungi in its habitat in Southeast Asia. Researchers at Exeter University in England are investigating the scales to develop new ways to whiten high-grade paper, which is brightened by a coating of minerals. Mimicking the beetles' scales to make paper whiter could also reduce its weight, slashing transportation costs.



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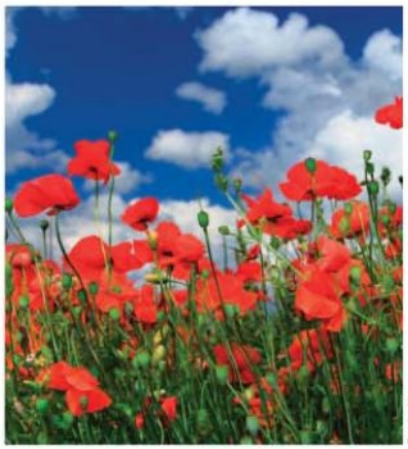
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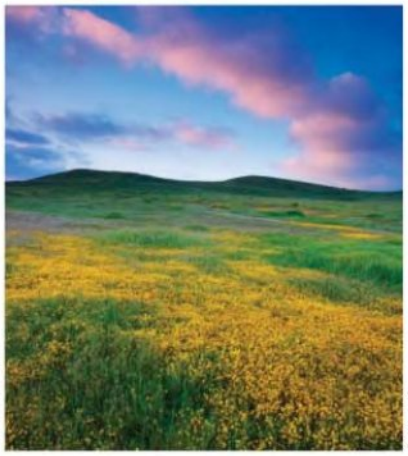
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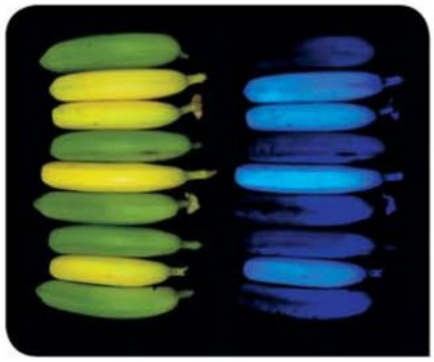
P. 19
The birth of new stars



P. 20
Building wind farms in the ocean



P. 22
How some fish see in the dark



Color in the ultraviolet wavelength may indicate fruits' ripeness to animals.

Blue Bananas May Be Best

BIOLOGY Ripe bananas appear to glow blue in ultraviolet light. Chemists from Columbia University and the University of Innsbruck in Austria made that discovery last fall while studying what happens to chlorophyll in fruit and leaves as they age. During ripening, chlorophyll in banana skin breaks down and releases fluorescent substances that cause the fruit to luminesce in UV light, a wavelength visible to many animals that eat bananas. The bright blue hue may signal ripeness to the animals.

FLASH! **The discovery in Antarctica of a chunk of granite similar to rock normally found in North America bolsters the theory that all the landmass of Earth belonged to one supercontinent, known as Rodinia, around a billion years ago. Research funded by the National Science Foundation has concluded that the granite has an almost identical chemical makeup to a belt of igneous rock in California.**



An engineer adjusts the optics in the Airborne Laser.

Airborne Lasers to Blast Down Missiles

Boeing 747 freight planes go ballistic in a U.S. military weapons program

WEAPONRY Lasers mounted on modified cargo aircraft may one day shoot enemy missiles out of the sky. Defense-system firms Boeing, Lockheed Martin and Northrop Grumman are developing a prototype Airborne Laser (ABL) for the U.S. Missile Defense Agency and the Air Force. The ABL is mounted on a Boeing 747 cargo jet equipped with tracking, weaponized and environmental lasers that compensate for atmospheric variables. Designed to target incoming missiles when they are still rising and at their most vulnerable, the ABL system will detect and destroy missiles autonomously while pilots do the flying.

In June, the prototype successfully tracked a missile during a test flight, and this fall, the defense system will attempt to shoot down a missile. To be fully operational, the Air Force will need a fleet of seven ABLs to patrol enemy missile-launching sites from the air. Plans to develop a full fleet may be scaled back by budget cuts, but work on the prototype is continuing.



The Airborne Laser, mounted to a cargo jet, has a range of hundreds of miles.

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Among other tricks, the "smart" helicopter can fly upside down.

Self-Taught Robot Copter

TECHNOLOGY Stanford University engineers have created a "smart" helicopter that uses artificial intelligence to learn tricky aerial acrobatics. Computer-control systems for the four-foot-long robotic aircraft learn the moves by simply "watching" a radio-controlled model helicopter.

After tracking a pilot's various maneuvers, algorithms in the smart helicopter's software analyze the pilot's commands, as well as wind speed and direction, to determine the ideal flight path that the pilot was attempting and then sets the helicopter off on the improved flight path. The researchers believe the technology could be used in situations too dangerous for human operators, such as searching for land mines or mapping critical areas in forest fires.

FLASH! **A group of European scientists have discovered why we go gray—and wisdom has nothing to do with it. Hair follicles produce small amounts of hydrogen peroxide, which is usually broken down into oxygen and water by an enzyme in the body. The amount of that enzyme declines as we age, allowing the hydrogen peroxide to increase over time. When the chemical reaches a level that interferes with melanin production, hair grows out with little or no pigment.**

Treating Severe Obesity without the Knife

A simple procedure may be an alternative to common surgeries

MEDICINE A cheaper and less invasive procedure than the two surgeries most often used to combat obesity is on the horizon. GI Dynamics, a Massachusetts-based medical device company, is developing a gastrointestinal liner called the EndoBarrier.

Doctors slide the impermeable polymer liner into place down a patient's throat with the aid of an endoscope during a half-hour outpatient procedure. The method could be an alternative to gastric banding, in which a silicone band is fastened around the top of the stomach to make the patient feel full faster, and gastric bypass, in which the stomach is made smaller and the intestines are rerouted. As with the liner, gastric bypass prevents part of the intestines from absorbing nutrients and calories from food and may also change hormonal pathways, a key to weight loss.

Conventional operations can lead to significant weight loss, yet they do have a slight risk of death. Inserting the liner is nonsurgical and therefore carries less risk. The procedure may only require conscious sedation, rather than general anesthesia, and has virtually no recovery period. According to the company's estimates, it will cost around half as much as banding and a third as much as gastric bypass.

In human clinical trials, more than 250 volunteers lost an average of 30 pounds over a three-month period, compared with fewer than 10 pounds lost by control groups. The U.S. Food and Drug Administration is reviewing the device.

Woolly Rhino Adapted for Ice Age

PALEONTOLOGY More than 50 bone fragments discovered around 1900 in a quarry in central Germany have finally been pieced together, revealing the oldest woolly rhinoceros ever found in Europe. Scientists at the Senckenberg Research Institute in Frankfurt, where the 460,000-year-old skull was reconstructed, say it suggests how *Coelodonta tologoijensis* adapted to the Ice Age climate that spread through Europe and Asia during the Pleistocene epoch 1.8 million to 11,500 years ago.

The rhino had a wide mouth and large teeth, which allowed it to grab chunks of tough grass and chew it efficiently. The adaptations made the animal an effective eater on the grassy steppes that dominated Europe during the Pleistocene ice age.

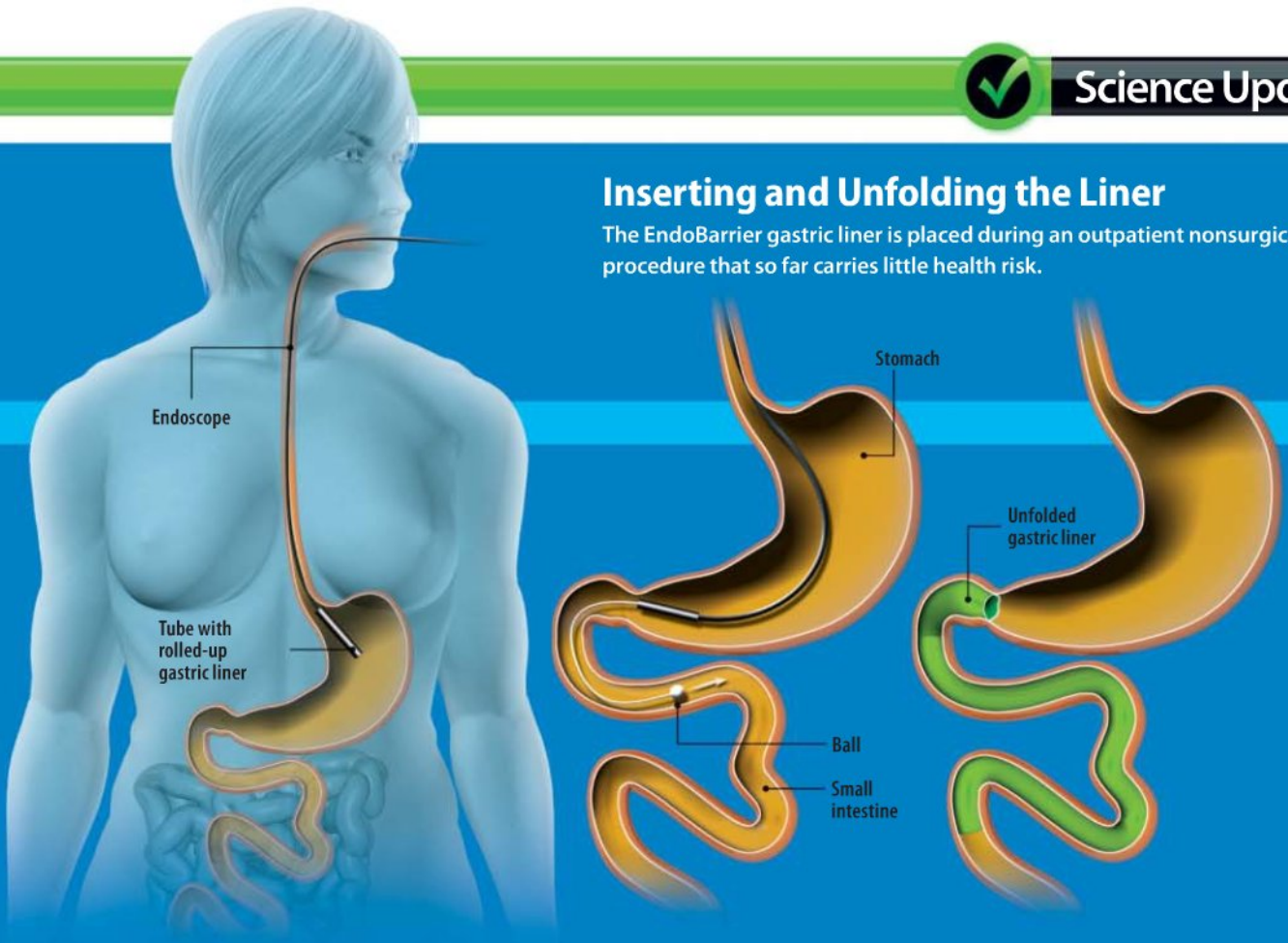


This fossil skull is 90 percent complete.

FROM TOP: B. TSE/STANFORD UNIVERSITY; SENCKENBERG RESEARCH INSTITUTE

Inserting and Unfolding the Liner

The EndoBarrier gastric liner is placed during an outpatient nonsurgical procedure that so far carries little health risk.



1. The sleeve and an anchor are placed inside a capsule on the end of a catheter-based delivery system. The gastrointestinal liner is then inserted through the mouth with the aid of an endoscope.

2. At the junction between the stomach and intestine, the catheter pushes a ball, which pulls the liner out of the capsule and enables it to cover the small intestine.

3. The liner is anchored at the beginning of the intestine with the help of a self-expanding stent. The ball is excreted. The liner can be removed endoscopically in a 10-minute procedure.

How Some Stars Are Born

ASTRONOMY An expanding bubble of ionized gas from a star about 4,200 light-years from Earth is creating cold clumps of gas that could become the nuclei of new stars.

The observations contain strong evidence for the "collect and collapse" theory of triggered star formation. According to the theory, ultraviolet radiation from a hot, massive star ionizes an area of gas around it. As the gas expands, its shock wave pushes a layer of cold gas and dust before it. The layer becomes unstable, and cold, dense clumps begin to form as it collapses under its own gravity.

The Large APEX Bolometer Camera (Laboca) at the Paranal Observatory in Chile discovered the clumps in a region called RCW120. Such clumps emit weak heat apparent only in the submillimeter-wavelength range. Only the Laboca camera can detect such cold radiation.



Bubbles of ionized gas [red] in the RCW120 region may create stars as they expand.

How Old Are We?

Recently dated stone tools found in Ethiopia in the 1970s are at least 276,000 years old—80,000 years older than the earliest known* Homo sapiens *bones. Modern humans may be older than previously thought, say researchers at the Berkeley Geochronology Center in California, or perhaps an earlier species made the tools.



FROM TOP: CLAUS LUNAU; EPA/SCANPIX; P. RENNE AND L. MORGAN

Building Offshore Wind Farms Faster

A bigger, speedier ship will improve wind-turbine installation

TECHNOLOGY A new vessel is set to make the growing offshore wind industry a more efficient business. Installing a 300-foot-tall wind turbine in the middle of the ocean is a tricky matter, and the design of the ships that carry the towers out to sea and erect them is less than ideal. These self-elevating, or jack-up, vessels set down legs on the ocean floor and rise out of the water to become platforms from which a crane can install the turbines. The ships can hold just two to four turbines at a time and must return to port often to pick up more. Because of their carrying limitations, coupled with narrow windows of calm weather when installation can safely take place, on average crews can install only one turbine per day.

By 2012, Gaoh Offshore Limited, a British company that specializes in the installation of offshore wind farms, plans to put a bigger, faster and more efficient self-elevating ship into service. The 26,000-ton vessel, designed by OSK-ShipTech in Copenhagen, Denmark, will carry as many as 18 turbines at a time. "This means fewer trips to and from a site, which dramatically lowers the transport time per turbine and thus increases the number installed per day," says Gaoh CEO Kurt Thomsen. The vessel, which could double the number of installations, will be used in European waters, where the vast majority of wind farms are found.



Gaoh's new self-elevating ship will carry more turbines to farms faster.



Male elands use knee clicks to assert dominance over competitors.

Why Antelopes Click Their Knees

BIOLOGY Among antelopes called elands, males produce clicking noises with their knees, and until now no one has understood why. Biologists from the Zoological Society of London and the University of Copenhagen followed a group of elands for two years in an area of southwestern Kenya that straddles the Masai Mara National Reserve and the Olare Orok Conservancy to determine the knee-clicks' function.

The researchers found a direct correlation between the size of an eland and the pitch of his clicks: The larger the male, the deeper the sound. Males deduce the size of nearby competitors based on their click pitches, thus allowing them to avoid dangerous combat with larger antelopes. The sounds are produced when a tendon slips over a bone in the knee, making the tendon vibrate like a plucked string on a guitar.

FLASH! University of Florida anthropologists recently reported that the ruins of 28 settlements in the Upper Xingu region of the Brazilian Amazon rainforest that date back to between A.D. 1250 and 1650 display more complex urban planning than medieval European and ancient Greek cities. The Indian villages may provide a model for alternative ways to approach sustainable urban development, researchers

FROM TOP: J. BRO-JØRGENSEN/UNIVERSITY OF LIVERPOOL; GAOH-OFFSHORE.COM

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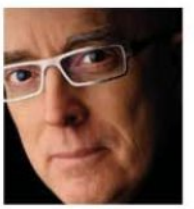
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Girls Beat Boys in Taste-Testing

MEDICINE When it comes to recognizing sweet and sour tastes, girls are better than boys, even though there is little difference in the number of taste buds between the sexes. Food scientists at the University of Copenhagen tested 8,900 children ages 5 to 19 for their sense of taste. Boys needed around 10 percent more sourness and 20 percent more sweetness than girls to detect each taste. Teenagers of both sexes were more sensitive to sourness than younger kids were.

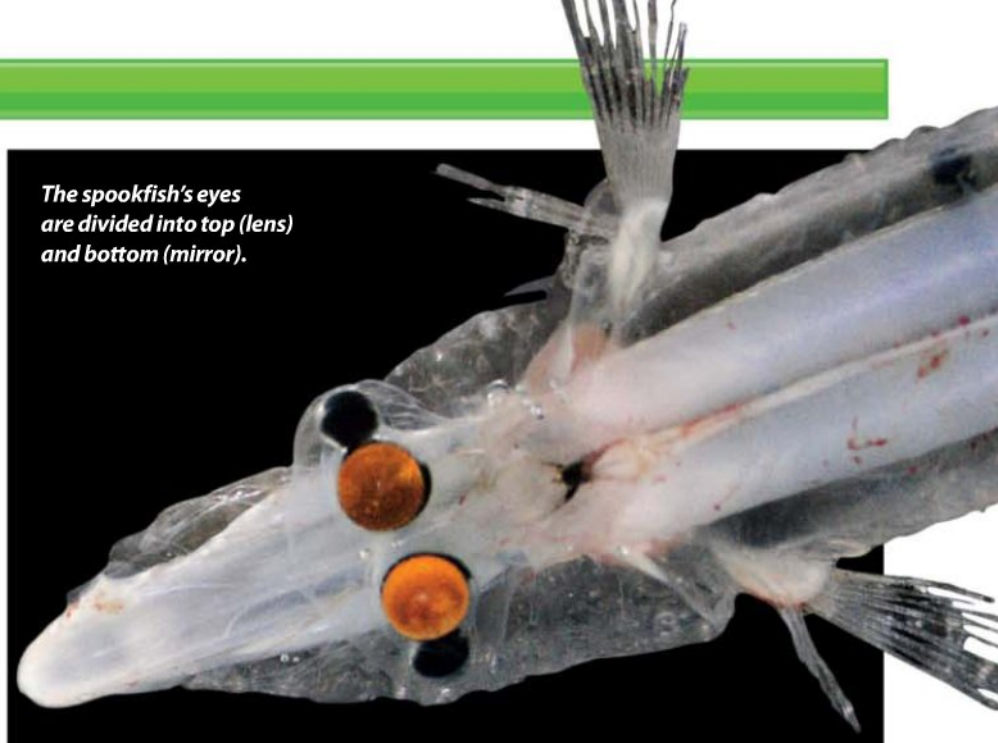
Boys preferred very sour and sweet foods more than girls did, which the scientists say indicates that males like more-extreme flavors. Research has shown that children who generally like sour tastes are also more open to trying new foods.

There were some surprises. Seventy percent of the children said they liked fish, a food kids have a reputation for disliking. And around a third of the children—a larger group than expected—preferred unsweetened soft drinks over sugary ones.



Boys like sour tastes more than girls do.

FLASH! An Australian chemist has discovered that gold particles in decorative coatings in the stained-glass windows of some medieval churches and castles remove harmful gases called volatile organic compounds (VOCs) from the air when activated by the sun. The effect was unknown to people of the time.



The spookfish's eyes are divided into top (lens) and bottom (mirror).

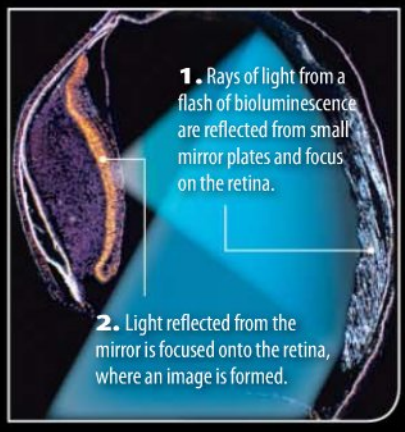
Mirror Vision

Reflective plates help spookfish see in deep-sea darkness

BIOLOGY The first spookfish to be captured alive has revealed an eye adaptation unknown in any other vertebrate species: mirrors that focus light. The saltwater species, *Dolichopteryx longipes*, was first discovered 120 years ago, but the reflective properties of its eyes were not discovered until last year, when an international group of scientists caught a single live specimen off the coast of Tonga in the South Pacific Ocean. Until now, reflective mirrors have been found only in the eyes of a few invertebrates, such as scallops.

Although the spookfish, whose name may come from its ghostly appearance, seems to have four eyes, it actually has just two. Each eye is split, with one half pointing up to detect prey and predators above, and the other half pointing down and slightly outward. The top of each eye has a lens to focus light like any other vertebrate, but the lower part is composed of small mirror plates arranged in layers. The scientists believe that guanine crystals, the material that gives some fish scales their silvery appearance, may make up the plates.

In the spookfish eye, the precisely arranged crystals reflect and focus light so that it reaches the retina to create a high-contrast image. Unlike the mirror eyes of scallops, which produce poor contrast, spookfish mirrors are better than lenses at gathering light and creating clear images in the dark depths (more than 3,000 feet) of tropical and temperate waters worldwide. Spookfish are on the lookout for flashes of bioluminescent light from deep-water predators and prey, so the better their vision, the better their chance of survival.



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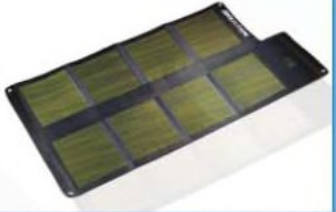
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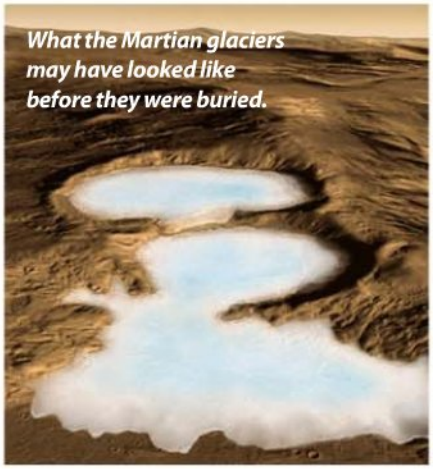
A phallic figurine [far left] and a knife were uncovered in a Stone Age grave site [above] in Israel.

Hunters Were Honored with Gifts and Bones after Death

ARCHAEOLOGY Scientists recently found the remains of at least 65 people—most of them young men between the ages of 20 and 30—while excavating a Stone Age tomb near Nazareth in northern Israel. More significant than the skeletal remains was the variety of objects buried alongside them, which researchers say attests to a highly ritualistic culture.

The men, who lived between 8500 and 6750 B.C., were interred with symbolic objects that may have been intended to honor their hunting skills, according to the lead excavator, Nigel Goring-Morris of Hebrew University in Jerusalem. The bones included fox jaws, gazelle skeletons and even the carcasses of an entire herd of an extinct species of cattle. A collection of human remains at the site was arranged in a pattern representing an animal. Other items, including weapons and jewelry were also found.

FLASH! Experiments at the University of Tokyo suggest that Asian elephants can count. Cognitive scientists allowed the animals to listen to fruit being dropped into a bucket one piece at a time. A different amount was then dropped into a second bucket. Eight out of 10 times, the elephants chose the bucket with more fruit, even though they couldn't see inside.

