

SCIENCE ILLUSTRATED



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The Turtles' Odyssey

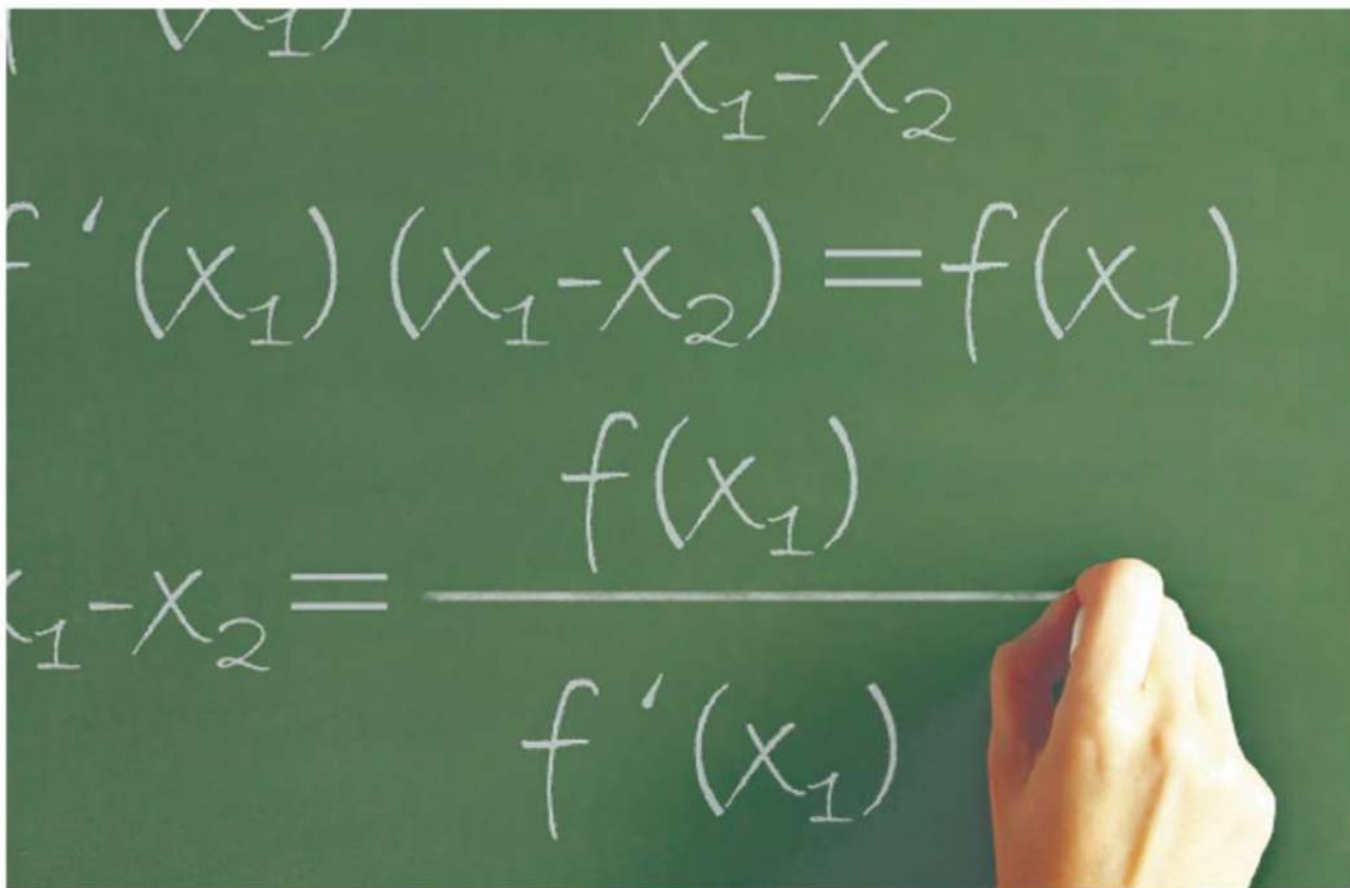
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Sunken 'Scope

How an Undersea
Device Will Reveal
Cosmic Secrets





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GET A GRIP ON CALCULUS

Calculus has made it possible to build bridges that span miles of river, travel to the moon, and predict patterns of population change. Yet for all its computational power, calculus is the exploration of just two ideas—the derivative and the integral—both of which arise from a commonsense analysis of motion. Master them and open a new world for yourself!

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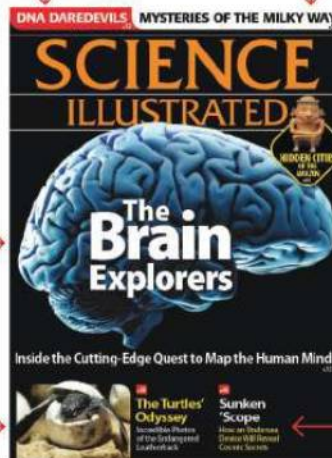
The Spitzer Space Telescope is giving us a new perspective on our own galaxy.

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Meet the innovators behind the most detailed diagram of the brain's circuitry.



**"The more we learn,
the clearer it
becomes that the
brain is more than
the sum of its parts."**

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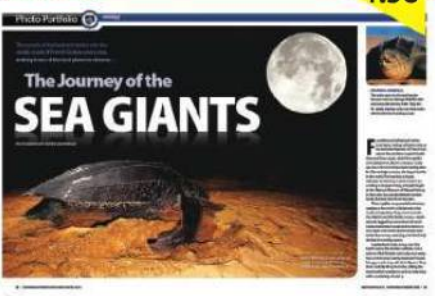
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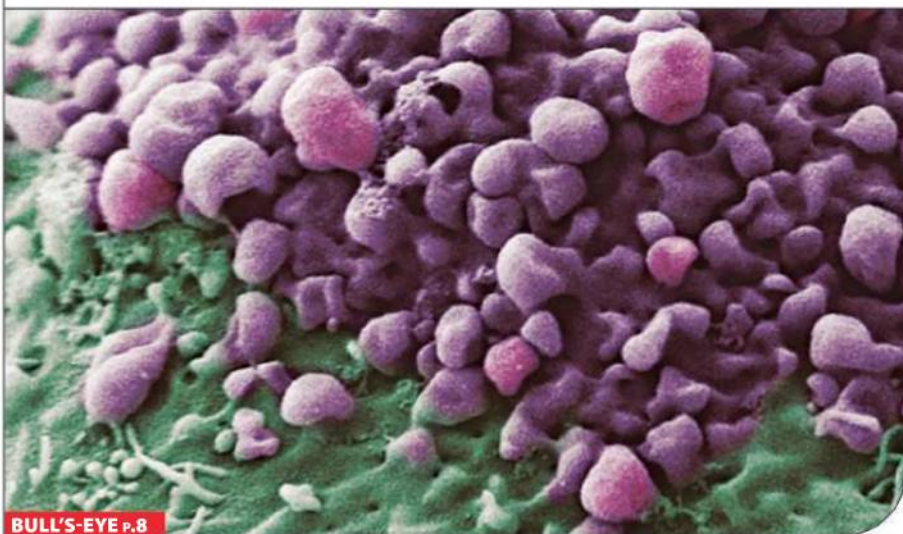
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TODAY - The United States Rare Coin & Bullion Reserve has scheduled the final release of U.S. Gov't Issued \$5 Gold Coins previously held at the U.S. Mint at West Point. These Gov't Issued Gold Coins are being released on a first-come, first-serve basis, for the incredible markup-free price of \$126 each. This "at-cost" Gov't Gold offer could be cancelled at any time. Do not delay. Call a Sr. Gold Specialist today.

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▶ From the Editors

This month we're excited to unveil some changes in *Science Illustrated* that we think further our mission to deliver fascinating topics in the most visually engaging way. Every issue, we'll highlight the innovative Tools+Techniques used by researchers in a particular field, like genetic engineering (page 52). In By the Numbers, we'll give you vital statistics on a scientific topic—the Earth, for example (page 72). Finally, the images in Contrast will showcase the contradictions inherent in nature and technology (Barren versus Fertile, page 74). We'd love to hear what you think of these new sections.

E-mail us at letters@scienceillustrated.com



The Lowdown

In "Who Will Survive?" [January/February], you state that pikas live at altitudes from 8,000 to 13,000 feet. Yet other populations have recently been found at elevations well below 8,000 feet, according to Embere Hall of the Teton Science Schools's Conservation Research Center in Jackson, Wyoming. This shows that they are

capable of living at a broader range in the Greater Yellowstone Ecosystem than previously thought.

Marilyn Stone Via e-mail

Darwin Debate

"Origins of a Revolution in Hardcover" [November/December 2009] was most interesting. In the 1926 authorized edition of *The Origin of Species*, however, the final sentence actually reads: "There is grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being evolved." By editing the quote [to remove "by the Creator"], you continue to foster the unnecessary debate between science and religion.

Richard J. Erdlac, Jr. Via e-mail

EDS: Darwin added "by the Creator" to the book's second edition. Modern edits of his first edition, the article's subject, do not include these words, according to science historian Ronald Numbers of the University of Wisconsin.

Corrections

The London Underground has 155 miles of train tracks, not 250 [World of Science, Nov./Dec. 2009]. It still holds the record for the longest distance traveled by different routes by slightly more than 10 miles.

Sea-ice decline is threatening some polar bear populations in the Arctic, not in Antarctica ["Who Will Survive?", Jan./Feb.].

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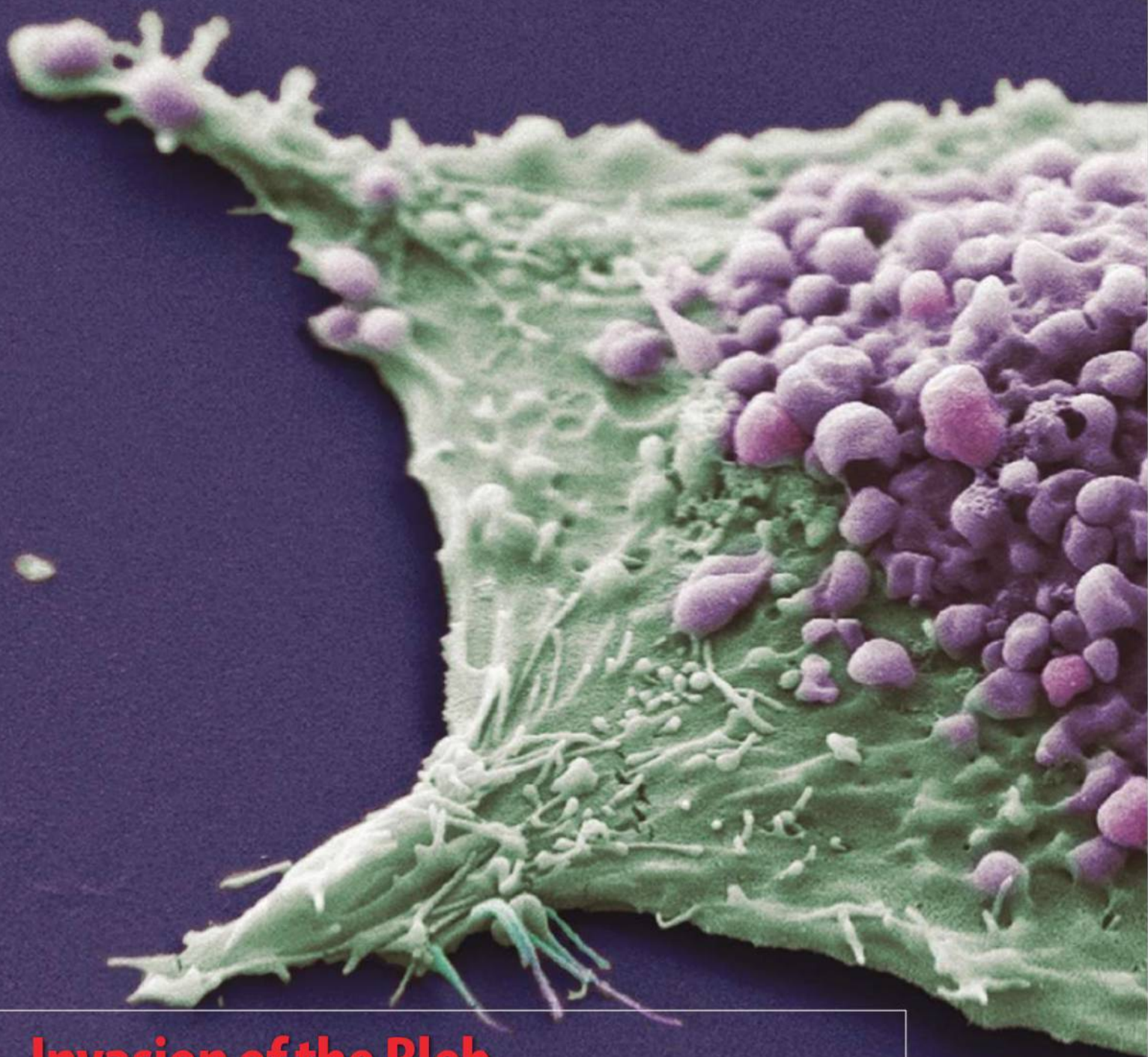




For the Birds

Vultures eat the remains of the deceased as part of a Tibetan Buddhist “sky burial” in northwestern China. After a death, monks pray over a person’s body to help the soul transition to a new existence. The corpse is then dismembered and, as the deceased’s final act of charity, left on a mountain in an area frequented by vultures. Historians believe the ritual may have had practical origins in the high altitudes of Tibet, born from a lack of timber for cremation or the difficulty of interment in the rocky terrain.

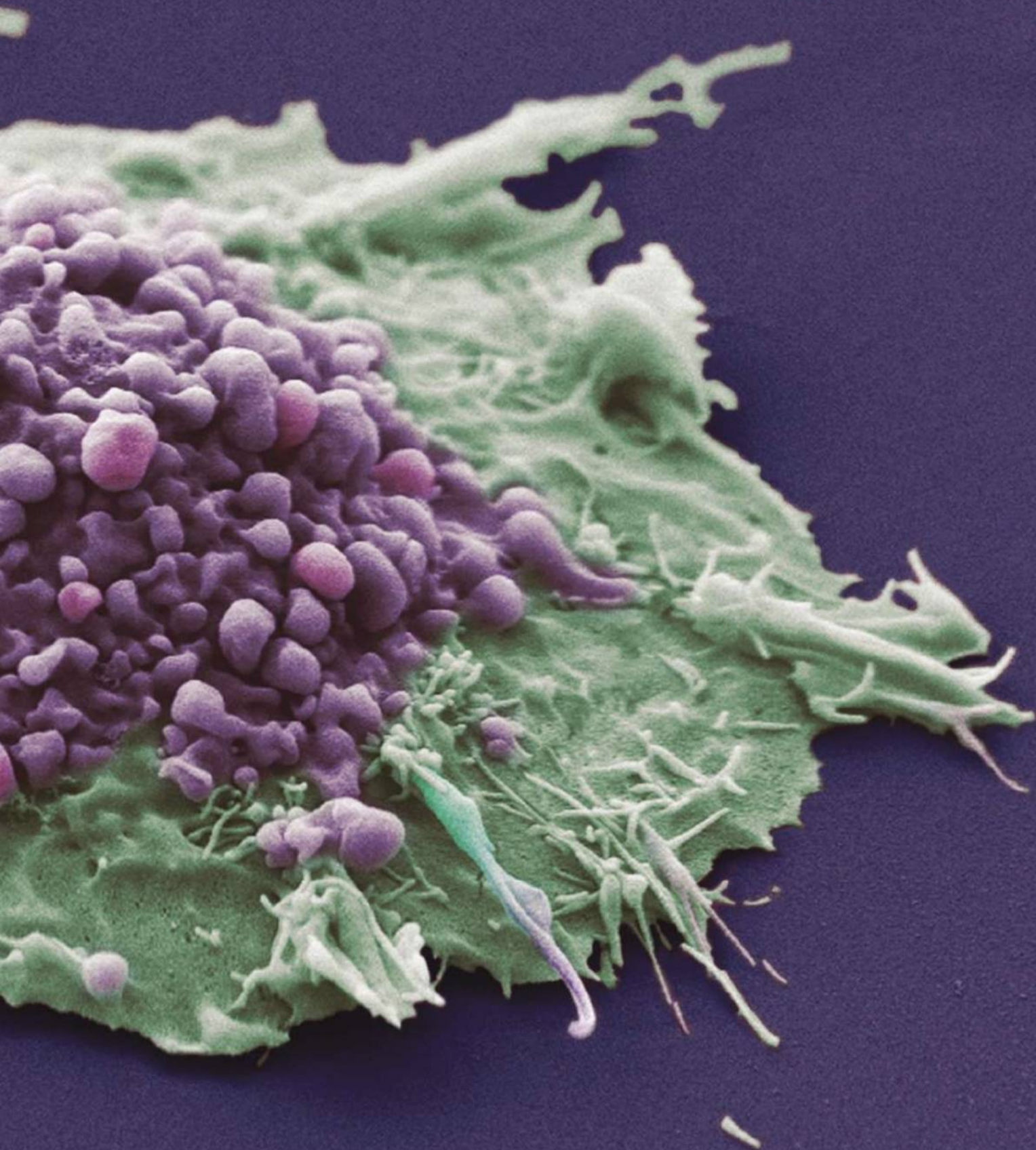
ALEX LEE/EPA/CORBIS



Invasion of the Bleb

This lone lung-cancer cell, shown with enhanced color, is topped by purple blebs, bubbles that form when a cell's structure degrades, divides, or is placed under physical or chemical stress. During this process, the cell membrane detaches from the cytoskeleton, the scaffolding that maintains a cell's shape, and forms spherical bulges. Scientists at Cancer Research UK are using such images to examine how cells maintain normal functioning and to learn how cancer cells disrupt the process. This microscopy image, by researcher Anne Weston, won a 2009 Wellcome Image Award, given for outstanding scientific and medical photography.

ANNE WESTON/
LRI/CRUK/Wellcome Images



Itty-Bitty Blossom

So thin that they're nearly transparent, the blooms of one of the world's smallest orchids measure just over 0.08 inch across. Lou Jost, an ecologist with EcoMinga, a plant-conservation foundation, discovered the yet-to-be-named species in a cloud forest at an altitude of almost 10,000 feet on the Cerro Candelaria mountain in Ecuador. The minuscule orchid, shown here beside a ruler, was flowering among the roots of a larger orchid that Jost had brought back to his greenhouse for study.









Start Your Engines

A jet of flame shoots out of the *Lynx* rocket's main engine during tests in the Mojave Desert last March. XCOR Aerospace hopes to make a splash in the budding space-tourism market with the craft, which is designed to take a pilot and a passenger to suborbital altitudes of up to 200,000 feet. Roughly the size of a small plane, *Lynx* is powered by four engines that burn liquid oxygen and kerosene. The company is still testing the main engine, with the rocket's first test flight scheduled for later this year or early next.



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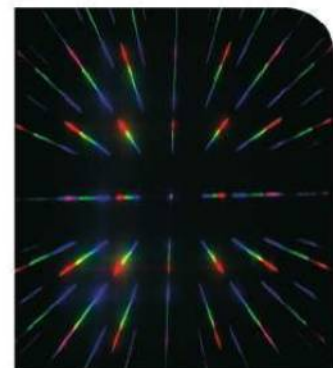
Red Planet's Ancient Lake

Photos from space reveal landforms that held water on Mars

ASTRONOMY Shorelines on the surface of Mars, most likely the remnants of a 3.4-billion-year-old lake, are the best evidence yet that standing bodies of water once existed on the planet, say researchers at the University of Colorado. Deltas adjacent to the lake bed could be explored for signs of past life beneath the surface.

NASA's High Resolution Imaging Science

Experiment (HiRISE), a camera on the Mars Reconnaissance Orbiter, took pictures of the area in 2008 from 200 miles above the planet. The images have revealed evidence that an 80-square-mile lake as deep as 1,500 feet once existed there. The finding suggests that the planet's wet-and-warm period ended more recently than 3.7 billion years ago, as previously believed.



Ultrashort laser pulses are amplified and slowed so a computer can convert them.

