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Jan/Feb 2010

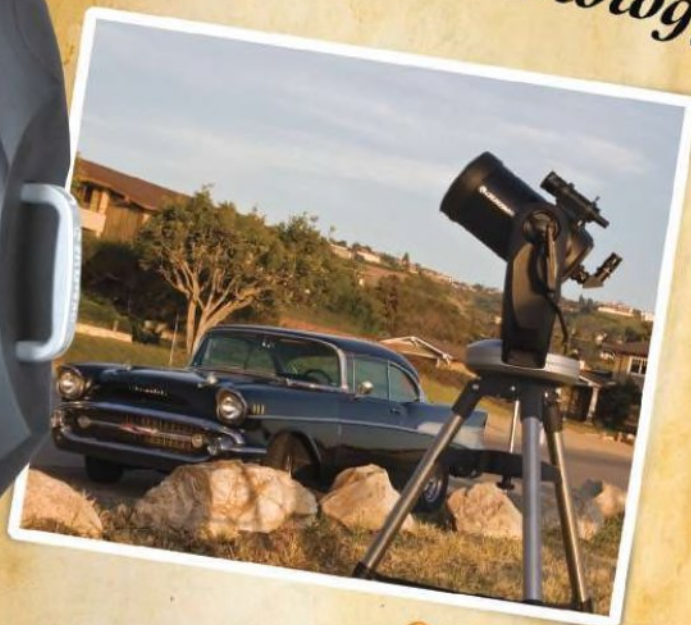
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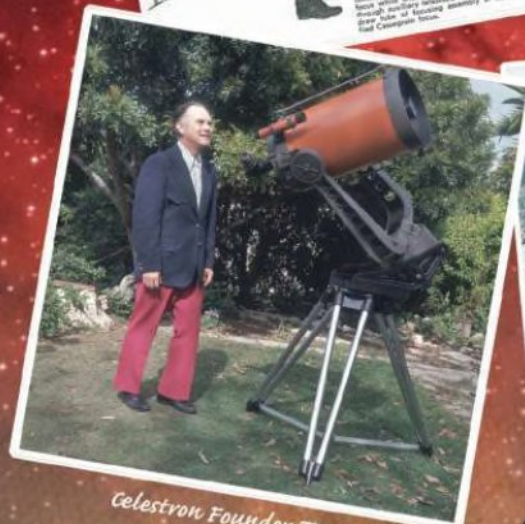
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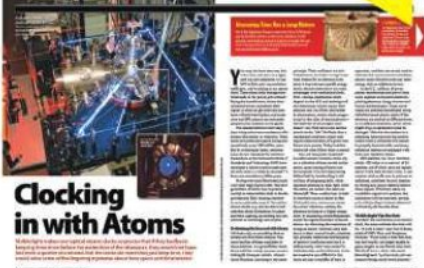
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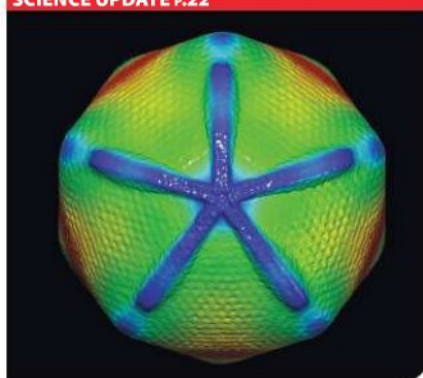
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You asked, we answered: How do aquatic insects breathe? When did Earth's atmosphere form? How do fireworks explode in shapes?

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"Henry Philip Hope would be impressed with the superfine deep blue of the Stauer Eternal Hope Necklace. Ever since the original first surfaced centuries ago, it has been shrouded in legend and mystery."

**— JAMES T. FENT,
Stauer GIA
Graduate Gemologist**

This colossal, brilliant cobalt blue stone is enlarged to show details.

World's Most Famous Diamond Found Inside Toaster

Stauer introduces a scientifically created tribute to the legendary Hope Diamond!

It's a wonder that the *Hope Diamond* survived the 20th century. In the hands of eccentric millionaire heiress Evalyn Walsh McLean, the 45½ carat deep blue diamond was treated more like a fancy plaything than a precious gem. McLean wore it on rollercoasters, while swimming and when doing yard work. She hid it underneath couch cushions and from time to time, even kept it inside her toaster!

These days, the *Hope Diamond* is the superstar of the National Gem Collection at the Smithsonian's Museum of Natural History. And even though the spectacular blue stone attracts millions of visitors a year, it looks lonely stuck behind that 3-inch bulletproof glass. So we decided to set it free.

Science recreates a legend of luxury. We challenged our gemologists to reimagine the largest and most perfect blue diamond in existence. They came back with the magnificent *Eternal Hope Necklace*, a lab-created beauty inspired by the \$350 million original. Using the legendary *Hope* as their guide, they carefully cut lab-created blue spinel to match the color, shape and geometric angles of the world famous stone. And, because of our advanced science, our lab-created stone's clarity is superior to the original.

The *Hope Diamond* remains one of the world's most unattainable treasures, but we've set the price of our *Eternal Hope Necklace* at an unbelievably accessible \$195!

When being called a "jewel thief" is a badge of honor. The final product is so convincing that it will surely have museum curators double checking their vault. Our update keeps the allure of the original, the magic that captivated Maharajahs, kings and queens.

The custom-cut stone is brilliant cobalt blue lab-created spinel. Spinel is considered the greatest impostors in gemstone history. One of the most valuable gemstones in the world, the *Black Prince* in the British Crown Jewels, was only recently discovered to be a spinel. They are favored by jewelers because of their brilliance and hardness. And the structure of a spinel is similar to a diamond—they both have the same high symmetry (4/m bar 3 2/m).

Add the world's most famous rock band. Enhance the look of your stunning Necklace with the *Eternal Hope Ring*, a gorgeous ring version of the pendant stone, prong-set on a .925 sterling silver band. Flanked by 10 dazzling, lab-created DiamondAura®, the Ring perfectly complements the Pendant.



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Targeting the Flu

Now that we know that swine flu replicates better in lungs than seasonal flu [Bull's-Eye, November/December 2009], we can develop a targeted treatment. Unlike when the Spanish flu hit in 1918, modern medicine will let us target the cause, rather than just treating the symptoms.

Ronald Edwards Via e-mail

Defining Day

"What does the 'D' in D-day stand for?" [Ask Us, Nov./Dec.] omits the term's true origin and meaning. "D-day" was not used for the many invasions prior to the June 6, 1944, Normandy invasion. Dwight D. Eisenhower and his staff coined the term for an unknown date with a purpose: the debarkation of troops from their ships to the shore. Hence "D-day" is "debarkation day."