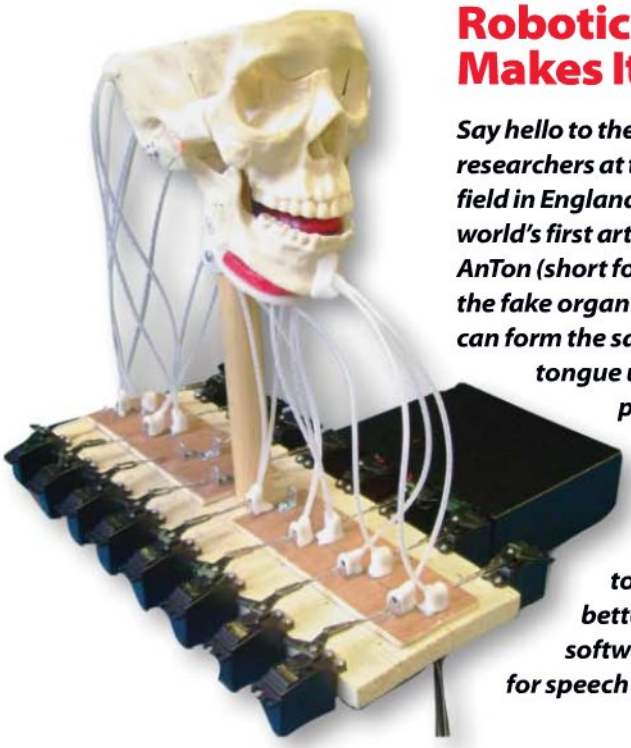


What the Martian glaciers may have looked like before they were buried.

Mars Ice Gives Hope for Life

ASTRONOMY Water ice recently found to be incredibly widespread beneath Mars's surface means there's a better chance that life once existed there. The Mars Reconnaissance Orbiter detected hundreds of glaciers buried under a 30-foot layer of soil halfway between the Martian equator and south pole, near a crater called Hellas Basin. The thickest ice examined so far is around 1,200 feet deep, and one area of merged glaciers is the size of Los Angeles. Others are even bigger, says John Holt, a geologist at the University of Texas and a principal investigator on the project.

The glaciers may be remnants of large ice masses that covered much of the planet millions of years ago. Clear signs on the surface that ice flowed on Mars in the past indicate that it was once warmer there. In warmer conditions, the glaciers may have had liquid water within or, more likely, beneath them—an environment where life has been found on Earth.



Robotic Tongue Makes Its Moves

Say hello to the tongue 'bot. Last year, researchers at the University of Sheffield in England developed one of the world's first artificial tongues. Known as AnTon (short for "animatronic tongue"), the fake organ is made of silicone and can form the same shapes a human tongue uses for speech. Motor-powered fibers create the movements by imitating the muscle fibers of the human tongue. The researchers hope to use AnTon to develop better speech-recognition software and new therapies for speech problems.

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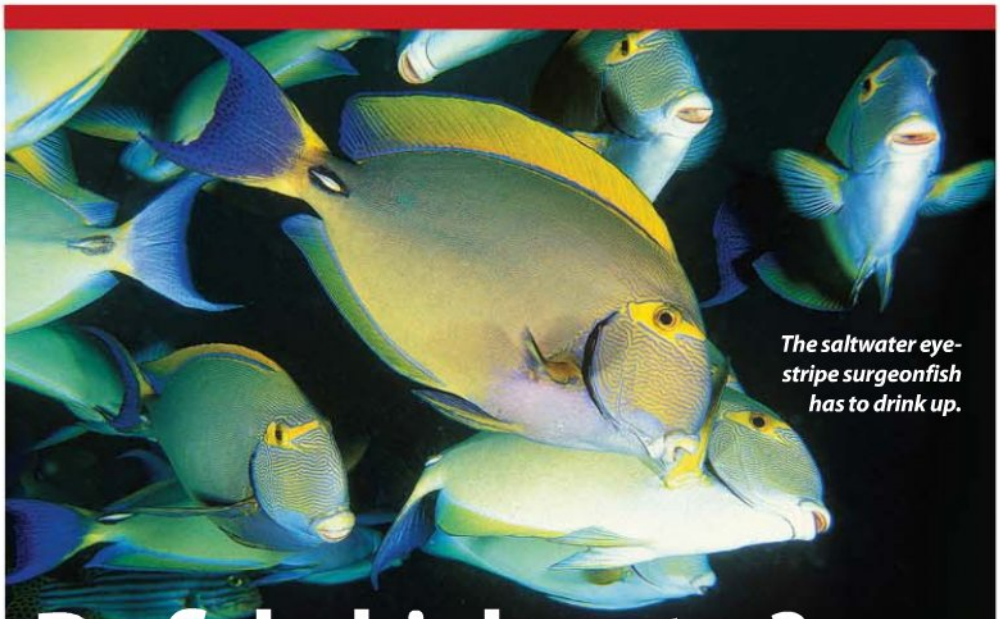
What is quicksand?

It's essentially sand that has become oversaturated with water, losing the friction between grains that normally allows it to support weight. So when an object applies pressure to the surface of quicksand, the particles become unstable and flow downward, causing the object to sink. The phenomenon is common at the mouths of large rivers and along stretches of shoreline where sand mixes with pools of water but a clay base prevents drainage.

In 2005, a research team from the University of Amsterdam tested the plausibility of someone being submerged in quicksand. They found that a person will sink into it but only about halfway up their body. Despite quicksand's reputation, its downward flow generates only enough force to trap, not swallow, a person.

HOW MUCH OF OUR SOLAR SYSTEM'S MASS COMES FROM PLANETS?

Surprisingly little. Astronomers estimate that the sun makes up 99.86 percent of the mass. The planets (including Pluto, now considered a dwarf planet) account for just 0.135 percent; comets, asteroids, gas and dust make up the remaining 0.005 percent.



The saltwater eyestripe surgeonfish has to drink up.

Do fish drink water?

Some do. Whether or not a fish drinks has to do with differences in salt concentrations between the animal's tissues and the water it swims in. For most species, there is a large difference between the two. Through the principle of osmosis, water diffuses through fish gills and skin from lower to higher salt concentrations. "Because fish must maintain salt concentrations different than their environments, they are always combating this diffusion," says Ray Owczarzak, assistant curator of fishes at the National Aquarium in Baltimore.

The bodies of most saltwater fish are only a third as saline as their surroundings, so they constantly lose water. These fish must therefore regularly drink to replace their body's water content. Freshwater fish, on the other hand, don't swallow water. Their bodies contain a higher concentration of salts than the surrounding environment, so water is constantly being absorbed. They must conserve salts by controlling this flood of freshwater. These fish have developed a system that allows them to quickly get rid of water as diluted urine.

Some primitive saltwater species, such as the hagfish, lack such abilities to adjust to changes in salinity. Hagfish have the same concentration of salt in their tissues as the water around them. They must stay within narrow salinity ranges in their ocean habitat.

How Fish Fight Osmosis

SALTWATER FISH usually have a lower concentration of salt in their bodies than the water around them does. Water therefore diffuses out of their bodies, and they must drink to remain hydrated. Some primitive species have the same salinity levels as their habitat and don't have to drink.

FRESHWATER FISH have more salt in their tissues than the surrounding water. Consequently, water constantly diffuses into their bodies, and they must excrete it through dilute urine.

CLOCKWISE FROM LEFT: GETTY IMAGES/ALL OVER; COLOR BLIND IMAGES/GETTY IMAGES/ALL OVER; NGS; PASCAL KOBEH

Have scientists found dinosaur DNA?

Not yet, and they probably never will, says John Asara, a pathology instructor at Harvard Medical School who led a team this May that successfully extracted proteins from two dinosaur fossils found in Montana. The team is sequencing the proteins to investigate how birds are related to dinosaurs, but it may not be possible to get dinosaur DNA from such fossil proteins because genetic material breaks down over time.

"There is very little DNA left in fossils that are more than 100,000 years old, explains Michael Hofreiter, a geneticist at the University of York in England. "It is fragmented and there is a lot of contamination from other organisms, including bacteria, fungi and usually humans." Although scientists have successfully recovered prehistoric DNA from other creatures, dino remains are simply too old. DNA is also unstable and degrades unless constantly repaired inside a living cell. Even under optimal preservation conditions, it is very doubtful that DNA could last a million years, let alone the 65 million that have passed since the dinosaurs died out.

Despite the lack of dino DNA, genetic material has provided many insights into more-recent extinct animal species. Last November, researchers at Penn State University announced that they had successfully recovered a large section of the woolly-mammoth genome from 20,000- and 60,000-year-old hairs. The scientists hope that analysis of the extinct animals' DNA will shed light on processes driving species toward a similar fate today.

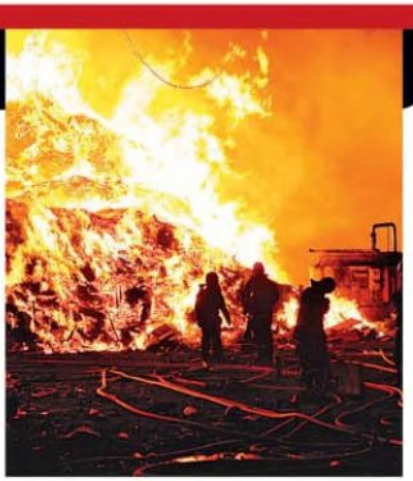


Dinosaur fossils are probably too old to ever produce viable DNA.

How does spontaneous combustion occur?

Spontaneous combustion is a slow-forming process caused by a combination of chemical reactions and super-efficient insulation. Take, for example, oil-soaked rags. When the oil reacts with oxygen in the air, it produces heat, and since the rags provide good insulation, the heat cannot escape. If the temperature reaches 400°F, the rags will burst into flames.

In other cases, it is living organisms that cause temperatures to rise. Stored sawdust may contain bacteria that through biological processes can increase the temperature inside a sawdust pile to 140°. Known as self-heating, this process is not dangerous by itself, but it can kick-start chemical reactions that cause fires. The risk is especially high if more fire-fueling oxygen suddenly becomes available—for instance, if the door to a sawdust-storage area is quickly opened. Fires started by spontaneous combustion in grain, hay, wood chips, garbage or coal often burn slowly but are hard to extinguish. These smoldering fires can be prevented by keeping the temperature in storage areas below the flash point, which differs for each material.



Spontaneous combustion, which sometimes occurs in garbage dumps, is caused by heat from chemical reactions.

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The annual *American PHOTO* Images of the Year event is an international competition that is a definitive showcase of the very best of contemporary photography. This juried photo contest offers unmatched exposure to both established and emerging photographers in a wide range of fields, from documentary/photojournalism to cutting-edge commercial work and will provide an unprecedented opportunity for peer review of your work by professional photographers, museum curators, art critics and influential editors. Winners will be selected on the basis of originality and the overall quality of concept execution.

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- Nature • Extreme

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Entries must be postmarked no later than midnight, September 12th, 2009.

ENTRY FEE

Single Entry: $25 | **Series:** $40 |
Student Work: $10
Extended Entry (September 17th): $50
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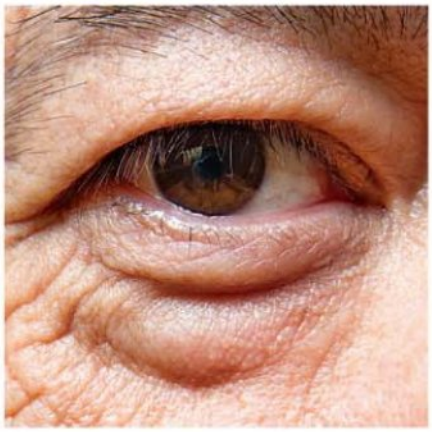
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Bulges under the eyes are filled with fat.

Why do we get bags under our eyes?

The long-standing explanation for the dreaded "bags" is that connective tissue under the eyelids loses its elasticity, causing the lower lid to bulge out or droop. But it may have more to do with the anatomy of the eye area, where the eyeball is surrounded by a thick layer of fat. Last year, a study of 40 people between 12 and 80 years old at the University of California at Los Angeles indicated that, as we age, more fat is deposited around the eyelids, so they are subjected to greater pressure. That excess fat can create the appearance of bags beneath the eyes, even if the connective tissue remains elastic.

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Why does the full moon sometimes look so big?

The distance between the moon and Earth differs over the course of the year; when it's closer, it appears bigger and brighter. The moon travels in an elliptical orbit around Earth, and the distance between the two bodies usually varies from between 225,000 and 252,000 miles. At its closest to the planet, the moon is said to be at perigee. When both at perigee and in its full phase, it appears extra large and bright—roughly 14 percent larger and 30 percent brighter than when at apogee, its farthest distance from Earth.

You may have noticed an unusually large and bright full moon last December and this January. During those months, the moon's orbit was closer to Earth, giving us a better view of it. But according to Michael Shara, the curator of astrophysics at the American Museum of Natural History in New York, there's more to the story. He explains that the moon is exposed to gravitational forces from not just the Earth but from the sun as well, which cause the distance of the moon at perigee to vary. The closest perigee actually brings the moon to within 221,580 miles of Earth, and that's where it was early this year, when it was also full. This coincidence—a full moon at its closest perigree—rarely happens, and scientists don't expect to see it again until November 14, 2016.

At its brightest, the moon is impossible to overlook. Yet the difference in size may be more difficult to notice because of an optical illusion: The moon looks larger when it is near the horizon than when it is higher in the sky. In reality, the moon is slightly farther away when it is on the horizon and closer when it is high in the sky. But our eyes perceive the opposite because when the moon lies near the horizon we can compare it with other objects in our view.

A Closer Moon Looks Bigger

The moon moves in an elongated orbit around Earth, so the distance between the two bodies can vary by more than 25,000 miles.



A full moon appears both larger and brighter when it is closer to Earth.



When the moon is closest to Earth, it is at perigee. At its farthest, it is at apogee.

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Not all animals have sex chromosomes. The temperature of the eggs during incubation determines the sex of turtles.

Three Types of Sex Chromosomes

	Name of sex chromosomes	Egg cells contain	Sperm cells contain	Sex determined by
Humans and other mammals	X, Y	X	X or Y	male's sperm cell
Birds	Z, W	Z or W	Z	female's egg cell
Some insects, such as grasshoppers	X	X	X or absence	male's sperm cell

Do all animals have X and Y chromosomes?

Even though most organisms have both male and female sexes, the mechanisms that determine sex are diverse.

In humans, females have two X chromosomes, while males have one X and one Y. Egg cells always contain an X chromosome, so the sex of offspring is determined by whether the sperm cell contains an X or a Y. All other mammals—from mice to whales—also use this X-Y system. Generally, when a female organism is homogametic (having two identical sex chromosomes) and the male is heterogametic (having two different sex chromosomes), the chromosomes are referred to as X and Y.

Among birds, whose females are heterogametic and males homogametic, the chromosomes are labeled Z and W. Some insects, like cockroaches and some species of grasshoppers, have sex chromosomes, but there is only one type, called X, that determines sex. Whether a cockroach is male or female depends on if it carries one (male) or two copies (female) of the chromosome. Fish have various methods of determining sex.

Other types of animals lack sex chromosomes altogether. Among turtles and crocodiles, for example, the sex of offspring is determined by egg temperature during incubation. Turtle and crocodile eggs that are incubated at low temperatures usually produce males, while higher temperatures result in females.

Plants, by the way, are a mixed bag. Most flowering plants are hermaphroditic, meaning one plant has both male and female sex organs.

Why do ice cubes crack when they're put in a glass of water?

That familiar crackle sound and splitting is caused by thermal tension that occurs when the ice is heated by comparatively warm water. When solid materials are exposed to heat, they expand. In the case of the ice cubes, the water in the glass warms the outside of the ice while the center of the cube remains freezing cold. This causes the ice cube's exterior to expand more than its center, which cracks the ice.

Thermal stress is certainly not limited to ice cubes—it often causes big problems in metal structures like railroad tracks. In the summertime, when steel tracks absorb a lot of heat from the sun, they can expand. To prevent the tracks from deforming, jointed tracks have small gaps between rails to accommodate expansion, and welded rails are restrained with clips or anchors to prevent movement.

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The Dawn of



Paleontologists discovered dinosaur bones inside a fossilized mammal's stomach in 2005.

CM STUDIO AND R. MICKENS/AMNH AND CLAUS LUNAU; INSET: R. MICKENS/AMNH

Mammals

Some of our oldest relatives dined on dinosaurs. This and other surprising findings are changing our understanding of the first mammals



The mammal **Reponomamus robustus** *[above] could have preyed upon a young* **Psittacosaur** *dinosaur [left] 130 million years ago in China.*

Two hundred million years ago, the earliest mammals lived in the shadow of dinosaurs. With the agile, hungry reptiles lurking around every corner, mammals had to hide under the cover of night, eat bugs, and stay small—around the size of a mouse or a shrew. With that kind of pressure, they didn't have a chance to spread their evolutionary wings and diversify until the last of the non-avian dinosaurs went extinct 65 million years ago. The disappearance of the dinos, which had dominated for 165 million years, left a vast range of ecological niches suddenly vacant, ready for new fauna to move into the spotlight. Mammals grabbed hold of the opportunity, resulting in the explosion of species that led to today's familiar forms. Or so we thought.

This account of early mammalian evolution has long been the standard, but new fossil finds and

genetic research are shaking up our understanding of vertebrate life during the Mesozoic era, which spans 251 to 65 million years ago. And although scientists still believe that diminutive, mouselike critters were the most common mammals during this time, several unexpected discoveries in the past few years show surprising diversification of body plans and lifestyles in the company of dinosaurs.

The Trouble with Fossils

Describing extinct fauna based on fossils has always involved a great deal of uncertainty. Because a fossil can give us information about only a single animal in one place at a specific moment in time, it's almost impossible to determine a species' population, range or even how long it survived before going extinct from the fossil record alone. And the majority of fossils aren't complete, perfectly preserved remains—often, paleontologists must make their conclusions based on a lone skull or a handful of teeth. As a result, new discoveries—a better-preserved vertebra here, a more complete skeleton there—often revise ideas about the appearance, diet, movements and habitat of prehistoric animals. Many species of dinosaurs, for instance, have had both their appearance and their behavior revised as paleontologists have unearthed new finds. (Paleontologists are still debating whether *Tyrannosaurus rex* ran or lumbered along at a slower pace.)

Our ideas about the mammals that coexisted with dinosaurs have similarly changed over time. Twenty years ago, most of the Mesozoic mammals scientists knew of were small insectivores like *Henkelotherium guimarotae,* a three-inch-long shrewlike animal, with a tail of almost equal length. It used its little, sharp teeth to live off insects and other small invertebrates that shared its subtropical swamp habitat 150 million years ago in what is now Portugal.

The species gets its name from Guimarota, the coal mine where it was found and a particularly rich source of Mesozoic mammalian fossils from the Jurassic period, which spanned from around 200 to 145 million years ago. Paleontologists dug up about 10,000 teeth, 1,000 jawbones and two complete mammal skeletons there during the 1970s and '80s—most of which looked a lot like *H. guimarotae*—and our early understanding of the first mammals was based largely on these and other similar finds.

Improvements to fossil-collecting techniques have brought new discoveries. Most Mesozoic mammals were small, and their teeth—the most abundant evidence of their existence—can be hard to spot. The number of early mammal samples that paleontologists sifting through dirt have unearthed



S. szalayi's shoulders, limbs and feet indicate that it could climb trees.



ON LAND

The Oldest Marsupial

Molecular dating indicates that marsupials and placentals diverged 150 million years ago. Discovered in China in 2003, a fossilized *Sinodelphys szalayi* [above] is the oldest relative of modern marsupials ever found. The six-inch-long animal had developed the anatomy required to climb trees along rivers and lakes in its habitat 125 million years ago. Today more than 300 species, including koalas and kangaroos, are classified as marsupials, defined by the maternal pouch in which offspring develop after they are born.

FROM LEFT: M.A. KLINGLER/CMNH; Z.X. LUO/CMNH

has vastly increased over the past two decades. Whereas 100 Mesozoic mammal groups were known 25 years ago, today there are closer to 300 recognized genera, indicating a greater level of speciation during the age of dinosaurs than was previously assumed.

What Makes a Mammal?

From the tiny hog-nosed bat, which weighs less than an ounce, to the blue whale, which can reach over 400,000 pounds, today's mammals are a study in diversity. Platypus, koala, aardvark, elephant, rat, dog, dolphin, human—they're all mammals. But what do they have in common? Among many other defining factors, the more than 5,000 species in the class Mammalia are vertebrates with body hair whose females produce milk to nourish their offspring. Most (but not all) of those offspring are born live rather than hatching from an egg, and all possess middle-ear bones that transmit sound waves to the brain and a lower jaw hinged to the skull.

The fossil record shows that mammals evolved from reptiles 250 million to 200 million years ago. The intermediate species, mammal-like reptiles called synapsids, gave rise to true mammals during that time. Two hundred million years ago, the live-bearing

IN WATER

The Oldest Swimmer

Castorocauda lutrasimilis **used its wide, flat tail to propel itself through rivers. Paleontologists found fossil remains of the 164-million-year-old beaverlike species in Mongolia in 2006. The 17-inch-long creature, which probably weighed between one and two pounds, is the oldest known semiaquatic mammal. Its body was adapted to swimming, its teeth were made for eating fish, and its arms were designed for digging.**



The* C. lutrasimilis *fossil is the oldest to be found preserved with hair. In the specimen, its pelt was carbonized.

Z.X. LUO/CMNH

Theria split off from the more reptile-like egg-laying Prototheria—the two subclasses of mammals—and around 50 million years later, the therians further divided into marsupials and placentals. Egg-laying mammals are called monotremes.

The placentals, which are characterized by fetal development inside the mother's womb (rather than in an egg for monotremes or an external pouch in the case of marsupials), represent the largest group of mammals, with approximately 4,750 species living today. Recent molecular dating, in which the differences between species' DNA determine how long ago the animals diverged from a common ancestor, has revealed that this diversification began surprisingly early. The ancestors of almost all groups of living placentals are present in the fossil record as of 100 million years ago—35 million years before the dinosaurs' predation and competition for resources finally ended.

Fantastical Fossils

New fossil discoveries are also expanding our knowledge of the earliest mammals. Many of the finds come from China and Mongolia. The region is rich in specimens from the Cretaceous period, which ended the Mesozoic era between 145 million and 65 million years ago.

In 2003, researchers from the Chinese Academy of Geological Sciences and the Carnegie Museum of Natural History (CNMH) unearthed *Sinodelphys szalayi*, the oldest known relative of modern marsupials, in the Liaoning province in China. The small creature, which was about six inches long and weighed around an ounce, made its home in woods or shrubs on lakeshores or riverbanks. *S. szalayi* lived approximately 125 million years ago, but the anatomy of its shoulders, hips and feet indicate that it had already developed the ability to climb trees.