Laser Camera Is World's Fastest

TECHNOLOGY Some phenomena in physics, chemistry and biology happen so quickly that even high-speed cameras cannot capture them—until now. University of California at Los Angeles engineers have designed a camera that takes photos by emitting laser pulses a billionth of a second long. With the ability to take roughly six million frames per second, the researchers say it's the world's fastest camera.

STEAM technology (for "serial time-encoded amplified microscopy") could one day image rare, ultrafast events, such as shock waves or early-stage cancer cells flowing through the bloodstream. Catching these few rogue cells among the billions of healthy ones is difficult with current microscopy techniques.



*A 3.4-million-year-old lake
bed on Mars may be studied for
signs of past life on the planet.*

FROM LEFT: G. DIACHILLE; SPL/FOCI



The Secret of Slithering: Friction and Shifting Weight

Special belly scales and subtle movements help propel snakes forward on flat terrain

BIOLOGY Scientists have long been aware that snakes push off laterally against objects like rocks and branches to help them move. Their movement over surfaces such as sand and paved roads with no helpful objects has been more of a mystery. Now research from New York University and Georgia Tech is explaining how friction generated by a snake's scales, combined with almost imperceptible shifts in its body weight, helps the reptile move forward on flat

ground, and possibly on any terrain.

Researchers anesthetized snakes and then measured the resistance created by sliding them in different orientations on a tilted board. When the board was covered with a piece of fabric, sideways movement resulted in twice as much friction compared with forward sliding (friction was calculated based on the angle of the board). The researchers say the snake's belly scales, which overlap like roof shingles, are oriented to "catch"

the ground during sideways and backward movement. This keeps it heading forward as it slithers from side to side.

Next, snakes were placed on gelatin rigged to light up when the reptiles applied force. The experiments revealed that snakes also slightly lift segments of their body when they move, which limits unwanted friction and gives greater leverage to their body waves. The findings could help engineers design better snakelike robots for search-and-rescue missions.



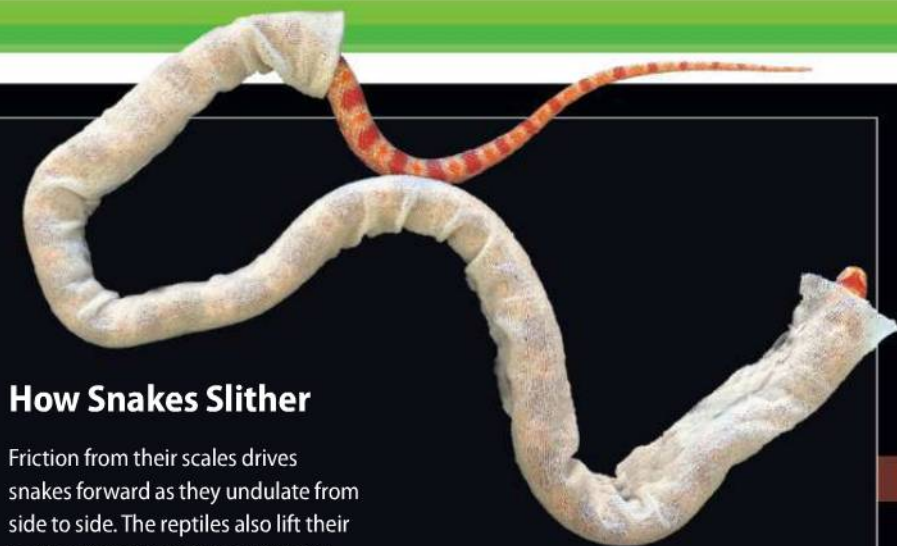
Snakes lift parts of their body to give leverage to their body waves.



Babies Pick Out Emotions Early On

PSYCHOLOGY At just six months old, babies can already speak dog. In a recent experiment at Brigham Young University, researchers showed 32 infants with little or no previous experience with a dog two different photos of the same pup, one displaying an aggressive posture and the other a friendly stance. When the researchers played recordings of friendly yaps and angry snarls, the babies spent most of the time gazing at the picture that matched the sound. Researchers say the study supports the notion that humans pick up emotional cues long before we can speak. A previous study at Brigham Young indicated that babies can identify mood variations in classical music.

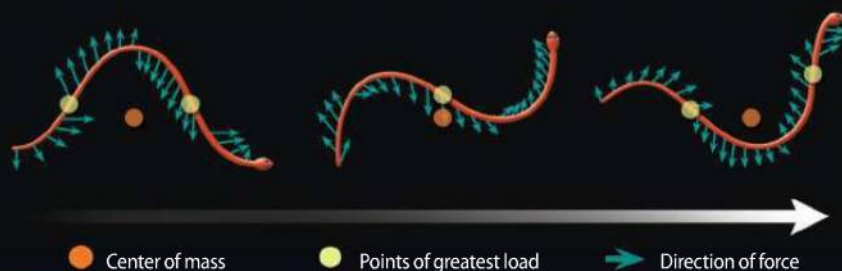
FROM TOP: NEW YORK UNIVERSITY AND GEORGIA TECH;
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How Snakes Slither

Friction from their scales drives snakes forward as they undulate from side to side. The reptiles also lift their bodies slightly when they slither to reduce unwanted friction and increase pressure to the parts of the body wave that generate the advancing motion.

Snakes had trouble moving when wrapped in cloth. The fabric eliminated the friction typically produced by their scales.



NEWS FLASH



Columbia University geo-physicists say buried volcanic rocks along the East Coast of the U.S. could be used to sequester industrial carbon dioxide emissions. The basalt rocks react with CO_2 to form carbonate minerals such as limestone.

Two New York City high-school students, aided by researchers from the Rockefeller University and the American Museum of Natural History, used a process called DNA bar coding to expose 11 cases of food mislabeling in local markets.

An international team of researchers has identified a genetic marker associated with cancerous facial tumors that are decimating Australia's Tasmanian-devil population. The finding will help differentiate the growths from other tumors.

A Car for the Blind

Students at Virginia Tech have designed a prototype car to put steering in the hands of the blind. The retrofitted four-wheel dirt buggy uses laser range finders, voice commands and vibrating gloves, among other features, to direct the driver. Two Ford Escape hybrids equipped with the technology are planned for this year.





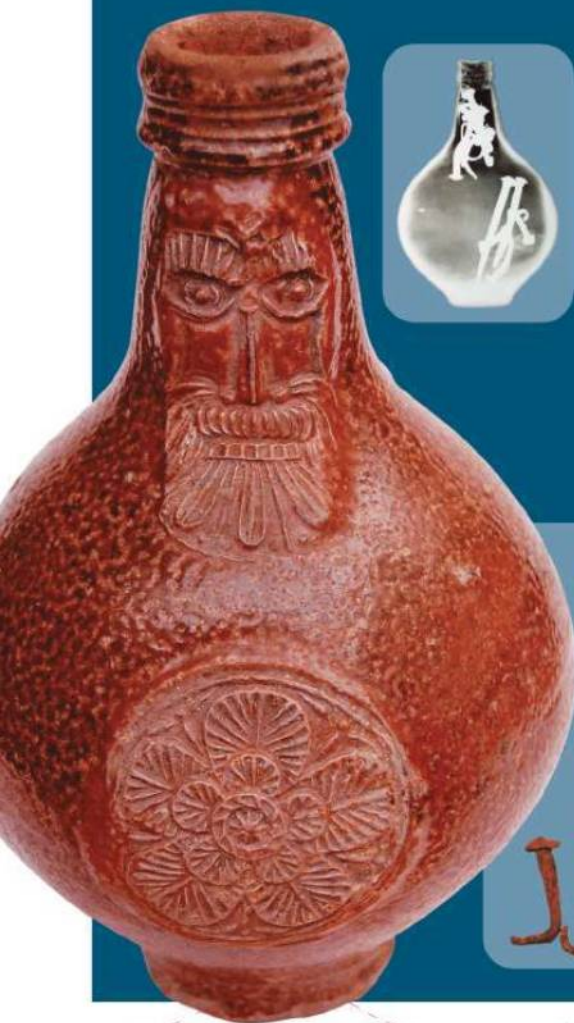
Potbellied Bottle Warded Off Witches

Scientists in England uncover an ancient artifact with curious contents

ARCHAEOLOGY A handful of iron nails and brass pins, a lock of hair, 10 fingernail clippings, some navel lint and human urine are among the bizarre contents of a “witch bottle” currently being analyzed by Alan Massey, a retired chemist and witch-bottle expert.

Workmen found the bottle buried in a Greenwich, England, cottage in 2004. According to superstition, the contents of such bottles could ward off witches and reflect their spells—commonly believed to be responsible for human ailments—back onto them. Roughly 200 witch bottles dating from the 16th and 17th centuries have been uncovered by archaeologists in England, but the Greenwich jug, which was delivered to scientists sealed, is the only completely intact witch bottle to undergo chemical analysis.

Massey also found iron sulfide in the bottle, probably the result of a chemical reaction between the urine and sulfur (a.k.a. brimstone). The sulfur may have been a nod to the biblical mention of fire and brimstone. Stoneware jugs known as bellarmines, for the visage of Italian Cardinal Roberto Bellarmino (1542–1621) stamped on the front, were often used for witch bottles, although some glass versions have also been found.



A typhoon as seen from a satellite

Tropical Storms Prevent Quakes

GEOLOGY Typhoons can cause widespread destruction, but they can also prevent some disasters. So say geophysicists from the Carnegie Institution of Washington and the Institute of Earth Sciences at Academia Sinica in Taiwan, who found a correlation between the tropical storms and so-called slow earthquakes in eastern Taiwan.

Between 2002 and 2007, the scientists measured 20 of these nonviolent quakes, which last from hours to more than a day rather than just seconds like the more familiar, destructive earthquakes. Eleven of the small quakes coincided with typhoons in the region, and none occurred during non-typhoon months. The storms reduce air pressure over land but not at the ocean floor. This pressure imbalance may trigger the slow quakes, researchers say, frequently releasing stress from areas of a fault—and explaining why devastating earthquakes are rare in eastern Taiwan.

The miles most likely covered by millions of globe skimmer dragonflies during their annual journeys from India to Africa and back, according to a new study. It's the longest insect migration known.

11,185

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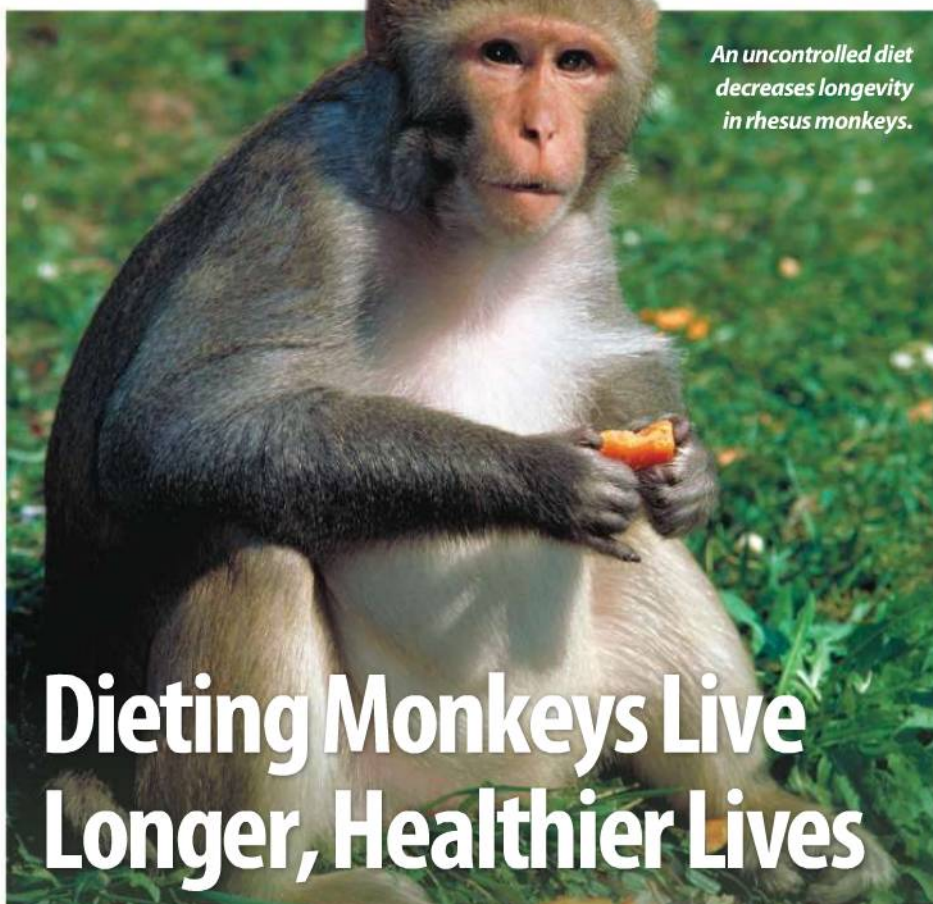
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An uncontrolled diet decreases longevity in rhesus monkeys.

Dieting Monkeys Live Longer, Healthier Lives

Reducing calories benefits humans' close relatives

MEDICINE The results of an ongoing, decades-long study are coming in, and the message is clear: Cutting back on calories leads to a longer, healthier life, at least for rhesus macaques. Researchers from the University of Wisconsin began following 76 monkeys and their food intake in 1989. One group of monkeys is allowed to eat freely, while the other is on a restricted diet of 30 percent fewer calories than their normal intake. Since the study began, half of the monkeys in the control group have died, whereas 80 percent of the dieting monkeys are still alive

(macaques live an average of 27 years in captivity). The restricted group has also had significantly fewer cases of cancer and cardiovascular disease, less loss of brain mass and no cases of diabetes.

The researchers caution, however, that such long-term calorie reduction would be extremely difficult for humans. "We hope to use our research to better understand the mechanisms behind the positive effects of calorie restriction so that we may devise other ways in which people may remain healthier longer," says lead study author Ricki Colman.

NEWS FLASH



A network of cameras deployed by NASA and the Canadian Space Agency has identified the origin of mysterious explosions in the northern lights called substorms. The eruptions are caused when a slow-moving aurora and a faster-moving one collide.

Scientists at the Medical College of Georgia have engineered a mouse that displays schizophrenic-like behavior by eliminating a gene associated with the disease. The mouse, which responded to medication often used to treat patients with schizophrenia, is providing the first animal model of the disorder.

Archaeologists in Israel have uncovered evidence of sophisticated human behaviors 750,000 years ago, some half a million years earlier than previously estimated. The researchers found organized living spaces, stone tools and the earliest evidence of fish consumption by humans.

The European Space Agency's Herschel Space Observatory, launched last year, is capturing the most detailed images yet of galaxies in the early stages of formation 12 billion years ago, roughly a billion years after the big bang.



Ancient Symbols: Not Just Pretty Pictures

ARCHAEOLOGY Undeciphered markings on objects created by the Indus civilization, which existed between 2600 and 1900 B.C. in what is now eastern Pakistan and northwestern India, appear to be words or letters. A recent University of Washington computer analysis shows

that the sequence of the marks more closely resembles linguistic systems than non-linguistic systems (such as images depicting deities). The research provides evidence against a recent hypothesis that the Indus script represented pictures or icons rather than words.

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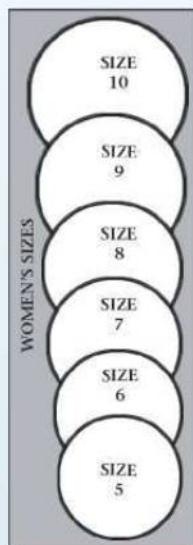
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USING THE RING SIZE CHART

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Some fence lizards have adapted longer legs to thwart predators.

Savvy Lizards Shake Off Venomous Ants

BIOLOGY Fence lizards in the south-eastern U.S. are providing a significant example of just how fast native animals can adapt to invasive species.

Venomous South American fire ants invaded North America in the 1930s and have since colonized states from Texas to Florida. The ants, which operate in groups to inject paralyzing venom into prey before feasting on the animals, are expected to eventually invade more than half of Earth's landmasses. Biologist Tracy Langkilde of Penn State University recently observed how the fence lizards from four regions—three that contain fire ants and one that doesn't—respond to the predator.

Langkilde found that lizards that hailed from ant-infested habitats will often cast off the bugs by twitching their bodies and then flee the scene, whereas those with no prior fire-ant experience are more likely to simply close their eyes and stand still. The ant-exposed lizards also have longer hind legs, which may give them an advantage during twitching and fleeing. Both adaptations probably evolved as shorter-legged and less-reactive lizards were killed off by ants at higher rates than longer-limbed animals.

Thank the Cold for Our Big Brains

Cooling temperatures may have allowed the human brain to develop



ANTHROPOLOGY Two recent studies are adding weight to a decade-old theory that global cooling played a big part in the evolution of our large brains.

Human brain activity generates a tremendous amount of heat, which the body must release to prevent overheating. Ten years ago, biologists David Schwartzman and George Middendorf of Howard University hypothesized that prehistoric brain size was constrained by a hot climate. Humans probably weren't able to develop big brains until the environment was cool enough. The researchers posited that a cooling trend over the past 50 million years allowed for increases in human brain size.

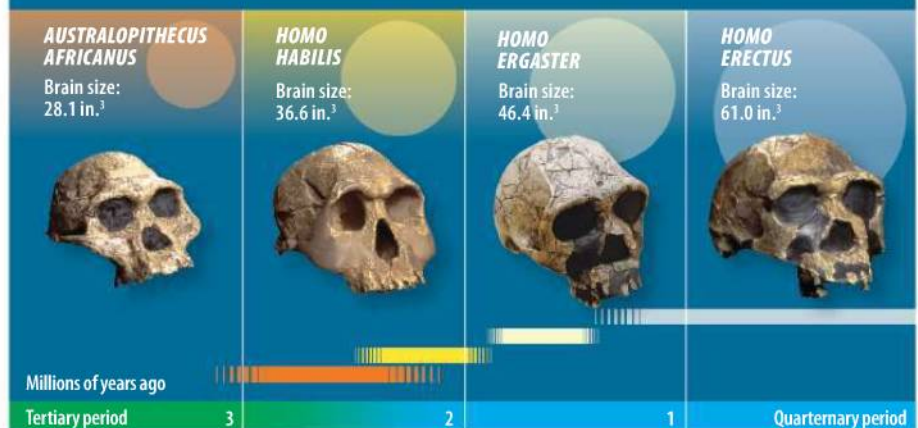
Recent work by climate researcher

Axel Kleidon of the Max Planck Institute for Biogeochemistry in Germany supports a theory of temperature-restricted development. According to his climate models, both temperature and carbon dioxide levels can affect human metabolic activity, including brain function.

Schwartzman and Middendorf have since calculated that air temperatures would have had to drop just 2.7°F to allow for the brain-size changes that took place between *Australopithecus africanus* and *Homo habilis*, as well as between *Homo ergaster* and *Homo erectus*, the likely predecessor of modern humans. This change in temperature is consistent with global cooling at the time, Middendorf says.

Cooler Heads Prevailed

Air-temperature shifts correlate to brain size, say researchers. Over the past 50 million years, a worldwide cooling trend may have allowed large-brained humans to develop from the smaller-brained *Australopithecus* line.



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Ask Us



P. 27
Which canines wag their tails in greeting?



P. 28
What happens to liquids in a vacuum?



P. 30
Why are birds attracted to red flowers?



Ceramic amphorae were once used for storage and shipping.

Why did amphorae have pointed bottoms?

The jars' cone shape made them convenient for storing and transporting liquids like olive oil and wine in ancient Greece and Rome. Amphorae were designed to be stacked in layers. The pointed bottoms could be situated firmly between the necks of the layer below, with the tips of the bottommost layer secured in sand or pebbles.

Their pointy shape gave the ceramic jars structural strength, allowing them to hold large volumes of liquid—the largest vessels contained up to 20 gallons. Their design also made it easier for a person to carry and pour from the heavy jars (they weighed as much as 80 pounds when empty).

Can mountains shoot up overnight?