Robert Marsh Via e-mail

EDS: Michael J. Edwards, a historian at the University of New Orleans Eisenhower Center, says that the "D" in D-day was first

used during World War I as a stand-in for the actual date of an upcoming operation. He suspects that alternative definitions, including "debarkation," "death" and "doom," may have been coined by World War II troops during the invasion at Normandy.

Increasing Visibility

"The Search for Another Earth" [September/October 2009] points out how difficult and indirect the process for finding other "Earths" is. Perhaps we should change our strategy. What can we do to become more visible to searchers from other planets?

Ben Dubner Via e-mail

EDS: The Search for Extra-Terrestrial Intelligence (SETI) Institute used the Arecibo radio telescope in 1974 to broadcast a simple pictorial message into space. According to SETI astrophysicist Frank Drake, it's unclear whether repeating such a transmission would be cost-effective. The Earth's many high-power radio transmissions may already make it visible enough.

Corrections

The world speed record held by the Blackbird jet is 2,193 mph, not 1,293 mph [World of Science, Nov./Dec.].

In "Colors of Infection" [Bull's-Eye, Sept./Oct.], the image of virus-infected cells was not fully credited. The image was captured by Anthony Ambrosini, a Princeton University molecular-biology graduate student. It is part of Princeton's 2009 Art of Science Exhibition (princeton.edu/~artofsci).

Two alternative solutions were omitted from question #5 in Brain Trainers [Nov./Dec.]: 4, 2, 3, 4, 7, 1 and 3, 3, 2, 5, 6, 2.

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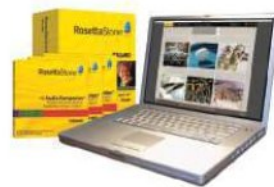
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Puppet Masters

The Royal de Luxe street-theater group marches its Little Giantess and Big Giant puppets through Berlin. The wooden marionettes, operated by ropes, pulleys and hydraulics, are recurring characters in the French troupe's performance-art saga, adapted for six countries so far. This four-day event, starting last October 1, celebrated the 20th anniversary of the reunification of Germany. The giantess started her journey in East Berlin, while her "uncle" crawled out of the Spree River and walked toward her from West Berlin. They were reunited at the historic Brandenburg Gate.





COMTES PASCAL VIC D'ARTOMARI ROYA DE LU



NATHAN DENETTE/THE CANADIAN PRESS/AP PHOTO



Wind-Blown Look

Canadian alpine skiers Jan Hudec [left] and Tyler Nella show the scale of the 43-foot-tall propeller in the world's largest wind tunnel at the General Motors Aerodynamics Laboratory in Warren, Michigan. The skiers used the facility to refine their form before the World Cup races in Alberta last November. The hundreds of GM cars tested at the lab every year are subjected to winds of up to 138 mph, while the skiers endured a maximum of 75 mph in the tuck position [inset].



Mind Mapping

In research led by scientists at the University of California at San Diego, doctors implant electrodes into the brains of epilepsy patients to pinpoint seizure-causing regions for removal and to map healthy brain functions like language and hearing. As revealed in this x-ray, electrodes on the left frontal and anterior temporal lobes send electrical data from the brain to ribbonlike cables along the back of the head, which then connect to computers for analysis.



COURTESY NED T. SAHIN, PH.D.



Mane Attraction

A lion relaxes after a meal of Cape buffalo in Kenya's Masai Mara game reserve, home to more than 200 of the cats. During an early morning drive through the park in 2008, nature photographer Marc Sloommaekers came across this lion and two other males finishing up with their night's kill. Surrounded by buzzing flies, the animal's blood-soaked mane and piercing eyes earned Sloommaekers, who lives in Belgium, a win in the Veolia Environnement Wildlife Photographer of the Year contest, which is organized by the Natural History Museum in London and *BBC Wildlife Magazine*.



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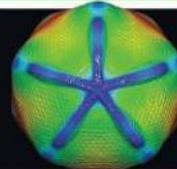




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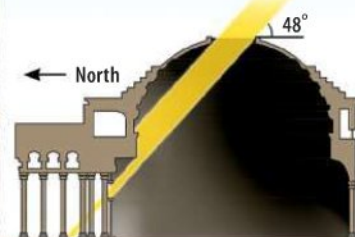
GEOLOGY It's hard to believe, but Antarctica was once a pretty livable place. Then, around 33.7 million years ago, during the Eocene-Oligocene (E-O) boundary, the ice sheets set in. So what turned the southern continent from greenhouse to icehouse? Until recently, scientists believed that changing ocean circulation in the southern hemisphere caused local ocean temperatures to fall. But new research suggests instead that a rapid drop in carbon dioxide levels in the atmosphere caused worldwide cooling, resulting in Antarctica as we know it.

An international team of researchers led by University of Hong Kong geologist Zhonghui Liu studied deep-sea cores from 11 locations around the world, the largest sample size so far. The researchers revealed that global sea-surface temperatures fell by an average of 4.5 to 6°F at the E-O boundary, with temps near the South Pole and the North Pole dropping 9 to 11°. An atmospheric CO₂ drop is the most likely culprit for such widespread cooling, Liu says. But what caused the theoretical greenhouse-gas plunge remains to be shown.



The Entrance Was Illuminated at Equinox

On the equinoxes, which fall around March 21 and September 23, the sun penetrates the oculus in the temple's dome at a 48-degree angle. The light passes through a grill over the doorway, lighting the porch outside.



A Roman Sundial?

The Pantheon's design allows for keeping track of time and the equinoxes

ARCHITECTURE The designers of the Pantheon may have had more in mind than honoring their deities when they built the Roman temple. In his recent book, *Time in Antiquity*, Robert Hannah of the University of Otago in New Zealand claims that the building, completed around A.D. 128, is also a giant sundial.

The Pantheon is lit by the sun through a 27-foot-wide hole in its roof. At noon, the sun shines in, hitting the domed ceiling above the doorway during the autumn and winter and the walls and floor during the spring and summer. The dome, Hannah says, closely resembles roofed spherical sundials built in

antiquity. These smaller stone structures were hollowed-out hemispheres with a hole at the top allowing light to strike interior engravings to mark the time of year and day. No such engravings are apparent in the Pantheon, where light marks only midday.

On the equinoxes, the two days when the sun is exactly above the equator, the noontime light hits where the temple's dome meets its walls. The event may have been a nod to the resting place of emperors after death: the celestial equator—a projection of Earth's equator out into space—symbolized by the junction of the dome and walls.

FLASH! Scientists in Beijing have sequenced the complete cucumber genome, making it only the seventh plant to have its DNA fully mapped. The sequencing will help producers raise new varieties and study plant development. In the U.S., commercial cucumber crops brought in \$242 million in 2008.