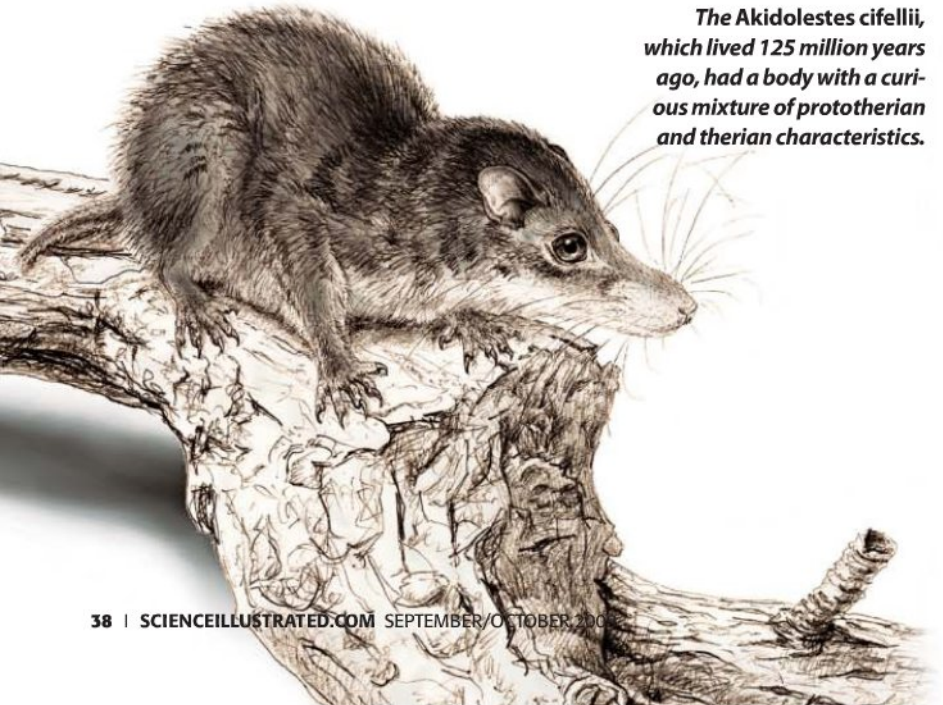
Another mammal that lived at the same time and was also discovered in China, *Akidolestes cifellii*, is more of a mystery. The four-inch-long critter appears to possess a mix of prototherian and therian anatomy, with the back of its body resembling the more primitive monotremes and the front resembling marsupials and placentals. Researchers from CMNH, who found the fossil in 2006, believe that over time the animal may have reacquired the sprawled-out, lizardlike shape of its hind end.

Aquatic mammals—the predecessors of animals such as whales, seals and otters—made their appearance even earlier. Researchers from the same institutions that found *S. szalayi* went on to discover the 164-million-year-old beaver-like *Castorocauda lutrasimilis* in Mongolia in 2006. The remains are the earliest evidence of a semiaquatic mammalian lifestyle. *C. lutrasimilis*'s 17-inch-long body was highly specialized, with skeletal and soft-tissue features developed for swimming, teeth designed for eating fish, and limbs made for digging. Its tail resembles those of today's beavers and was probably used in the same way, to provide propulsion while swimming.

C. lutrasimilis might have looked up into the air and seen *Volaticotherium antiquum*, an animal similar (though not related) to today's flying squirrels. This 125-million-year-old mammal, discovered in 2006 by researchers from the American Museum of Natural History (AMNH) and the Institute of Vertebrate Paleontology and Paleoanthropology at the Chinese Academy of Sciences (CAS), is the earliest known to have developed skin membranes stretching between its legs. The membranes enabled it to glide from tree to tree to avoid predators, as well as to save time and energy while seeking food.

By far the most startling recent fossil finds, however, are two species in the genus *Repenomamus, R. giganticus* and *R. robustus.* Both were impressively large for Mesozoic mammals, but *R. giganticus* was the bigger of the two—at more than three feet long, it was twice the size of its cousin and would have weighed as much as 30 pounds. The 130-million-year-old marsupial probably looked something like today's Tasmanian devils, only larger. The species' sizes, though, are only part of the story. In 2005, researchers from AMNH and CAS discovered an *R. robustus* specimen fossilized with the remains of its last meal: a six-inch-long juvenile *Psittacosaurus* dinosaur. The teeth of both *Repenomamus* species indicate that they may have been predators, not just scavengers—and researchers believe that they probably competed with dinosaurs for both food and territory.

Tree climbers and gliders, river dwellers and dinosaur eaters—the new fossils show that mammals did well for themselves during the Age of Dinosaurs. The more we learn about our earliest mammalian predecessors, it seems, the more we realize how much still remains to be uncovered. ■



The* Akidolestes cifellii, *which lived 125 million years ago, had a body with a curious mixture of prototherian and therian characteristics.

M.A. KLINGLER/CMNH

IN THE AIR

The Oldest Glider

Although true flight didn't evolve in mammals until perhaps 45 million years ago, when bats appear to have developed fully powered flight, mammals took to the air long before then. By 125 million years ago, *Volaticotherium antiquum* was sporting skin membranes between its legs, an adaptation that allowed it to glide from tree to tree much like today's flying squirrels. The tactic would have helped the species save time and energy while on the hunt for insects, and it gave the mammal a novel way to escape predators.



The fossil remains of* V. antiquum *include evidence of membranes [see arrow] that allowed it to glide through the air.

AMNH (2)

The Search for Another Earth

The Kepler mission, launched in March, is the most sophisticated effort yet to look beyond our own solar system for planets circling other suns. If the telescope can spot a rock similar to our own, it could be a strong indication that life is possible on another planet—or that it already exists there

Scientists believe that planets similar to Earth in dimension and temperature are the most likely to foster life. Planets that are much larger or smaller than Earth are violently inhospitable. An orb more than twice the diameter of our own generates so much gravity that it holds onto hydrogen, the universe's most abundant element, and bloats into a lifeless gas giant like Jupiter and Saturn. A small planet less than half the mass of Earth is equally unlivable because a lack of gravity prevents the formation of a protective atmosphere. In addition, to sustain any sort of surface biology as we understand it, liquid water must be present. And to have any chance of supporting life, a planet must revolve around its parent star in a comfortable band termed the habitable zone, where water neither boils nor freezes indefinitely.

NASA's Kepler satellite, currently orbiting the sun, is our best hope for finding such a world. Launched from Cape Canaveral on March 6, the satellite is on a three-and-a-half-year mission to look for signs of exoplanets—defined as planets outside our solar system, rotating around stars other than our sun—in the Cygnus and Lyra constellations.

Keeping that many celestial objects in its view is delicate work. In mid-September, Kepler will execute one of its seasonal adjustments, twisting 90 degrees to keep its solar panels exposed to the energizing sun and its radiator cooled by the darkness of space. The satellite isn't sophisticated enough to spot life itself, but through quarterly pirouettes, Kepler will remain focused on the 100,000 or so stars that represent our best prospects for finding habitable planets. But uncertainty persists. If a warm, midsize hunk of rock similar to our own sways across the telescope's vision, how will we learn if such a world harbors life?



Kepler will indirectly detect exoplanets by recording the effects they have on the brightness of their parent stars.

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The Light and Sound of Life

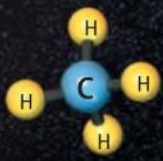
When the Galileo probe cruised past Earth in 1990 en route to Jupiter, astronomer Carl Sagan and his colleagues noted four important signs of life on our planet, which could also be used to help us find life elsewhere.



- During photosynthesis, chlorophyll absorbs red wavelengths of light. If vegetation covers a planet, light leaving its atmosphere should appear less red than expected.



- Plants consume CO_2 and emit oxygen. The chemical signature of molecular O_2 in a planet's reflected light may indicate organic life. Unless plants replenish it, O_2 will vanish from the atmosphere.



- Some type of life may be present if analysis of the planet's reflected light reveals signs of methane. This gas will break down unless replaced by biological processes, such as the decay of organic matter.



- Beyond plants or microbes, evidence of narrowband modulated radio transmission would indicate technologically advanced beings. No natural process is known to emit this type of radiation.

Looking for E.T.

In 1995, Swiss astronomers discovered the first known exoplanet when they used a ground telescope to infer that a planet they called 51 Pegasi b was in orbit around an ordinary star. Since then, other telescopes have detected more than 340 similar celestial bodies. Exoplanets can be diverse in size and composition, and scientists suspect that billions of them could exist. Those already discovered, however, are Jupiter-like gas giants unlikely to harbor life as we understand it. With its special light-analyzing telescope, called a photometer, creating 95-million-pixel images of glimmers 3,000 light-years away, Kepler is the first satellite capable of detecting Earth-size exoplanets.

Kepler is not expressly designed to find extraterrestrial life. The Search for Extraterrestrial Intelligence (SETI) program, championed by the famed astronomer and writer Carl Sagan before his death in 1996, is the most prominent program working toward that goal—it scans the cosmos with large antennas for signs of extraterrestrial intelligence by way of radio transmissions. The chief scientist with the Exoplanet Exploration Program at NASA, Wesley Traub, points out that Kepler's mission bears little relation to that of SETI.

Still, the hunt for exoplanets, especially those similar to Earth, is a dramatic endeavor that has become one of the most popular enterprises in astronomy. The quest has been compared with Columbus's explorations of the New World. But the universe is the widest and darkest ocean ever confronted, and the vast distance between our star—the sun—and the billions of others that flicker across the galaxy is staggering.

Indirect Observations

While the world awaits Kepler's discoveries, astronomers will continue to use time-tested methods that have already revealed hundreds of distant worlds. These methods have huge limitations, though.

Because of immense galactic distance, exoplanets can mostly be detected indirectly, by perceiving the subtle effects they have on their much larger parent stars' brightness.

A planet doesn't shine by itself, but its gravitational pull can cause its parent star to wobble and obscure the light the star casts to Earth. To detect the presence of a planet indirectly, scientists can use a highly sensitive prism to monitor these variations. Normally when starlight passes through a prism it generates a unique rainbow called a stellar spectrum. If the star teeters in the direction of the



Life As We Know It (or Don't)

In 2007, the Committee on the Origins and Evolution of Life sought to define the limits of possible life within the solar system and beyond. Some essential features included an aqueous habitat and a capacity for molecular bonding. Other factors, like Darwinian evolution, remained unclear. The group, an arm of the National Research Council, also warned against terracentricity—confining our perceptions of life to what we see on Earth. Future searches for extraterrestrials must acknowledge that whatever is found on other planets, if anything, may be totally alien.

astronomer's telescope, the light will appear bluer than usual. If it teeters away, the light is redder. A periodic shifting of a spectrum from red to blue suggests that a star is wobbling, probably because of a nearby planet. Most exoplanets have been inferred by this method, called the radial velocity method. The technique is limited, however, to detecting heavy gas titans that exert sizable changes in their parent stars' motions. Jupiter, for example, exerts a measurable change in the sun, about 42.7 feet per second. Earth, with only 3 percent the mass of Jupiter, contributes a barely detectable 0.3 f/s to the solar wobble.

Kepler's Method

Another indirect way to detect exoplanets has been tested on Earth and will be applied with far greater sensitivity by the Kepler satellite. The transit photometry technique, as it's known, involves watching a star for long periods of time and gauging any variations in its brightness. If the star dims at regular intervals for regular lengths of time, that's a strong indication that a dark planetary speck is passing across its surface. One analogy for the great distance and relatively small size of an orbiting exoplanet is that of a gnat crawling across a car's headlight many miles away. Kepler's 42 charge-coupled devices, which gather light, are similar to but larger than those found in digital cameras and are capable of observing drops in a star's overall brightness of as subtle as 10 parts per million. Such precision means that, for the first time, Earth-size exoplanets may be detected. Here's how: A star's size can be estimated from the light it emits, and an exoplanet's dimensions can

STRANGER STILL

Gas Giant
Planets more than 10 times the mass of Earth, like Jupiter, have enough gravity to cling to elements like hydrogen and inflate. The National Research Committee noted that life could possibly exist in a gas.

Ice Body
Bonds needed for carbon-based life can stabilize even at very low temperatures, like those on Jupiter's moon Europa. The radiation that strikes this moon, however, could kill a human in a minute.

Diamond Planet
A planet composed mostly of carbon could have a graphite surface or, given sufficient pressure, a diamond shell capable of protecting it from intense stellar radiation. Whether life could flourish in its tarry oceans is unknown.

INHOSPITABLE

Too Small
A rocky planet with less than half of Earth's mass would not possess enough gravity to sustain a life-giving atmosphere. The presence of organic beings on such a world seems highly unlikely.

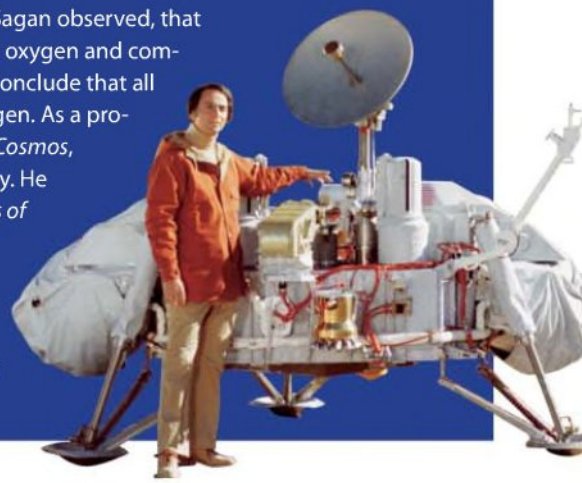
Too Hot
The committee dismissed the possibility of a carbon-based organism surviving above 980°F. At that temperature, at any pressure, bonds between atoms break down.

then be calculated given what fraction of that light it dims during transit. By watching for more than three years, Kepler will also be able to accurately measure the time between transits, and therefore the distance between star and planet.

Knowledge of these two factors—size and orbital distance—will determine if an exoplanet has the right dimensions to support an atmosphere and if it is warm enough for liquid water. It will then be up to other missions to determine whether life could somehow adapt to conditions on such a planet—or if the world already hosts life of its own. ■

Bringing Space Down to Earth

It is unsurprising, astronomer Carl Sagan observed, that carbon-based organisms breathing oxygen and composed of 60 percent water should conclude that all life requires carbon, water and oxygen. As a producer of the 1980 television series *Cosmos*, Sagan helped popularize astronomy. He won a Pulitzer Prize for *The Dragons of Eden*, a nonfiction book about the evolution of human intelligence, and worked on missions to Venus and Mars, including NASA's Viking missions of 1975 that first searched for signs of Martian life.



NASA

Ancient Mariners

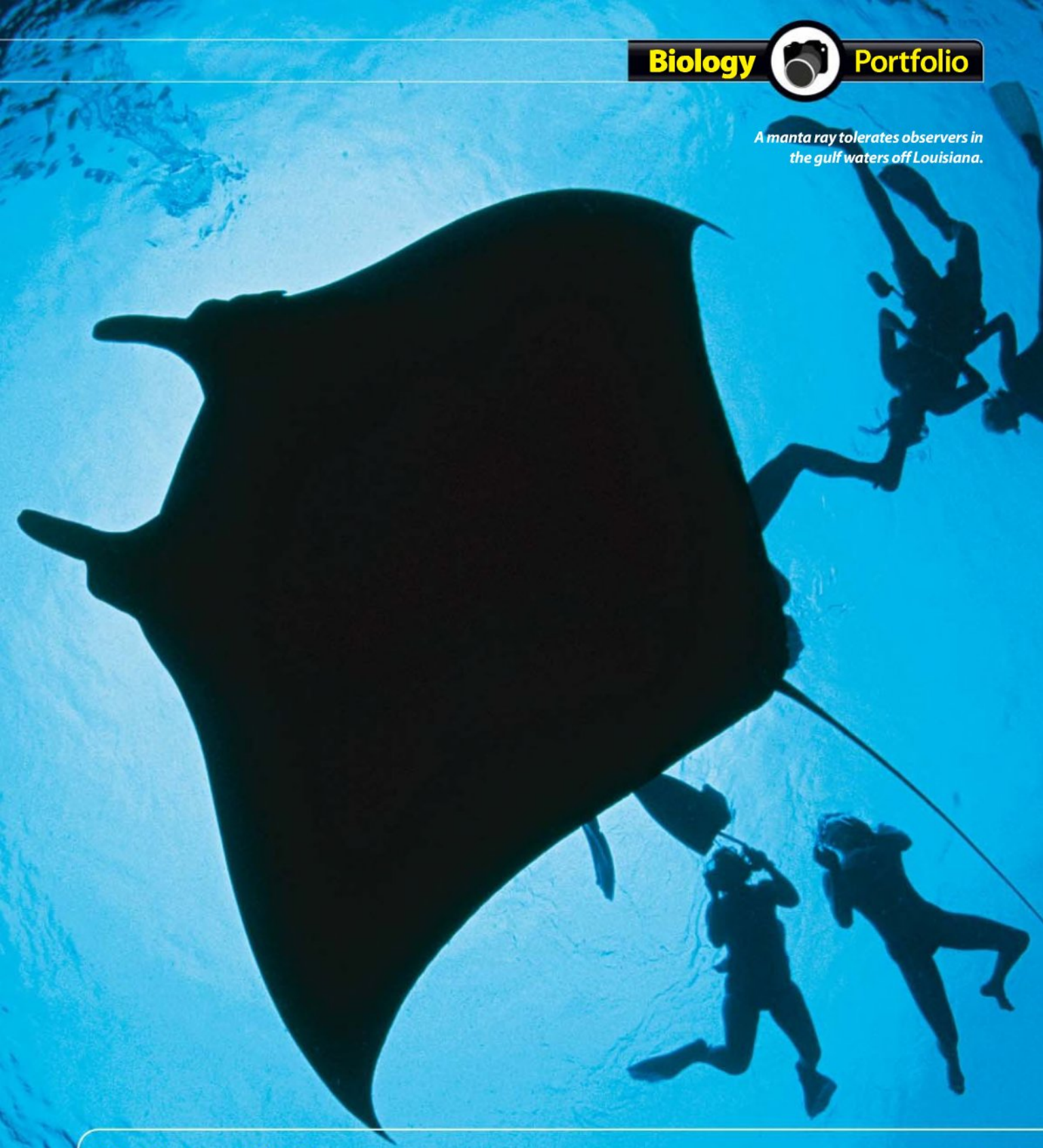
Diverse and elusive, rays have flourished for 150 million years. But modern hazards threaten the fish just as research is beginning to reveal the secrets of their longevity

Glimmering in the depths like swimming constellations, some rays flaunt starry camouflage on their backs. Some hover in the shallows, coaxing human caresses, while others impale unwelcome visitors with tails studded with venomous barbs. Some rays launch their flat, disk-shaped bodies above the ocean foam, and still others nestle into freshwater riverbeds.

These fish have traversed the world's waters for as long as 150 million years. Together with sharks, rays belong to an exclusive subclass of fish known as *Elasmobranchii*, from the Greek for "plated gills." Unlike other fish, they lack an air-filled swim bladder and will sink unless kept afloat by fluttering pectorals that resemble bats' wings more than traditional fins. Scientists therefore refer to rays—a group divided into stingrays, skates, electric rays, guitarfish and sawfish—as batoids.

Predators as well as scavengers, most of the more than 500 known ray species feed on mollusks, crustaceans, plankton and darting fish. Marine biologists have recently discovered that large pores on rays' heads detect weak electrical signals, like those generated by the beating heart of otherwise hidden prey. To ward off predators like whales and tiger sharks, ray skin is armored with innumerable tiny denticles that are more like teeth than fish scales, each composed of a root, a crown and an enamel-like substance. Yet rays may be most famous for another, more deadly defense, the venomous sting-

FLIP NICKLIN/NGS



A manta ray tolerates observers in the gulf waters off Louisiana.

Mysterious Giants

Defying their wicked name and intimidating size—adults can be as large as 20 feet across—members of the devil-ray family, including mantas, possess placid, sometimes shy, temperaments. Their approachable nature and harmless tails make these rays popular with divers, and tourism can be lucrative in areas with devil-ray populations. Mantas have an extraordinary ability to smell chemicals, hormones and even amino acids in the water. Every manta is also uniquely colored and patterned, a characteristic that helps scientists identify individuals. But basic facts about devil-ray biology, including their reproductive and migratory habits, are still unknown.

ers that many species brandish on their long, slender tails.

Rays have a skeleton made of cartilage rather than bone, making them light and flexible as they skim the seafloor in waters around the world. Recent evidence suggests that these skeletons are stronger than once thought. Studies of the cownose ray's jaw, for instance, reveal that the fish uses a strong, specialized ligament to enhance its boneless bite, enabling it to shatter hard-shelled mollusks in the Atlantic waters it calls home. Cartilage may have also helped large rays, like the 3,000-pound giant manta, attain their impressive dimensions. Fish with heavy bones are less buoyant than their cartilaginous counterparts, and a larger body would impede their ability to swim—decreasing their likelihood of survival.