Even the fastest-sprouting mountains, built from volcanic lava, took at least a decade to form, says geologist Nathan Niemi of the University of Michigan. In Parícutin, Mexico, for example, a mountain grew 1,391 feet between 1943 and 1952. "A small volcano just erupted for 10 years straight and in the end left this mountain standing there," Niemi says. "That's probably the closest you can come in terms of an instantaneous process." He adds that although asteroid impacts can't build actual mountains, they can create a large dif-

ference in elevation—like the 600-foot-deep Meteor Crater in Arizona—within minutes.

Most mountains are created by collisions between Earth's tectonic plates and are formed over millions of years. These plates never move faster than a few inches a year, of which only a fraction goes into building a mountain. Mountains also affect the weather around them, bringing rain and snowstorms that lead to erosion. Many are therefore in a steady state of equilibrium, getting torn down as fast as they rise.

Volcanic eruptions constantly change the height of Sicily's Mt. Etna.



How did the heavy elements form?

Cosmologists consider the 116 elements that come after hydrogen and helium on the periodic table to be “heavy” elements. The vast majority of these were formed after the big bang by nuclear reactions inside stars.

An element becomes heavier as its atomic mass—the sum of neutrons and protons in its nucleus—increases. The “light” elements, hydrogen and helium (along with a small amount of the heavier lithium) were formed by nuclear reactions during the big bang. The elements beryllium, boron and most of the lithium that exists are probably continuously produced by the breakdown of heavier elements or by the collisions of cosmic rays with interstellar carbon, oxygen and nitrogen. The rest of the elements are produced inside stars and released into space as the stars die.

Young and middle-aged stars generate a number of heavy elements by nuclear fusion, such as when three helium nuclei fuse at incredibly high temperatures to form one carbon nucleus. Fusion, the process that fuels stars, can create all of the elements up to iron, but the 92 elements heavier than iron are mostly created by a process called neutron capture that takes place inside dying stars.

Neutron capture occurs when an element takes up free-floating neutrons into its nucleus. The capture makes the element unstable, and it releases energy in the form of radiation to stabilize itself. When this process transforms a neutron into a proton, the element’s atomic number increases by one, turning it into a heavier element. Xenon, for example, captures neutrons to become cesium.

Low-mass stars like the sun live for billions of years, becoming red giants toward the end of their lives. They produce heavy elements in a relatively slow process, known as s-process, of neutron capture as they die. More-massive stars live for only a few million years and go out in the blaze of huge supernova explosions. In the lead-up to the supernova, these stars run out of hydrogen to fuel fusion in their core and start burning heavier elements instead. Eventually the stars burn iron in their cores. As these unstable cores collapse, large quantities of free neutrons are created, and several of these neutrons can be taken up simultaneously by lighter elements in the rapid process (r-process) of neutron capture. The supernova explosions that follow produce and eject heavy elements like gold and platinum into the interstellar gas.



Trans-fatty acids are found in popular foods like french fries.

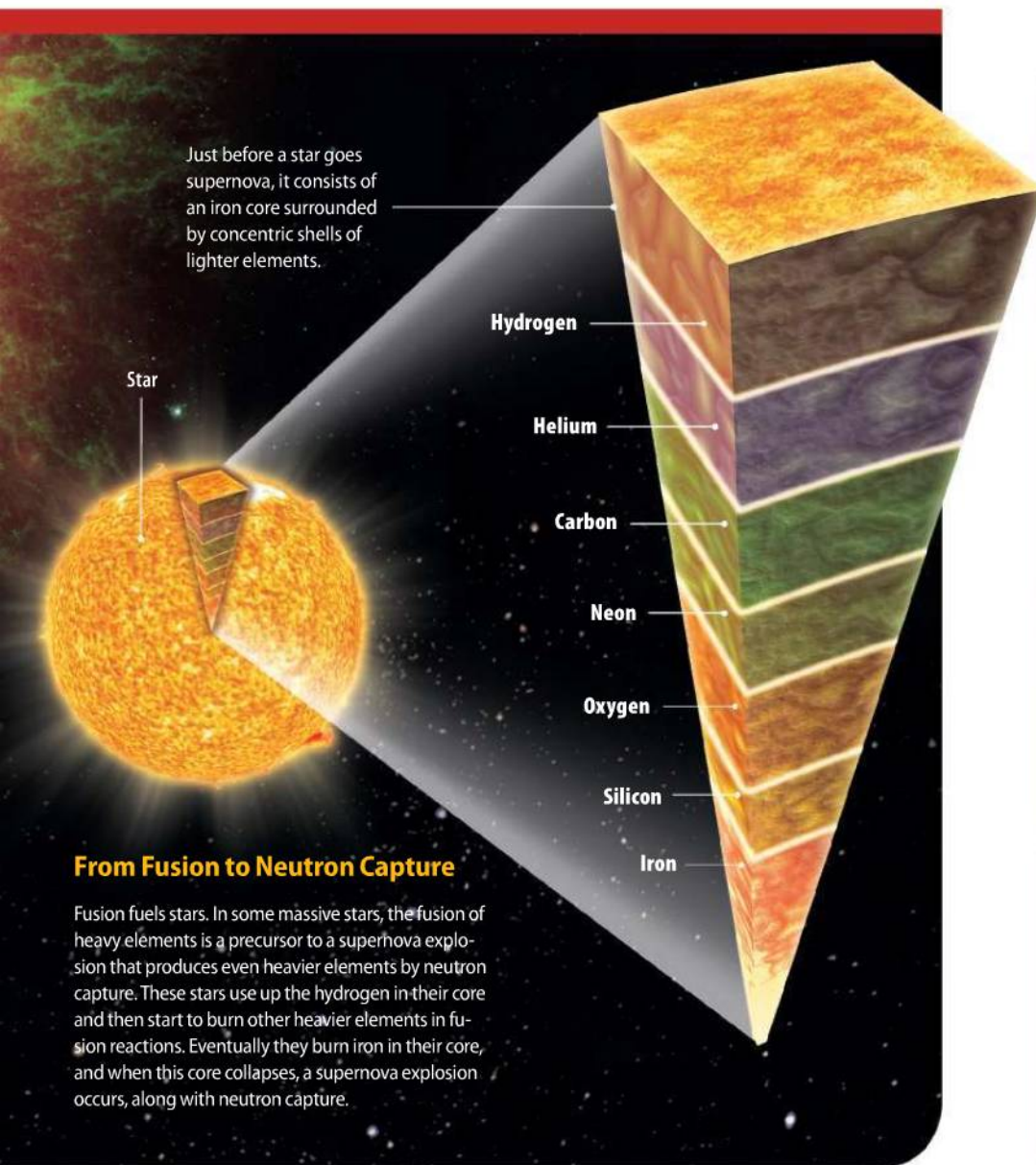
Why are trans fats so unhealthy?

Most of the trans-fatty acids found in fast foods and packaged snacks are artificially created by the partial hydrogenation of unsaturated fats—those that contain a double bond between carbon atoms. This process creates a single twist in the trans fats’ chemical structure and transforms liquid fatty acids into an artery-clogging semisolid.

Artificial trans fats also turn the blood’s “good” cholesterol, or high-density lipoprotein, into “bad” cholesterol, or low-density lipoprotein. Plus they can cause inflamma-

tion and affect fatty-acid metabolism. It’s no surprise, then, that eating these fats is associated with increased risk of coronary heart disease, atherosclerosis, stroke, cardiac death and possibly Type 2 diabetes.

Because of the harmful effects of trans fats, the Food and Drug Administration ruled in 2006 that nutrition labels should indicate their content. New York City and Denmark, among other places, have passed legislation to eliminate trans fats from restaurants and food supplies.



Just before a star goes supernova, it consists of an iron core surrounded by concentric shells of lighter elements.

Hydrogen
Helium
Carbon
Neon
Oxygen
Silicon
Iron

From Fusion to Neutron Capture

Fusion fuels stars. In some massive stars, the fusion of heavy elements is a precursor to a superhova explosion that produces even heavier elements by neutron capture. These stars use up the hydrogen in their core and then start to burn other heavier elements in fusion reactions. Eventually they burn iron in their core, and when this core collapses, a supernova explosion occurs, along with neutron capture.

WHO ...?

Who discovered oxygen?

Oxygen was first discovered in around 1772 by the Swedish chemist Carl Wilhelm Scheele, although Joseph Priestly, an English chemist, independently discovered it in 1774 and published his findings before Scheele. Soon after, the French chemist Antoine-Laurent Lavoisier identified oxygen's role in respiration and combustion.

Who invented the cannon?

The Chinese concocted the recipe for early gunpowder in the 9th century and used it in the first crude cannons. By the late 14th century, Europeans were using powerful modern cannons, initially called bombards, as weapons.

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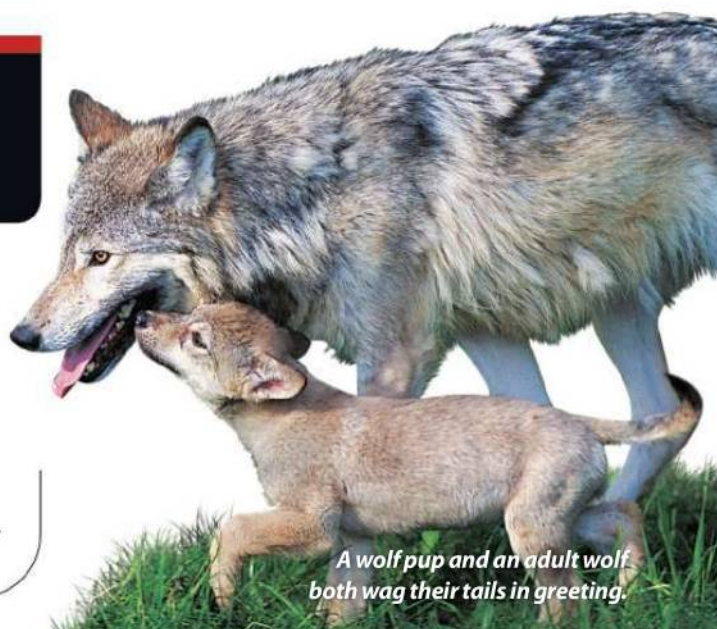
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Are dogs the only animals to wag their tails?

Nope. Tail wagging is an important form of communication among all canines, including dogs, wolves, foxes, coyotes and jackals.

Canines, particularly those that are social, communicate through a variety of howls, snarls and barks that are often associated with their body language. Along with tail wagging, other visual signals include ear movement, baring of teeth and raising areas of fur. These signals can indicate dominance, aggression or fear. A dominant wolf will stand erect and might signal its aggressive intent through curled lips, bared teeth and raised hackles. In contrast, submissive wolves hold their bodies low to the ground, often greeting dominant members enthusiastically by wagging their tails.



A wolf pup and an adult wolf both wag their tails in greeting.

Why do some salmon die after their first spawn?

Sockeye salmon often don't survive long after the trip to their freshwater birthplace.



The simple answer is that the perilous journey to their birthplace takes a fatal toll on the fish. Yet salmon that breed just once evolved from fish that breed multiple times, so "you also have to ask why salmon that die after one spawn have been favored by evolution," says biologist Thomas Quinn of the University of Washington.

Salmon live part of their life in the ocean or in lakes but return to the stream where they hatched to spawn. Many species die soon after spawning. Salmon hardly eat during their return upriver, and the fish use up energy reserves during this dangerous quest for reproduction. Their resistance to

disease breaks down, and they develop high levels of the stress hormone cortisol, all of which, Quinn says, may have some part in their death.

As for why salmon species that risk all their reproductive effort on one roll of the dice have evolved, part of the explanation, says Quinn, is that "a fish that tries to breed more than once must devote less energy to the present round of reproduction." Less energy equates to less success. For example, some repeat-breeding species swim away as soon as their eggs or sperm are released into the water, so their offspring are less likely to survive than those of one-off spawners that guard their nests until they die.

WHAT . . . ?

What's the Kelvin scale?

It's the international scientific standard for measuring temperature, named after the 19th-century Scottish physicist William Thomson, a.k.a. Lord Kelvin. The scale begins at absolute zero, or -459.67°F , the theoretical temperature at which a substance's molecules have the lowest energy.

What's the origin of the dollar sign?

According to one theory, the symbol evolved from the Mexican or Spanish sign "P's," which stood for pesos, the currency that we adapted into the dollar. The "S" eventually migrated over the "P" in written texts, resulting in the "\$" symbol.

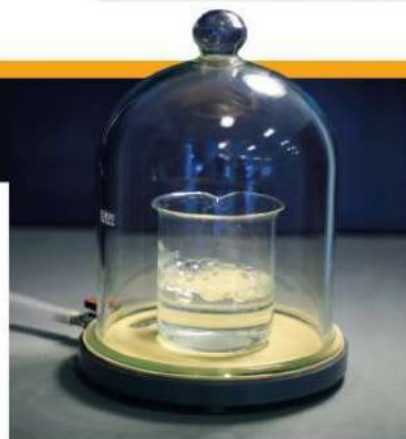
What is hypothermia?

Hypothermia refers to an abnormally low body temperature in a warm-blooded animal. Because the condition slows the body's vital functions, accidental hypothermia can be life-threatening. Artificially induced hypothermia, however, can reduce the body's need for oxygen and protect organs during some surgical procedures.

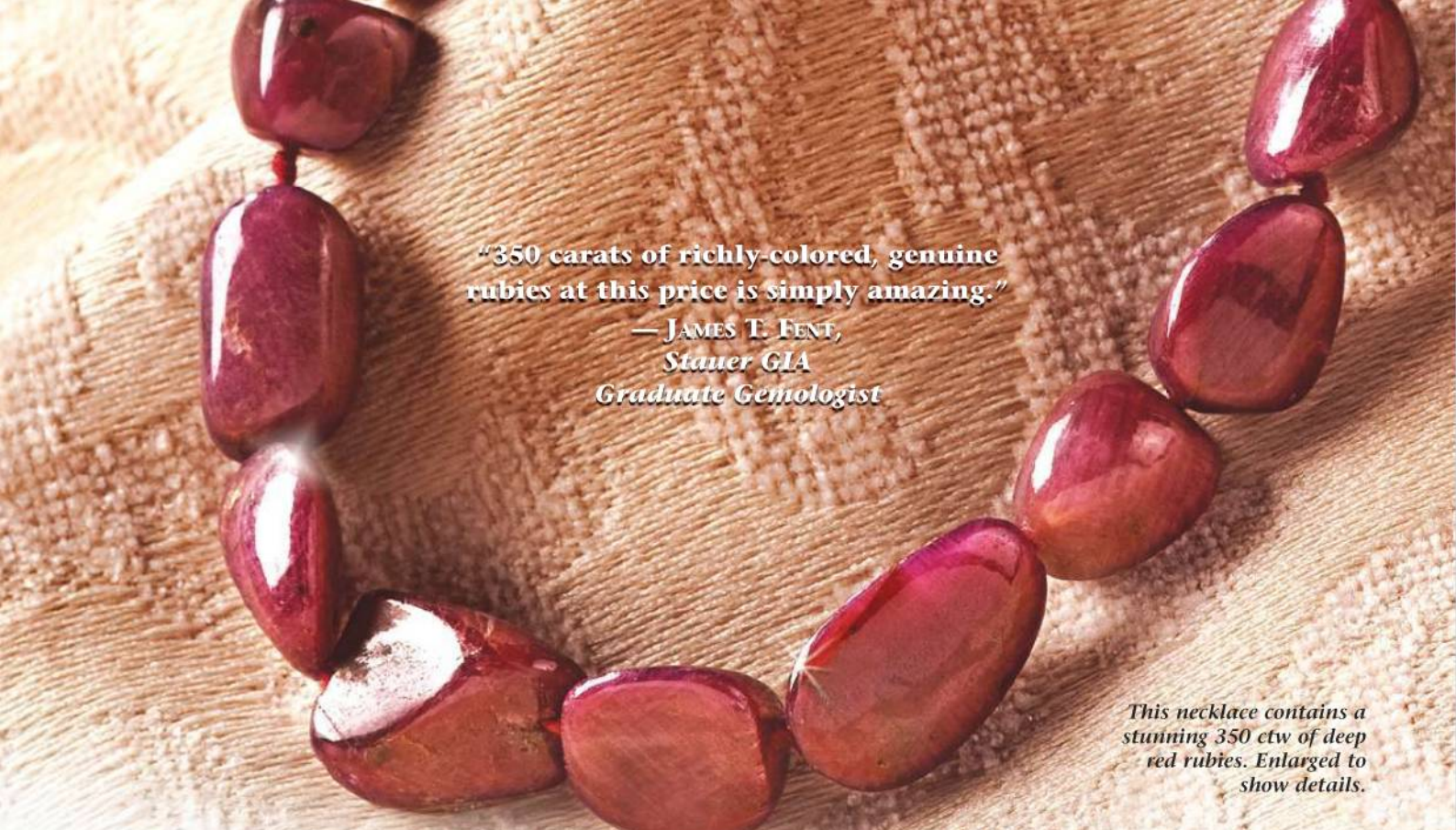
What happens to liquids in a vacuum?

Put a fluid in an airless environment, and it will start to boil vigorously as it tries to reach thermodynamic equilibrium. Why? For a liquid to be at equilibrium, its vapor pressure has to equal the pressure that is exerted on it from its surroundings. In a vacuum, the surrounding pressure is extremely low, so liquids must evaporate to reduce their vapor pressure in an effort to reach equilibrium.

Evaporation also causes liquids to cool down, so after boiling they will often freeze and turn into solids. For example, once water in a vacuum cools to a certain temperature—dependent on pressure, surface area and heat flow—it will change to ice. The frozen solid often turns directly into vapor in a process called sublimation, as the ice continues its attempt to reach thermodynamic equilibrium.



Nature's search for equilibrium drives the behavior of water in a vacuum.



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Why are tropical flowers so colorful?

Bright hues attract pollinators like hummingbirds, which prefer red flowers.



Flower color depends on the means of pollination, and animal pollinators, which are plentiful in the tropics, prefer colorful blossoms. Most of the world's flowers are pollinated by insects and birds (although other creatures, such as bats and lizards, may play a role). Different animal pollinators are attracted by certain colors in flowers. Wasps like brown flowers, for example, whereas nighttime pollinators like moths and bats are attracted to strongly scented pale or white flowers.

Most daytime pollinators, including

butterflies, bees and birds, seek brightly colored flowers. Birds see a similar range of colors as we do, but their eyes are most sensitive to red hues, so bird-pollinated flowers tend to be bright red or orange. These flowers also attract some butterflies, but most butterflies and bees are blind to red light. Instead, they are particularly sensitive to yellow, blue and ultraviolet light. Bee-pollinated flowers thus tend to be blue or yellow and may have additional features that are visible only under ultraviolet light.

WHERE ... ?

Where do most earthquakes occur?

Most of the world's earthquakes occur in the circum-Pacific belt, a circular zone in the Pacific Ocean that coincides with tectonic-plate boundaries and follows several island chains. The belt's numerous volcanoes are the origin of its nickname, the Ring of Fire.

Where do stem cells come from?

It depends. Stem cells are unspecialized dividing cells. Embryonic stem cells are derived from cells in developing embryos; adult stem cells are found in tissues like the skin's epidermis, bone marrow and the lining of the small intestine.

Where is the moon's water located?

Under the entire lunar surface, with the most quantity at the poles. Three spacecraft recently revealed water molecules in the top quarter-inch or so of the moon's soil throughout its surface. A subsequent NASA probe found more water in a crater near the moon's south pole.

How does a smoke alarm work?

Smoke detectors are triggered by changes to the electrical current that runs through them. The devices come in two basic varieties: photoelectric alarms and ionization alarms. The first type uses a light-sensitive photoelectric cell. A light source causes the cell to constantly generate a current. If the light is interrupted by smoke particles, the circuit breaks and the alarm sounds. Another type of photoelectric detector will detect the rays from the light

source only when they are scattered by smoke particles. This generates a current and sets off the alarm.

Ionization detectors use tiny amounts of a radioactive material to ionize the air molecules between a pair of electrodes, allowing the air between the electrodes to conduct electricity. Smoke particles entering the space between the electrodes attach themselves to ions and reduce the flow of current, setting off the alarm.