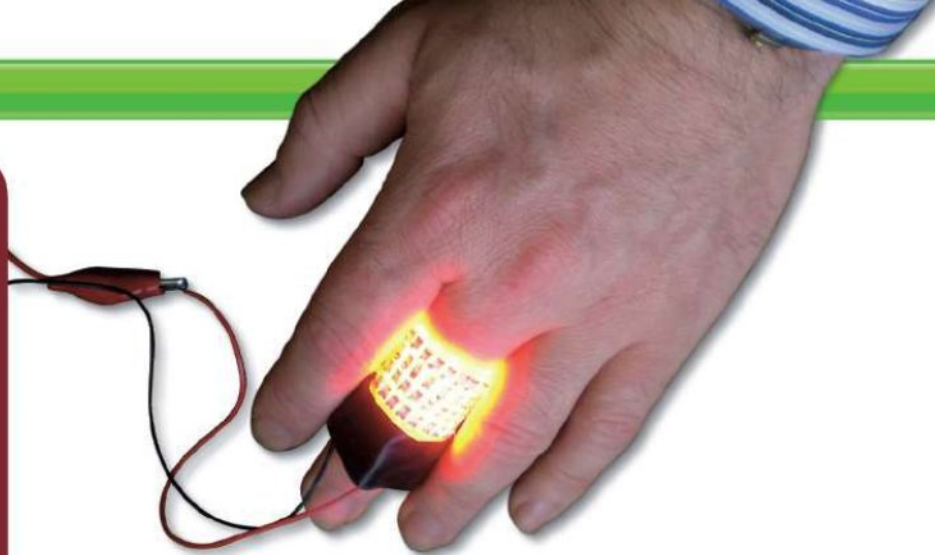
35,000-Year-Old Sex Symbol

ARCHAEOLOGY It's just over two inches tall. But what it lacks in height, it makes up for with age. Researchers from the University of Tübingen in Germany excavated this mammoth-ivory carving from southwestern Germany's Hohle Fels cave in 2008. About 35,000 years old, it is among the oldest known examples of figurative art. Exaggerated sexual features and a de-emphasized head, face, arms and legs evoke European figurines dating back around 27,000 years. Such so-called Venus statues are believed to have been fertility expressions. The carving's age, determined by carbon dating of associated animal bones and charcoal, pushes back the known origin of female figurines in Europe by at least 5,000 years.



The Hohle Fels figurine was discovered in six pieces; the left arm and shoulder are missing.

FLASH! Research from Japan explains why red wine and fish don't pair well: An ion in the naturally occurring iron in many red wines is a key compound in forming an overly fishy aftertaste, most likely because it reacts with the meat's fatty acids.



Bright Idea for Treating Skin Cancer

An LED bandage developed by Polymertronics in Oxford, England, could soon make skin cancer treatment easier. It uses photodynamic therapy, in which light-activated creams destroy nonmalignant melanomas. Typical treatments use large, costly light sources. The Wearable Photodynamic Therapy Light-Bandage shows the same results and costs less, and it lets patients stay mobile. Polymertronics expects it to hit the market this year.

Sea Tourism Dives into the Deep with Airplane-Like Sub

The Deep Flight Super Falcon is one of the first recreational winged submarines

TECHNOLOGY Most people have never had the opportunity to get a live glimpse of the ocean 1,000 feet below the surface. With a price tag of \$1.5 million, the *Deep Flight Super Falcon*, one of the first recreational winged submarines, is not going to change that reality. But for underwater adventurers who have the cash, the *Super Falcon*, unveiled last year by inventor Graham Hawkes, just might be worth the cost: For one thing, it travels at up to six knots, 3 to 10 times the speed of traditional scientific subs, which operate like balloons.

That's fast enough to keep up with large seafarers like humpback whales.

Hawkes and his team married speed and agility with airplane-like wings, a lightweight hull and an electronic system that allows for precise, computer-controlled movements. Whereas balloon-shaped subs fill ballast tanks with water to descend—and can mostly just go up and down, in the manner of an elevator—the airplane-shaped *Super Falcon* employs lithium-battery-powered thrusters, allowing the sub's pilot to move forward and

FROM TOP: POLYMERTRONICS LTD.; AFP/SCANPIX



Bumblebee Flight Revealed

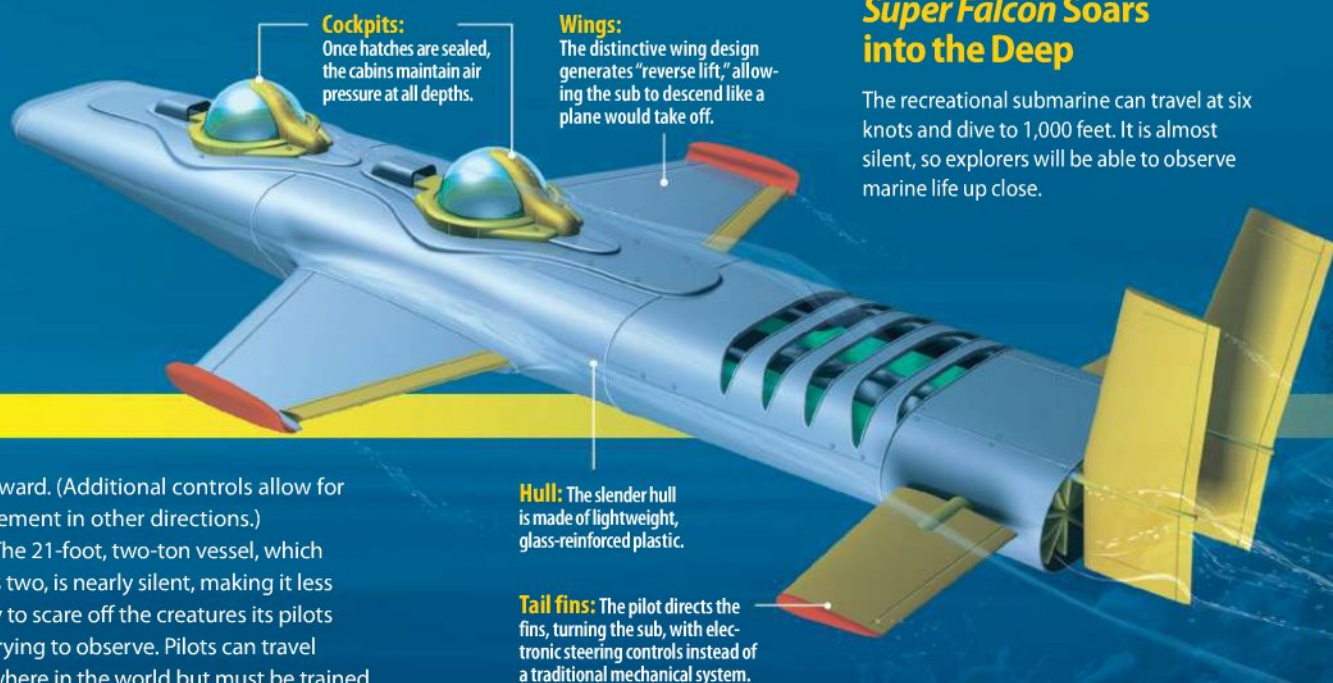
ZOOLOGY Bumblebee flight is surprisingly inefficient. So say zoologists at the University of Oxford who sent 100 bees through a smoke-filled wind tunnel to reveal how air moves around flying bees.