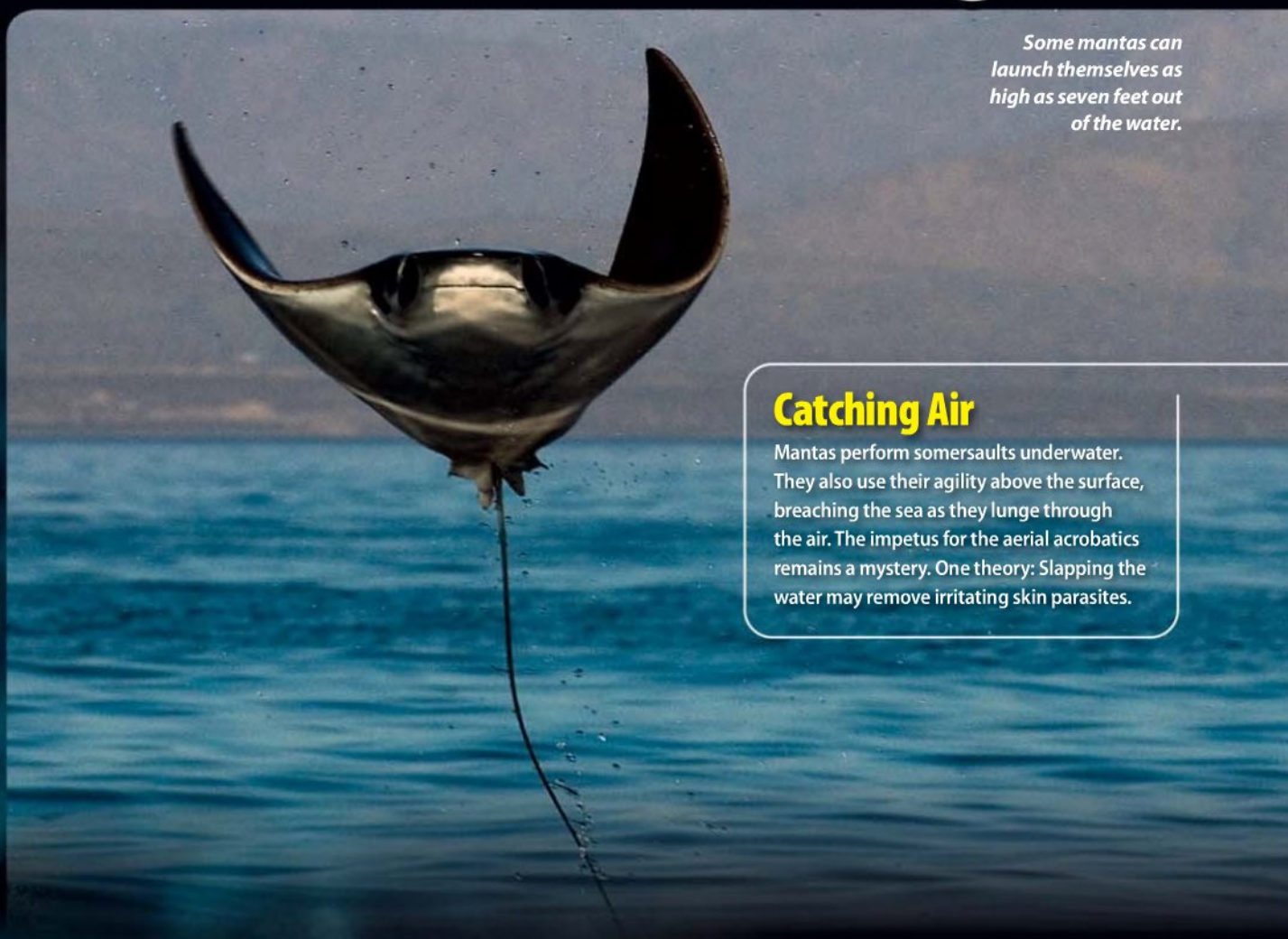
Features of batoid brains, including an exquisite sense of smell, night vision and the ability to navigate using Earth's magnetic field, fascinate biologists. But although the areas for study are endless, scientists warn that opportunities to learn about the fish are dwindling. Overfishing and marine pollution are predictable culprits, but carelessness is also decimating the ray population. According to the Shark Specialist Group of the International Union for the Conservation of Nature (IUCN), unintentional netting by commercial fishing boats has left one in five species of batoids at risk of extinction. ■

Blades in the Waves

Sawfish get their name from their elongated snout flanked by jagged teeth. These rays make up a family of seven species that inhabit warm, shallow waters, including those of the Caribbean, the African coast and the South Pacific. Sawfish are renowned for their valor against sharks, which have been observed bearing the distinctive scars of the ray's snout blades. The snout, or rostrum, may help sawfish dig for crabs in sediment. Sadly, they also snag fishing gear. Tuna fisheries' unintended culling of rays is the greatest threat to the species, says marine biologist Nicholas Dulvy of Simon Fraser University in British Columbia. The most imperiled of the batoids, all species of sawfish are considered critically endangered by the IUCN.

GEORGE GRALL/NGS

The serrated sawfish snout helps battle sharks.



Some mantas can launch themselves as high as seven feet out of the water.

Catching Air

Mantas perform somersaults underwater. They also use their agility above the surface, breaching the sea as they lunge through the air. The impetus for the aerial acrobatics remains a mystery. One theory: Slapping the water may remove irritating skin parasites.

Special Delivery

Many rays bear live young, and clever adaptations exist to protect laboring mothers from their offspring's developing defenses. Newborn eagle-ray pups, for example, have temporary sheaths over their tail spines, and sawfish pups have similar protective sheaths covering their jagged snouts. The tail spines and snouts also remain soft and pliable until after birth.



A manta is born in an aquarium in Japan.

FROM TOP: BRIAN J. SKERRY/NGS; OKINAWA CHURAUMI AQUARIUM

Defensive Maneuvers

Stingrays are infamously armed with tail barbs that deliver deadly nerve-damaging venom to predatory sharks. The serrated stingers can grow to as long as 15 inches and regenerate after being left behind in an unlucky victim. In Greek mythology, the hero Odysseus perishes under a barb-tipped spear. In real life, the Australian naturalist and popular TV host Steve Irwin (a.k.a. the Crocodile Hunter) died in 2006 after a stingray punctured his heart. Yet biologists say stingrays are generally docile and attack only when startled. Some stingrays inhabit shallow coastal waters, while others flourish in freshwater locales, like the Amazon basin and Florida's St. Johns River.



A diver embraces a docile stingray.

The underside of a Pacific torpedo ray in a California kelp forest

FROM TOP: DAVID DOUBILET/NGS; PHILLIP COLLA/SEAPICS.COM



Mantas cruise through a Micronesian channel in feeding formation. The pair of fleshy lobes called cephalic fins curl downward to funnel plankton into their wide mouths.

A Bolt from the Blue

The 20 species of electric rays that inhabit the world's warm waters discharge electric shocks from organs on the sides of their head. The shocks, which can reach 220 volts—a jolt equivalent to that from about 150 AA batteries—are used to stun prey and fell attackers. The word "narcotic" derives from the Greek name for the electric ray, a holdover from the traditional practice of numbing afflictions like headache and gout with the shocks of torpedo rays. The most ancient group of rays, torpedoes date back to the time of the dinosaurs.

M. VEITCH/SEAPICS.COM

F1 Soups Up the Family Car



CORBIS/SCANPIX

The same technologies that make Formula One racecars go faster can make ordinary cars more fuel-efficient.

Formula One Takes the Wheel

Built-in controls developed for the steering wheels of Formula One cars [below] have now been adapted for passenger cars [right]. The controls make it easier for a driver to keep his hands on the wheel and his eyes on the road.





As drivers maneuver at high speeds during daylong races, even incremental savings of time and fuel can add up to a big win. In effect, Formula One is a supercharged laboratory, and the technologies that give the pros an edge also trickle down into passenger cars

When a driver is zipping along at 200 mph in the winged, open-cockpit racecar known as a Formula vehicle, trying to stay off the wall as the gravitational force of a turn makes it hard to breathe, taking a hand off the wheel to shift gears is a life-or-death risk. In the early 1990s, engineers realized that racecar drivers would be able to shift faster, safer and more smoothly if they didn't have to reach for a gearshift. Over time, more and more functions migrated to the wheel. A modern Formula One steering wheel contains an LCD screen that displays instrument readings, warns of approaching hazards, and flashes bright lights signaling the optimum time to shift gears. Wheel-mounted buttons and switches allow the driver to shift, talk to the pit crew on the radio, take a drink through a tube in his helmet, and adjust the car's fuel mixture. Except for the throttle, all the controls are at the driver's fingertips.



FROM LEFT: REUTERS/SCANPIX; BMW

Just about any passenger car built today offers something similar. The wheel of your car may have buttons for changing the radio station and setting the cruise control, rather than for engaging a pit-lane speed limiter or changing the front-to-rear braking ratio. But the benefits are the same: You get to keep your hands on the wheel and your eyes on the road.

More professional driving advantages are poised to make their way into our everyday lives. Since 2006, the International Automobile Federation, the sport's governing body, has issued mandates that require innovations in Formula One design, like gasoline-electric hybrid engines, to have a practical application in passenger vehicles. Supercomputers that analyze Formula One cars are now used to assess noise and fuel efficiency in passenger cars. And a host of engine improvements, from transmissions to energy-recovery systems, also lead double lives. In Formula One cars, these innovations increase power. But in family cars, the emphasis is on environmental gains. The new technologies can result in significant savings in fuel, which also reduces carbon dioxide emissions.

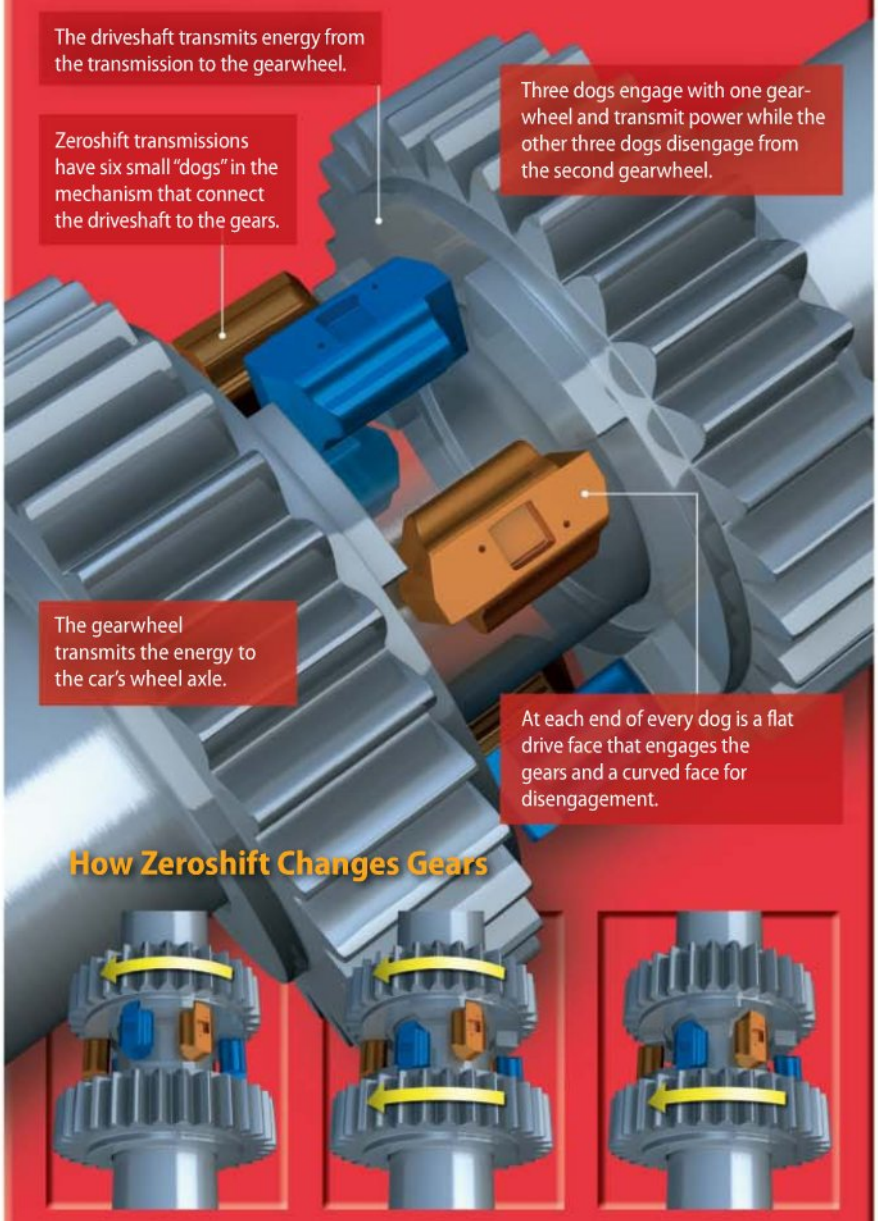
Shifting in Milliseconds

The most revolutionary technology headed from Formula One to the family car is a transmission system called seamless shifting, first introduced to racing in 2007. In road cars, the system is known as a Zeroshift transmission, developed by a British company of the same name. Zeroshift enables drivers to change gears in just a few milliseconds, without any interruption of power to the wheels.

Like any gearbox, Zeroshift has toothed wheels that transfer energy from the drive shaft to the car's axle. But unlike a conventional manual

Zeroshift Leaves Ordinary Gearboxes in the Dust

In a traditional gearbox, only one gear at a time delivers power from the engine to the wheels. The gears must be decoupled during shifting, so the car loses a little speed each time the driver changes gears. The Zeroshift gearbox solves this problem using gears that overlap, which makes it possible to shift without any loss of velocity.

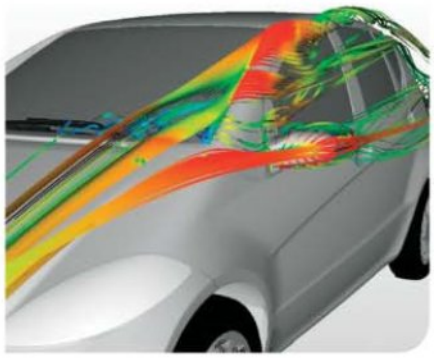


How Zeroshift Changes Gears

1. During acceleration, half the dogs [orange] are loaded and transmitting power, with their drive faces engaging the teeth on the first gearwheel. The other three dogs are not exerting any force on the gearwheel.

2. To shift into second, the three unloaded dogs [blue] move toward the second gearwheel to engage it. At this instant, the car is actually in two gears at once.

3. Because one gearwheel is rotating faster than the other, it takes just a few milliseconds before the first gearwheel is unloaded and the dogs [orange] that had engaged it are released. The car is now in the higher gear.



Supercomputer technology is used to analyze fuel efficiency and noise reduction in road cars as well as in racecars.

transmission, which passes into neutral between gears, Zeroshift changes gears using six small "dogs," mechanical devices that lock the transmission into gear. The dogs move in sets. While one set of three dogs is engaged in first gear, the next set moves into position to engage second. One set of dogs stays in position until the other set is engaged. For an instant, the car is in two gears at once, although only one set of dogs is actually transmitting power [see "Zeroshift Leaves Ordinary Gearboxes in the Dust," left].

A car equipped with a conventional gearbox loses speed, and thus time, whenever a driver shifts from one gear to the next. This is a major problem when the object is to go as fast as possible. In Formula One cars, seamless shifting has reduced the time lost during shifting to almost nothing. Given that a typical Formula One race involves as many as 5,000 gear changes, seamless shifting can save 5 to 10 seconds over the course of a race—often the difference between winning and losing.

For road cars, saving a few seconds is less important than reducing fuel consumption and lowering emissions. Replacing an automatic transmission with seamless shifting offers the fuel efficiency of a manual-transmission car and can reduce carbon dioxide output by 12 percent. Zeroshift is developing seamless shifting for passenger vehicles and expects it to be available in 2011.

FROM LEFT: ALLAN HØJEN; DAIMLER AG

Flywheel Provides Extra Power

Another technology that is having a big influence on Formula One racing is a category of devices known as KERS, short for kinetic energy recovery systems [see "Braking Energy Delivers Extra Horsepower," below]. Like seamless shifting, a KERS system can reduce fuel consumption and emissions. A battery-based KERS made its debut in Formula One cars this racing season.

When any car brakes, the kinetic energy of its motion is transformed into heat, which is released into the air flowing over the brakes. Formula One cars' brakes are made of carbon fibers that can withstand temperatures above 1,800°F. KERS enables the car to store and reuse that heat energy.

According to Jon Hilton, an engineer with Flybrid Systems in England—one of the companies that is developing the device for both Formula One cars and passenger vehicles—KERS takes over for 10 percent of conventional braking torque. This mechanical energy is used to spin a small flywheel at speeds as high as 65,000 rpm. The energy is stored for later use; for example, when the driver needs a burst of power to pass another car. A KERS device may be able to deliver as much as 80 extra horsepower (the upper limit set by race regulations), which is roughly a tenth of a Formula One car's engine power.

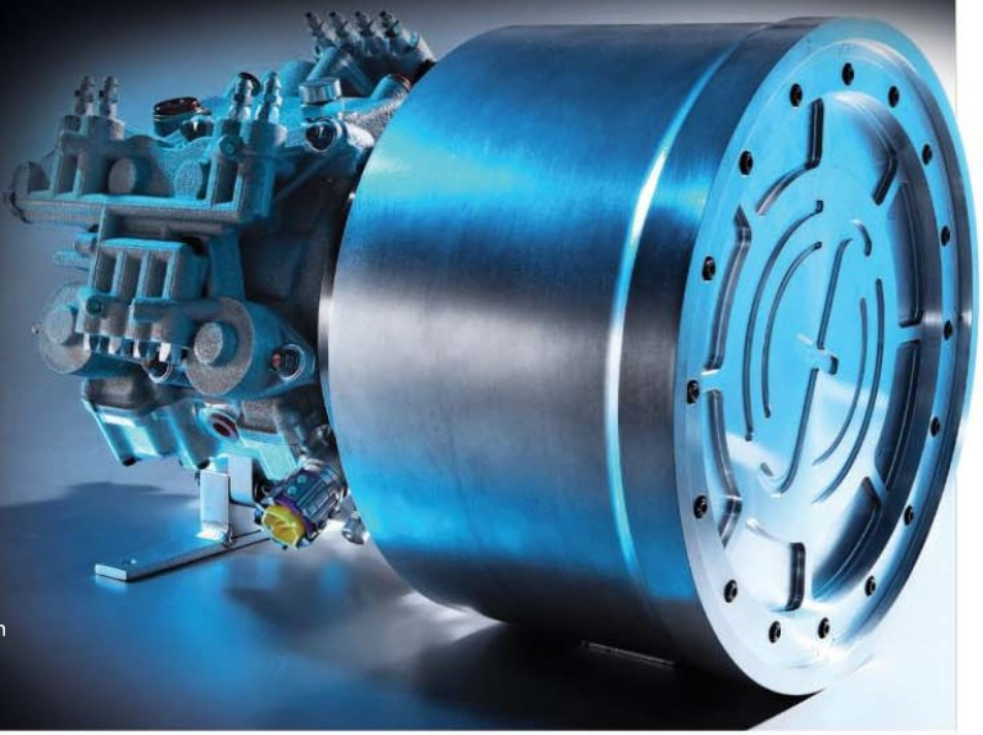
Zeroshift has reduced the time lost during shifting to almost nothing, and seamless shifting can reduce carbon dioxide output by 12 percent.

In passenger cars, KERS aims to save fuel rather than boost power. Hilton estimates that real-world implementation of KERS could increase fuel efficiency by as much as 30 percent.

There are already a few vehicles on the road that have braking-energy recovery systems. Hybrid gasoline-electric cars, such as the Toyota Prius, capture braking energy and store it in the battery, where it can be used to power the car's electric motor. Flybrid is working with Jaguar to produce a KERS system for its passenger cars, and it and other companies hope to introduce flywheel-based systems in the next five years that are similar to the ones developed for Formula One cars—the latest eco-friendly developments from a sport that once rewarded speed at any cost. ■

Braking Energy Delivers Extra Horsepower

Kinetic energy recovery systems, or KERS, allow drivers to recover energy during braking, store it, and then reuse it to improve acceleration in Formula One vehicles and to save fuel in road cars. During braking, some of the energy is recovered by a KERS flywheel device [right]. The engineering company Flybrid has estimated that its systems deliver storage efficiencies of 80 percent. A flywheel spinning as fast as 65,000 rpm holds onto kinetic energy mechanically (rather than electronically, as is the case with battery systems) and releases it with the push of a button, delivering an extra boost of power to the car.



FLYBRID SYSTEMS



Paleontologist Paul Tafforeau [facing page] studies lumps of amber that will soon reveal a hidden wealth of ancient plants and animals.



ANT
(family Formicidae)

Ancient Bugs See the Light of Day

With the help of extremely powerful x-ray beams, paleontologists can now peer into 100-million-year-old opaque amber. The tiny creatures inside tell a story of life on Earth in the age of the dinosaurs



BEETLE
(superfamily Elateroidae)



SOWBUG
(family Oniscidae)



SPIDER
(family Segestridae)

PHOTO CREDITS
PHOTO CREDITS

Paleontologists Borrow Physicists' Extreme Machine

The European Synchrotron Radiation Facility (ESRF) in Grenoble, France, produces the strongest x-rays of any research facility in Europe by accelerating electrons to nearly the speed of light in a half-mile-long ring. Rather than a perfect circle, the ring is made of sections in which the electrons either move in a straight path or are deflected by magnets. At the 42 locations where the electrons are deflected, they emit electromagnetic radiation. Each time electrons are pulled in a new direction by the magnets, they throw off a colossal amount of synchrotron radiation in the form of x-rays that are beamed into the labs surrounding the ring. Inside one of these labs, scientists use the radiation to scan amber specimens to determine what life, if any, has been preserved inside.

FACTS ON ESRF

Measuring half a mile around and 885 feet across, ESRF looks like a giant bagel.

Six thousand researchers from 33 countries visit the site every year, and their experiments lead to about 1,500 scientific articles.

The synchrotron operates 24 hours a day, 289 days a year. The 76 days of downtime are used for maintenance and upgrades.

Eighteen European countries contribute financing to the ESRF, which opened in 1994. The equipment at the ends of the beamlines will be upgraded over the next nine years to facilitate experiments in growing fields such as nanotechnology.



The circular accelerator, as seen in this aerial view, is almost 900 feet in diameter.

PETER GINTER/ESRF; PRECEDING PAGES: PASCAL GOETGHELUCK/SPL/FOCI

From dark amber that resembles ordinary rock, paleontologists extract hundreds of insects, spiders and plant fragments that have not been seen since dinosaurs walked the Earth. And they recover these treasures without damaging the amber or its contents.

The scientists use enormous machines that produce x-rays about a trillion times as powerful as those your dentist uses. Physicists have employed these machines to study protein crystals and molecule shapes. But paleontologists are now training them on 100-million-year-old fossils encased in amber.

During the Cretaceous period, Earth was very different from today. The polar regions had lush forests, and North America and Greenland were still joined to Europe and Asia. Most mammals were mouse-size animals that hunted insects by night. During the day, dinosaurs roamed the land. And then as now, insects occasionally became trapped—and later embalmed—in thick, sticky resin oozing from coniferous trees.

Resin usually traps crawling or flying animals on the trunk and branches. But in four locations in the Charente-Maritime province of southwestern France, ancient coastal forests produced unique amber fossils. The resin came from roots and was carried across the ground by waves and storms. It engulfed flying, crawling and swimming creatures—and preserved them perfectly.

From Ape Enamel to Insects

Not all amber is the beautiful, transparent golden material that is made into jewelry. More than 80 percent of Cretaceous amber is opaque. Even if such amber is polished, it is impossible to see any of the fossils inside without cutting into it and perhaps damaging what might lie within. Fortunately, a graduate student in paleontology at the University of Montpellier in France discovered a new technique for studying the hidden fossils.

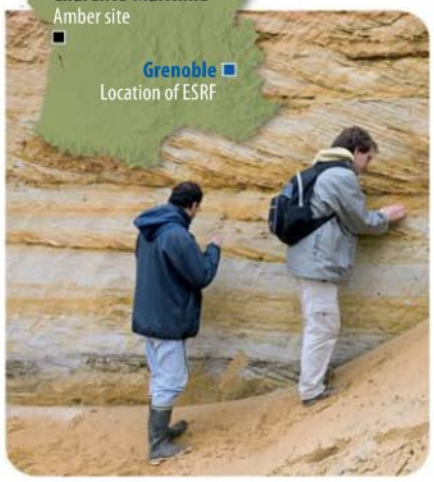
In 2000, Paul Tafforeau was faced with the tedious work of sawing fossil ape teeth into slices and mounting them on microscope slides so that he could study the tooth enamel. Preparing the fossils destroyed the rare samples. He knew there had to be a better method.