Smoke alarms go off when their electrical circuits are either disrupted or induced by the presence of smoke.

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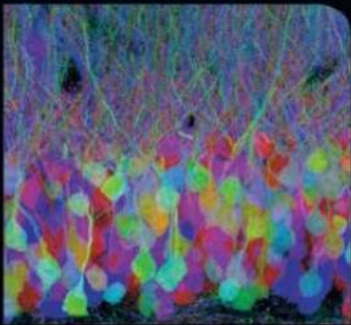
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How Are We WIRED?

Cutting-edge imaging techniques are creating the first circuit diagram of the brain. With billions of neurons, and trillions of connections between them, it's going to take some of the most innovative minds in neuroscience to see it all

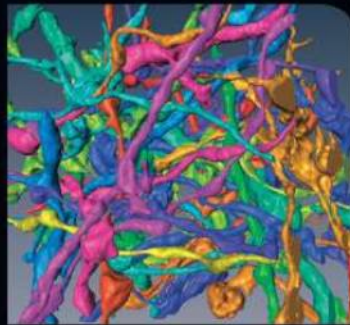
1



How do the brain's connections form?

Developmental neurobiologist Jeff Lichtman tracks how the brain's wiring changes during development.

2



What do the brain's circuits look like?

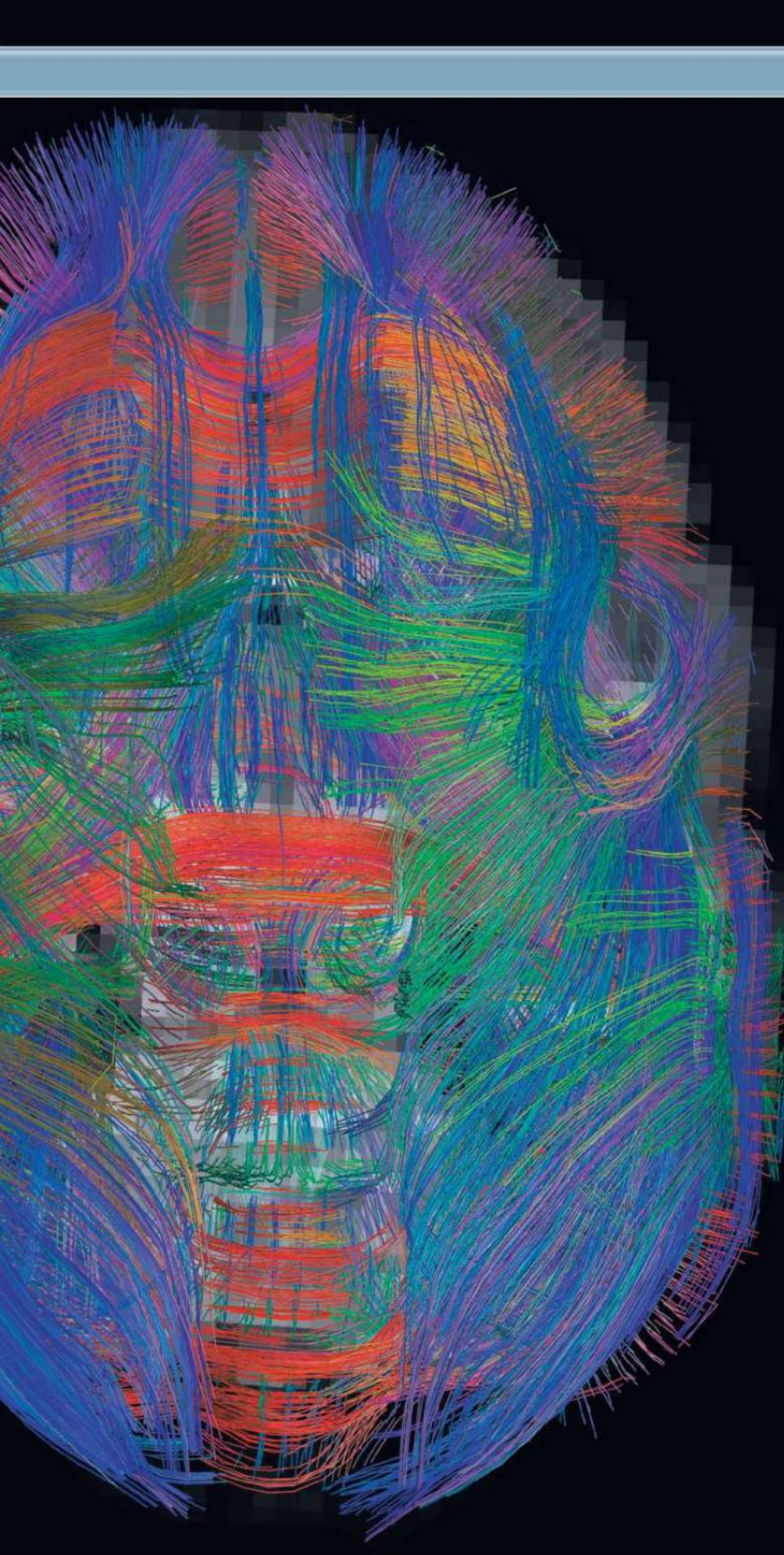
Neurobiologist Winfried Denk maps the activity and structure of the brain's neuronal circuits.

3

How are the different regions of the brain networked?

Imaging scientist Van Waden tracks the connections between different areas of the brain.

A composite of neural pathways in the brain of an owl monkey



Ever since individual nerve cells were first imaged in the late 1800s, biologists have tried to understand how these cells give the brain its incredible abilities. We now know quite a bit about nerve cells, or neurons, and how they generate and transmit signals. We can also pinpoint the roles played by many regions of the brain. But the more we learn, the clearer it becomes that the brain is more than just the sum of its parts.

Researchers are now investigating the bigger picture—how the connections between individual neurons and between different brain centers allow our brain to function the way it does. For example, although we know where visual stimuli are processed, we have less understanding of the physical path visual information takes from the eyes to the visual centers, or the connections between these centers and other regions of the brain that allow us to interpret what we see and react to it. As a key step toward grasping how the brain functions, scientists are using a variety of new techniques to map how it is wired.

The Connectome Takes Shape

Several of the world's leading biologists are interested in mapping the brain's connections. But the challenge is colossal. The human brain is a tremendously complicated

The connectome of a tiny muscle in a mouse's neck



1 How do the brain's connections form?

Jeff Lichtman, a developmental neurobiologist at Harvard University, studies how the brain's wiring changes as we learn. He hopes that studying the structural changes in

the brain will eventually show him how information is encoded in our wiring. "Where is your memory of your grandmother—how is that arranged, what does it look like?" Lichtman asks.

One imaging technique he uses, called thin-section-scanning electron microscopy, uses a diamond knife to shave slices of tissue from a rotating mouse brain. The slices are fixed onto a plastic strip prior to microscopy. Afterward, the path of each individual nerve cell must be traced. Initially researchers did this by manually identifying the same cells in different slices, but Lichtman and his colleagues at Harvard and the Massachusetts Institute of Technology are working on computer algorithms to speed up the process.

Jeff Lichtman studies the connections between neurons.



▲▲ A Mouse Neuron Tree

In February 2009, Jeff Lichtman's lab imaged the entire network of neurons that control the movements of a mouse muscle, chosen for its relatively simple connections. The researchers genetically modified mice to express yellow fluorescent protein in nerves that control muscles. A computer created 3-D stacks of images just 0.2 micron thick. Nerve connections from about 150 stacks were identified and manually aligned to form the final model. Each muscle neuron was then given a distinct color, ranging from red, signifying the largest number of muscle-fiber connections, to blue, representing the smallest number.

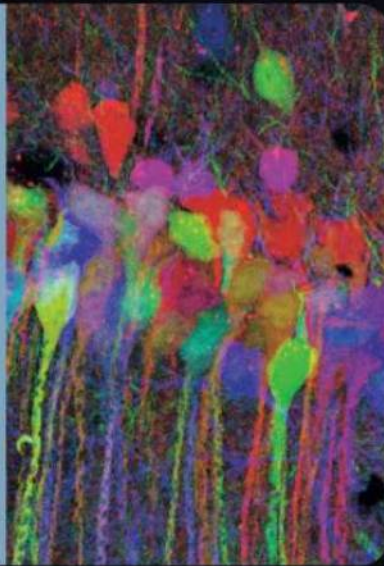


Plastic Brains

Researchers cut thin slices from mouse brains and affix them to plastic strips before imaging them with an electron microscope. Neurobiologist Bobby Kasthuri displays a strip of the plastic.

Brainbow of Neurons

In the Brainbow technique, mice are genetically engineered to produce yellow, blue and red fluorescent proteins in neurons. The colors combine to mark individual neurons in about 100 hues in images like this one, from the hippocampus region of a mouse brain. The method allows researchers to quickly distinguish and follow the path made by each neuron.



Lichtman also relies on optical microscopy, which he has used to map the nerve fibers controlling a muscle in an adult mouse ear. Axons—fibers that carry signals away from nerve cells—had to be manually traced between different three-dimensional stacks of images, a task Lichtman calls “sobering.” The first tracing of ear axons took six months.

Advancements to an imaging technique first developed by Lichtman’s team in 2007 have recently helped simplify the task of tracking individual nerve fibers. In this method, dubbed Brainbow, a snippet of DNA with genes that code for random amounts of yellow, blue and red fluorescent proteins in nerve cells are inserted into mice. By manipulating DNA, researchers can give individual neurons different colors. The colors

allow them to determine which synapses—the junctions where axons transmit their signals to other cells—correspond to which axons.

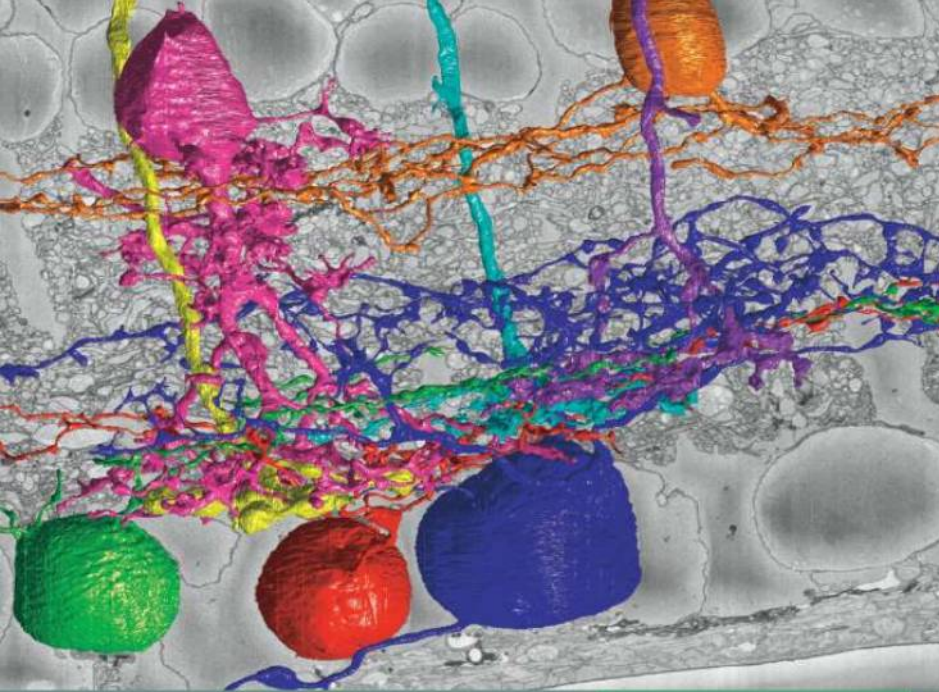
The real advantage to understanding the brain’s connections, Lichtman believes, may come from connectomics, or the ability to find patterns in the wiring. Connectomics offers a way to investigate thought disorders, such as mental illnesses and learning disabilities, that may be caused by wiring errors. In his latest research, Lichtman tracked the nerve connections in an ear muscle of a juvenile mouse using Brainbow. When he looked at only a few axons, “it was just a massive tangle of wires,” he says. But after imaging all the axons, connectomics revealed a strict arrangement, with each axon usually connecting to only one other axon.

organ, containing billions of neurons that form trillions of connections with one another. Many scientists are starting their work on smaller brains, like those of mice and rabbits, before they tackle human ones. Still, the task demands that researchers automate existing analytic techniques to run like an assembly line. They will also need to create technologies to attack the problem in new and more effective ways.

Currently scientists have two basic approaches to choose from—one uses microscopy and the other magnetic resonance imaging. Microscopy provides detailed insights into individual neurons’ connections to one another. The downside is that it can be used to study only a tiny part of the brain at a time, so it provides little insight into connections between various parts of the brain. Using a variant of the classic MRI scanner, however, researchers can study large parts of the brain, or even the entire brain at once, but without much detail. Although individual neurons cannot be distinguished from one another with this method, scientists can study them as bundles of nerve cells. Each method has its own advantages and limitations, and it is only by using both and combining results that researchers will be able to get a complete picture of the brain’s structure.

Researchers have already begun to draw a map of the brain’s neural pathways, dubbed the connectome. Interest in this field is increasing rapidly thanks to the promise it holds for understanding many conditions that may have their origins in abnormal brain connections, such as schizophrenia, autism and learning disorders. If scientists can find the underlying causes of these disorders, they may be able to develop new and more effective ways of diagnosing, treating, or even preventing them.

Researchers also hope the connectome can reveal how the brain’s network changes as we develop from birth. The plasticity of the human brain’s wiring is one of its greatest strengths, and scientists hope to learn more about how we learn and adapt as we grow. Ultimately, brain researchers want to



2 What do the brain's circuits look like?

Winfried Denk, a physicist and neurobiologist at the Max Planck Institute for Medical Research in Heidelberg, Germany, used to study the movement and activity of nerve cells. But he became frustrated by the lack of a more fundamental understanding of the brain's connections.

Working toward this understanding, Denk now uses a technique called serial block-face scanning electron microscopy, in which a diamond knife cuts thin slices off the top of a block of tissue. By imaging the block with an electron microscope while going through the tissue section by section, Denk is able to reconstruct the entire block in 3-D. He stains the tissues with heavy-metal atoms to identify nerve fibers within each block, but the difficulty comes in tracking them across blocks. Denk's latest efforts have focused on using computers to take over this arduous task. A major strength of the technique is that Denk can first image nerve-cell activity with one type of microscopy and then figure out the circuitry responsible for it by imaging the same sample with serial block-face scanning.

Reconstructing the Retina

In a rabbit retina, bipolar cells [here, yellow, aqua and violet] transmit electrical signals to ganglion cells [dark blue], which make up the optic nerve that carries visual information to the brain. Amacrine cells [pink, orange, green and red] send signals between ganglia.

Winfried Denk uses his scanning electron microscope to examine brain slices.



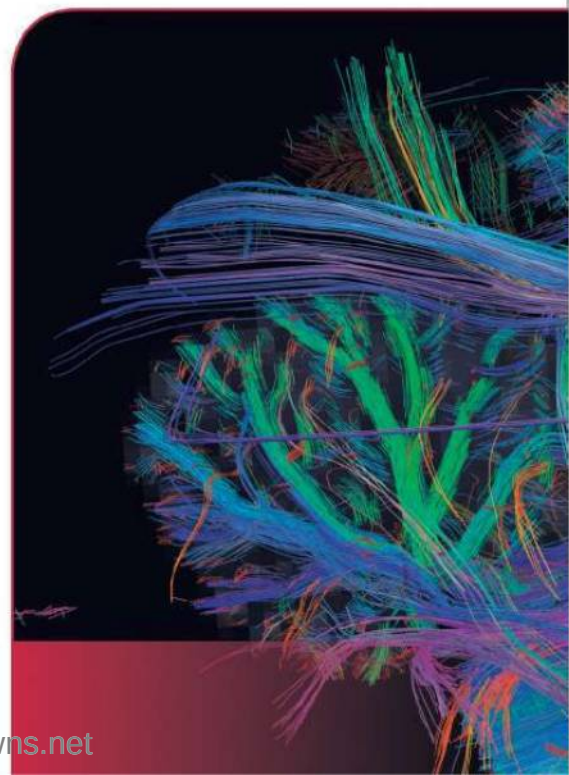
understand how the organ stores information and how its wiring influences our personality and behavior.

Mission Impossible?

At first glance, it might seem impossible to map the brain's incredibly complex network. But by joining forces, research teams could achieve results far more quickly than expected. To this end, the National Institutes of Health launched the Human Connectome Project last July. This \$30-million effort aims to combine a variety of imaging technologies to systematically map the brain's wiring. Researchers will collect information on the connections of a healthy adult human brain, and the data will be freely available to the research community, forming a basis for future studies. The project also aims to develop a combination of noninvasive tools that might allow healthy brains to one day be compared with those of people with neurological disorders, to look for clues about the source of these abnormalities.

The mapping, which is one of three NIH neuroscience challenges, will also provide information about higher-level organization and patterns in the brain. That could help us understand how the connections between billions of neurons give rise to a single conscious mind. ■

FROM TOP: WINFRIED DENK; VOLKER STEGER



How are the different regions of the brain networked?

to find differences between brains, but to identify previously unknown anatomy, Wedeen uses brains from human or animal cadavers, which he leaves in the scanner for days at a time. These images have a resolution of a hundredth of an inch. According to Wedeen, diffusion-sensitive MRI will have a central role in the NIH's Human Connectome Project. He would like to image hundreds of healthy human subjects to fulfill the project's goal of developing a circuit diagram of the brain's wiring. This, he hopes, would eventually allow him to scan for neurological problems, including psychiatric disorders and autism, that currently can't be detected by MRI.



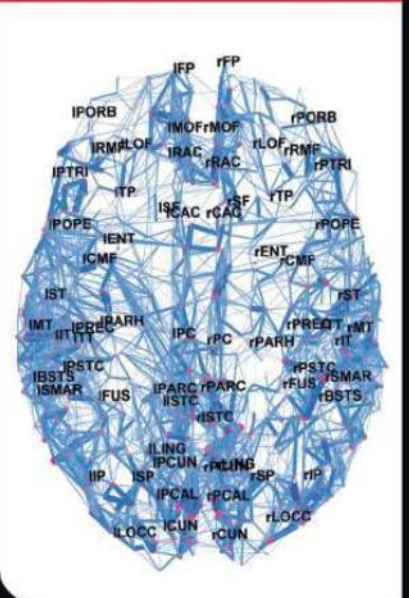
Experimental MRI equipment allows Van Wedeen to scan the brain faster.

Vision's Long Path through the Brain

Using high-angular-resolution diffusion MRI scans like this one, Van Wedeen can use the movement of water molecules in nerve fibers to track the path of the fibers. This image shows nerve fibers crossing a virtual slice of an owl monkey brain. The colors represent the direction of each fiber, with the x, y and z axes in red, green and blue, respectively, and all other colors representing diagonals. The blue arc toward the top left relays visual information from the optic nerves [hidden behind the green-orange bundle, bottom right] to the visual cortex toward the back of the brain. The green treelike structures are the pathways of the cerebellum, which coordinates rapid muscle responses to sensory input.

Highways and Byways

MRI scans show that the brain's network connections are organized around three or four hubs consisting of many interconnected subregions. A map of the network of nerve connections among different anatomical subsections is shown here in a human brain.





Thousands of leatherback turtles visit the sandy coasts of French Guiana every year, making it one of the best places to observe ...

The Journey of the SEA GIANT

PHOTOGRAPHS BY OLIVIER GRUNEWALD



TS



BY THE LIGHT OF THE MOON

Female leatherbacks take advantage of high tide during full and new moons to help ride onto the beach.