For birds, bats and most flying insects, the wing's downstroke provides powerful lift. "But unlike those animals," explains Oxford zoologist Richard Bomphrey, "bumble-

bee wings narrow toward their base and are a long way from each other." Some of the air thus accelerates upward at the base of the wing, reducing lift. Bumblebees need more energy to complete each flap, he says. They use the raw power of their big bodies, fueled by calorie-rich nectar, to fly. Such bees, Bomphrey adds, are probably "optimized for control and heavy load lifting."



Bumblebee wing beats are revealed in a smoke-filled chamber.



Cockpits:

Once hatches are sealed, the cabins maintain air pressure at all depths.

Wings:

The distinctive wing design generates "reverse lift," allowing the sub to descend like a plane would take off.

Hull: The slender hull is made of lightweight, glass-reinforced plastic.

Tail fins: The pilot directs the fins, turning the sub, with electronic steering controls instead of a traditional mechanical system.

Super Falcon Soars into the Deep

The recreational submarine can travel at six knots and dive to 1,000 feet. It is almost silent, so explorers will be able to observe marine life up close.

backward. (Additional controls allow for movement in other directions.)

The 21-foot, two-ton vessel, which seats two, is nearly silent, making it less likely to scare off the creatures its pilots are trying to observe. Pilots can travel anywhere in the world but must be trained in the "flight schools" Hawkes conducts in the Monterey Bay National Marine Sanctuary. The *Super Falcon* is positively buoyant, which means the sub will automatically return to the surface if the vessel's power system shuts off for any reason.

So far, only one person, venture capitalist Tom Perkins, has snapped up a *Super Falcon*. But Hawkes has already designed his next attempt to open up the deep—

the *Deep Flight II*, which he hopes will dive to an astounding 37,000 feet—and the inventor has several more models in the works as well.

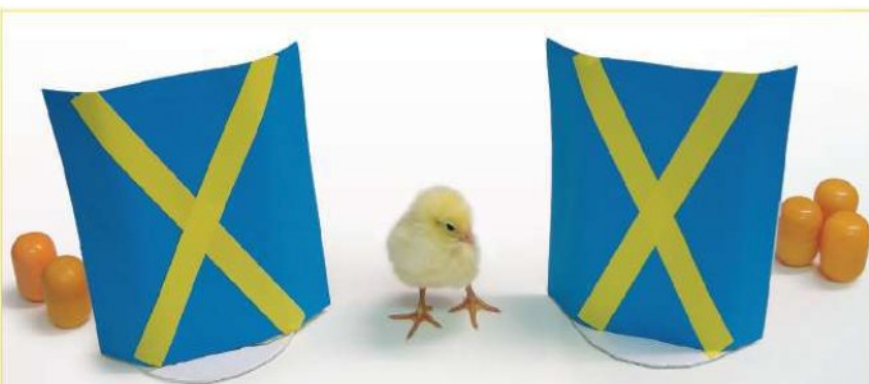


This spiral galaxy's rotation distributed stars across it.

Why Galaxies Are So Smooth

ASTRONOMY Stars form in clusters, yet within several hundred million years, those same stars are smoothly distributed across spiral galaxies such as the Milky Way. Now NASA's Spitzer Space Telescope is revealing how the even distribution of stars occurs over time, a question that has long puzzled astronomers.

New high-resolution infrared images from Spitzer show, for the first time, streams of young stars in faraway galaxies flowing outward from their natal clusters. These streams indicate that the shearing motion of rotating galaxies spreads the stars out evenly.



Chicks must do math to choose the screen concealing the most balls.

Baby Birdbrains Prove Good at Math

Mathematical aptitude may exist from birth for chickens

BIOLOGY Baby chicks can do arithmetic. In a recent experiment, researchers led by Lucia Regolin, an animal-cognition expert at the University of Padua in Italy, showed that three- to four-day-old chicks have the ability to add and subtract.

The researchers reared newborn birds with five yellow plastic balls at birth to make the balls desirable to them. A few days later, the researchers split the balls into groups of two and three and hid them behind two screens while the chicks watched. Not only did most chicks walk toward the screen hiding three balls, but they also figured out which screen hid more when the balls were moved around one by one. Such mathematical aptitude has never before been shown in such young animals, and it provides new evidence that the ability to perform simple arithmetic may be present at birth in some species.

Female alligators can stay with one mate for several years.



Gator Couples Stick Together

BIOLOGY Up to 70 percent of female alligators stay loyal to their mate, sometimes for several years, according to a decade-long study conducted in the Louisiana Department of Wildlife and Fisheries's Rockefeller Wildlife Refuge. This is the first evidence of partial mate fidelity in a crocodilian species and is surprising, since females move freely through male territories. The finding shows a similarity between bird and alligator mating habits. Researchers hope the connection may shed light on pair bonding among the two groups' common reptilian predecessors, including dinosaurs.

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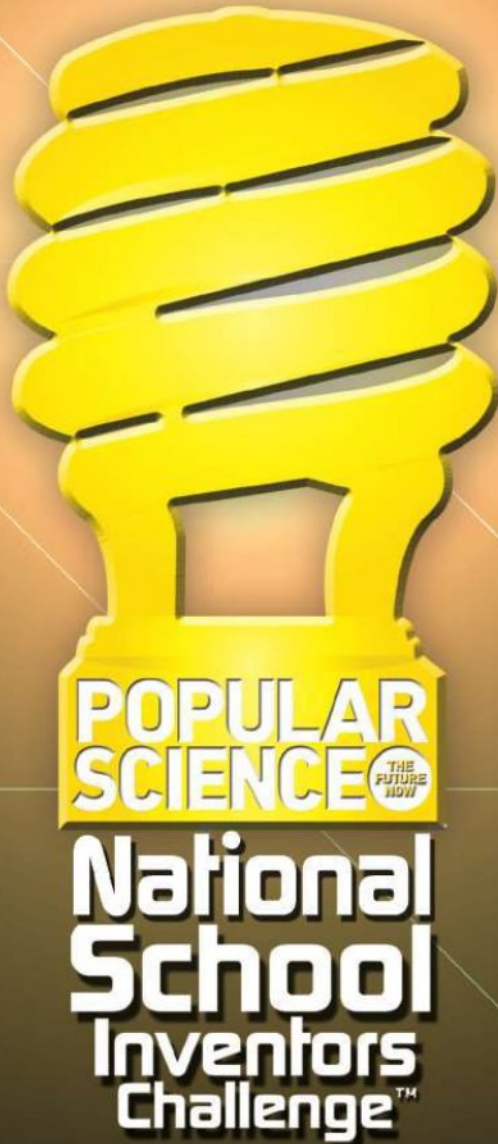
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A landscaper stumbled upon these Stone Age tools during a yard work project.