Tafforeau wondered whether x-rays could be used to peer into the fossil teeth, in the same way that a dentist uses x-rays to check for cavities. Medical x-ray scanners work by sending radiation through a body part and using film to detect the absorption of the x-rays. Dense tissues like tooth and bone absorb more radiation—and thus appear lighter on the film—than soft tissues like skin and muscle. But as Tafforeau soon learned, heavily mineralized fossils don't show up well using conventional "white" x-rays, which—just as white light includes all the visible colors in the rainbow—cover a broad spectrum of electromagnetic radiation. To resolve fine details, the x-rays had to be filtered down to a narrow band of wavelengths, the x-ray equivalent of one color. Filtering x-rays, however, reduces their ability to pass through rock.

In search of a more powerful x-ray source, Tafforeau went to the European

Synchrotron Radiation Facility (ESRF) in Grenoble, France. ESRF's filtered beam, which penetrates thick specimens with ease, allowed Tafforeau to take clean images without slicing apart his fossil teeth. Using a technique called micro-tomography, objects are rotated in the x-ray beamline to take cross sections from top to bottom. These are then assembled into a 3-D computer image. The resolution allows researchers to see features smaller than 0.0004 inch.

Tafforeau used this procedure to look not only at fossilized molars but also eggs and even whole skulls. In 2003, he set out to analyze amber. Previously, scientists had viewed amber only under the microscope, and finding fossilized organisms in opaque amber had been a time-consuming task that, as with the fossil teeth, required the destruction of the samples. Proving that the x-rays could provide quicker and better images, Tafforeau successfully tested the technology on two pieces of transparent amber, one containing a small fly and one a spider.



Paleontologists use sand deposits to date amber fossils found in France's Charente-Maritime province.

Scanning the Amber

Two years later, Didier Néraudeau, a professor of paleontology at the University of Rennes in France, read about Tafforeau's technique and realized that it could be used to see inside the university's opaque amber specimens from Charente-Maritime. They began a collaboration in which doctoral student Malvina Lak would do the experiments with Tafforeau at ESRF.

During an exhilarating four days in 2006, Tafforeau and Lak scanned about four pounds of opaque Charente-Maritime amber. In that short time, they found more than 356 plants and animals embedded in the 640 specimens—an astonishing bounty considering that Néraudeau and his doctoral student Vincent Perrichot had discovered only about 600 fossils during three years of earlier work using traditional light micro-

Ant's Path from Stone to Plastic 3-D Model

With synchrotron radiation, researchers create images of ancient insects contained in 100-million-year-old opaque amber. A printer then constructs large 3-D models of the insects.



1. Researcher Paul Tafforeau fills tubes with amber for a coarse scan by the synchrotron. He hopes to reveal any fossilized animals.

PASCAL GOETGHELUCK/SPL/FOCI



2. Once the coarse scan finds an insect, the lump is precision-scanned and rotated, as about 1,000 images are made from top to bottom.

scopes. (They had looked only in transparent Charente-Maritime amber, which accounts for about one fifth of the amber from the region.)

From that initial batch of 356, the scientists chose 80 animals to scan using microtomography. After days of processing, images of ants, spiders, wasps and beetles began to pop up on the screen.

Reproduced in Plastic

The trip back in time was completed when the scientists reconstructed physical models of some of the specimens using 3-D printing. Invented in 1986 at 3D Systems, a South Carolina company, this technology enables product designers, mechanical engineers and architects to turn computer renderings into solid models. Software instructs a special printer to build the models by laying down one thin layer of plastic after another. The French paleontologists thus converted their digitized cross sections of tiny animals into scale models as long as a foot, making it easier to classify the finds by genus and species and to get a better idea of how they evolved into modern animals.

Some of the printed models are now holotypes, standard specimens against which others are compared. Like natural specimens, the plastic holotypes contain the organs and other internal structures of the animals, which help the scientists to identify them.

Hidden in the Charente-Maritime amber, the researchers uncovered and reconstructed a shell from a snail in the Ellobiidae family, now found in warm, brackish water and on rocks near the sea. They also discovered small crustaceans that resemble *Ligia oceanica*, the sea roach that inhabits temperate coastal areas like those between Cape Cod and Maine.

The amber also helped to clarify the evolution of ants. Ants reside in social colonies in which individuals are divided into castes, such as soldiers and workers. Scientists have long believed that the ancestors of ants emerged more than 100 million years ago.

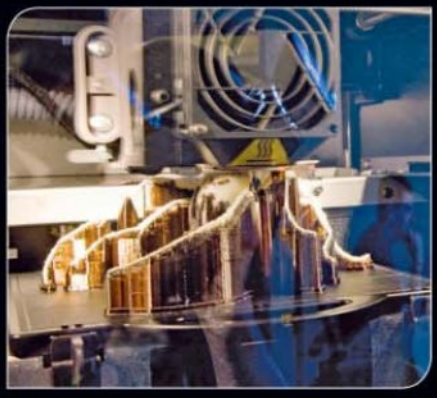
Researchers who examined ants in Burmese amber had previously confirmed the age estimate, but evidence of ants' social nature came from the French paleontologists. Their scans showed worker ants and a queen within the opaque Charente-Maritime amber, proving that a hierarchy was already in place 100 million years ago. "We have found animals that are apparently the ancestors of modern ants, and they reveal that sociality among



MILLIPEDE
(family Synxenidae)



3. Computer software combines the many x-ray images into an impressively detailed 3-D view of the insect once hidden inside the amber.



4. A special printer uses the digital data to create a large plastic model of the insect, building it up layer by layer.



WASP
(family Falsiformicidae)

PASCAL GOETGHELUCK/SPL/FOCI

ants is very, very old," Néraudeau says. Scientists now believe that ants arose at least 130 million years ago.

The amber also contained a spider that exclusively ate a different group of ants, in the genus *Zodarion*. With such diverse organisms hidden in it, the Charente-Maritime amber is helping scientists to unspool the complex web of life that existed during the Cretaceous period.

Clues to Climate

Néraudeau continues to use Tafforeau's technology, but now he is looking for even tinier organisms, including cyanobacteria, amoebas, nematodes and algae in amber from France, Spain and Lebanon.

These samples come from a period of rapid evolution. Flowering plants had already moved inland, along with insects that evolved to pollinate them. The spread of these and other plants produced major changes affecting, among other things, climate and the diet of dinosaurs.

Further studies of amber could shed more light on these events. For example, Jon Harrison of Arizona State University hopes to use the Advanced Photon Source's synchrotron at Argonne National Laboratory in Illinois to visualize respiratory structures in fossilized insects. By measuring the size of insect tracheae, Harrison and his postdoctoral fellow John Vanden Brooks believe that they can calculate the concentrations of oxygen and carbon dioxide in the atmosphere at the time these animals lived. This data will help evolutionary biologists follow organisms' adaptations to temperature fluctuations—vital information for understanding changes in the past, as well as for our future. ■



5. When the 3-D printer is finished, the scientists have a larger-than-life plastic model they can compare to living species.

ANT (family Formicidae)

PASCAL GOETGHELUCK/SPL/FOCI



Resembling a spruce twig, this prehistoric feather is an evolutionary step on the path to modern bird feathers.

Lump of Amber Hid a Dinosaur Feather

The Charente-Maritime amber specimens have also yielded information about the origin of feathers. In February 2008, Didier Néraudeau, Paul Tafforeau and their colleagues published 3-D images of seven primitive feathers, which they gave to the Museum of Natural History in Paris. The fossils represent an intermediate stage in the evolution of modern bird feathers from even more-primitive ones with bunched filaments. Scientists have long searched for this transitional type of feather from the Cretaceous period and have previously found only six specimens.

In the preceding evolutionary stage, feathers looked like palm trees, with bunched filaments extending only from the top of the central shaft. Feathers from later stages have needlelike filaments in two rows along the shaft. The amber-encased feathers resembled banana trees, with all feathers emerging from the same point. They help to rule out a theory that intermediate-stage feathers were organized like pine trees—branched arms with needles sticking out in all directions.

The fossil feathers came from dinosaurs and served as insulation or as a colorful signaling device. It was not until later that birds would use feathers for flight.

Ocean Currents Are the WORLD'S

VITAL SIGNS

Currents Are Never at Rest

Ocean currents encircle the globe like ribbons [right]. Some currents are warm, others cold. They are driven by the wind as well as by changes in temperature and salinity in areas like the North Atlantic. There, the high salt content of seawater makes the water dense and heavy, causing it to sink and creating enormous, slow-moving masses of deep water that circulate throughout the world's oceans and help drive currents closer to the surface. In the Northern Hemisphere, surface currents run clockwise, while south of the equator they move counterclockwise. And many surface currents create swirling masses of water, or gyres, that encompass vast areas of the sea.



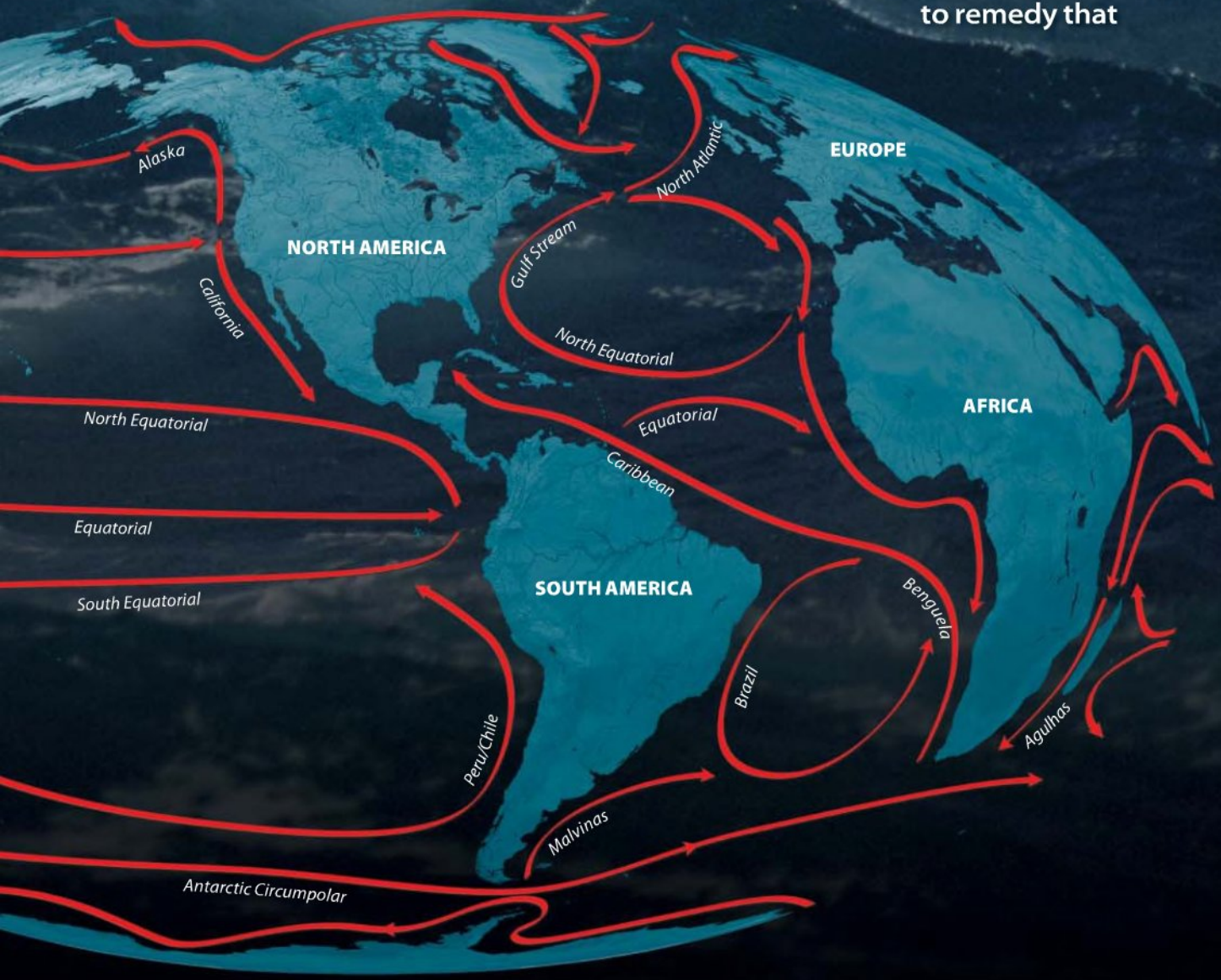
The Argo project's buoys upload readings from every ocean to satellites.

Argo, an international research project involving 23 countries, is collecting data on ocean currents. Since 2000, the project has placed floats in every major ocean area, and the total number of floats now stands at more than 3,300. Every tenth day, the floats plummet to 6,500 feet and then rise to send their collected data to a satellite. The many measurements will help researchers chart the currents' course and forecast climate changes.



PULSE

Ocean currents are vital to life both in the water and on land. Researchers know that the currents have a powerful influence on the climate, but in many ways they're a mystery. The ambitious Argo project is designed to remedy that



Upwelling Sets Off a Flurry of Eating

Algae in the world's oceans support huge marine ecosystems, providing food for an array of marine wildlife. To maintain their high productivity, these algae need both sunlight and nutrients, but the two are seldom found in the same spot. Sunlight hits the seas' surface but does not penetrate very far down, even in the clearest polar waters. On the other hand, iron, nitrogen, phosphorus and other nutrients are most often available near the oceans' dark bottom. There is one place where these ideal conditions mix, though: upwelling zones, where upward currents bring nutrients to algae on the surface. The world's richest fisheries are found in upwelling zones, and seabirds form colonies close to these bountiful sources of fish.

CURRENTS CARRY ESSENTIAL FOODS TO THE SURFACE



Nutrients driven to the surface provide a rich diet for fish and birds.

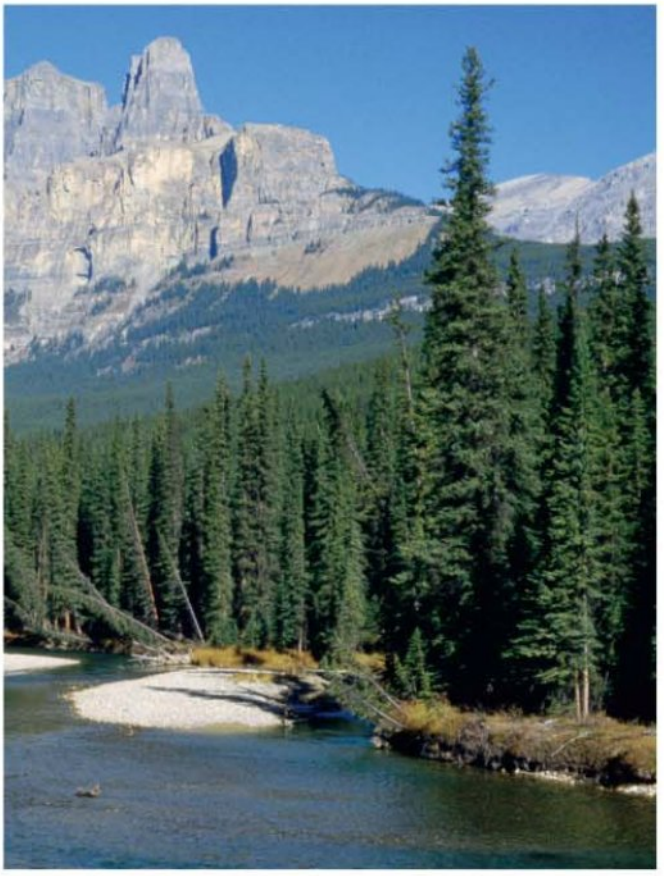
Enormous quantities of water move in ocean currents, transporting heat, cold, nutrients and animals thousands of miles. Some currents warm entire continents, bringing life to lands that would otherwise be locked in arctic cold. Others carry sustenance for wildlife, contributing to rich and productive ecosystems.

To understand the power of these currents, consider that in just one hour, the Antarctic Circumpolar current, one of the planet's largest, moves 468 billion tons of water. And even the seas' smaller currents can move more water than all the continents' rivers combined.

The ocean currents derive their strength from a combination of the wind on the seas and the difference between the densities of various types of water. Currents near the surface are generally powered by the wind. Because of the Earth's rotation, winds tend to drive currents clockwise in the northern hemisphere; south of the equator, they flow in the opposite direction. Well below the surface, differences in water

F. LANTING/NGS; PRECEDING PAGES: G. MOTIL/CORBIS/POLFOTO AND MIKKEL JUUL JENSEN/INSET: COMMONS





The Gulf Stream helps raise temperatures in Western Europe by several degrees. This is why palmlike trees [left] can survive on England's southern coast, but a Canadian forest [right] at a similar latitude on the other side of the Atlantic is all conifers.

temperature and salinity provide the motor for the deep-sea currents that bind the world's oceans together.

Currents Keep the Oceans Together

Some ocean currents are just a few hundred miles long, and others extend over thousands of miles and encompass vast areas of water. Some are cut short by landmasses, and others take detours around islands. Only the Antarctic Circumpolar current flows all the way around the Earth uninterrupted.

For at least 25 million years, the Antarctic current has helped insulate the waters around Antarctica from other oceans. The current helps keep warmer water away from the continent.

At the other end of the world, the Arctic seas are open—directly connected to the Pacific or Atlantic, for example by the Greenland Sea between Greenland and Norway's Svalbard archipelago. As a result, the Arctic Ocean shares more species and weather patterns with other bodies of water than the Antarctic seas do.

In just one hour, the Antarctic current moves 468 billion tons of water.

As long ago as the beginning of the 20th century, scientists have been interested in tracking the 321 million cubic miles of water that circulate the globe every year. Now researchers are embarking on a project to record the movement, as well as the temperature and salinity, of all the world's seawater.

Researchers Launch More Than 3,000 Floats

Ocean currents help transport heat and cold, playing a key role in Earth's climate. There is, therefore, a need for data about the currents, so that scientists can monitor their strength, natural variation and any alterations that come about as a result of climate change.

A project called Argo, supported by more than 50 agencies around the world, plans to take near-continuous measurements of the world's oceans. Beginning in 2000, Argo researchers launched floats to collect samples from the water column—think of a chimney from the surface

FROM LEFT: T. DOBNER/IMAGESELECT; A. BROWN/CORBIS/POLFOTO



VITAL SIGNS

Turtles Follow the Currents

In the early months of autumn, Florida's sandy beaches come alive. Tens of thousands of eggs laid by loggerhead sea turtles hatch overnight, and the newly hatched young burrow up out of the sand to launch themselves into their first voyage.

They swim from the coast toward the Gulf Stream for a period of a few days, known as a swim frenzy because the turtles are constantly in motion. There they are caught up in the North Atlantic Gyre system of currents, which loops around the Sargasso Sea, where the small turtles seek shelter from predators in clumps of *Sargassum*, a seaweed native to the area. In the years to follow, the turtles will be drawn along in the North Atlantic ocean-current system, which the Gulf Stream is part of. No one knows their precise route or exactly how long the young turtles remain in the system (it may be as long as five years). While in the currents, the young turtles feed on crustaceans, snails and jellyfish. When they have achieved a certain size, they move into coastal waters in the western Atlantic. Here they feed and grow large, before the adult females seek out beaches on which to spawn. Some scientists believe they return to the beaches where they were born.



THE NORTH ATLANTIC GYRE

Just after hatching, this turtle moves toward the water to take its place in the Atlantic Ocean's currents.

to the seafloor—in all the major ocean regions: Pacific, North Atlantic, South Atlantic, Indian and Southern. As of two years ago, the network achieved its full scope; an average of just 180 miles separates any two of the floats. By this July, 23 nations were taking part, with more than 3,300 floats collecting data on salinity, temperature and currents in the top 6,500 feet of the water column. Most of the time the floats sit at various specified depths, but every 10 days, each one drops to 6,500 feet and then slowly rises to the surface in order to sample the entire water column. Once a float reaches the surface, it transmits its data to a satellite. Every year, the Argo project records a total of 100,000 such temperature and salinity readings.

Each float, however, has a limited service life—up to 150 dives, or about four or five years in the water. Researchers launch 800 new floats every year to replace older ones. Within one day of the measurements being transmitted by an Argo float, they are available on the project's Web site for use by scientists at universities, government research agencies and meteorological centers. More than 100 research papers a year contain Argo data, and the scientists behind the project expect that their data will continue to fuel better predictions about the evolution of ocean currents, as well as improve the large computer models of present and future climate.

More than 3,300 floats collect data on salinity, temperature and currents.

Climate Can Change Currents

It's known that currents influence climate, but it remains unclear to what extent changes in atmospheric conditions will affect currents, in turn causing further climate change. The Gulf Stream has a great impact on an

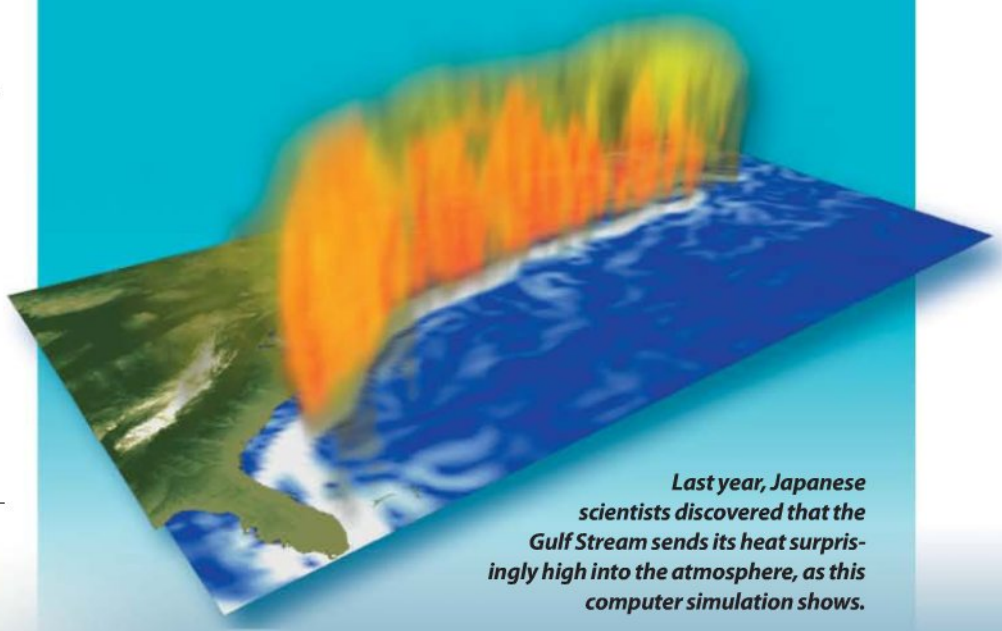
D. PERRINE/*SEAPICS.COM*

entire region's climate. It begins as a minor current in the Gulf of Mexico but sweeps up more water along the way, eventually becoming one of the world's most powerful ocean currents, pushing 13 trillion tons of water toward Western Europe daily. This water releases its warmth into the atmosphere as it travels, making Western Europe several degrees warmer than other regions at the same latitude. Winters, in particular, are surprisingly mild there, thanks to the heat carried by the Gulf Stream.