▲ MAKING LANDFALL

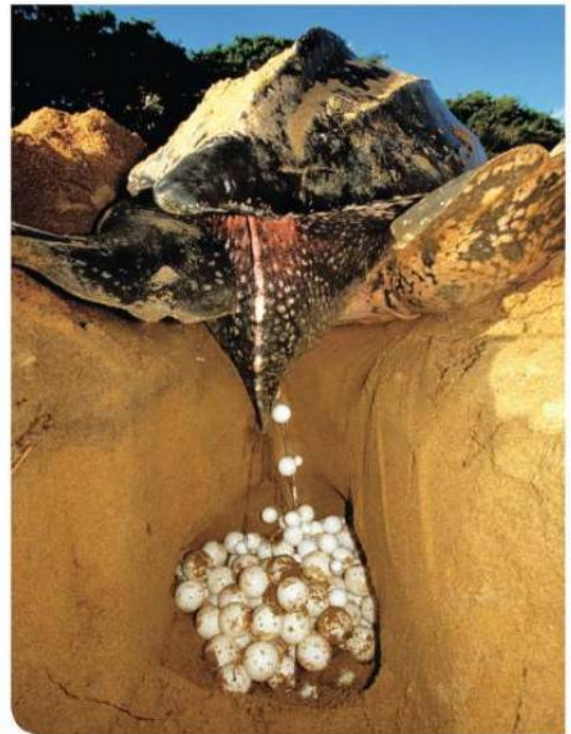
The turtles nest on soft-sand beaches because rocks can damage their thin skin and namesake leathery shells. They aim for steeply sloping coasts near deep water, which make beach landings easier.

For millennia, leatherback turtles have been coming ashore to nest on the secluded beaches of French Guiana on the northern coast of South America. These sands, which the reptiles visit nightly from March to August, make up one of the most important nesting sites for *Dermochelys coriacea*, the largest turtles in the world. The beaches at Awala-Yalimapo hosted 6,421 nests in 2007, according to Jacques Fretey, a herpetologist at the National Museum of Natural History in Paris who has studied Atlantic leatherbacks for more than three decades.

These reptiles are powerful swimmers, ranging as far north as Alaska and as far south as Argentina. They crisscross both the Atlantic and the Pacific oceans—leatherbacks tagged by researchers in French Guiana have been recaptured in Morocco and Spain. The turtles spend almost their entire lives at sea, venturing onto land only during the nesting season.

Leatherbacks mate at sea, near the beach where the females will later come ashore. Adult females nest only once every two or three years, laying dozens of round, fat eggs in pits dug with their flippers. They then carefully fill up the holes, hiding the entrance from predators such as stray dogs with a scattering of sand. ▶





▲ OUT OF HARM'S WAY

Female leatherbacks lay clutches of roughly 80 eggs in nests some 30 inches deep. They may do this as many as 11 times during a season, typically at 9- to 10-day intervals.

▲ NESTING INSTINCT

Once the females choose a site above the high-tide line, they use their wide front flippers to sweep the sand clean. They then dig down with their curved back flippers.

The turtles are ancient mariners, having survived for more than 100 million years, but today they are critically endangered. In 2004, researchers warned that their numbers may have declined by as much as 97 percent in the Pacific since 1982. Industrial fishing and ocean pollution remain big threats to leatherback populations around the world. The U.S. Fish and Wildlife Service estimates that only 26,000 to 43,000 females now nest annually worldwide, a dramatic decline from 115,000 in 1980.

Here on the beaches at Awala-Yalimapo, local and foreign volunteers are doing what they can to help. Patrols monitor the leatherbacks the moment they land on the beach, significantly reducing the dangers the gentle giants face from hungry predators. ■

PORTFOLIO CONTINUES ►►

BREAKING FREE

Following two months of incubation, a hatchling emerges, tearing its egg's membrane with the beak on the end of its snout. Adults can reach eight feet long and 2,000 pounds, but newborn leatherbacks weigh less than two ounces. They measure just two to three inches from nose to tail, with front flippers as long as their bodies.



KEEPING COOL

Just below the surface of the sand, the baby turtles wait for dusk, when the temperature is lower, before hitting the beach. The sun can be fatal, killing them by dehydration or sunstroke.

**DIGGING OUT**

After they hatch, newborns abandon their nest and begin tunneling upward simultaneously using their tiny flippers. This process goes on for four or five days.





PATH TO THE SEA

Emerging from their hole in the sand, the hatchlings spread out and struggle toward the sea, drawn by the reflection of the moon and stars on the water.

DANGERS ABOUND

Stray dogs from nearby villages often eat eggs and hatchlings. Volunteer patrols have reduced such threats in recent years.

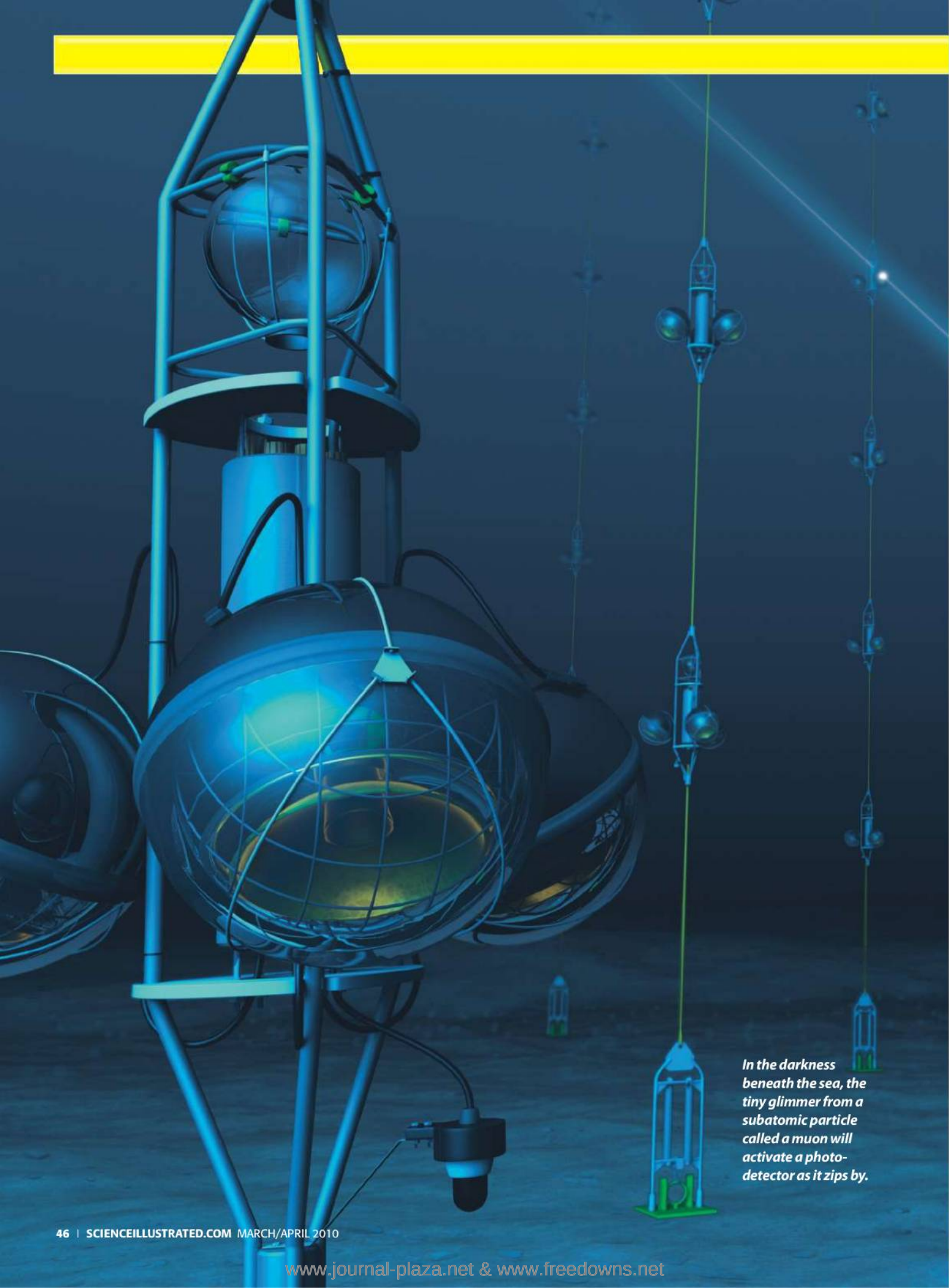
Adult leatherbacks feed largely on jellyfish, yet jellies that have washed ashore may be obstacles for young leatherbacks as they cross the beach.



**PERILOUS JOURNEY**

A newborn leatherback escaping to the waves may face an attack from predators, including black vultures, great horned owls, yellow-crowned night herons, ghost crabs and requiem sharks. Only one of every 500 to 1,000 hatchlings reaches adulthood, making each one a precious commodity.





*In the darkness
beneath the sea, the
tiny glimmer from a
subatomic particle
called a muon will
activate a photo-
detector as it zips by.*

Searching the Depths

A telescope on the seafloor of the Mediterranean will help scientists study neutrinos, hard-to-spot subatomic particles that can shed light on some of the greatest mysteries of the cosmos

Photo detector

How Telescopes Catch the Elusive Neutrino

Neutrinos rarely interact with ordinary matter and can pass right through large celestial objects like the sun and the Earth. But occasionally a neutrino collides with an atomic nucleus and is transformed into a particle that can be detected, such as a muon. The faint light in the wake of a muon's passing can be picked up by photodetectors.

Muon

Atomic nucleus

Neutrino

At the bottom of the Mediterranean Sea off the coast of the French port of Toulon, at a depth of just over 1.5 miles, sits a most unusual telescope. It is impossible to see daylight there, let alone anything in the night sky. Yet this is the home of a powerful optical device. Called ANTARES (Astronomy with a Neutrino Telescope and Abyss environmental RESearch), it studies the cosmos by staring down, not up. Its detectors face the center of the planet and scan for traces of some incredibly small and mysterious particles called neutrinos. Studying the data from these elusive cosmic visitors could give astronomers a new perspective on some of the most violent events in the universe.

A Ghostly Mystery

Neutrinos are tiny juggernauts, barreling through walls, mountains, planets and stars as if these giant impediments were not there. This is one of the characteristics that make them so interesting to astronomers.

How do neutrinos manage to travel where other particles can't? Unlike most other subatomic particles, neutrinos possess no charge and almost no mass, so electromagnetic forces cannot divert the neutrinos' flight paths, and the particles are only slightly affected by gravity. This means neutrinos rarely interact with the other particles zooming around the universe—on their way through Earth, only about 1 in 10 billion neutrinos smashes into and reacts with a particle such as a proton or neutron, while the others just fly on by.

But those rare reactions can tell us a lot. When a neutrino interacts with another particle, for instance in the

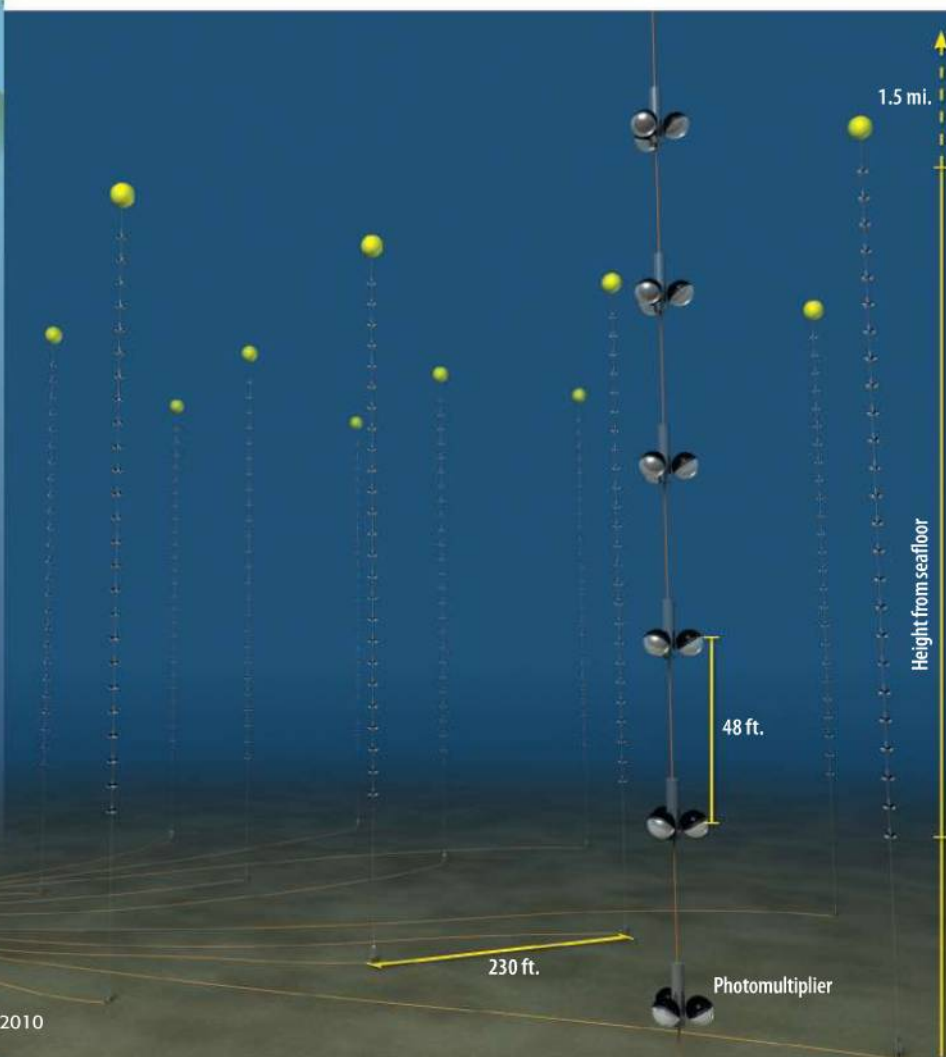
nucleus of an atom, it reveals characteristics about itself, such as the direction it came from and which of three possible forms it was in when it got here. Scientists can use such clues to determine where and how it was produced and what it encountered on its trip.

Neutrinos are released by some of the most powerful events and objects in the cosmos, such as supernovae and black holes. But our observations of even these spectacular moments are often limited, as strong gravity, intervening planets, and clouds of gas and dust can make it difficult or even impossible for light and other particles from these events to reach us here on Earth, and what does make its way to our planet can tell us only so much. The neutrinos themselves, however, are able to avoid these obstacles on their way to our planet. When they arrive, they can provide information about the cosmic event that birthed them.



900 Detectors at the Bottom of the Sea

The ANTARES detector array rests on the Mediterranean seafloor off the coast of France at a depth of about 1.5 miles. Researchers installed 12 upright cables, each of which is 1,476 feet long and approximately 230 feet apart. The cables have 25 levels, 48 feet apart. At each level, there are three optical modules containing photomultipliers—highly sensitive cameras that will pick up and amplify the slightest glimmer of light created as a neutrino interacts with another particle—making a total of 900 in the array. A 25-mile-long cable links the detectors to the coast.



Super-K helped to prove that neutrinos have mass.

The Solar Neutrino Problem

Scientists had long been baffled by what was known as the “solar neutrino problem”—the number of neutrinos from the sun detected here on Earth were far fewer than what was expected based on our knowledge of the sun’s interior. The problem was first identified in the 1960s, when American physicists Raymond Davis, Jr., and John Bahcall installed a tank holding 100,000 gallons of a dry-cleaning solvent containing chlorine in an abandoned gold mine in South Dakota. When a neutrino strikes a chlorine atom, the chlorine is transformed into radioactive argon, so the device worked by simply counting the argon atoms.

Davis and Bahcall observed just two or three neutrinos a week, a fraction of what was expected. To explain this lack of neutrinos, scientists first proposed

that they had been wrong about the conditions in the interior of the sun—that the temperature or pressure was lower than they had believed—but research over the next decade showed that their solar models had been correct all along. This meant they must have been wrong about neutrinos.

Some physicists hypothesized that neutrinos could oscillate between three “flavors,” called electron, muon and tau neutrinos. Small particles, such as neutrinos, can also behave like waves. Neutrinos might come prepackaged as multiple waves, scientists suggested, which allows a neutrino to spontaneously switch flavors as it travels through space.

The South Dakota detector, like those that followed it, was focused on finding electron neutrinos. But in 1998, researchers from Canada’s Sudbury

Neutrino Observatory, which could detect electron neutrinos, and Japan’s Super-Kamiokande detector, which could detect but not distinguish among all three flavors, teamed up to determine whether neutrinos were oscillating on their way from the sun to Earth. If solar neutrinos didn’t change from electron neutrinos to other flavors, then Sudbury and Super-K would detect the same numbers of neutrinos; if they did change, Super-K would detect more neutrinos. Super-K overwhelmingly detected more neutrinos than Sudbury, proving that electron neutrinos produced by the sun indeed oscillated among flavors on their journey to Earth. Not only that, but the result also proved the hotly debated hypothesis that neutrinos do, in fact, have mass. Particles with no mass would not be able to change flavors.

But they also present a challenge: A particle that can pass through a planet unimpeded can be extremely difficult to capture and observe with conventional astronomy tools.

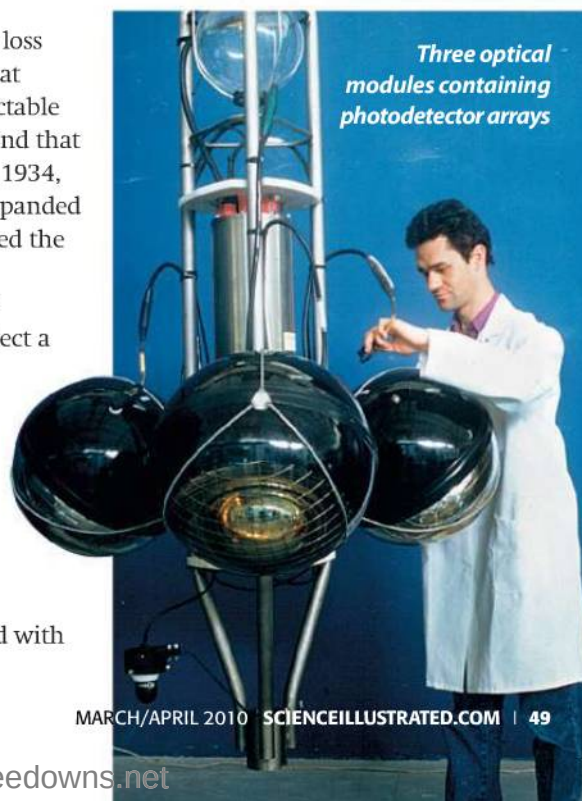
The Neutrino Theory

For decades, neutrinos were purely theoretical. The Austrian physicist Wolfgang Pauli first posited their existence in 1930 to explain a puzzling aspect of beta decay, a process in which an atom’s nucleus emits or captures an electron or emits a positron. Researchers studying beta decay knew that the end result of the process must possess the same amount of matter and energy as the atom it started with. But in experiment after experiment,

beta decay seemed to result in a loss of energy. Pauli hypothesized that there was an additional, undetectable particle involved in beta decay and that it carried the missing energy. In 1934, Italian physicist Enrico Fermi expanded on Pauli’s explanation and named the mystery particles neutrinos.

But it wasn’t until 1956 that scientists finally managed to detect a neutrino. American physicists Frederick Reines and Clyde Cowan installed a 105-gallon tank containing a mixture of water and cadmium chloride at the Savannah River Plant in South Carolina. When a neutron from the plant’s reactor entered the tank and collided with

Three optical modules containing photodetector arrays



the proton at the center of a hydrogen atom, it created a positron and a neutron. That neutron then reacted with other subatomic particles in the tank and they emitted photons—flashes of light that were recorded by Reines and Cowan's detectors. This specific series of events, in the energy ranges expected to produce the proper subatomic particles, proved that neutrinos did exist.

Over the next five decades, physicists used similar detectors to study neutrinos from nuclear reactors and particle accelerators here on Earth, as well as those bombarding the planet from extraterrestrial sources such as the sun. Experiments at CERN, the European center for particle physics in Switzerland, and the Brookhaven National Laboratory and Fermi National Accelerator Laboratory in the U.S. showed that the neutrino came in three forms, or "flavors": the electron

neutrino, the muon neutrino, and the tau neutrino. (Each neutrino is named after the particle that produces it.) Until recently, scientists debated whether neutrinos had mass or not, but further research has since proven that, because of the particles' ability to oscillate among flavors after their creation, they do have slight mass [see "The Solar Neutrino Problem," preceding page].

Where Do Neutrinos Come From (and Why Do We Care)?