Stunning Stone Age Tool Cache Found

American artifacts used for butchery were untouched for 13,000 years

ANTHROPOLOGY Ice-age camels, horses, bears and sheep—they were all on the menu 13,000 years ago for the famed Clovis people, who were among the earliest Americans. A recent analysis of 83 stone tools discovered by chance in 2008 in the yard of a home in Boulder, Colorado, turned up the animals' protein signatures. The rare cache of tools, found tightly packed a foot and a half underground, is the second Clovis cache to be analyzed for animal proteins, making it invaluable for understanding the prehistoric peoples' diet.

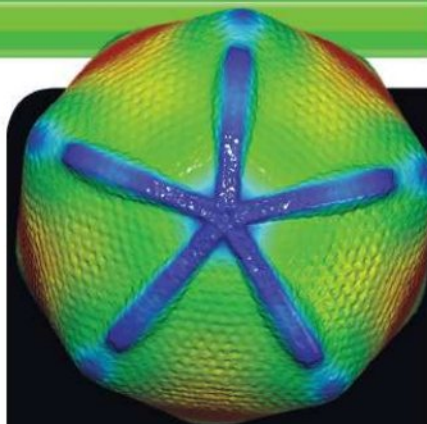
The Mahaffy Cache, named for Patrick Mahaffy, the Boulder resident on whose property the ancient tools were unearthed, is a significant discovery from the Clovis period. Only a small number of other caches have been found in North America, says anthropologist Douglas Bamford of the University

of Colorado at Boulder, who is analyzing the tools. The implements include salad-plate-size knives, smaller blades and a uniquely shaped ax. The stone the tools were made from originated west of the Continental Divide, which means they were valuable enough to be carried through the Rocky Mountains.

Mahaffy originally thought the tools were just hundreds of years old, but their style and the age of the sediment in which they were found clearly link them to the Clovis culture; the presence of proteins from animals that disappeared from



the area more than 10,000 years ago clinched it. One oval-shaped bifacial knife so closely resembles a Clovis obsidian knife discovered in Yellowstone National Park that Bamford suspects it was crafted by the same toolmaker.



The mimivirus has curious parts.

Giant Virus Takes Shape

VIROLOGY Scientists already knew that the so-called mimivirus has some unusual characteristics: At half a micrometer across, it's the largest virus known and more than 10 times as large as the one that causes the common cold. That size, along with a peculiar genome, helped it masquerade as a bacterium for a decade.

Now a recent American and French study of the mimivirus's outer shell is giving researchers the first good look at its uncommon parts, including mysterious holes and a starfish-shaped feature that may open like a flower to deliver its DNA to the amoebas it infects. Its size, genetic makeup and unusually complex structure suggests that the virus may have inherited some genes from microbes like bacteria, adding weight to a theory that it's a missing link between viruses and cellular life.

FLASH! Two Clemson University scientists say blue-green algae may have caused the mass extinction 65 million years ago that killed off the dinosaurs by releasing disease-causing toxins that also could have depleted oxygen. The fossil record shows an increase in the algae, possibly due to global warming and increased nutrients, around the time of the extinction event.

CLOCKWISE FROM TOP LEFT: G.J. ASAKAWA/UNIVERSITY OF COLORADO; MICHAEL ROSSMANN, PURDUE UNIVERSITY; CLAUDIUS LUNAU

Exhausted, But Just Can't Fall Asleep?

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

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

Consequences Of Too Little Sleep

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

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

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Results not typical.

Lack Of Sleep Impacts 1 In 6 Adults

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

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Results not typical.



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

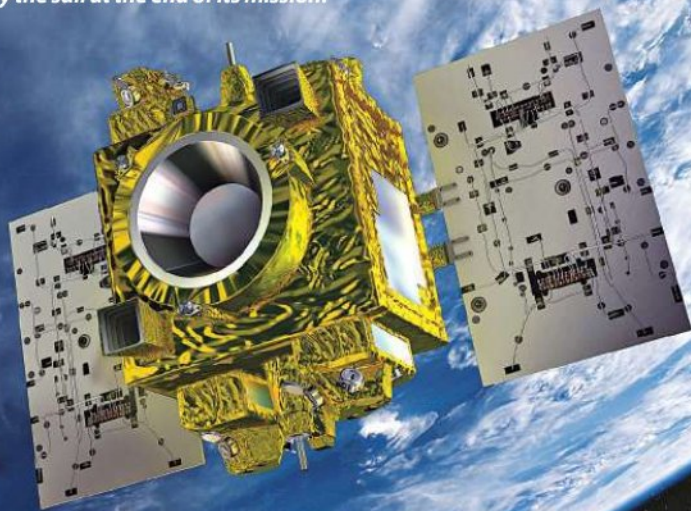
Melatonin – is a hormone produced by the body that naturally increases sleep efficiency.

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

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



The sail's golden booms release silver wings [right]. France's Microscope satellite [below] will employ the sail at the end of its mission.



A Faster Way to Bring Space Junk Home



Aerobraking sail will shorten the time dead satellites spend in orbit, reducing the likelihood of crashes

SPACE Last February, an American commercial satellite and a Russian military satellite crashed in orbit 500 miles above Siberia. Russia's Kosmos 2251 was out of service for 14 years before colliding with the U.S.'s active Iridium 33. Both became hundreds of pieces of debris, which now threaten to damage other craft. Approximately 3,000 active and inactive satellites orbit Earth today, and crashes are likely to continue. One solution in the works from

European aerospace company EADS Astrium: Give the satellites drag-inducing sails to facilitate their return to Earth's atmosphere, where they will burn up.

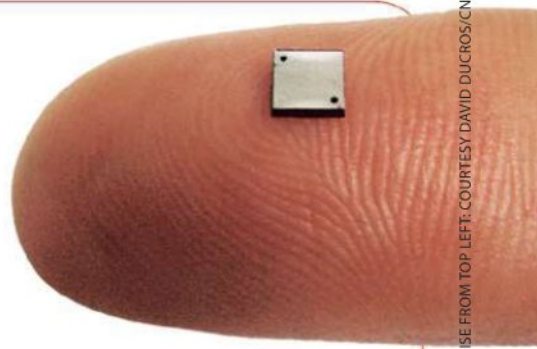
EADS Astrium engineers Brice Santerre and Max Cerf designed the aerobraking sail for France's Microscope satellite. Slated to launch in 2014, Microscope will finish its mission to collect data for gravitational studies a year later. Then its braking system will engage two inflatable

masts, or booms, that will unfurl heat-resistant, lightweight polymer wings. This will increase the satellite's surface area to catch more drag, slowing its orbital course enough to bring Microscope back to Earth within 25 years instead of 50 to 100, reducing its chances of a crash.