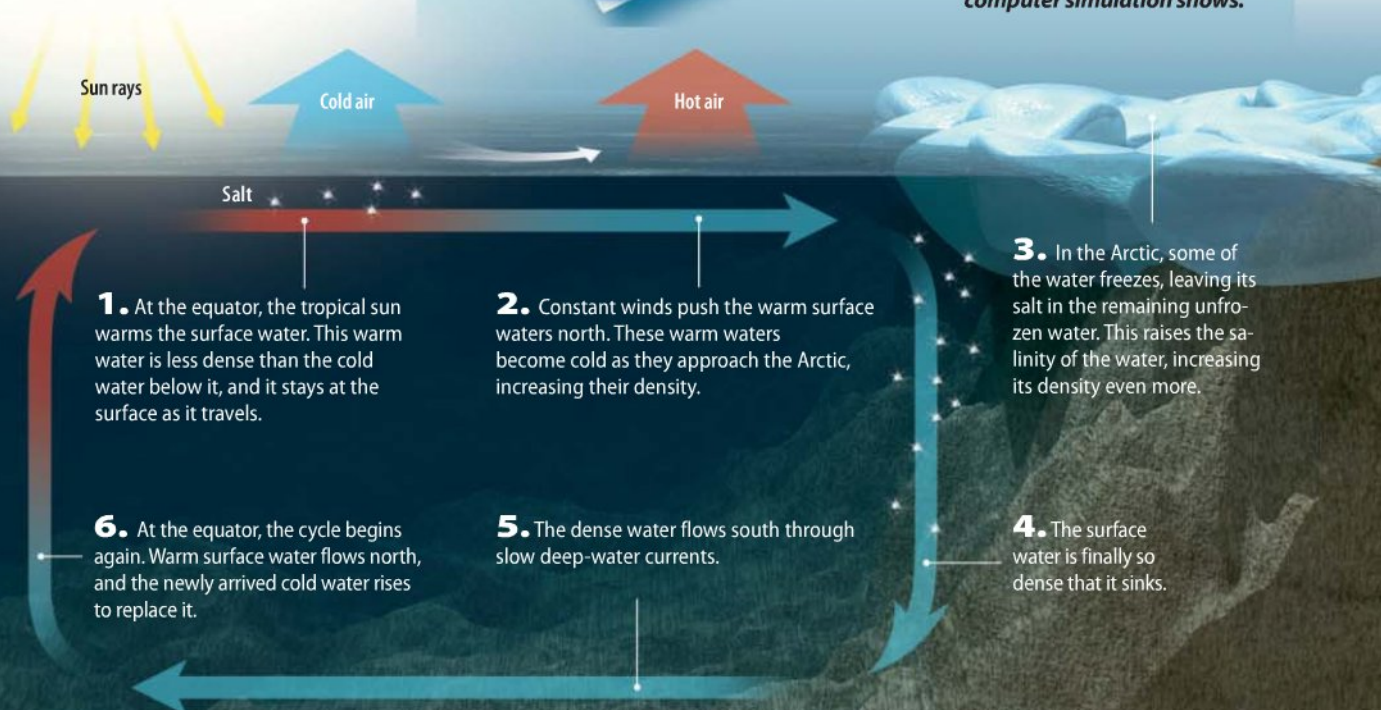
Even though scientists have known for almost 50 years that the Gulf Stream transports heat, they are still making discoveries about the way it affects weather. Last year, a research team led by Shoshiro Minobe of Hokkaido University in Japan took an important step forward. The scientists discovered that the warm water releases its heat not into the lower 6,000 feet of the atmosphere, as had been believed, but into almost the entire troposphere—the section of the atmosphere where weather is formed—and affects the air seven miles above

Temperature and Salinity Help Drive the Gulf Stream

Variations in seawater's temperature and salinity help the Gulf Stream force 400 billion tons of water from the equator toward northwestern Europe each hour, releasing heat into the atmosphere as it goes. This process, known as thermohaline circulation, is especially strong in the North Atlantic, where water cools to extremely low temperatures and becomes saltier as parts of the ocean freeze.



Last year, Japanese scientists discovered that the Gulf Stream sends its heat surprisingly high into the atmosphere, as this computer simulation shows.



JAMSTEC



The land goes thirsty while the oceans bloom. Peru's Pacific coast is a land of barren deserts [left], but fishermen catch huge quantities of fish off its coast [right]. Upwelling causes nutrient-rich water to surge to the surface, where it feeds a multitude of marine wildlife.

the Atlantic. At this altitude, the heat can also activate atmospheric waves that may allow it to affect areas farther east than the coast of Europe. The Gulf Stream could prove to be even more influential than was originally believed.

The Gulf Stream's Engine Can Die

Nature, agriculture, fisheries—all sources of food and livelihood for many millions of people in densely populated Western Europe depend on the life-giving warmth of the Gulf Stream. Many researchers are, therefore, concerned that global climate change could slow or even stop the current. Their concerns are focused on a phenomenon called the thermohaline circulation: a slow, constant movement of the ocean's waters, powered by differences in water temperature and salinity. The Gulf Stream is partially driven by the thermohaline circulation in the North Atlantic, where water cools so much as it approaches the highest latitudes that it sinks—cold water is more dense than warm water—and then flows south back toward the equator. Meanwhile, the less-dense warm water floats north over the cold water to replace it as it leaves. This warm water cools and begins flowing south, and the cycle continues [see illustration, preceding page].

Halting the thermohaline circulation could halt the Gulf Stream itself.

For years, some scientists have speculated that the melting of icebergs in the Arctic caused by global warming will result in an influx of freshwater into the North Atlantic. Because freshwater is less dense than saltwater, this will lower the density of the North Atlantic to the point where the surface waters can never be cooled enough to sink and start their southward journey. This would effectively halt the thermohaline circulation—and, according to the most severe hypotheses, halt the Gulf Stream itself.

New research reveals that the thermohaline circulation may indeed be at risk. In 2005, a team from the National

FROM LEFT: GEORGE STEINMETZ/CORBIS/POLFOTO ; B. LITTLEHALES/GETTY IMAGES/ALL OVER

Oceanography Centre in England found that the Atlantic meridional overturning circulation—the process that moves warm surface waters north in the Atlantic Ocean and sends deep cold waters south—had slowed by 30 percent. This dire conclusion was based on scientific measurements carried out between 1957 and 2004.

Last year, scientists from Denmark, the Faroe Islands, Germany and Norway combined new measurements with historical data in their computer models and showed that the deep-water currents between Greenland and Scotland that feed into the Atlantic meridional overturning circulation (which is, in turn, part of the thermohaline circulation) have maintained an astonishingly constant level for the past 50 years. The researchers also found, however, that despite the steadiness of the currents in this area, the Atlantic meriodional circulation itself was weakened by changes in other areas of the North Atlantic.

The close connection between climate and currents is only beginning to reveal itself. With more comprehensive data from efforts like the Argo project, researchers could someday have the information they need to make predictions about the future of our planet's entire surface, rather than just watching from the shore. ■

VITAL SIGNS

Current Creates the World's Largest Fishing Grounds

Between May and July, the Agulhas current off the southeastern coast of Africa exhibits one of nature's miracles. It occurs without any warning: Suddenly the current shines silvery bright. The silver comes from a vast mass of Pacific sardines using the cool seasonal water as a corridor to carry them from their native waters south of South Africa into the Indian Ocean north of Madagascar. This is one of the largest schools of fish in the world, and it can extend miles in length and width.

The biomass of these sardines is 30,000 tons, and thousands of whales, seals, sharks and other predators feast on them. (In terms of biomass, the thousands of tons of sardines shimmering through the current rival the East African migration of great blue wildebeests.) Following along are countless gannets, cormorants and gulls. Dolphins and sharks plan their attacks to isolate small groups of sardines out of the mass and corral them into "bait balls," compact masses of desperate fish. The prey are doomed to be attacked from every side. From below come dolphins, whales, penguins and predatory fish, while the seabirds await their chance on the surface.

Some years, the sardines don't show, and the feast is canceled. Biologists do not understand why the sardines follow the Agulhas current most years but not all.



THE AGULHAS CURRENT

Pacific sardines use the Agulhas current as a conveyor belt. For sharks, dolphins and other predators, it's a movable feast.

D. PERRINE/NATURE PL

Our Atomic Time Stamp

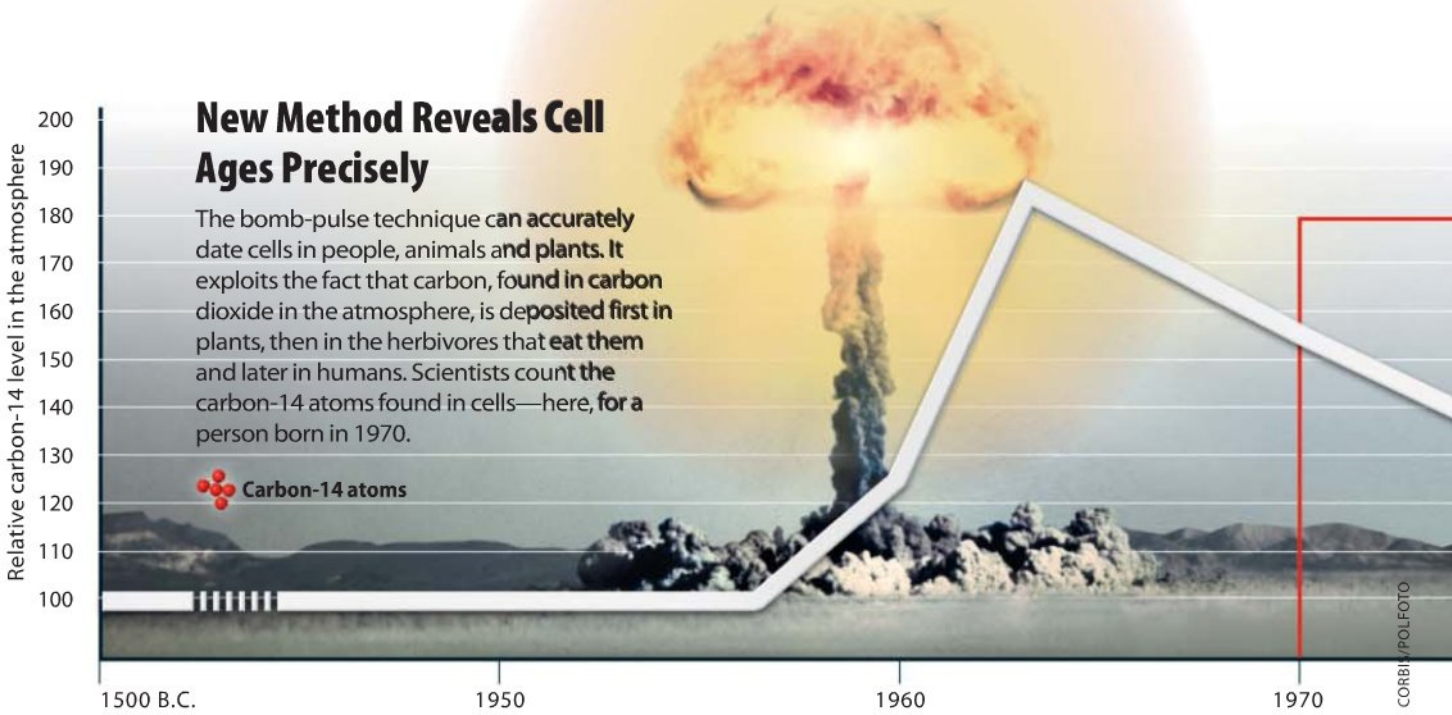
Nuclear weapons testing half a century ago left radioactive markers in every living thing on Earth. An innovative technique exploits this phenomenon to explore the life history of the cells in our body

Atomic bombs may be a scourge of modern society, but they have given biologists a way to determine the age of the cells inside all living creatures. All cells contain carbon from the atmosphere, and depending on how much of it is radioactive, scientists can calculate how long after the nuclear tests of the 1950s and '60s a cell was born. Known as bomb-pulse dating, the method has been gaining traction in brain-physiology and forensic-medicine research for the past decade.

How Radioactive Carbon Enters Your Cells

Living cells are built around carbon atoms. Plants absorb carbon dioxide from the atmosphere during photosynthesis, the process of making food from light and air. Animals then ingest the carbon when they eat plants or other animals that have eaten plants. The carbon atoms are used to create many molecules in both plants and animal cells, such as DNA, proteins and fats. This happens with any kind of carbon atom, so living cells include both ordinary carbon and a radioactive version, called carbon-14. The more carbon-14 in the atmosphere, the more will be incorporated into cells.

The atmosphere's amount of radioactive carbon stayed fairly steady for thousands of years—until humans began exploding nuclear bombs. Between 1945 and 1963, the U.S., the former Soviet Union and a few other countries detonated more than 500 atomic weapons during tests. These



released neutrons that reacted with atmospheric nitrogen to create carbon-14 atoms, which combined with oxygen to form carbon dioxide. The bomb tests doubled the quantity of carbon-14 in the air. But after a 1963 treaty halted the tests, the amount declined each year. (Today the levels are just 10 percent higher than before 1945.)

How Scientists Date Your Cells

Carbon dating is also used in archaeology, but archaeologists measure the decay of the carbon-14. In bomb-pulse dating, researchers are interested in what percentage of carbon atoms in a sample are carbon-14, which corresponds to its atmospheric level when the cells were formed.

Researchers analyze millions of cells at a time, which lets them collect enough DNA to ensure a measurable amount of the rare carbon-14 atoms. The atoms are counted using a mass spectrometer, a machine that distinguishes carbon-14 atoms from the other carbon isotopes based on their different masses. Knowing the amount of carbon-14, they can find the year on the bomb timeline with a corresponding level of radiation in the atmosphere.

Solving the Riddle of Brain Cells

One of the pioneers of bomb-pulse dating is Australian scientist Kirsty Spalding of the Karolinska Institute in Sweden. In 2002, she used the technique to investigate one of the biggest mysteries in brain research: Do new neurons in the cortex, the area responsible for learning, appear throughout life or are their numbers fixed from birth?

It has been well established that neurons in some parts of the brain, such as the hippocampus (which helps form memories), renew themselves over time. But it is debated if neurons in the area responsible for the highest level of consciousness, the neocortex, regenerate. To find out, Spalding took tissue samples from seven cadavers. She also looked at the occipital cortex, an area that processes visual stimuli, from 17 additional autopsies.

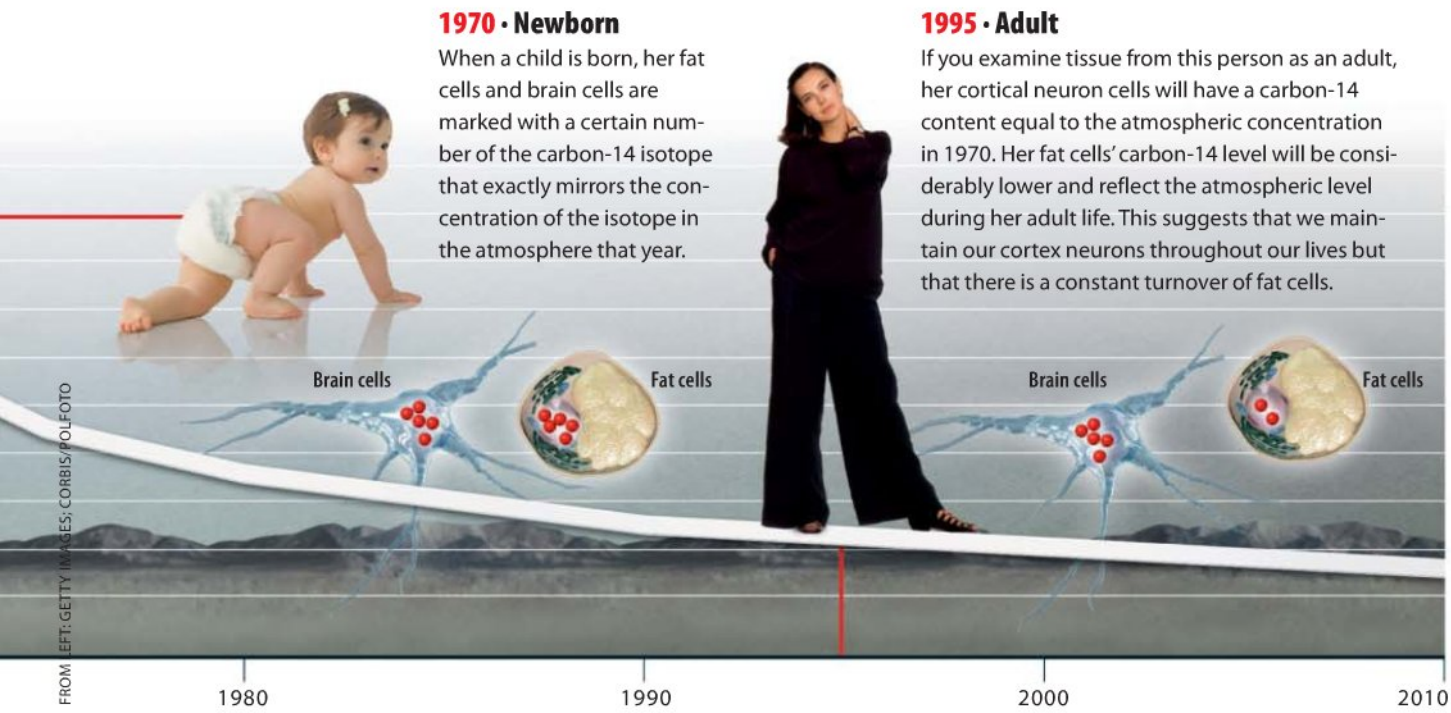
Spalding found that neurons in both these brain regions had a carbon-14 level equal to the amount in the atmosphere the year that each person was born. In other words, no new neurons had formed since their birth. This evidence suggests that there is little or no neural regeneration within these areas of the cortex.

Some critics have asserted, however, that the bomb-pulse technique is not sensitive enough to spot small groups of new neurons. It is likely that if neural regeneration happens in the cortex, it occurs in a small fraction of the total cell population. Spalding now plans to use her approach to search for neurogenesis in other parts of the brain.

The Secret to Age Is in the Eyes

The bomb-pulse technique has proved its usefulness outside the academic laboratory setting as well. Scientists at the University of Copenhagen and the University of Aarhus in Denmark have adapted the method to assist in forensic investigations. Other existing methods can determine the age of an unidentified body to within only a couple of years. Now forensic scientists can use bomb-pulse dating on the proteins within the lens of the eye (which are fixed at birth) to ascertain the individual's exact birth year.

These breakthroughs are just the beginning. Scientists are currently using carbon-14 cell dating to study the regeneration of the heart and insulin-producing cells, possibly leading to treatments for diseases. ■



FROM LEFT: GETTY IMAGES; CORBIS; POLFOTO

Gravity Probe-B was designed to confirm Einstein's general theory of relativity, our current model of gravity.





Newton said that an apple inspired his law of gravitation. This tree in Cambridge, England, is said to be descended from Newton's apple tree.

ANSWERING
THE BIGGEST QUESTIONS
IN
SCIENCE

What Is Gravity?

It keeps our feet on the ground. It holds the moon in orbit. And it is responsible for the stability of galaxies. Gravity controls our world, but mysteries remain:

- **Does dark matter exist?**
- **Is general relativity flawed?**
- **Are there gravitons?**
- **Can gravity fit into a "theory of everything"?**

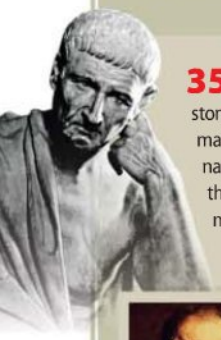
In 1666, legend has it, a 23-year-old man sat in the garden of his childhood home in Woolsthorpe, England. Gazing up at the moon, he saw an apple fall from a tree to the ground. Could there be a universal force that could explain the motion of both the apple and the moon, he wondered?

The man, of course, was Isaac Newton, and the universal force he wondered about, gravity. Two thousand years before Newton was born, Greek philosophers believed that "earthly" objects were attracted to their natural place, Earth. Newton's concept of gravity reached beyond our planet, unifying the laws that govern Earth and the heavens for the first time. Newton proposed that objects fall to the ground because of a mutual attraction between them and the planet, and that the same principle of attraction applies to all objects having mass anywhere in the universe. Newton was also the first to quantify the force of gravity through mathematics, establishing the principles on which Albert Einstein would build his general theory of relativity, the standard model of gravity used today.

Putting the Puzzle Together

The Search for a Theory of Gravity

For two thousand years, people believed that objects fell because they were seeking their natural place. Today the principle of mutual attraction is the model.



350 B.C. Aristotle claims that a stone falls to Earth because it is made of earth and thus seeks its natural place. A stone falls faster than a feather because it contains more earth.



CIRCA 1590 Galileo Galilei demonstrates that all objects, regardless of their mass, fall equally fast in a vacuum.

1600 Johannes Kepler posits that a force emitted by the sun affects the planets' motion.



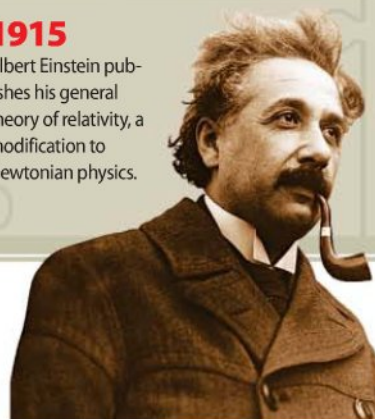


1687 Isaac Newton publishes his universal law of gravitation in the *Principia*, which states that all objects with mass attract one another.

1855 Urbain Le Verrier studies the anomalies in Mercury's orbit that break with Newton's formulas.



1915 Albert Einstein publishes his general theory of relativity, a modification to Newtonian physics.



1967 John Wheeler coins the term "black hole" as a massive star that has collapsed under its own gravity.



Gravity is one of the four fundamental forces that govern the physical universe—the other three are the strong and weak forces, which govern subatomic particles; and the electromagnetic force, which produces the attraction and repulsion of charged particles. But there is a lot we do not understand about gravity even today, including how it fits into an elusive "theory of everything" that links all four forces together.