Two confirmed astronomical sources of neutrinos are supernovae and our own sun, and neutrino observation has deepened our understanding of both. One of the best-known events in the history of neutrino astronomy was the observation in 1987 of a supernova, known as 1987A, in the Large Magellanic Cloud. Supernova 1987A was so bright that even from 160,000 light-years away it could be seen on Earth

with the naked eye. Astronomers detected its neutrinos three hours before they were able to see its light, allowing researchers to learn more about the earliest stages of the star's explosion. Of the estimated 10^{58} neutrinos emitted by the supernova, just 24 were detected on Earth.

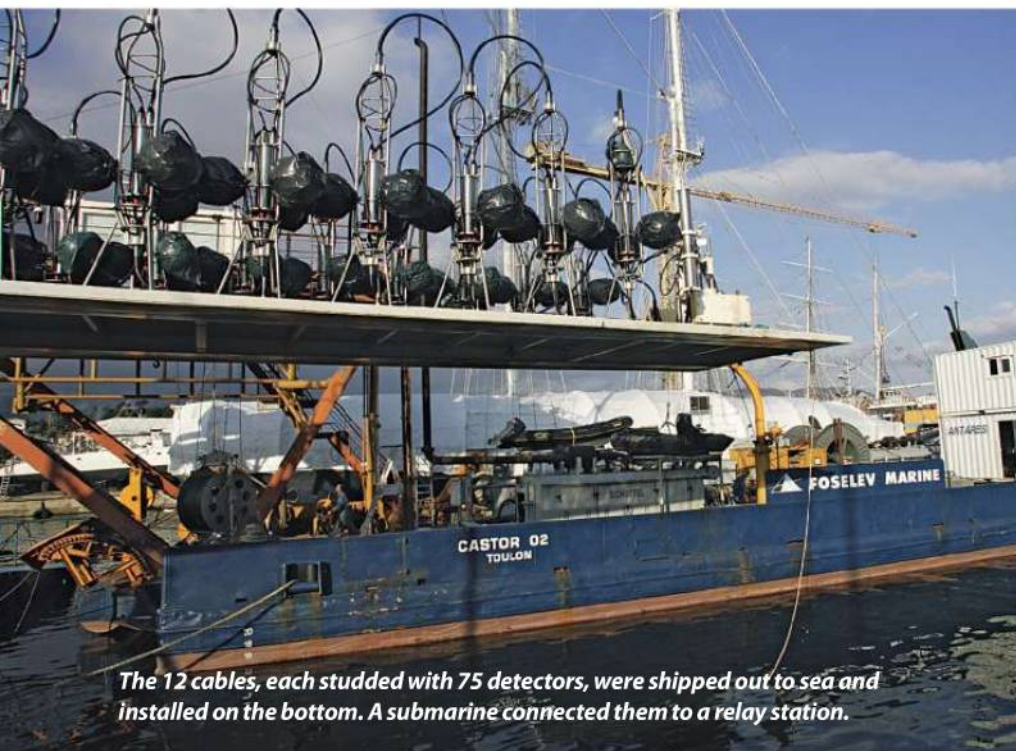
Solar neutrinos from the sun's core arrive at our planet more quickly and more directly than solar photons originating in the same spot. That gorgeous sunlight you see outside? Those photons are more than a million years old. The particles we see as visible light and detect as radio waves and x-rays require that amount of time to travel from the sun's core to its edge, bouncing off gas molecules as they go. Neutrinos, however, can pass straight through the various elements within the sun's core, taking just eight minutes from the moment of their creation to travel from the core to Earth's atmosphere and carrying with them important information about the reactions inside the sun.

Now scientists hope telescopes will help them locate more neutrino sources—and learn more about the inner workings of the universe in the process. Candidates for neutrino observation include black holes, which cannot be observed visually, and gamma-ray bursts, bright explosions which may prove to be the origin of the mysterious charged particles known as high-energy cosmic rays.

Neutrino astronomy could even help unlock the mysteries of dark matter—the "missing" matter in the universe whose gravitational pull affects the movements of stars and perhaps entire galaxies, but that scientists cannot thus far directly observe. Scientists believe there is at least 50 times as much dark matter as ordinary matter in the universe. One hypothesis proposes that dark matter consists of heavy, slow-moving particles known as weakly interacting massive particles, or WIMPs. WIMPs, which would have little interaction with other matter beyond gravity, are thought to collect in the cores of stars,

ANTARES may collect information about black holes in distant galaxies, as well as about supernovae like SN 1987A, the remnants of which are shown here.





The 12 cables, each studded with 75 detectors, were shipped out to sea and installed on the bottom. A submarine connected them to a relay station.

where they would cause particles to decay and emit neutrinos.

A Ray of Light

Like Reines and Cowan's original neutrino detector, the ANTARES telescope finds neutrinos by detecting the traces they leave behind. The particles it searches for are muons created by muon neutrino interactions. But muons can also be created by cosmic rays entering the atmosphere, so ANTARES uses Earth itself as a gigantic filter to eliminate cosmic rays from the equation. Each of its 900 photomultipliers is pointed down toward the seafloor and, beyond that, to the other side of Earth. As a result, the scope will see only the results of particles that can pass through Earth's core unscathed. Located in total darkness, ANTARES consists of 12 floating cables tethered to the bottom to which the researchers have attached the photomultipliers—these capture even the slightest glimmer of light generated by a passing neutrino.

Those weak glimmers of light arise when particles created by neutrino collisions pass through the water. Because the speed of light in water is 75 percent slower than the speed of light

in a vacuum, these undersea particles created by the collisions are able to move faster than light. As they zip past, the particles excite the electrons of the surrounding water molecules; the excited electrons emit photons as they return to their unexcited states, leaving a trail of light along the particles' path, known as Cherenkov radiation.

ANTARES, which was completed in May 2008 after two years of construction, is situated in the Northern Hemisphere, and the neutrinos it observes are primarily coming from the Southern Hemisphere's sky. The IceCube Neutrino Observatory, currently under construction at the South Pole, will correspondingly view neutrinos from the Northern Hemisphere. IceCube is similar to ANTARES but with one important difference: Its photomultipliers will be frozen in the Antarctic ice about a mile beneath the surface. Still other detectors are being built underwater, all in a bid to capture neutrinos.

With a December 2009 announcement from scientists working in Minnesota that they might have detected WIMPs, the data from telescopes like ANTARES, IceCube and their brethren is keenly anticipated. ■

ANTARES Investigates a Deep-Sea Mystery

There are many deep-sea animals that emit light, so researchers were aware in advance that the detectors on ANTARES would pick up short flashes from fish and other creatures swimming by. But it came as a surprise when in 2006 they detected a diffuse but lasting light at the bottom. Christian Tamburini, a marine biologist at the University of the Mediterranean in France, was called in to consult and found that the light most likely came from a strain of luminescent bacteria in the water.

During the following year, the quantity of light detected by ANTARES from deep-sea bacteria had declined to just one tenth of the initial level. Biologists are now working to determine why the bacterial luminescence decreased during that time period. Instruments to measure the water's temperature, oxygen level and current velocities cling to ANTARES's cables, and Tamburini and his team are working on methods to measure microbial vital signs, such as respiration, in the deep sea.



Luminescent marine animals give biologists a glimpse at deep-sea life.



DNA Daredevils

From building better crops to fighting disease, genetic engineers are changing our world

Genes are the instructions to make proteins, which are responsible for almost all of the processes that keep organisms alive. In 1973, biochemists Stanley Cohen of Stanford University and Herbert Boyer of the University of California at San Francisco first transferred genes for antibiotic resistance into *E. coli* bacteria. These early pioneers of genetic engineering may not have imagined how influential their work would become. These days, genetic engineering techniques are used, for example, to insert genes from other organisms into bacteria, which then churn out proteins that produce hepatitis-B vaccine and insulin for diabetics. Botanists genetically modify crops to boost hardiness and nutritional value.

Yet geneticists do more than bestow organisms with new characteristics. They also manipulate DNA to study the role of individual genes. Scientists add, delete, or modify genes, thus altering the corresponding proteins' structure or levels in the cell and revealing the genes' role.

Researchers have tinkered with the DNA of organisms as varied as mammals, birds, fish, insects, worms, plants, fungi and bacteria. These studies have given scientists invaluable insights into how the human body functions and why disease arises. Which genes predispose us to breast cancer and which protect against heart disease? Which genes allow a bacteria or virus to cause illness? Identifying these genes can pro-



Bacterial DNA is injected into eggs of the Indian meal moth, an agricultural pest.

vide targets for new antibiotic and antiviral drugs. Further, gene therapy could someday allow us to cure diseases like cystic fibrosis and some cancers by replacing defective genes. Genetically engineered microbes could produce new biodegradable polymers or clean up radioactive wastes. Although we've sequenced the complete genomes of many organisms—humans included—we still don't understand what all those genes do. As our quest for knowledge continues, the role of genetic engineering will only expand. ■

Four Ways to Manipulate Genes

Amplify a characteristic

PURPOSE: To learn more about a gene's role in an organism

SOLUTION: Manipulate or add an extra copy of the gene to increase its activity.

CASE STUDIES: Overexpression of a gene responsible for a cell's ability to respond to a protein called epidermal growth factor is associated with most cancers. This finding has led to the development of anti-cancer drugs that target the expression of this gene.

Delete a characteristic

PURPOSE: To learn more about a gene's role in an organism, this time by seeing what happens when the gene is removed

SOLUTION: Scientists remove or replace the normal functioning version of the gene.

CASE STUDIES: Deleting certain genes in mice has shown how their absence affects disease. Knocking out genes like PINK1 or DJ-1, for example, can lead to Parkinson's symptoms in mice, providing an animal model to study the disease.

Modify a characteristic

PURPOSE: To identify the specific sequence of DNA that is responsible for a gene's function

SOLUTION: A mutated gene is inserted into an organism. The gene produces a modified protein.

CASE STUDIES: Modified genes may explain how enzymes bind to other molecules. Angiotensin-converting enzyme, for example, plays a role in heart function and diabetes. Protein sequences allow the enzyme to bind to ions, which helps to regulate its activity.

Map a characteristic

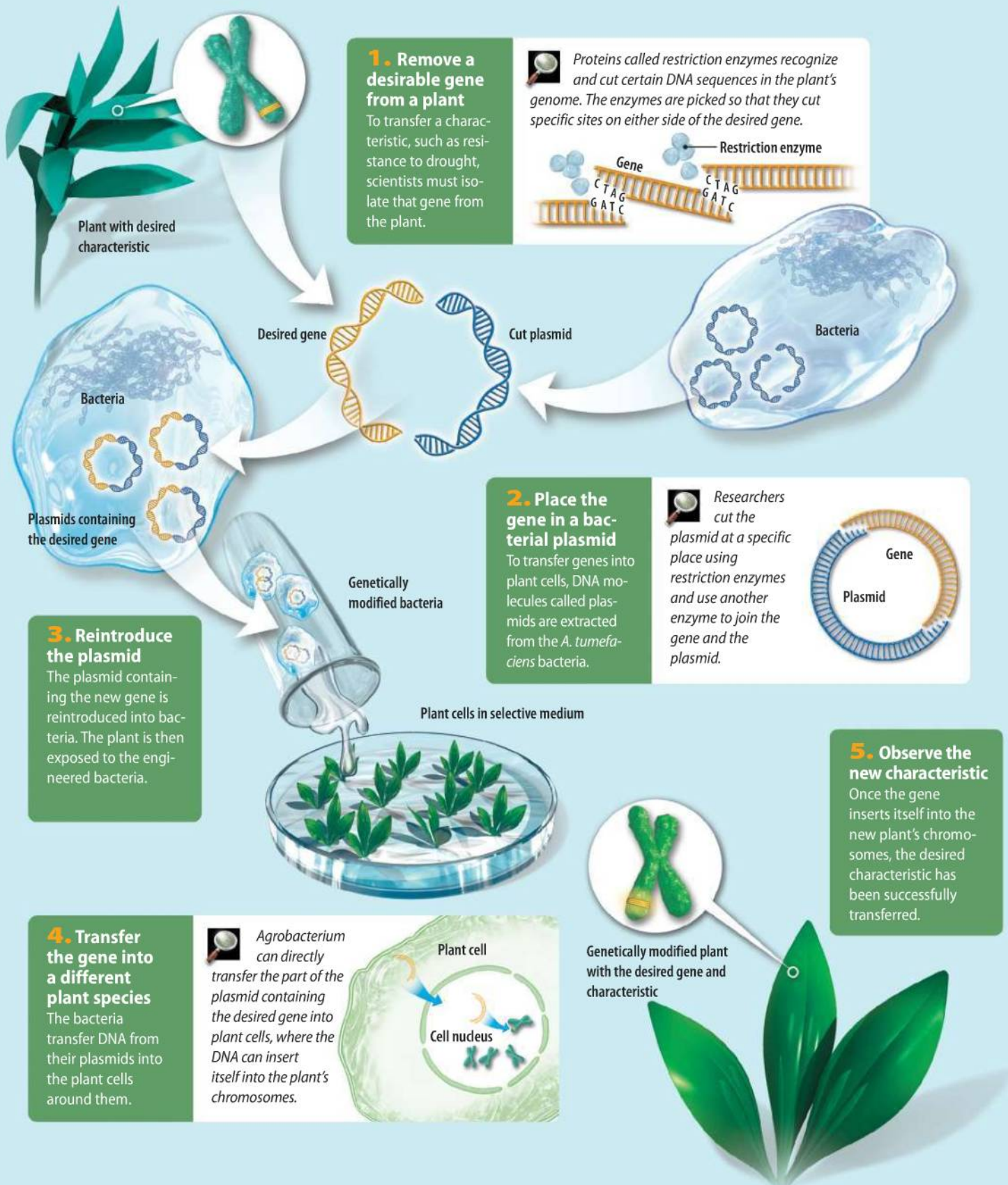
PURPOSE: To understand the activity of a gene and its protein

SOLUTION: A "marked" gene is transferred into an organism's cells.

CASE STUDIES: Proteins of marked BRCA1 genes, whose mutation can increase the risk of breast and ovarian cancer, were found in the cells' mitochondria. BRCA1's presence there may be important for its function in suppressing tumors, because cancer is often associated with mutated mitochondrial DNA.

Using Bacteria to Engineer Plants

Plant geneticists often use a bacterium called *Agrobacterium tumefaciens* to transfer a desirable characteristic from one species to another. Here's how:





Fly Factory

Flesh-eating screwworm flies once caused tens of millions of dollars in damage to livestock annually in the southern U.S. We profile a factory in Mexico that breeds sterile flies to keep history from repeating itself

Workers prepare screwworm flies for egg laying in a factory in Tuxtla Gutiérrez, Mexico. The plant can produce as many as 500 million sterile flies per week.



A factory in the southeastern Mexican city of Tuxtla Gutierrez is hard at work churning out an unusual product: bugs. Sterile screw-worm flies (*Cochliomyia hominivorax*) have been bred here since 1976 as part of a U.S. Department of Agriculture eradication program.

In the wild, female screwworm flies lay as many as 400 eggs near open wounds on animals. The maggots that develop use two needle-sharp, hook-shaped mouthparts to burrow deep into the



1. Flies lay their eggs in cages in the reproduction room. The lighting is adjusted to simulate night and day.



2. The maggots that hatch from the eggs are fed a mixture that includes dehydrated beef blood, eggs and milk.



3. The maggots are placed in sawdust, where they mature into pupae within five days.



animal's flesh. The swarm of screw-worms can consume so much tissue that the victim is virtually eaten alive from within.

Screwworm flies, which are found in most tropical regions around the world, were first documented on Devil's Island off the coast of French Guiana in 1858. From there they spread throughout the warmer regions of the Americas, and by the first half of the 1900s, the parasites were wreaking havoc on livestock in the southern U.S. Texas alone suffered \$10 million in losses in 1935.

By the late 1940s, scientists were aggressively seeking a method to control the flies. In the early '50s, USDA entomologists Raymond C. Bushland and Edward F. Knipling developed a technique to irradiate the flies, rendering them sterile. Sterile males released into the larger population would mate—but not breed—with fertile females. Female screwworms mate only once, so with no offspring, the species would gradually die out. At first, Bushland and Knipling's theory faced widespread skepticism. But experiments like a 1953 trial on the Caribbean island of Curaçao, in which the screwworm was successfully eradicated after the introduction of sterilized males, vindicated them.

Sterile males were introduced in Florida in 1957, and by 1966, the pests were eradicated in the U.S. To keep the flies from reentering the South from Mexico, the Agricultural Research Service branch of the USDA opened the Tuxtla Gutierrez factory, which at its peak produced billions of sterile flies every year. By 1991, screwworms were wiped out in Mexico and, since then, in all of Central America. (In South America and the Caribbean islands, the financial toll of screwworms is still more than a billion dollars annually.) Last May, the ARS opened a new factory in Pacora, Panama. The plant produces 40 million flies a week to maintain the Central American eradication, while the Mexican factory serves as a backup source. ■

4. The pupae are collected and blasted with radiation, sterilizing the developing flies inside the cocoon.

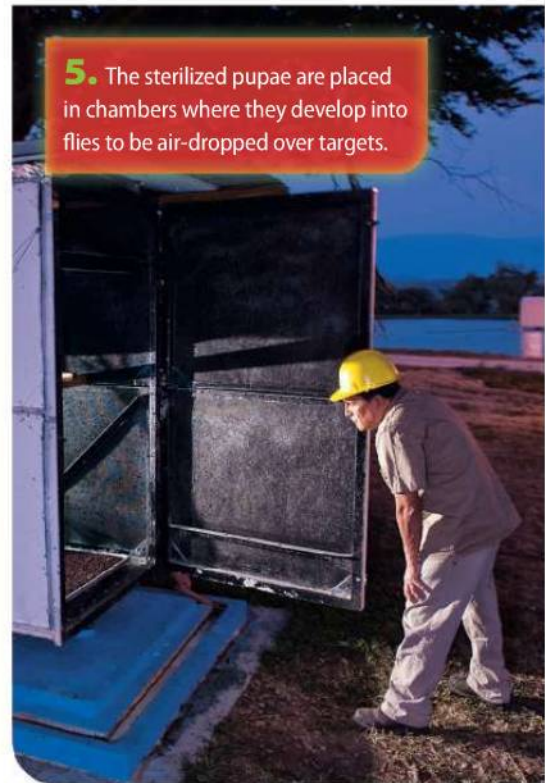


Keeping Screwworms South of the Border

USDA scientists hatched a plan to eradicate the screwworm by releasing sterile flies into the wild population in the 1950s. Since then, the "fly line" has slowly pushed southward. The U.S. eradicated the screwworm by 1966, and by 1991, Mexico followed suit. Now the line has been pushed to the northern border of Colombia. The "no-fly zone" there is broad enough to keep flies from reentering Central America and the U.S. (The map shows when the screwworm was eradicated from each country.)



5. The sterilized pupae are placed in chambers where they develop into flies to be air-dropped over targets.



A New View of the Milky Way

A powerful telescope finally gives us a good look at an elusive heavenly body: our own galaxy

Although we live inside it, astronomers know less about the Milky Way than they do about galaxies that are many more light-years away. In the midst of our galaxy's collection of roughly 400 billion stars, we aren't able to get a clear view of its structures. The Spitzer Space Telescope, launched in 2003, is changing that.

In other galaxies, seeing overall shape is the easy part, says Robert Benjamin, a physicist at the University of Wisconsin and a member of the Galactic Legacy Infrared Mid-Plane Survey Extraordinaire (GLIMPSE) project. "In the Milky Way, we can see the individual trees but it's hard to make out the forest." GLIMPSE, a Spitzer project, has mapped more than 100 million stars throughout a 130-degree swath of the Milky Way. An extension of the project, GLIMPSE360, plans to complete a 360-degree map of the spiral galaxy by next year.

Spitzer is the last telescope from NASA's Great Observatories Program, which charts the universe using various wavelengths of light (other missions include the Hubble Space Telescope and the Chandra X-Ray Observatory). Spitzer sees through cosmic dust and gas, which obscures much of the galaxy, and it's the most powerful infrared telescope ever launched.