The team is researching potential candidates for a larger version of the sail for rockets, possibly including the European Space Agency's Ariane 5.

Tiny Power Source Unveiled

TECHNOLOGY Behold the world's smallest functioning fuel cell. This hydrogen cell, designed by engineers at the University of Illinois at Urbana-Champaign, measures just over a tenth of an inch wide. Researchers scaled down the cell's size by replacing cumbersome, power-sucking peripheral components, which typically manage factors such as air, fuel and water flow, with a self-regulating control mechanism. The micro fuel cell produces 0.7 volt and 1.5 milliamperes of electricity. That's not enough juice to power the thinking, insect-size military spybots it was designed for, but a higher-output version should be able to power more-energy-efficient robots in the future, says lead researcher Saeed Moghaddam.



The silicon cell measures 0.12 inch across.

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Should babies eat spinach?



P. 30
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Why does music trigger goosebumps?

The hair-raising power of music is linked to adrenaline. Goosebumps occur when tiny muscles in the skin (*erector pili*) connected directly to hair follicles contract, making hairs stand up. The muscles respond to adrenaline, a hormone whose release is triggered by various stimuli, including feeling cold or experiencing a strong emotion. Listening to music can also produce a strong emotional response, releasing adrenaline and causing goosebumps to appear.

Goosebumps serve no purpose in humans and are probably a remnant of our primate ancestors, but the bumps can be very useful for animals whose bodies are still covered with fur. When these animals feel cold, goosebumps can make the fur stand up, creating a heavier layer of insulation around their body. Goosebumps can help animals ward off predators, too. When animals feel threatened, they release adrenaline, which makes their hair rise and helps them look bigger—and scarier.

When did Earth get its atmosphere?

Earth's atmosphere started to form around the same time as the planet, roughly 4.5 billion years ago, according to geoscientist Jim Kasting of Penn State University. This atmosphere was lost, possibly as a result of a colossal impact between Earth and another celestial body. Countless small planetary bodies and comets rich in water and other compounds are thought to have then struck Earth. The compounds may have been released into the atmosphere on impact or could have accumulated on the surface and

evaporated as temperatures increased during the formation of the planet's crust. "Much, or even most, of the current atmosphere may have arisen during this time," Kasting says.

By the impacts' end around 3.8 billion years ago, liquid oceans had appeared. The atmosphere probably then contained mostly water and carbon dioxide, with some hydrogen, methane, nitrogen, sulfur and argon. Gases such as methane and sulfur were probably released from volcanoes.

The earliest photosynthetic bacteria probably arose to produce oxygen around this time. But iron and sulfur deposits in the ground rapidly reacted with and trapped the oxygen molecules. "Free oxygen was scarce in the Earth's atmosphere until about 2.4 billion years ago," Kasting says. Oxygen did eventually reach the atmosphere, and for the past two billion years, it has consisted mostly of oxygen and nitrogen.

3 Atmospheric Stages

- 1 4.5 billion years ago:** Earth's first atmosphere probably consists of water, carbon dioxide, carbon monoxide and hydrogen. This atmosphere is lost, most likely during a major collision between Earth and another object.
- 2 3.8 billion years ago:** Millions of years of smaller collisions spawn an atmosphere composed mainly of water and carbon dioxide, with some nitrogen and methane.
- 3 2.2 billion years ago:** The modern atmosphere is in place. It mostly consists of oxygen and nitrogen.

Earth's atmosphere was virtually oxygen-free for two billion years.

Why are maps oriented north?

"It's a completely arbitrary decision," says Matthew Edney, a cartographer at the University of Southern Maine and the University of Wisconsin. "The choice of a seemingly physical reason—the poles—is a function of modern rationality, plus, in part, Eurocentrism. It could equally be a south orientation."

In the past, the direction in which maps were oriented depended on political, cultural and religious interests. Medieval Christian world maps placed east, the supposed direction of Paradise, at the top. The first Islamic mapmakers chose south, the relative direction of Mecca from their location in Babylon in what is now Iraq. Edney also points out that the invention of the magnetic compass had no influence on

whether maps were oriented north or not. The first compasses in Europe were actually painted to point south, which helped people in the Northern Hemisphere define their local meridian, a useful point of reference for sailing and astronomy.

Geographical maps began to be oriented north in the 15th century, when cartographers started making maps based on those by the Greek astronomer Claudius Ptolemy. Ptolemy tried to map the known world, which to him was just the Northern Hemisphere, so he constructed his maps due north. The proliferation of Ptolemy's system led most European and North American world maps and sea charts to have north at the top by the 18th century, although there were still some exceptions.



This 11th-century Anglo-Saxon world map is oriented east, with Asia at the top, Africa at the right and Europe to the left.

In the 19th century, attempts were made to standardize cartography, "and that's when north at the top became the real standard," Edney says.

Why is spinach dangerous for babies?



Eating spinach is perfectly healthy during pregnancy.

Many vegetables, including spinach, absorb nitrate, a naturally occurring chemical, from the soil. Nitrate itself is harmless, but enzymes produced by the plants, or by bacteria from the soil or in our gut, can convert the nitrate into nitrite, a potentially harmful compound.

Nitrites can affect blood's ability to transport oxygen. In small amounts, they are harmless to most children and adults. But babies under three months have more nitrite-producing gut bacteria, as well as fetal blood, which reacts more readily to nitrites. Nitrites can drastically reduce the oxygen carried by their blood, which can affect a baby's breathing. The American Association of Pediatrics recommends against feeding homemade vegetable dishes, especially those with spinach, to babies under three months. (Kids aren't supposed to get solids before four to six months, but many parents start early.) Store-bought baby foods, which are generally checked for nitrate levels, don't pose the same risk.

WHY DO WE GET SLEEP GUNK IN THE CORNERS OF OUR EYES?

Because we don't blink when we sleep. The gunk is composed mostly of the oil that our eyes make to keep the corneas lubricated, as well as bacteria that live around the eyes, says ophthalmologist Rachel Bishop, a spokesperson for the National Eye Institute. Glands located along the eyelid produce the oil, which drains into the nose when we blink. But when our eyes are closed for some time, it dries up and accumulates, appearing in the morning as that gunk.

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Scientists have made significant contributions to the safety and well-being of the human race. They have identified laws of nature that explain the functioning of the universe, Earth's flora and fauna, and especially of the physical activities of Homo sapiens. But "why" planet Earth and its occupants *exist* is still an admitted mystery to them. What follows explains an important part of that mystery.



Richard W. Wetherill
1906-1989

For millennia great developmental progress has taken mankind from a simple desire to survive to our present complex systems of social laws and inherited customs. Most readers would agree that despite those man-made systems, human affairs are still in a state of confusion with problems and trouble growing daily.