Gravity before "Gravity"

Newton's understanding of gravity as an attractive force between objects was in opposition to the ideas of Aristotle, the Greek philosopher born in 384 B.C.

In Aristotle's universe, four elements made up earthly matter—earth, water, air and fire. The elements were arranged with Earth—the heaviest—at the center, surrounded by spheres containing water, then air and then fire. Motion on the planet was explained as the elements returning to their natural place. Flames, for example, rose away from the Earth toward their sphere, and a stone fell to the ground when thrown because it was seeking the center of the Earth. Aristotle's theory of natural place and motion influenced European thought for almost 2,000 years.

During the 14th through the 17th centuries, Renaissance theories backed by observation and mathematics were replacing classical notions about the universe. Johannes Kepler, a German astronomer, proposed that the sun exerts a force on the planets. This force, he stated in his three laws of planetary motion, controls the speed of the planets' revolution around the sun, and its strength is proportional to the distance between the sun and the planets.

The Italian philosopher, astronomer and mathematician Galileo Galilei was the first to observe evidence of bodies revolving around the sun. Shortly after 1600, Galileo started to experiment with inclined planes and rolling balls. Although he didn't know it, he was studying gravity. Galileo's experiments refuted another of Aristotle's assertions: that heavier objects fall faster than lighter ones. Galileo demonstrated that in a vacuum all bodies fall with the same speed; lighter objects, like feathers, are slowed outside a vacuum by air resistance. He also determined that falling bodies accelerate at a constant rate, which we now call g. He even accurately worked out the value of that rate on Earth's surface as an average of 9.8 meters per second squared (32 feet per second squared), a value Newton would use in his second law of motion 50 years later.

Newton Changes Science

Twenty years after his fabled apple fell to the ground, Newton began publishing his three-part masterpiece, *Philosophiae Naturalis Principia Mathematica*. In the *Principia*, as it is commonly known, he explained that all objects are attracted to one another by a force that he dubbed gravity.

His universal law of gravitation stated that the force of gravity is proportional to the masses of the two bodies attracting each other and is inversely proportional to the square of the distance between them (Kepler, on the other hand, believed that force was directly proportional to distance).

FROM TOP: GETTY/ALL OVER (2); THE BRIDGEMAN ART LIBRARY/GETTY IMAGES; GETTY/ALL OVER; SCANPIX; GETTY/ALL OVER; NASA; PRECEDING PAGES: MAIN: SPL/OCI; INSETS, FROM LEFT: GETTY/ALL OVER; ALAMY/IMAGESELECT

Physicists Try to Prove Einstein Right

Finding dark matter and gravitational waves would help bring to an end the dispute over the general theory of relativity.



Fermilab scientists use detectors made of silicon and germanium to listen for the sound of dark-matter particles underground.



Laser beams housed in long tubes will help find extremely small disturbances produced by gravitational waves.

LABORATORY SEEKS ELUSIVE DARK MATTER

Dark matter is believed to make up 26.5 percent of the universe and is necessary for the formulas in Einstein's general theory of relativity to work. Yet although its existence is widely accepted, dark matter has never been detected directly and therefore remains hypothetical. Scientists from Fermi National Accelerator Laboratory (Fermilab for short) are hoping to finally find it. Detectors began to seek dark-matter particles at Fermilab's Soudon Underground laboratory in Minnesota in 2004. Cooled to almost absolute zero (–459.67°F), silicon and germanium crystals will create a tiny, detectable vibration if hit by a dark-matter particle.

OBSERVATORY MEASURES GRAVITATIONAL WAVES

Einstein predicted that gravitational waves—ripples in spacetime created by the acceleration of massive objects—would someday be found. The National Science Foundation–funded Laser Interferometer Gravitational Wave Observatory (LIGO) is looking for the waves from two locations, one in Washington State and the other in Louisiana. If a gravity wave passes through LIGO, it will disturb the positions of two test masses in relation to each other. This movement will be detected by two laser beams that bounce between the masses: If the masses move, the beams will be out of phase with each other, generating an interference pattern in the light.

Newton also introduced his three laws of motion in the *Principia*. The second law states that the force on a body in motion is equal to the body's mass times its acceleration. The value of that acceleration is Galileo's formula for *g*.

Newton was convinced that his law applied to apples, the moon and the entire universe, regardless of whether it was obvious to the naked eye. Two small rocks, for example, attract each other, but since their masses are so insignificant, we are not aware of the force. But the force attracting a rock to the Earth is very apparent, because of the planet's much larger mass.

The law flew in the face of a classical worldview, which divided the universe into the earthly and the heavenly, and the theoretical wall between Earth and the cosmos was forever shattered. But universal gravity was not without its share of controversy. Many at the time were uncomfortable with the metaphysical implications of an unseen force acting at a distance. To them, the notion of gravity seemed like magic or the occult.

In the 19th century, calculations based on Newton's law predicted the existence of a planet that was exerting a gravitational force on Uranus. In 1846 the German astronomer Johann Gottfried Galle discovered the planet Neptune near the predicted location, bolstering the case for universal gravitation. In truth, gravity's universality can never be directly proven. It has been demonstrated convincingly enough, though, to be widely accepted.

It's All Relative

Newton's law, however, is not perfect when considering extremely massive objects with strong gravitational fields, such as the sun, or objects that achieve velocities near the speed of light. Gravity is universal,

FROM LEFT: FERMILAB; LIGO LABORATORY/CALTECH MEDIA PRESS

but it turns out it's also relative.

One of the first inklings that Newtonian physics needed amending came in the middle of the 19th century, when French mathematician Urbain Le Verrier studied an irregularity in Mercury's orbit. Newton had predicted that planets follow a perfect, closed ellipse around the sun, but by Le Verrier's time, physicists were aware that all planets' orbits change slightly with every revolution because of the gravitational pull of the other planets in the solar system. This change is measured at a planet's closest approach to the sun, called the perihelion. The planets' shifting perihelion position is called its perihelion advance, or precession. Using formulas laid out in the *Principia*, physicists were able to predict not only each planet's precession with high accuracy but could also determine exactly how the other planets were causing it. But Mercury, the planet closest to the sun, didn't fit the model.

Mercury's actual precession slightly exceeded the predictions. Scientists assumed that a yet undiscovered planet they called Vulcan would someday explain away the anomaly. Vulcan, however, was never discovered. Forty-six years later, in 1915, Albert Einstein was finally able to explain Mercury's deviation by making a correction to Newton's theory.

In Einstein's general theory of relativity, gravity is not a force itself. Rather it is the result of matter acting on spacetime, which is three-dimensional space combined with time into a single manifold. The theory of general relativity states that all objects bend the spacetime surrounding them. The larger the object, the more it bends spacetime. Imagine a large sheet of rubbery material. When a tennis ball rolls across the sheet, it wants to move in a straight line. But if there is a bowling ball in its path pressing down into the sheet, the tennis ball will move down into this depression and then up and away again. An observer would say that the two balls attracted each other. But in reality, the motion is the result of a bend in spacetime. According to Einstein's theory, the solar system's planets are not attracted to the sun as such, but are instead following the curve in spacetime around the sun.

Einstein's theory predicted that spacetime would be warped close to the sun, a departure from flatness that would make it impossible for Mercury to follow a closed ellipse when its orbit brought it closest to the star. "Essentially, there would not be enough space near the sun to make the full 360-degree revolution in one orbit," explains Daniel Kennefick, a physicist at the University of Arkansas. Einstein's calculations of the warp in spacetime matched up with Mercury's anomalous perihelion advance. "Thus Einstein's theory correctly predicted the motion of all the planets, even Mercury, whereas Newton's theory had been unable to," Kennefick says.

The Birth of Dark Matter

General relativity isn't perfect, either. In the 1930s, researchers at the California Institute of Technology calculated that the mass of a cluster of galaxies called the Coma cluster was not enough to hold them together in their orbits. Scientists began to speculate that invisible matter, called dark matter, was spread throughout the universe, adding its gravity to the cosmic mix. Dark matter, however, has never been observed directly, and it functions exclusively as an explanatory model to reconcile the behavior of all visible matter with the established laws of gravity.

Although dark matter is widely accepted as part of the standard model

PERSPECTIVES

Building on Newton's Law

Isaac Newton coined the term gravity and devised the first equation to determine its force. Our current understanding of gravity is built on his theories:

In 1687, Isaac Newton published his universal law of gravitation. Two bodies with mass (m_1 and m_2), separated by a distance (r), will each experience the mutual attractive force (F) of gravity. In his equation, G is the universal gravitational constant.

$$F = \frac{G \times m_1 \times m_2}{r^2}$$

Although Newton's math works fine for most practical purposes here on Earth, many scientists eventually recognized that the law did not work with stronger gravitational fields, such as in the case of Mercury, the planet closest to the sun and with the strongest attraction to it. Einstein solved this problem with his general theory of relativity, which adds a term to Newton's law. A is a quantity that can be calculated from Einstein's theory.

$$F = \frac{G \times m_1 \times m_2}{r^2} + \frac{A}{r^3}$$

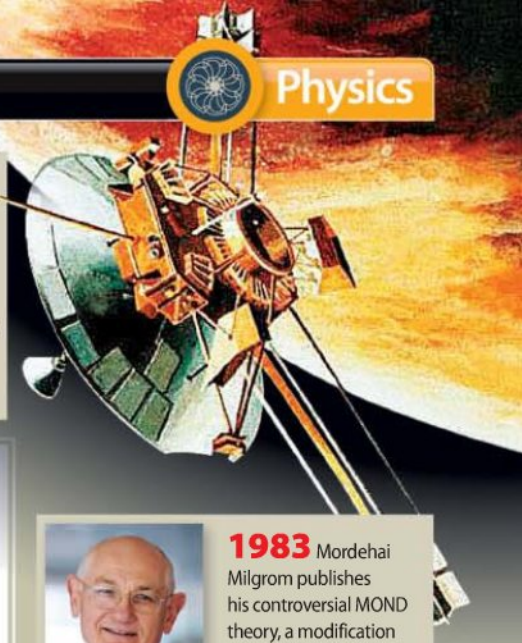
Quantum physicists say the equation is not yet complete because it does not adequately describe the extremely weak gravitational fields that exist on a very small scale. These scientists seek a still-unknown quantum theory of gravity. Such a modification, however, will not affect the larger understanding of how gravity works.

$$F = \frac{G \times m_1 \times m_2}{r^2} + \frac{A}{r^3} + \frac{?}{?}$$

1970
Vera Rubin discovers that the velocity of the Andromeda galaxy's outer regions is increasing and not decreasing, a condition attributed to dark matter.



1980
Scientists notice that every year the *Pioneer 10* [right] and *Pioneer 11* spacecraft fall 3,000 miles behind their expected positions based on gravitational theory, which calls into question our understanding of the laws of physics.



of gravitation, it is not without its skeptics. Some have proposed modifications to Newton and Einstein's theories that eliminate the need for dark matter. In 1983, Mordehai Milgrom, a physicist at the Weizmann Institute of Science in Israel, published a modification to Newton's law of acceleration that sought to explain how galaxies hold together without dark matter. His theory, modified Newtonian dynamics, or MOND, states that the force of gravity actually becomes stronger when acceleration, or g, falls below a certain critical level at incredible distances. According to MOND, "this extra gravity, rather than dark matter, holds galaxies together," explains astrophysicist Glenn Starkman of Case Western University. MOND, too, has been modified by physicists since it was published. More recently, in 2006, physicist John W. Moffat of the University of Toronto introduced his modified gravity theory (MOG), which introduces a fifth universal force that is responsible for the asymmetrical behavior of the universe, rather than dark matter.

The vast majority of scientists, however, stand behind dark matter, and they are hopeful that they can prove its existence by detecting the particles directly. One such project is being conducted at the Fermi National Accelerator Laboratory in Illinois, where scientists are seeking dark matter particles with sensitive detectors located half a mile underground.

General relativity itself is also being tested by NASA and Stanford University's Gravity Probe B (GP-B), a satellite that uses ultrasensitive gyroscopes to measure how spacetime is warped around Earth. Einstein's theory of relativity predicts that spacetime around Earth is warped by the planet's mass and twisted by its spin relative to spacetime far away from Earth. If Einstein was correct, then GP-B's gyroscopes will change their orientation to reflect the warped spacetime around Earth. Complete results are not expected until next year, but so far, the findings are consistent with Einstein's theory.

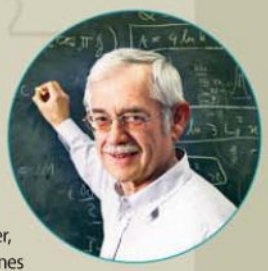
Gravity's Missing Particle

Quantum physicists hope someday to combine gravitation on the large scale (general relativity) with gravitation on the submicroscopic level (quantum mechanics) into a unified quantum theory of gravity.

They hypothesize that the force of gravity is transferred by the exchange of hypothetical particles called gravitons. In the standard model of quantum physics, the other three fundamental forces are mediated by elementary particles—gluons for the strong force, W and Z bosons for the weak force, and protons for the electromagnetic force.

The problem is that physicists have never seen a graviton—and they may never see one. Gravity is the weakest fundamental force, making it incredibly hard to detect. (On small scales of distance, the strength of the electromagnetic force is 10^{40} times as strong as the gravitational force.) An accelerator large enough to detect gravitons would have to be the size of Jupiter. Until gravity's particles are detected, a theory of quantum gravity cannot be written. Equally elusive is a long-sought "theory of everything" that would link the four forces of nature. For now, such unifying theories of gravity remain a glimmer in a quantum physicist's eye. ■

1983 Mordehai Milgrom publishes his controversial MOND theory, a modification of Newton's gravity law that eliminates the need for dark matter.



2004 Jacob Bekenstein's TeVeS theory applies MOND to our solar system by incorporating two geometries: One responds to the presence of matter, while the other determines the motion of moving bodies.



2006
Scientists detect the Bullet Cluster, two galaxies merging 3.4 billion light-years away. Its distribution of gas, visible matter and theoretical dark matter are consistent with the dark-matter hypothesis.

2009 CERN's Large Hadron Collider will test the idea of large extra dimensions. Gravity's theoretical particles, gravitons, may jump to these dimensions, explaining why gravity is such a weak force.



CLOCKWISE FROM TOP: ESA/NASA/HUBBLE SPACE TELESCOPE; AFP/SCANPIX; WEIZMANN INSTITUTE OF SCIENCE; S. TIRAM/HEBREW UNIVERSITY OF JERUSALEM; X-RAY: NASA/CXC/CFA/M.MARKEVITCH ET AL.; OPTICAL: NASA/STSCI; MAGELLAN/U. ARIZONA/D. CLOWE ET AL.; LENSING MAP: NASA/STSCI; ESO WFI; MAGELLAN/U. ARIZONA/D. CLOWE ET AL.; CERN

Gunning for a Tropical Killer

Dengue fever is a widespread and long-overlooked disease. But as climate change and rapid urbanization put more and more people at risk, the need for a vaccine has become acute. How will science curb the progress of this debilitating virus?



Dengue fever infects 50 to 100 million people every year

This fatal, mosquito-transmitted viral disease is most prevalent in the tropical and subtropical climates of Southeast Asia, South Asia and Central America. Medical science has been powerless to cure its victims, but there is now hope for an effective vaccine against the disease.

E. GUZMAN/REUTERS/SCANPIX

A single mosquito bite can cause it. The flavivirus that brings about dengue fever gets into the bloodstream and wreaks havoc. Also known as break-bone fever for the intense aches it inflicts, dengue strikes as many as 100 million people every year, predominately in urban and semi-urban locales in tropical and subtropical areas worldwide. According to the World Health Organization, every year around 12,500 people of the 500,000 who are hospitalized for a severe form of the disease, dengue hemorrhagic fever, die from it, and about 40 percent of the world's population (some 2.5 billion individuals) lives with the threat of catching some kind of dengue. There are no drugs available to kill the virus, and there is currently no vaccine available. But this may soon change.

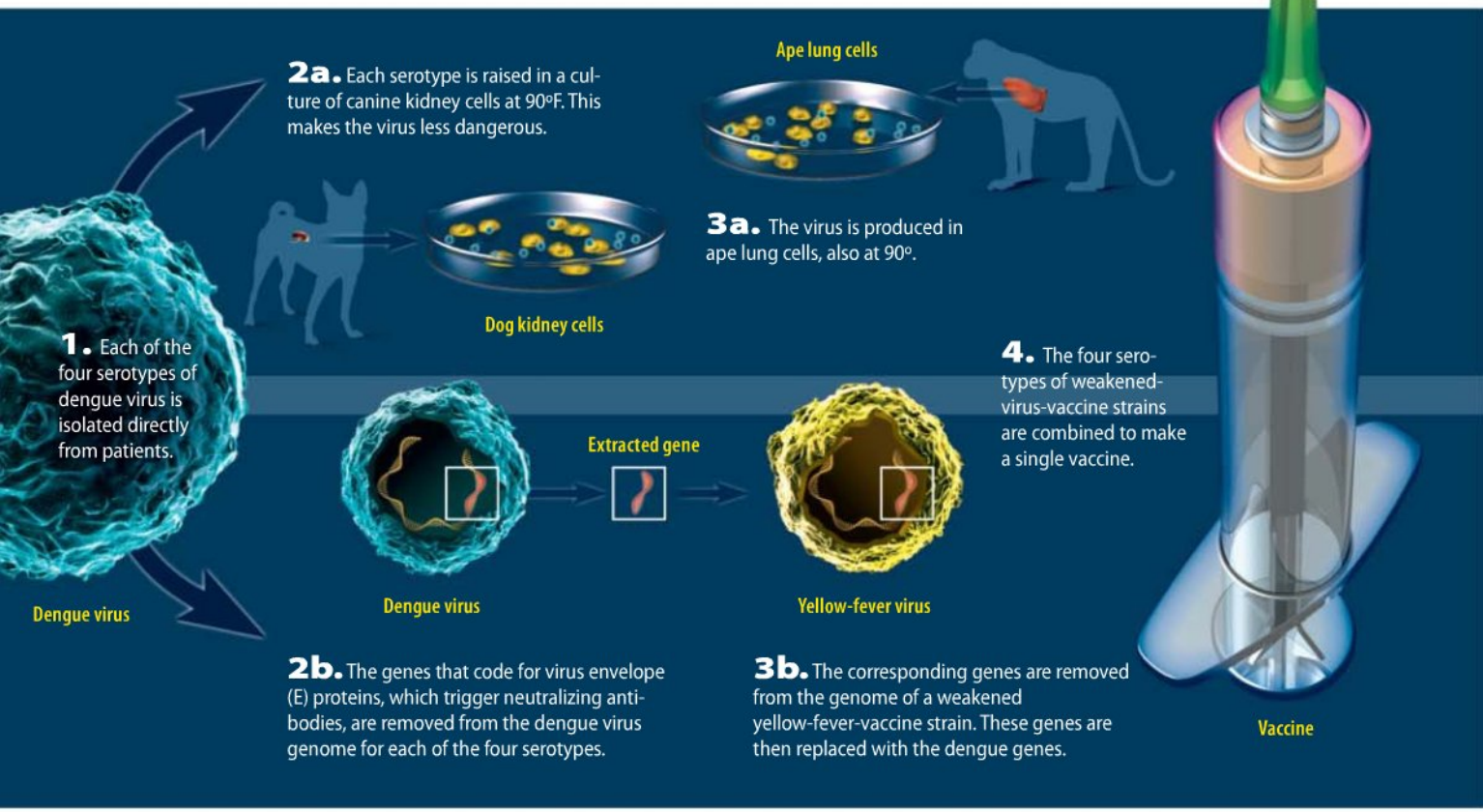
Several research groups are developing vaccines against the virus. Two pharmaceutical companies in particular, GlaxoSmithKline and Sanofi-Pasteur, are making great strides and are already in Phase II clinical trials. (A third, Novartis, is attempting to formulate a cure. The company has several possible treatments in very early stages but won't start clinical trials until 2012 at the earliest.) Both vaccines present the body with a weakened virus, which elicits the best immune response compared with other methods (like dead viruses). But the den-



About 12,500 people die every year from the most severe form of dengue illness, dengue hemorrhagic fever.

Two Different Routes Lead to a Future Vaccine

The race to be first with an effective vaccine against dengue fever is nearing its conclusion. The goal is to block all four variants, or serotypes, of dengue fever with a single immunization. So far, the companies that are furthest along in creating a vaccine have done this in two ways:



gue virus has a few tricks up its sleeve that make a vaccine difficult to develop.

Dengue Fever Fools the Body

Dengue belongs to the *Flavivirus* genus, which is transmitted by arthropod bites, typically from a mosquito or tick. Members of this virus family cause diseases such as yellow fever, which kills at least 30,000 people a year worldwide; Japanese encephalitis, which may kill as many as 25,000 a year; and West Nile virus, for which there are no reliable worldwide statistics on the number of infections but that kills as many as 15 percent of cases. In other words, a nasty family all around.

Of the millions of dengue cases every year, most result in dengue fever, a fairly mild disease. The victims suffer flulike symptoms for about a week and then recover. People who have been infected once, however, are at risk of a more serious illness if they catch the virus again. When a second infection occurs, the disease is more likely to become dengue hemorrhagic fever—which causes internal hemorrhaging, enlargement of the liver and circulatory failure—or dengue shock syndrome, a severe form of dengue hemorrhagic fever. Both can be fatal. Doctors can treat the symptoms of circulatory failure, in which the cardiovascular system stops delivering enough blood to body tissues, by giving patients blood transfusions, intravenous fluids and electrolytes to help prevent dehydration. These interventions can decrease mortality rates from 20 percent to 1 percent, but patients must receive medical attention quickly for the treatments to work, dooming those who don't have access to hospitals.

The dengue virus has four closely related variants called serotypes. Infection with one of the serotypes provides lifetime immunity to that type but makes a person more susceptible to a dangerous immune reaction to the other three forms. The very same antibodies that target the first dengue serotype increase the infectiousness of the other three varieties. How does this occur?

The surface of the dengue virus is studded with proteins. The virus uses one of the proteins (the envelope, or E, protein) to attach itself to the surface of human cells, including immune cells such as monocytes (a type of white blood cell) and vascular endothelial cells, which line the inside of blood vessels. In this way, the E protein serves

as a key for dengue's cellular invasion.

Those who have been infected with dengue produce many antibodies against the E protein, which are the immune system's best defense against the virus. The antibodies recognize the protein and bind to it, which neutralizes it so that it is no longer a threat. Because the E protein is slightly different in each serotype, when antibodies "see" a new dengue serotype, they bind to it but cannot neutralize it. To make matters worse, the dengue virus uses the bound E-protein antibodies to help it get swallowed up by immune-system cells, which the virus then hijacks to replicate itself. At the same time, the bloodstream is full of virus particles bound together with the antibodies, which makes the immune system explode in an uncontrolled cascade of reactions that damage both blood vessels and tissues, sometimes leading to internal hemorrhaging.