Surprising Structures

The original GLIMPSE survey, completed in 2008, has revealed new information about our galaxy, including how and where stars form and the physical properties of interstellar dust. Most of these discoveries are about young, hot stars. Some of the most surprising findings about the Milky Way's structure, however, came from its much older stars: red giants. According to Benjamin, whose GLIMPSE work focuses on these stars, nearly all stars eventually go through a red-giant phase.

Red giants are particularly useful in determining the shape of the Milky Way because their distribution gives a good idea of the overall distribution of stellar mass throughout the galaxy (they constitute around 90 percent of the total stars in the GLIMPSE data). Certain red giants also have constant brightness and temperature, making them useful "standard candles" — stars that help astronomers determine distances between celestial objects.

Using red-giant distribution and distances from the GLIMPSE survey, Benjamin has confirmed two discoveries about the Milky Way that had not been widely accepted: that the galaxy has two bar-shaped concentrations of stars in its center, and that it has two major pinwheel-shaped arms.

The stars in our galaxy orbit around its center, just as planets orbit a sun. More than 60 percent of spiral galaxies have a high concentration of stars at their center. These stars have a long and narrow orbit, and that thin orbit creates a bright, dense bar of light. Astronomers previously believed that the Milky Way contained one bar, known as the Galactic Bar, although a small group argued that a second one existed. Benjamin's work gives strong evidence that our galaxy indeed has a second bar, called the Long Bar. The two have very different thicknesses and shapes and are pitched at a significant angle from each other.

Benjamin's other major finding supports the idea that the Milky Way has two major spiral arms rather than four. GLIMPSE data showed a greater density of red giants distributed throughout the Scutum-Centaurus and Perseus arms. The other spiral arms are still present, Benjamin says, but they are not as bright as previously thought.

"In the grand scheme of things, astronomers want to understand galaxies — how they form and how they evolve," Benjamin says. GLIMPSE is helping astronomers to not only better understand the structure and evolution of the Milky Way but also how other galaxies were created.

GLIMPSE revealed the Milky Way's two major spiral arms, as well as its two center bars.

Completing the Circle

Barbara Whitney, a physicist at the Space Studies Institute and the principal investigator for GLIMPSE360, says the next-level project will examine many of the same topics as the original GLIMPSE, including star formation and galactic structure. It will also complete a 360-degree view of the Milky Way. Collecting data may even prove easier than it was during GLIMPSE, according to Whitney, because the outer galaxy "is cleaner and easier to study. The inner galaxy has so much going on that it is sometimes harder to detect various structures."

GLIMPSE360 started collecting data last fall, and it will probably wrap up next summer. Whitney says analysis will quickly follow: "We should end up with some interesting surprises—GLIMPSE did, so 360 will as well. That's part of the fun." ■

OUR SOLAR SYSTEM

Spitzer cooled itself with liquid helium, but its supply has now run out.

Spitzer: Getting Warmer...

The Spitzer Space Telescope launched in 2003 with 95 gallons of -457°F liquid helium to cool its infrared scope and protect its scientific instruments from the heat of both the sun and the spacecraft. Last May, the coolant supply ran out, and the telescope's temperature has since risen by about 50° , causing nearly all of its instruments to stop working. Scientists have planned many missions for this warmer Spitzer that require only its two remaining functional cameras. Along with the GLIMPSE360 star

survey, Spitzer will also provide a more exact measurement of the Hubble constant—the rate at which the local universe is expanding—and will look at objects such as exoplanets, which circle stars outside our solar system. Spitzer is currently almost 75,000 miles away from Earth, and in about 2013, the telescope will be so far away that it will no longer be able to reliably communicate with us. In 2014, its successor, the James Webb Space Telescope, should continue Spitzer's infrared observations.



BURIED



The lush jungles of the Brazilian Amazon were once considered uninhabitable. But now researchers have found the remains of dozens of communities in the rainforest, along with traces of a man-made miracle soil that may have provided food for tens of thousands of inhabitants

Researchers have found ornate pottery at the same sites as fertile soil called terra preta.



Mysteriously rich soil may have made it possible for Amazon societies to exist 1,000 years ago.

CITIES of the Rainforest

In a letter to his wife sent on May 29, 1925, Percy Fawcett, an English adventurer, reported that he was about to depart on an expedition into previously unexplored areas of the Amazon jungle in central Brazil. His goal was to find a hidden city that he referred to as “Z.” It was Fawcett’s last contact with the outside world—he disappeared without a trace—and whether he succumbed to disease, human violence or animal attack is still unknown.

Now, more than 80 years later,

anthropologist Michael Heckenberger of the University of Florida and his team, in collaboration with local indigenous people called the Kuikuro, Brazilian scholars and a group of archaeologists, have discovered the remains of pre-Columbian settlements in the Upper Xingu region of the Amazon rainforest in Brazil’s Mato Grosso state, the same area where Fawcett disappeared. Fawcett may not have been right about the existence of a city, but the recent discovery of the settlements—28 in all,

estimated to have had a combined population of more than 50,000—is helping to overturn the long-held theory that the Amazon rainforest is unsuited to human habitation.

Other discoveries are also softening the Amazon’s hostile reputation. In recent years, researchers have found indications that about 1,200 years ago, natives were able to tame large areas of the world’s largest rainforest and transform its poor soil into lush orchards and fields that could feed tens of thousands of

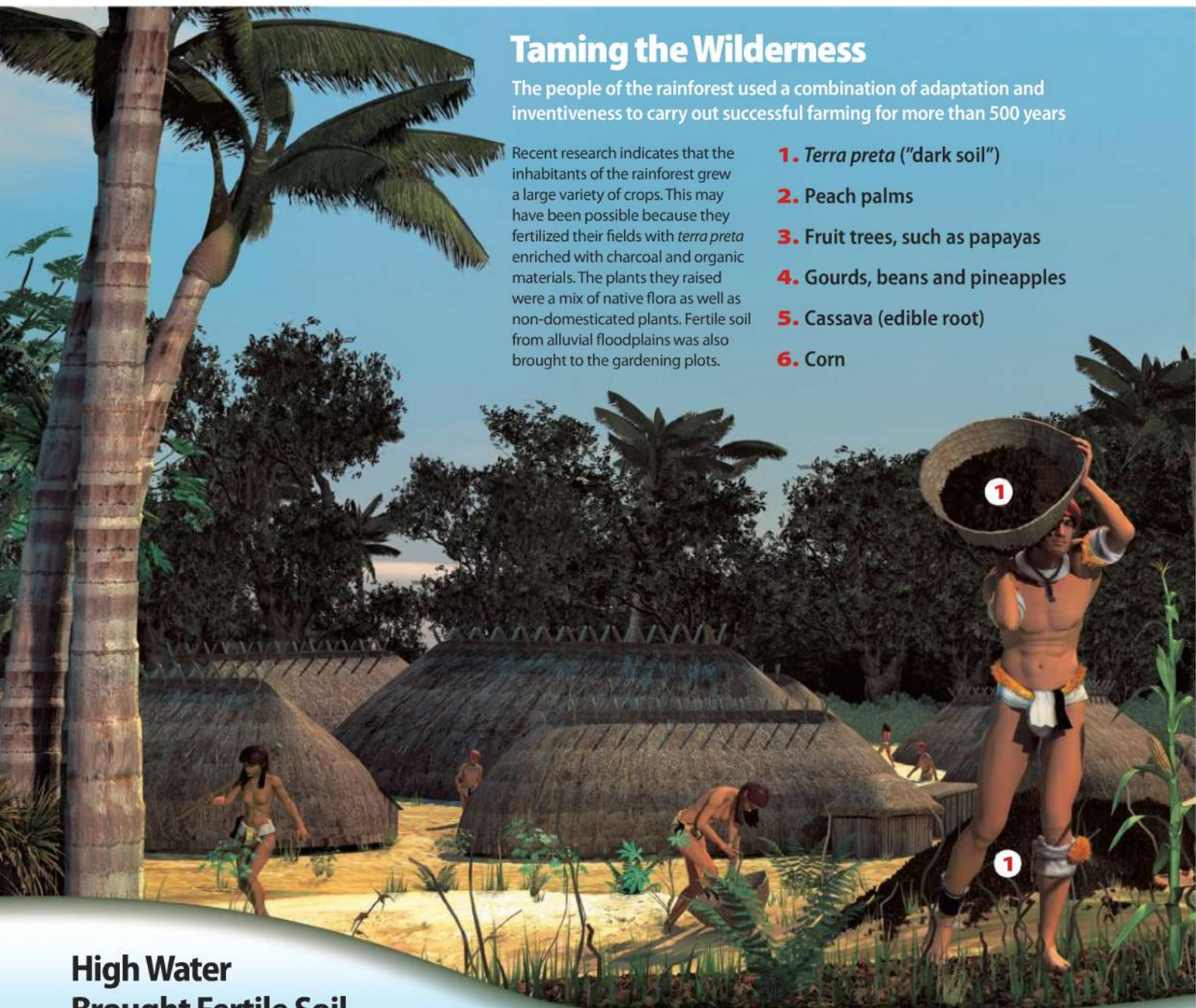
STORY CONTINUES ON P.64 ►►

Taming the Wilderness

The people of the rainforest used a combination of adaptation and inventiveness to carry out successful farming for more than 500 years

Recent research indicates that the inhabitants of the rainforest grew a large variety of crops. This may have been possible because they fertilized their fields with *terra preta* enriched with charcoal and organic materials. The plants they raised were a mix of native flora as well as non-domesticated plants. Fertile soil from alluvial floodplains was also brought to the gardening plots.

1. *Terra preta* ("dark soil")
2. Peach palms
3. Fruit trees, such as papayas
4. Gourds, beans and pineapples
5. Cassava (edible root)
6. Corn



High Water Brought Fertile Soil



White Rivers Nourished the Soil along Their Banks

The Amazon and its tributaries begin in the Andes mountains, and some of them are white-water rivers, which are full of nutrients. In the rainy season, these rivers overflow their banks and deposit their minerals on the floodplains, fertilizing the soil and making it suitable for agriculture.

River Silt Can Be Exploited for Six Months

Every year during high water, 3 to 4 percent of the Amazon basin lies underwater. This is an area almost twice the size of England. After the rainy season, during the six months until the next floods, the natives used the land that was covered with silt to raise crops like corn, rice and cassava.

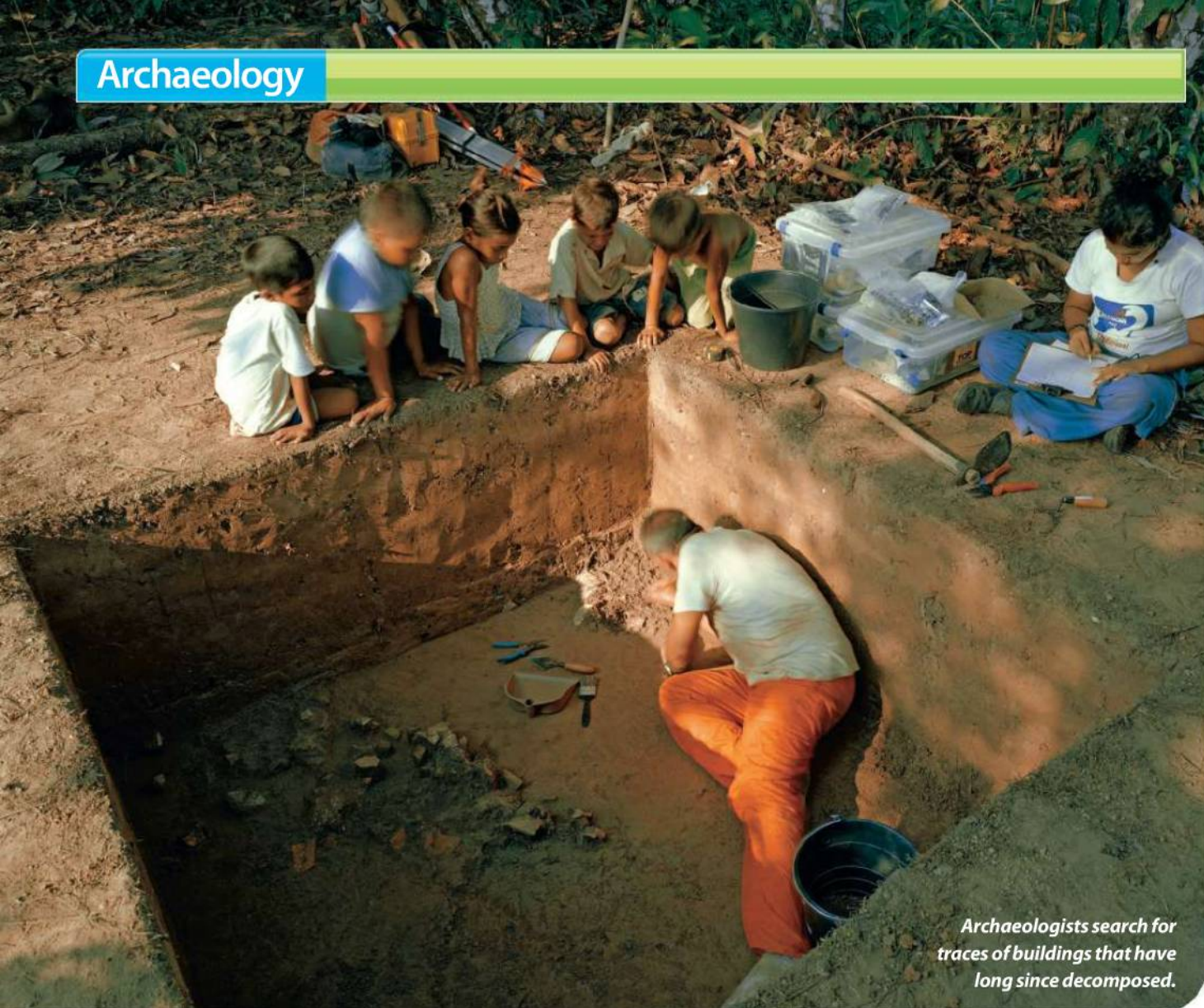


Fish Follow the Water Inland

During the approximately six months of high water each year, fishing became more difficult because the area of distribution of the fish became wider. Inhabitants of the forest survived mainly on crops harvested inland.

Mainland Was Fertilized with Terra Preta

The large areas of the Amazon rainforest that were never flooded were called *terra firme*, or mainland. The soils here were poor in minerals and, in some places, the farmers appear to have enriched the soil with *terra preta* so they could raise crops year-round. These fields were used for raising selected food plants.



Archaeologists search for traces of buildings that have long since decomposed.

Explorers Seek Ancient Towns

Areas of *terra preta* soil and other signs of settlements are being discovered between the Rio Negro and the Amazon and along the Xingu River.



people. This is one of the prerequisites for the potential development of any highly developed urban society.

The Amazon's rainforests cover approximately 2.3 million square miles—an area about twice the size of India—and are home to the world's richest plant and animal communities. But paradoxically, the soils here are highly acidic and contain few nutrients. About 10 percent of the rainforest's nutrients can be found in the soil; the rest are bound up in plants and animals. Only plants that are perfectly adapted to draw their nutrients from the closed cycle of life and death here can survive in the reddish or yellowish earth that dominates this area. They take up nutrients

and minerals from dead plants and animals before the rain can wash them away.

But some parts of the forest contain plots of Amazonian dark earth, also known as *terra preta*, which contains elevated levels of nutrients and organic matter perfect for agriculture in areas otherwise unsuitable for growing crops. The soil—a result of refuse piles usually including charcoal, fish bones, pottery fragments, animal bones, ashes and excrement—most likely correlates with important societal and cultural changes in the Amazon that allowed for the development of larger towns and villages.

This fertile soil is as deep as six and a half feet in fields sometimes as large as 50 acres. Researchers estimate that as much as 1 percent of the Amazon

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The Amazon has its source high up in the Andes mountains, and it carries with it white sediment that is rich in minerals.

Following the White Water

In the Amazon basin, there are limited places where it is possible to raise crops. Soil fertility depends on whether the river is white or black. The black-water rivers, the Tapajos among them, get their color from tannic acids from decomposing debris and carry almost no sediment. This means they cannot provide minerals to the riverbanks during the annual rainy-season flooding. But the white-water

rivers, which include the main channel of the Amazon, carry large amounts of sediment from the Andes mountains, and these enrich the land next to the streams.

From ancient times, settlements developed beside the white rivers, where corn, rice and cassava, among other crops, were raised during the six months between the end of one rainy season and the beginning of the next.

Towns may have once existed along this riverbank, which in the rainy season was covered by fertile sediment.



The rainforest floor has only a very thin layer of fertile soil because most of the nutrients are bound up in plants and trees.

rainforest is covered with it. The fertile pockets are concentrated near riverbanks, and some of these areas are still in use for growing crops, which develop at least twice as fast here as they do in other soils. One of the many miracles of *terra preta* is that it does not become depleted but retains its fertility for years.

Most of the plots are between 500 and 2,500 years old, and some researchers suspect that inhabitants of the area created and spread the rich soil intentionally. By exploiting *terra preta*'s extreme fertility, natives were able to put their previous existence as nomads behind them. Instead they settled in villages, surrounding themselves with green fields and groves of bountiful fruit trees.

Ancient Cities, Destroyed and Forgotten

Eduardo Neves, an archaeologist at the University of São Paulo in Brazil, has been studying these vanished cultures for 17 years, and from his discoveries in the Amazon forests, he is convinced that the jungle was relatively densely populated between 500 and 1,000 years ago. He suggests that at least five or six million people may have lived in the rainforest during that period. ▶



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Present-day natives have found hundreds of old pots in the ground. The pots were so well made that some are still functional.

Settlements comprised more than 1,000 people, Neves believes, yet the inhabitants left no mark on the archaeological record in the form of towns and buildings. In a region where stone was not available, they could only have constructed their homes and temples from wood, and as a result, the buildings would have long since rotted in the humid tropical climate. But in more than 100 locations in the region where the Rio Negro flows into the Amazon, Neves has found smaller relics of long-lost cultures. Among the finds are ceramic objects, including decorated and glazed figures, dishes, pots and large vessels able to hold more than 50 gallons of liquid. According to Neves, people who lived as nomads in the

rainforest would have neither made nor attempted to travel with such large containers. So the vessels were probably used for water storage in the towns where the people permanently settled.

The big question, then, is why such a large civilization disappeared. Researchers speculate that when the Spanish conquered Central and then South America in the 1500s, the natives had no innate resistance to diseases such as measles and smallpox, and huge numbers died from germs imported by the conquistadors. According to Neves's calculations, populations around where the Rio Negro meets the Amazon had mostly died off by the 1800s. ▶



Some of the ceramic vessels found were burial urns with human remains; others were used for food storage or cooking.

MARC STEINMETZ/VISUM/INA AGENCY

Reality forces us to recognize that whoever or whatever is the creator provided planet Earth for people to inhabit safely. In addition, that creator provided natural laws so that people would learn to conform to the functioning of those laws—gravitation, for example. The following text describes the creator's law that defines the *code of conduct* for mankind: a natural law that people unknowingly have long been ignoring to their detriment.



Richard W. Wetherill
1906-1989

Fortunately for us, that natural law was identified by the late Richard W. Wetherill, and he called it the *law of absolute right*. It states that ***right thoughts, words, and action get right results***. So the wrong results of people everywhere indicate they are not meeting the requirements of a natural law.

We find it helpful to think of natural laws as the creator's unseen hand, reaching into the affairs of men, women, and children, guiding their activities and teaching them that right action succeeds; wrong action fails.

Think about it. Are governments succeeding, are efforts to reduce crime succeeding, are programs to reform dysfunctional families succeeding, are huge sums of money succeeding to reduce poverty, create jobs, or improve economic stability?

In fact, are there any human endeavors truly resolving humanity's private and public failures?

The good news is that obedience to an inviolable behavioral law created by whoever or whatever is the creator does successfully resolve people's problems and prevent further trouble.

The first law of thermodynamics states that energy can be transferred from one form to another, but energy cannot be created or destroyed—evidence that natural laws have the upper hand in this world.

The *law of absolute right requires everybody's behavior to be rational and honest*. Any deviation from those requirements causes the wrong results that are wreaking havoc for humanity.