We have races pitted against one another, political groups pitted against one another, as well as individuals who pit themselves against one another in their careers, marriages, and sports to name a few obvious areas.

An appropriate question is, *Why?* Our answer follows: From the beginning people have been living by their own laws of behavior and inherited customs, but those man-made systems contradict a natural law, causing people to get wrong, troublesome results.

That natural law was identified by Richard W. Wetherill almost a century ago and was presented in his book, *Tower of Babel*, published January 2, 1952. It is a law of behavior that Wetherill called the *law of absolute right*, indicating that rightness in all human activities is required for successful outcomes.

As a result of Wetherill's identification of the law, he developed a program called *humanetics* to explain the wrongness of people's attitudes and behavior and how to correct them. Wrongness has not only been destroying people's lives but also increasingly is damaging the environment that supports the life of the planet.

When scientists identify natural laws, they apply their principles to better human existence and well-being—that is, usually, until the nuclear age developed. Scientists could now investigate nature's behavioral law and help to inform people of its principles. Wetherill used words to describe right behavior such as rational, honest, logical, and moral but cautioned that words

are just symbols. **The law is the final arbiter: Right begets right results; wrong begets wrong results.**

What are society's results? Are people rational and honest? Or do they act on their own motives to do, be, have, get, and become whatever they desire?

People know they must obey nature's laws of gravity, friction, and all the other laws of physics, but for nearly a century scientists, religionists, educators, and the public have resisted acknowledging creation's law of rightness. Is that sane?

Albert Einstein defined insanity as doing the same thing over and over again and expecting a different result. For millennia people have reasoned from man-made laws and inherited customs over and over again, expecting a different result. Instead, over and over again, humanity has been getting incalculable wrong results. Is that sane?

This essay/ad provides a brief description of the behavior that natural law requires of us. Are we going to comply and get out of the muddled mess of human affairs being caused by acting on man-made laws?

Visit our colorful Website www.alphapub.com where essays and books describe the changes called for by whoever or whatever created nature's law of absolute right. The material can be read and downloaded free. As people worldwide visit our Website, they can join those who are already benefiting from adhering to the behavioral law 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.

How do fireworks create shapes?

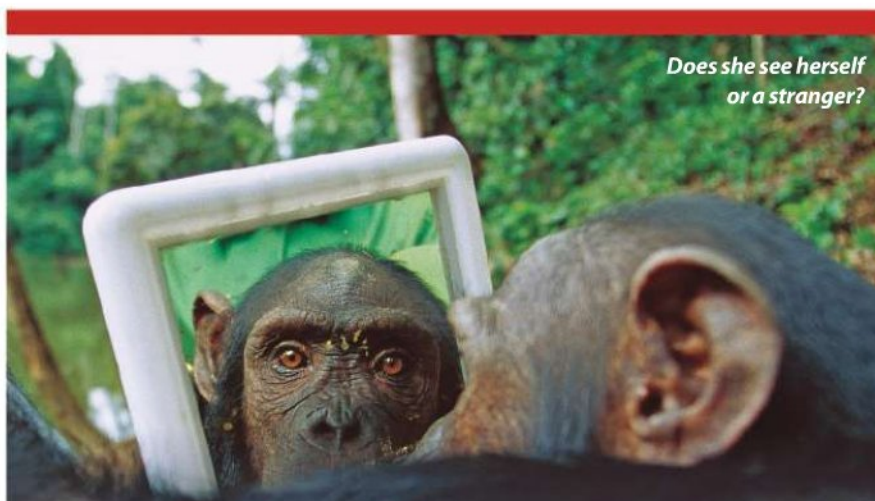
The positioning of chemical pellets inside firework shells determines the patterns, from the traditional round bursts to the more recent hearts, bow ties and smiley faces.

Fireworks contain an inner bursting charge of "black powder" (the original gunpowder). Manufacturers insert pellets of different chemical compositions that burn with different colors, called stars, around the powder in the pattern they want to create in the sky. When the bursting charge explodes it ignites the stars, and they spread out in the sky, retaining their relative distance from one another. The pattern inside the canister is thus re-created and magnified in the sky.

A time-delayed fuse inside a fireworks shell ensures that the stars will not ignite until the launched shell reaches the right altitude, which is typically 300 to 600 feet. This fuse can also sequentially ignite black powder in different compartments to spread stars of different colors in a coordinated manner.



Shapes like smiley faces are created by the arrangement of chemical pellets inside fireworks shells.



Does she see herself or a stranger?

Can animals recognize themselves in a mirror?

Most animals react to their image in a mirror as if it were a stranger, but scientists have shown that a few species aside from humans are able to recognize themselves. This includes dolphins and most great apes.

Scientists use the "mirror test" as an important tool to investigate an animal's conception of itself. To test for mirror self-recognition, researchers put a colorful mark on a part of the animal's body that it can't see directly. The animal is then placed in front of a mirror. If it looks for the mark on its body based only on seeing that mark in the reflection, it is considered to have recognized itself. This kind of self-recognition has been shown in humans, chimpanzees, bonobos, orangutans, dolphins and, most recently, magpies and elephants. Surprisingly, most studies conclude that gorillas are the only great apes that do not show mirror self-recognition, and scientists are still unsure why this is. A few individual gorillas raised in the presence of humans have passed this test, however, leading some researchers to suggest that the apes can learn mirror self-recognition if they spend enough time interacting with people.

Animals that can recognize themselves in a mirror tend to have relatively large and complex brains, well-developed social lives, and the ability to understand other individuals and display emotions toward them. Many researchers think that empathy and social intelligence rely on our ability to have a concept of self, without which we wouldn't be able to recognize ourselves in a mirror. Interestingly, human children are not able to recognize themselves in a mirror until one and a half to two years of age, a clear stage in child development.



Mirror, Mirror on the Wall

When an elephant looks into the mirror, it's clear that the animal recognizes itself. It uses the mirror to carefully examine different parts of its body.

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

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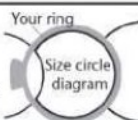
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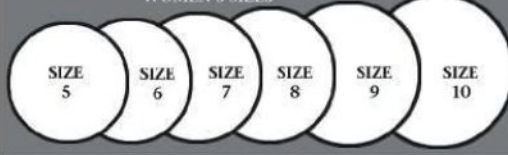
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WOMEN'S SIZES



Why are colors hard to see at night?

Our drab view of the nighttime world has to do with the two types of sensory cells that our eyes use to see: rods and cones. Rod cells are far more abundant than cones and are much more sensitive to light. We use rods to detect the size, shape and brightness of objects. But rods don't perceive color and fine detail; to do that, we require cones.

There are three types of cones, which detect specific wavelengths of light corresponding to red, green and blue colors. A particular color stimulates all three receptors to different degrees, and the color we perceive depends on how much each kind of cone is stimulated.