A Four-Way Cage Match

A dengue vaccine must therefore cause the immune system to produce antibodies against E proteins from all four serotypes of the virus. A single misstep could make the vaccinated person extra susceptible to a dangerous reinfection. Of the many groups attempting to make vaccines against the four serotypes, only a few have made it into clinical trials so far. GlaxoSmithKline, in collaboration with the U.S. Walter Reed Army Institute of Research, is using weakened dengue virus in its vaccines, whereas Sanofi-Pasteur has reengineered the yellow-fever vaccine—one of the most successful vaccines in the world—to make it effective against dengue.

Glaxo researchers developed new culturing solutions in which to breed the dengue virus and make it less dangerous. They used weakened versions of the four virus serotypes, all taken from the bodies of dengue-fever patients. By raising the virus for many generations in dog kidney cells and then ape lung cells, they created a virus that is just weak enough to evoke an immune response yet not cause an infection.

Phase II clinical tests on adults in the U.S. and Thailand are already complete, with promising results. The vaccine is undergoing similar tests in Puerto Rico. So far, researchers report no side effects, and most subjects developed antibodies to all four subtypes. In its final form, the vaccine will most likely be dispensed in two doses six months apart. The company expects to complete Phase II trials next year.

Sanofi-Pasteur, based in Lyon, France, and Mahidol University in Thailand are taking a different strategy. Their scientists started with the well-established yellow-fever vaccine, which uses a weakened version of that virus. Using genetic engineering, they substituted the genes that code for dengue E proteins, rather than yellow-fever E proteins, from all four serotypes of the dengue virus. The new vaccines each have the original version's effectiveness yet should activate the immune system against the dengue virus. The four serotypes will probably be administered using a multistage immunization schedule.

In trials of the Sanofi vaccine, test subjects from Mexico, Peru, the Philippines and Thailand developed antibodies to all four virus serotypes after a three-dose immunization schedule (the final vaccine may require only two doses). The vaccine is almost ready for Phase III clinical trials and is scheduled to enter the market by 2016. If successful, it will become one of the first vaccines created through genetic engineering. And although no vaccine can cure those already stricken with dengue, the treatments being developed should prove a boon to developing nations looking to curb this deadly epidemic. ■

Intense Eradication Campaign against Dangerous Insects

Dengue fever is spread by two mosquitoes in the Aedes family: *Aedes egypti* and *Aedes albopictus*. In very poor nations, it would be unrealistic to try to vaccinate the disease out of existence. Although vaccination will play a vital role in combating dengue, it will need to be supplemented by other strategies, such as a concerted mosquito-control program. Some of the most important techniques include treating homes with insecticide and blocking mosquitoes' access to water, where they lay their eggs.



Insecticides are an important tool in the fight to limit dengue's spread.

DADANG TRI/REUTERS/SCANPIX

Exhausted, But Just Can't Fall Asleep?

New breakthrough will help you fall asleep faster, sleep deeper and awake more refreshed.



"I used to lie in bed for hours and...toss and turn...I would only get 4-5 hours of sleep per night...which just wasn't enough for me. RestAid® has seriously helped me. I can sleep without a problem and sleep soundly all night long. It has improved my life in so many ways."

—Maggie R.

Results not typical.

Sleep is the only way we can recharge our brain and restore important neurotransmitters. Sleep is also the time when the body does most of its repair work including rebuilding and restoring muscle tissue. This is because growth hormones are secreted during sleep, which is essential to rebuilding tissues.

Consequences Of Too Little Sleep

There is a growing body of evidence indicating that chronic sleep deprivation increases risk of early death. In addition, one of the fastest growing areas of research is the link between chronic sleep deprivation and the risk of becoming overweight and obesity. Sleep deprivation can lead to:

- Greater risk of heart disease
- Increased risk of illness
- Thinking impairments, like slower reaction time, memory loss & confusion
- Poor work performance
- Mood problems like depression, anger & irritability
- Risk of unhealthy weight gain & loss

"I had problems sleeping for several years but never wanted to take prescription meds because of possible side effects. I have taken RestAid® every night for over two weeks, and I've never slept better. I fall asleep within a half hour of taking it, and I stay asleep longer. " —Scott M.

Results not typical.

Lack Of Sleep Impacts 1 In 6 Adults

The National Sleep Foundation's Sleep in America polls reveal that over a six year period only about half of adults get a good night's sleep every night. Sleep deficit is frequently related to too much caffeine, nicotine and alcohol. It is also related to stress, long hours at work, night shifts and working on home computers before going to sleep.

New Non-Prescription Breakthrough

Before resorting to expensive prescription sleeping pills with potential negative side effects, try RestAid®. RestAid® is an all-natural sleeping supplement that will help you fall asleep faster, sleep deeper and awake more refreshed.

RestAid® utilizes a Patented Cysteine Milk Peptide® that is clinically proven to break down natural stimulants, toxic substances, alcohol and caffeine – all known to interrupt your sleep cycles. Its delivery system gets the nutrients into the blood stream much quicker than other supplements.

HOW RESTAID WORKS

RestAid™ contains the perfect combination of Cysteine Milk Peptide® and Melatonin. Cysteine Milk Peptide® counteracts toxins, stimulants and alcohol which disrupt sleep patterns and Melatonin works naturally to synchronize your body's sleep rhythm.



Cysteine Milk Peptide® – Shown in clinical studies to immediately boost levels of Glutathione, which is a substance produced by the body that is needed to break down toxins such as caffeine and alcohol that disrupt our natural sleep patterns.

Vitamin B12 – is proven to cause an earlier release of Melatonin at night, which resets the sleep-wake cycle.

Melatonin – is a hormone produced by the body that naturally increases sleep efficiency.

Lemon Balm Extract – is a natural sedative that soothes and relaxes your mind and body.

Hops Extract – is used as a natural treatment for tenseness & restless sleep.

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- ☑ Can't sleep through the night?
- ☑ Concerned about the side effects of sleeping pills?
- ☑ Consistently wake up tired & foggy?
- ☑ Feel fatigued in the daytime?

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World of Science

Research Footnotes

Dog Fleas Do the Long Jump



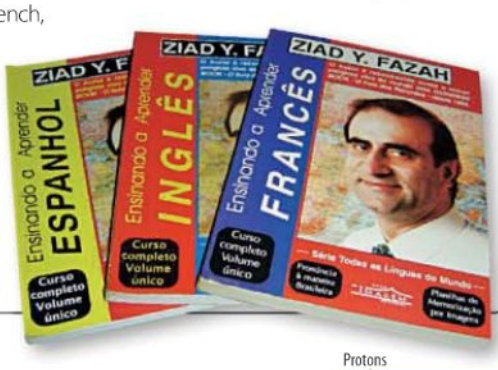
Dog fleas [right] are better jumpers than cat fleas. In a 2000 study at the National Veterinary School of Toulouse, France, researchers found that *Ctenocephalides canis* jumps a full foot forward on average—more than four inches farther than *C. felis felis*, its feline-infesting counterpart. The canine pests also reach greater heights: One dog flea in the study managed to jump up almost 10 inches, while the most athletic cat flea hit only 6.7 inches. Knowledge of their jumping behavior may someday help prevent infestations.

Linguistic Curiosities

59 Languages and Counting

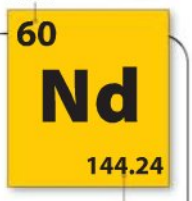
A hyperpolyglot, according to Richard Hudson, the linguist who coined the term, is a person who speaks six or more languages fluently. Try 11. Ziad Youssef Fazah is fluent in Arabic, Danish, English, French, German, Italian, Portuguese and Papiamentu (a Portuguese-based creole language), Russian, Spanish, Swedish and claims he can get by in 48 other languages .

Growing up near a harbor in Lebanon, Fazah loved to speak with sailors who came into port. When he was 11, he decided to learn as many languages as he could. He concentrated on one at a time and took about three months to learn each language.



Elemental Secrets

Neodymium

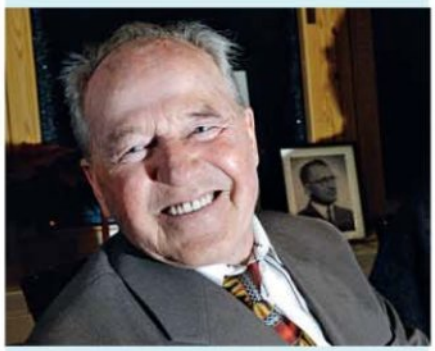


- Although neodymium is one of a collection of unusual elements known as rare-earth metals, it's not as difficult to extract as chemists once thought. It is twice as abundant as lead in the solidified magma of the Earth's crust.
- Alloys of the elements neodymium, iron and boron are used to make especially strong magnets. Two such magnets can be almost impossible to separate and will fly toward each other or toward iron with such force that they may shatter on impact.
- Glass containing neodymium can appear in a range of shades from violet to wine-red. When combined with praseodymium, another rare-earth element, the mixture filters harmful ultraviolet light and is used in welders' goggles.

Did You Know . . .



MERCURY, the solar system's smallest planet, rotates so slowly that a day there lasts 4,222 hours—more than 175 Earth days.



THE OLDEST CORNEA belongs to a Norwegian man named Bernt Aune. The 124-year-old cornea, transplanted into his right eye in 1958, came from a donor who was born in 1885.

FROM TOP: D.M. DENNIS/PHOTOLIBRARY; ARCHIVE; BJØRN TORE NESS/NAMDAL SAVISA



Highs and Lows

The longest coastline . . .

Canada has the longest seashore of any nation in the world. With its thousands of islands and coves, its shoreline totals more than 150,000 miles.

. . . and the shortest

With fewer than three miles of coast on the Mediterranean Sea, **Monaco** has the shortest coastline. Forty-four landlocked countries have no coast at all.

Weird Inventions

Your Very Own Tank

Ever dream about driving a tank? Now it can be a reality—if you have $14,000 to spare. The King Tiger radio-controlled tank from British company Mark 1 Tank is a 1:4-scale replica of the World War II German military vehicle. At six feet long and 550 pounds and featuring pyrotechnic rounds, it will satisfy your youthful fantasies. The King Tiger and other war-era tanks can be ordered at *mark-1-tank.co.uk*.



Nature's Rarities

Venomous Mammals Sting Prey

We normally associate poisonous bites with snakes and other reptiles, but there are some mammals that deliver venom too. This exclusive group includes three species of shrew and the male duckbilled platypus. The Haitian solenodon, a burrowing, nocturnal critter, is also toxic. The venom of *Solenodon paradoxus*, delivered from modified salivary glands through its lower front teeth, paralyzes prey such as beetles and other small animals. When bitten, humans experience swelling and a burning sensation where the skin was punctured.

With its long snout bristling with whiskers, the solenodon is a bigger version of its distant relative the shrew. Solenodons weigh more than two pounds (70 times as heavy as a shrew), making them one of the largest members of the group of insectivores to which they belong. The only other species of solenodon that still exists is *S. cubanus*, which is found in Cuba and also has toxic saliva.

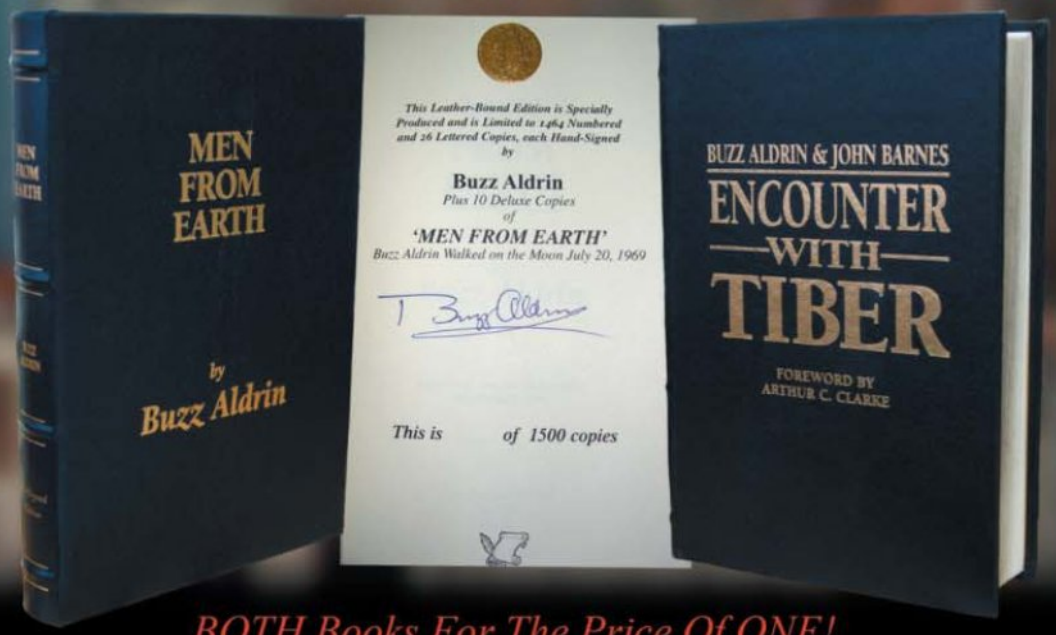


The Haitian solenodon delivers poison from glands under its front teeth.

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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
LANDMARKS	Name this **place**	It is the location of the government seat of a nation with more than 143 million people.	It was once home to the capital city's first public library and university.	Today this former marketplace is surrounded by a famous cathedral, a palace and the historic district Kitay-gorod.	In May 1987, a young German pilot, Mathias Rust, illegally landed his small plane in this square.	In Russian, it is called *Кра́сная пло́щадь*. The first of these words means red.
BOTANY	Name this **plant family**	The Spanish conquistadors brought one variety, *Solanum tuberosum*, back to Spain from South America.	Another member of the family, a juicy red fruit, came from Mexico, where its Nahuatl name was *xitomatl*.	This family, Solanaceae, consists of 102 genera and nearly 2,500 species, many of which are poisonous.	In addition to the potato and tomato, other relatives include tobacco, chili peppers, bell peppers, eggplants and petunias.	Its English name comes from the German *nachtschatten*, or "shade of night."
LANGUAGE	Name this **script**	French linguist Jean-François Champollion was the first to decipher this writing, in 1822.	Its symbols can stand for three different things: Some represent letters, others syllables, and the rest stand for an idea or object.	The text Champollion worked from was on a stone found by Napoleon's troops near the town of Rosetta on the coast of Egypt in 1799.	Its name comes from the Greek word meaning "sacred carving."	This ancient Egyptian writing is found on temple walls, and its symbols are made of small pictures.
MEDICINE	Name this **drug**	The first person to synthesize this drug was Albert Hofmann, a Swiss chemist, in 1938.	Psychiatrists once used it to treat alcoholism and to study schizophrenia.	Hofmann didn't discover its psychedelic properties until 1943, when he got a small amount on his fingers.	It was popular in 1960s hippie counterculture; its advocates included the novelist Ken Kesey, author of *One Flew over the Cuckoo's Nest*.	The common name for this now-illegal drug comes from the initials of its ingredients. The full name is lysergic acid diethylamide.
MYTHOLOGY	Name this **creature**	It is often artistically depicted holding a comb and a mirror.	According to legend, spotting one during a voyage at sea is an omen of shipwreck.	It is half human and half animal, but it is not a satyr, sphinx or centaur.	The creature may have been conceived of when people mistook the aquatic mammal manatee for it.	Hans Christian Andersen wrote a fairy tale about a "little" one in 1837, which inspired a popular 1989 Disney movie.

HISTORY: What year was it?

January 30, England
The last Beatles concert, on the roof of the Apple Records building in London [right], is shut down by the police.

February 3, Egypt
At a meeting in Cairo, the Palestine National Council names 39-year-old Yasir Arafat as the new head of the Palestine Liberation Organization.

July 20, Space
Neil Armstrong makes the first-ever moonwalk during the successful *Apollo 11* mission.

Your guess	Points
Correct year	5
± 2 years	4
± 4 years	3
± 6 years	2
± 8 years	1



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Your score:

24–30 Good show, Sherlock
17–23 Not bad, Watson
9–16 Good enough, Paris
0–8 Hit the books, Homer!

Answers appear on page 86

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Answer Key

TRIVIA COUNTDOWN ANSWERS

Landmarks: Red Square
Botany: Nightshade
Language: Hieroglyphics
Medicine: LSD
Mythology: Mermaid
History: 1969

BRAIN TRAINERS

1. 15 feet. Let h be the original height of the top of the ladder. By the Pythagorean theorem, we have $h^2 + 7^2 = 25^2$, so $h = 24$. Because $24 - 4 = 20$, the height at the top of the ladder is now 20 feet. Now let b be the distance from the wall to the base of the ladder. By the theorem again, $20^2 + b^2 = 25^2$, and $b = 15$.

2. F. In the other figures, the small square is joined to the longest side of the quadrilateral.

3. C. Note that figures A and C do not represent actual dice. Each pair of opposite sides of a real die contains a total of 7 dots, so 1 and 6 must be opposite each other, 2 and 5, etc.

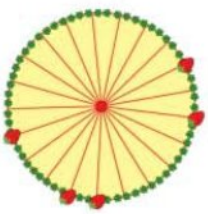
4. $24 + ((18 \div 2) \times 9) - 5 = 100$.

HEADBREAKERS

1. See diagram.

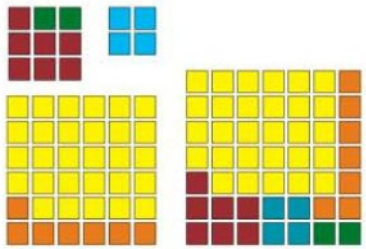


2. See diagram. There are 42 correct ways to arrange the strawberries, but all of them can be obtained by rotations and reflections of the solution pictured here.



3. 4 and 12. Let x and y be the two numbers. Then $xy = 3(x+y)$, and thus $0 = xy - 3x - 3y$. Adding 9 to both sides, we get $9 = xy - 3x - 3y + 9 = (x - 3)(y - 3)$. Since $x - 3$ and $y - 3$ are different integers whose product is 9, the only possibilities are that one of these integers is 1 and the other is 9, or else one of them is −1 and the other is −9. This yields two solutions: 4 and 12 or 2 and −6. Since positive numbers are required, the only remaining solution is 4 and 12.

4. See diagram.



5. 54. Let x be the father's age when the child was born. Since the father's age is 99, the child's age is $99 - x$. It follows that $(2/3)x = (4/5)(99 - x)$. Multiplying both sides by 15 to clear fractions, we get $10x = 12(99 - x)$, and thus $5x = 6(99 - x)$. This yields $11x = (6)(99)$, so $x = (6)(9) = 54$.

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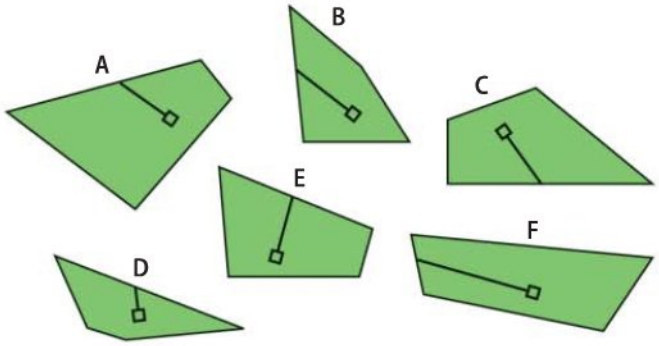
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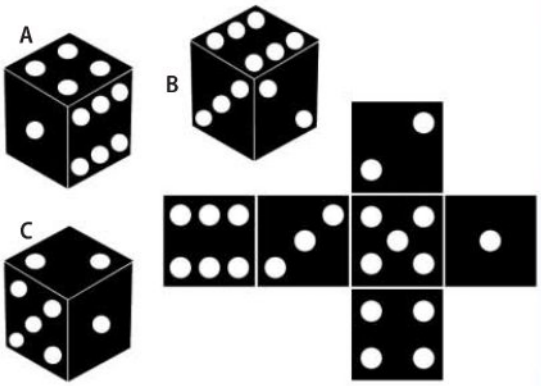
Brain Trainers

1 A 25-foot ladder is leaning against a wall, and the base is 7 feet from the wall. The ladder starts to slide down. How far from the wall will the base be when the top of the ladder is 4 feet below its starting position?

2 Which figure does not belong?



3 Which of these three imaginary dice—A, B or C—could be unfolded to create the fourth figure?



4 Make a true equation by inserting arithmetic operation symbols and parentheses between the numbers to the left of the equal sign.

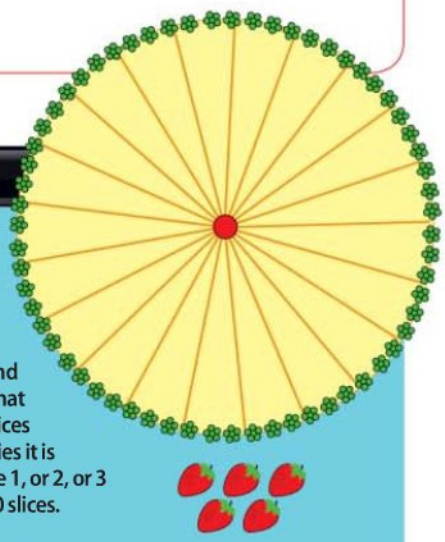
24 18 2 9 5 = 100

Headbreakers

1 Trace a path from the black to the red hexagon, moving either horizontally or vertically at each step. The path should touch hexagons containing each of the numbers 1 through 21 exactly once.

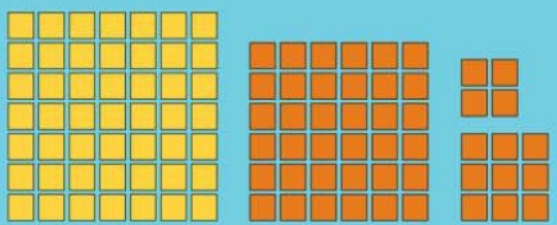
1	6	18	8	17	11	14
12	3	7	14	4	12	8
11	10	5	17	16	16	13
15	20	5	6	12	3	10
16	9	13	2	19	16	4
5	2	16	5	3	11	9
16	11	2	18	14	4	21

2 This cake has been cut into 21 equal slices. Place the five strawberries around the perimeter so that by choosing the slices between two berries it is possible to remove 1, or 2, or 3 and so on, up to 20 slices.



3 Which two different positive whole numbers, when multiplied, have a product that is triple their sum?

4 Divide the yellow square into five pieces that can be combined to make three smaller squares that measure 6 x 6, 3 x 3 and 2 x 2.



5 A 99-year-old man says to his child, "2/3 of my age when you were born equals 4/5 of your age now." How old was he when his child was born?

Answers appear on page 86

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