People know that obeying laws of physics requires taking the action specified by each law in order to get successful outcomes. In general, right action is not seen as obedience to laws of physics, which obviously

it is. So people originally had been reluctant to give attention to Wetherill's talks and papers regarding obedience to a natural law specifying their behavior.

Tragically, it is too late to benefit our deceased loved ones, but the law of right behavior tells us how and why we harm ourselves by disobeying it. As with the functioning of any natural law, this law's function is to tell people to be ***right as the law defines right***. People's definitions do not qualify. Instead, they are responsible for so many diverse problems that finally people are physically overcome. ***That is the ultimate penalty the human race has been paying for disobedience to creation's behavioral law.***

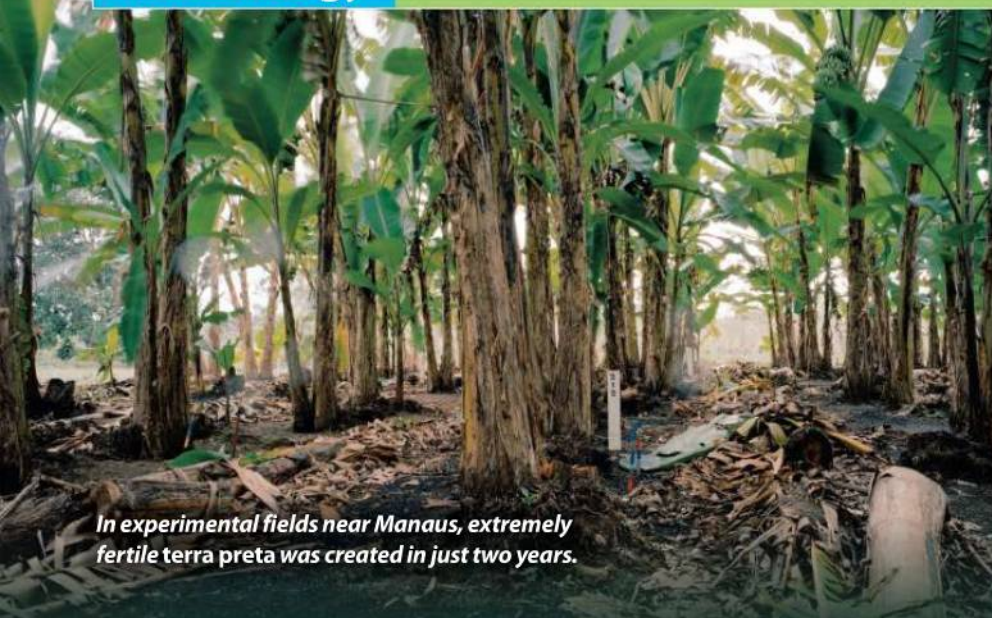
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As people conform to the behavioral law, they join those who are already benefiting from adhering to it with rational and honest thoughts, words, and action.

That is creation's way to change what is wrong until everything is made right: perfectly behaving people on the one planet in this universe that supports life as we know it!

This public-service message is from a self-financed, nonprofit group of former students of the late Richard W. Wetherill.



In experimental fields near Manaus, extremely fertile terra preta was created in just two years.

Experiments Re-create Miracle Soil

In test plots close to Manaus in western Brazil, researchers have had success in making *terra preta* using what they believe was one of the ancient recipes. Over a period of four harvests, an average yield increase of 100 percent was seen in bananas, rice and millet grown in soil using fertilizer and charcoal, compared with similar fields that contain Amazon-forest soil with only fertilizer added.

Scientists Wenceslau Teixeira of EMBRAPA (Brazilian Agricultural Research Corporation) and Christoph Steiner of the University of Georgia experimented with various compositions and discovered that porous bits of charcoal are an important ingredient. According to Steiner, it is difficult to increase and maintain soil's carbon—organic matter in the soil from decaying plants and animals—in the tropics. Adding charcoal seems to maintain

soil fertility. Analyses of original *terra preta* soils revealed that the natives had added excrement, perhaps both animal and human, as well as animal bones. Pieces of broken pottery were also included, probably giving the soil a looser consistency so that it could absorb more water.

There are experiments under way in many parts of the world, including Asia, Europe, Africa, the U.S. and Australia, to make modern versions of *terra preta* for use anywhere soil is infertile. Steiner believes that the introduction of biochar, made from biomass, will prove to be a valuable tool, for instance.

As an added benefit, the creation of *terra preta* may also slow emissions of carbon dioxide. The charcoal in the soil binds large amounts of CO₂ for perhaps thousands of years—CO₂ that would otherwise be released into the atmosphere.

Signs of Civilization

The Spanish, led by Francisco de Orellana, first explored the Rio Xingu in 1541 and 1542. Orellana reported seeing large settlements on the Amazon's riverbanks. When the first scientific expeditions entered the Amazon rainforest in the 1800s, they found no evidence of the villages that Orellana had reported.

Recent research now indicates that perhaps Orellana was not being untruthful, which most historians had thought was the case. With the help of his colleagues and the Kuikuro tribe, Michael Heckenberger has combed the jungle around the upper reaches of the Rio Xingu since 1993. Aided by satellite imagery, by 2008 he had found evidence of 28 settlements. They lie in an area of about 7,700 square miles and were once linked by roads and in some places by modified canals.

The towns were all laid out in the same pattern: a circular plaza with roads oriented in cardinal directions. The organization and planning of the towns show a degree of sophistication that was equal to, or even surpassed, the small cities of medieval Europe.

It's uncertain how many people lived in the rainforest settlements along the Xingu, but Heckenberger estimates that larger towns and clusters of settlements had between 1,000 and 5,000 inhabitants, for a total population of more than 50,000. In many places, Heckenberger has found large areas of dark soil like those studied by Neves 800 miles away. Today only 300 or so Kuikuro live in the region where Heckenberger works, and they may be descended from the unknown peoples who built those towns.

Fawcett set off on his last voyage in pursuit of a lost city, and Neves and Heckenberger's work may confirm the ancient explorer's suspicions. It seems likely that Amazon people attained a much higher level of development than had been indicated by the few towns discovered during the 20th century. As research proceeds, our assumptions about the fearsome Amazon will probably continue to be disproved. ■



Locals dig up terra preta in many places and sell it for use in backyards.



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3,226–4,025 miles: solid inner core

The distance to the northern edge of Antarctica from the world's most isolated island, Bouvet Island, in the South Atlantic. The next closest landmass from Bouvet Island is the southern tip of Africa, 1,500 miles away.



1 moon orbits our planet. Saturn and Jupiter have the most moons in our solar system, about **60** each.



A difference of **53 feet** separates high [left] and low tides in the Bay of Fundy on the eastern coast of Canada.



Mt. Everest
29,035 feet

Sea level

The Dead Sea
1,312 feet
below sea level

Mariana Trench
36,201 feet
below sea level

65,236 feet

The distance from the highest point on Earth, the summit of Mt. Everest in Asia, to the lowest known spot on the seafloor, the bottom of the Mariana Trench in the Pacific. The lowest body of water is the Dead Sea, with a surface at 1,312 feet below sea level.

The longest stretch of straight railroad track runs about **300 miles** across Australia's Nullarbor Plain.

10 inches

The distance the Tonga and Pacific tectonic plates move toward each other every year—the fastest plate motion on Earth



The relatively small country of Papua New Guinea is home to a whopping **860 languages**.

The Human Factor

6.8 billion

The number of people alive today. In 10,000 B.C., we probably numbered 10 million at most, and it wasn't until around 1800 that we reached one billion. In the 25-year period from 1974 to 1999, the world's population grew from four billion to six billion.

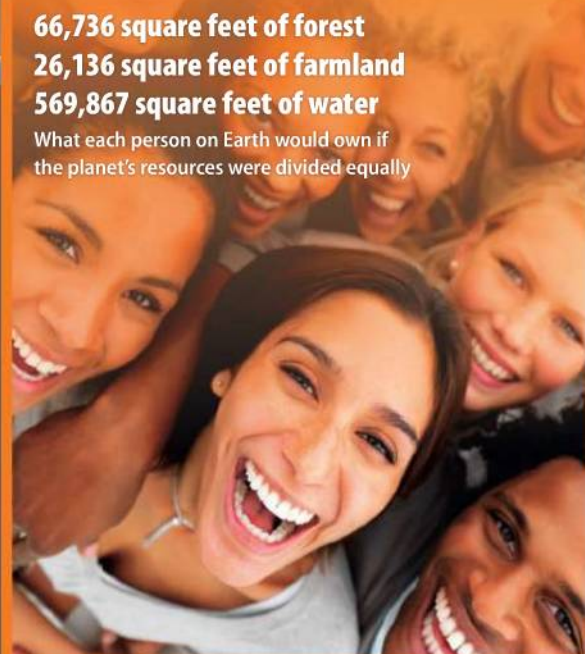


66,736 square feet of forest

26,136 square feet of farmland

569,867 square feet of water

What each person on Earth would own if the planet's resources were divided equally



23.59.56

The time of day when humans arose, if one day represents the age of the Earth

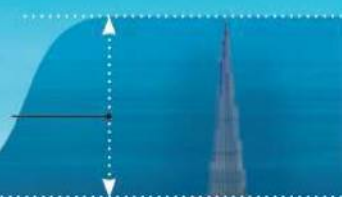


81% of the Southern Hemisphere is covered in water, while the Northern Hemisphere is just **61%** wet. Overall, **71%** of the planet is covered with water, but less than **1%** of that is freshwater.

2,686 feet of water would cover Earth if every hill and mountain were flattened. The world's tallest building, Dubai's Burj Khalifa [right], would be nearly submerged.

13,208,602,600,000,000 gallons

The amount of precipitation that falls on Earth annually





BARREN

Where Only Bacteria Survive

The McMurdo Dry Valleys, located just northwest of the Ross Ice Shelf in Antarctica, are part of the 2 percent of the continent not entirely covered by ice. It's not warmer: Low temperatures combined with unusually strong winds evaporate almost all moisture, which makes life unsustainable for anything except the bacteria that grow in rock crevices and in the relatively few bits of ice, the only water in the Dry Valleys.



M. STENZEL/NATIONAL GEOGRAPHIC



Reefs Overflow With Life

Coral reefs sustain a third of all known ocean species, attracting marine life from microscopic plankton to 30-foot whale sharks. Although one fifth of the world's reefs have been killed off by rising sea temperatures and other environmental factors such as ocean acidification, Red Sea corals like these survive when surface waters exceed 88°F, the point at which most others fail.

FERTILE

Trivia Countdown



Earn more points by using fewer clues to answer each question.		5 points	4 points	3 points	2 points	1 point
GEOGRAPHY	Name this country	More than half of its land is covered by forest, and it is the world's leader in pulp and paper production.	This nation's name comes from a Latinized version of the word for "village" in a now-extinct Iroquoian dialect.	It is the second-largest country in the world, but with only 33.5 million people, it is only the 37th most populous.	It gained its independence from Great Britain in 1982.	Since 1965, the country's flag has consisted of a white field with a red maple leaf in the center.
BOTANY	Name this plant	This group of plants, containing up to 15,000 species, is the botanical division Pteridophyta.	They are part of an ancient group of plants; some are perhaps more than 360 million years old.	The group's name may come from the Sanskrit word <i>parna</i> , meaning "wing" or "leaf."	These plants lack flowers, and reproduce by means of spores that are often released from the undersides of their leaves.	The young, tightly coiled "fiddleheads" of some species can be eaten.
SPORTS	Name this athletic event	It originated as a sport in the 1880s in both upstate New York and the Swiss Alps.	It has been a men's Olympic event since 1924, and women first competed in 2002.	Standard tracks are around 5,000 feet long with dramatic drops and curves.	Olympic teams have two or four members, and the heavier four-person groups race down the track at up to 80 miles per hour.	It earned its name from competitors bobbing back and forth, trying to increase the speed of their sled.
ZOOLOGY	Name this animal	All 17 species of this animal family, named Spheniscidae, live in the Southern Hemisphere.	Some species live in very large colonies, with hundreds of thousands of individuals.	Most people associate the animals with cold weather, but some live in temperate regions, and one species even lives near the equator.	These animals have flippers, which they evolved from wings.	Its name may stem from the Welsh <i>pen</i> , meaning "head" and <i>gwyn</i> , or "white."
BEVERAGES	Name this drink	It is made from a plant whose Latin name is <i>Camellia sinensis</i> .	In Russia, it may be served in hot water heated in a metal container called a samovar.	Its most important chemicals are tannins, which give the drink a bitter taste.	According to legend, it originated in China around 2700 B.C., when it was mainly used as medicine.	American colonists dumped three shiploads' worth into Boston Harbor in 1773.

What year was it?

May 31, Israel

Nazi extermination bureaucrat Karl Adolf Eichmann is hanged six months after his conviction and sentencing.

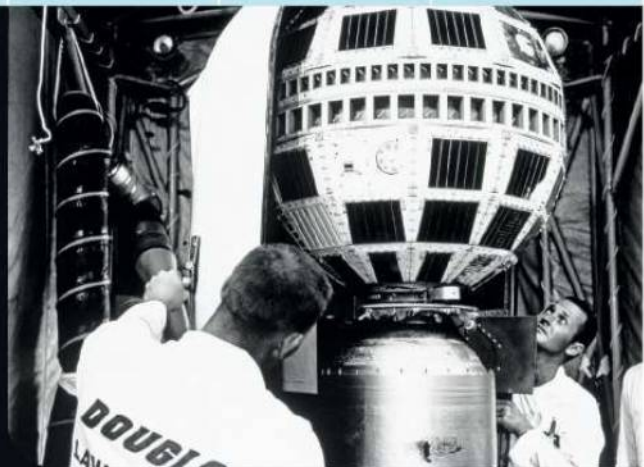
July 10, U.S.

A consortium of American, English and French companies launches the world's first communications satellite, Telstar-1 [right].

August 5, South Africa

Nelson Mandela is arrested and later tried for sabotage, treason and conspiracy. He is released in 1990.

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



Your score:

24-30 Genius!

17-23 Top of the class!

9-16 Passing grade

0-8 Hit the books!

Answers appear on page 78

WARNING: IS YOUR MEMORY FADING?

Breakthrough research reveals “senior moments” may be caused by “brain starvation”

You may be able to avoid long-term issues if you act before it's too late. Leading medical researchers reveal discovery that triggers body's own production of mental “superfuel” and may help reverse the damage caused by stress and age.

Do you remember your first kiss but not where you left your car keys? You're not alone. Millions are discovering that as they age, their short term memory and mental sharpness seem to be slipping. The cause of these inconvenient “gaps” in memory sits deep inside your brain, among the billions of tiny nerve connections. New brain cell growth starts dropping after age 25, and then dramatically after 50, starting a downward spiral that can lead to everything from those frustrating “senior moments” to even more severe memory breakdowns.

Downward Memory Spiral is Reversible

Studies have shown that the efficiency of brain cells declines after years of free radical damage and stress. It was long believed that as we got older, memory problems were inevitable. But medical experts have revealed that the downward memory spiral is reversible. Compelling new research shows that there's a simple way to stimulate new brain cell growth that can boost your memory, improve your focus and restore your mind's mental sharpness.

Achieve Peak Brain Performance

Challenging mental games aren't enough to build a better brain. Your mind is the most complex and demanding organ in your body. It's also a high-performance supercomputer that requires the right chemical “foods” to perform at its peak.

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- ☒ Do you sometimes get confused?
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- ☒ Do you often forget why you walked into certain rooms?
- ☒ Do you find it hard to concentrate?

manufacture new cells and improve vital neurotransmitters (the basic processes of thinking and memory). Until now, it was believed that there was no way to safely and naturally produce this remarkable mental “superfuel.” But after years of extensive research and testing, microbiologists and brain researchers in the U.S. at the University of North Carolina, in England at Newcastle General Hospital, and at one of the most prestigious research institutes in Israel have developed a way to help boost choline production. Their breakthrough formula also helps stimulate new brain cell growth, leading to a significant improvement in memory, concentration and helps clear stubborn “brain fog.”



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Protect Your Memory Now Before It's Too Late

Why wait until your lack of focus or forgetfulness creates an unsafe situation? Today it was your reading glasses, but tomorrow it could be the stove. You forget a phone number today, but tomorrow it could be where you parked your car at the mall.

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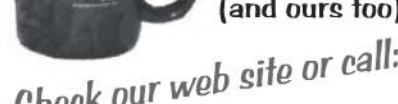
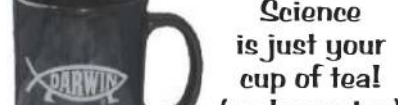
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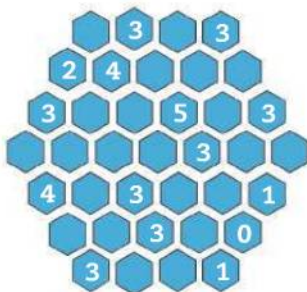
Brain Trainers



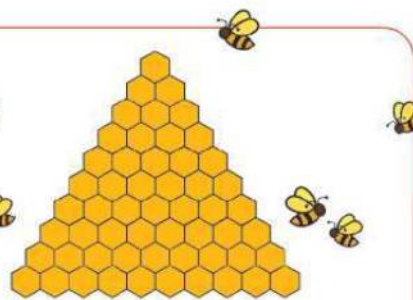
- 1** Beginning with the number 3 and moving counterclockwise around the C shape, insert a +, -, x or / in the empty tiles to solve the arithmetic problem. (Ignore the usual rule that you should multiply and divide first.)

$$\begin{array}{c} 9 \quad 4 \quad 3 \\ \square \\ 7 \quad 5 = 2 \end{array}$$

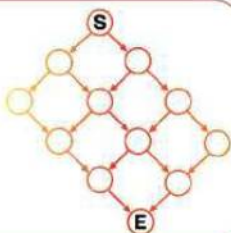
- 2** Mark some of the empty hexagons so that the digit in each numbered hexagon represents the number of marked hexagons adjacent to it.



- 3** Bees in this colony each occupy one hexagonal cell. They will attack each other if they must share a horizontal or diagonal row of cells. What is the maximum number of bees that can live in this colony peacefully?



- 4** How many different paths following the arrows lead from the start circle, S, to each of the other circles? How many paths lead to the end circle, E?



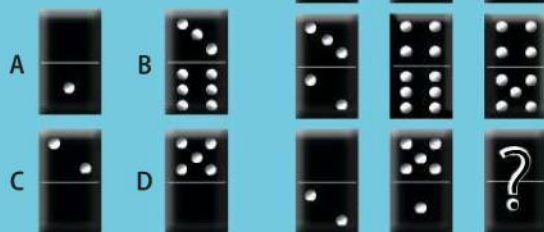
- 5** In the table to the right, each of the letters stands for a number, and the sums of the numbers in each of the first two columns and in the first row are shown. Find the sum of the numbers in the second row.

a	b	c	d	16
c	a	d	c	?
b	c	d	a	
b	c	a	c	
18	14			

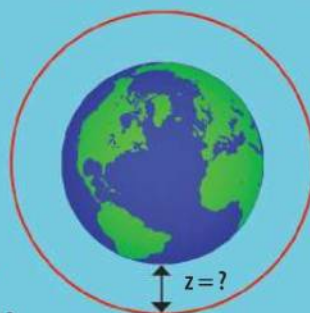
Headbreakers



- 1** Which of these four dominoes completes the third column at right?



- 2** Imagine the Earth as a perfect sphere and its circumference as a belt that is pulled tight around the planet. Lengthen that belt by 10 feet and pull it away from the Earth, so that it is the same distance, "z," from the planet all the way around. What is the distance between the belt and the Earth?



- 3** Who is telling the truth and who is lying?

Patricia says, "Either I am lying or Michelle is."
Michelle says something inaudible.
Catherine says, "If Michelle is lying, Patricia is too."

- 4** Fill in the four empty boxes so that the totals in all 3x3 squares of consecutive boxes are equal. What is the common total?

3	1	4	2	1	2
6	2	5	4	3	4
1	3			2	7
4	1			1	1
5	2	6	3	3	5
2	4	2	5	3	5

Answers appear on page 78

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