Cones become activated at illumination levels around those of bright moonlight, and during daylight we see exclusively using our cones. But in low-illumination conditions, light levels are a fraction of what they are in daylight. Cones are not sensitive enough to detect this light, and instead we see almost exclusively using rods. Because rods can't perceive color, we see the world at night in mostly black and white.

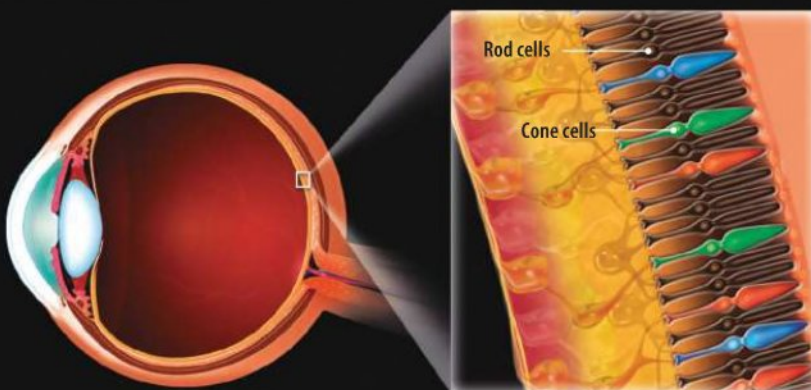
Destruction or loss of sensitivity of rods, commonly caused by inherited diseases or vitamin-A deficiency, can lead to night blindness, an inability to see in dim light or at night.



The human eye needs light to distinguish colors. So at night, we see the world in mostly black, white and shades of gray.

Rod Cells Give Us Black-and-White Night Vision

Cone cells are far less light-sensitive than rods. Rods take over in darkness, but they can't perceive colors, which is why people have difficulty seeing colors at night.



How do insects breathe underwater?

Aquatic insects have developed several ways of getting oxygen. Early on, mayflies and dragonflies have external gills that pick up oxygen and release carbon dioxide.

But most adult insects breathe through spiracles—pores connecting their circulatory system to the outside. Water beetles commonly stash surface air as bubbles under their wings. As a beetle uses a bubble, more oxygen diffuses into the bubble from the water, and carbon dioxide escapes.

Over time, the bubble shrinks. To avoid resurfacing, some beetles have developed plastrons, shells of dense hairs that hold a thin film of air tightly against their body. The air layer is endless: It doesn't shrink in size and doesn't have to be replenished.

Some aquatic insects, such as *Buenoa* and *Anisops*, store oxygen reserves in special hemoglobin-filled cells. And water spiders can weave themselves a silk diving bell, which they fill with air bubbles.



Diving beetles regularly fetch bubbles from the surface.

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Terror birds most likely whacked prey against a hard surface. They then held it down and tore meat from the carcass in shreds.

When GIANT BIRDS Reigned Supreme

Due to quirks in evolution, some birds grew to enormous sizes. Some of these frightening creatures lived millions of years ago, while others survived well into the last millennium. What happened to these massive beasts?

Say hello to the terror birds. Ten feet tall, 600 pounds and capable of running 40 miles an hour before felling a small horse with one mighty kick, these vicious carnivores first stalked the plains of South America 60 million years ago. Around the time they finally died out, two million years ago, a smaller version lived in North America. Scientists think terror birds were the dominant meat eaters of their time. But the birds aren't alone in the fossil record: A variety of giant birds once dominated the landscape, and some survived well into the time of modern humans.

Through fossils and chemical analysis, we know a fair bit about

such birds, including their habits and habitats. But questions linger. Why did these birds get so big? Could they fly? And why did they die out? Science has uncovered some clues to illuminate the lives—and deaths—of these avian colossi.

Who Were They?

Terror birds, a group of related beasts that share the family name Phorusrhacidae, were fearsome, but they weren't the largest or the most powerful birds to have walked the earth. Fossil remnants of birdlike monsters

have been unearthed in places as diverse as France, Madagascar and Australia. Here is a rogues' gallery of giant birds across the planet.

THE AMERICAS

Joining the terror birds of the Americas was the largest of the ancient birds that could fly. Six million years ago, *Argentavis magnificens* cast shadows over the Argentinean Andes Mountains with its 23-foot wingspan. Weighing 155 pounds and about the size of a Cessna 152 airplane, it was close to the weight limit for flight, and for many years, the question of how it could have gotten into the air at all was a mystery to paleontolo-

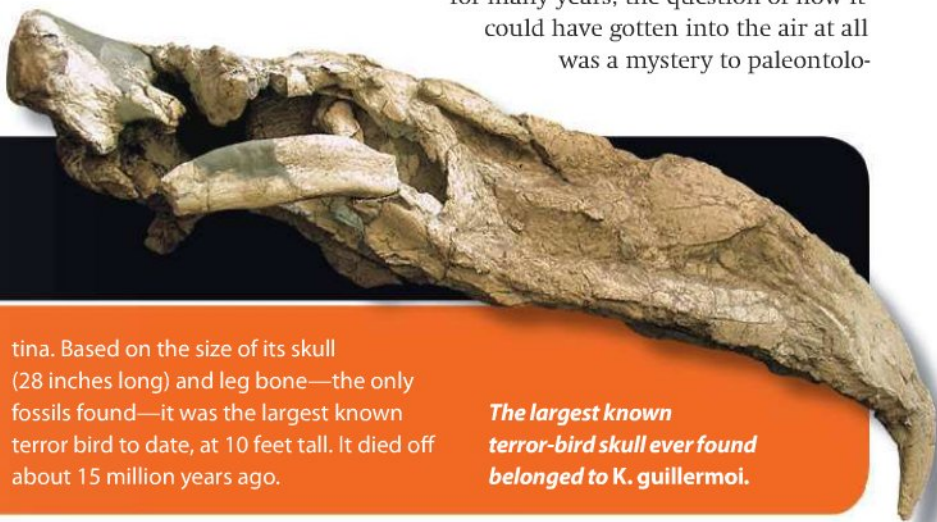
Terror Birds Dominated in the Americas

Fossils of *Titanis walleri* [left], the last terror bird to go extinct around two million years ago, have been found as far north as Texas.

In 2004, fossils of a similar bird, *Kelenken guillermoi*, were found in Comallo, Argen-

tina. Based on the size of its skull (28 inches long) and leg bone—the only fossils found—it was the largest known terror bird to date, at 10 feet tall. It died off about 15 million years ago.

The largest known terror-bird skull ever found belonged to *K. guillermoi*.



Elephant Birds Laid Massive Eggs

An unknown number of elephant-bird species once lived in Madagascar. The most impressive of these stood 10 feet tall and laid eggs that were about three feet around.

The last of these elephant birds vanished some 1,000 years ago, but it is still possible to find their eggshells. Scientists have analyzed the shells' composition, which indicates that the birds ate plants that grew in swampy environments.

A chicken egg is dwarfed by an eggshell from a Madagascar elephant bird.



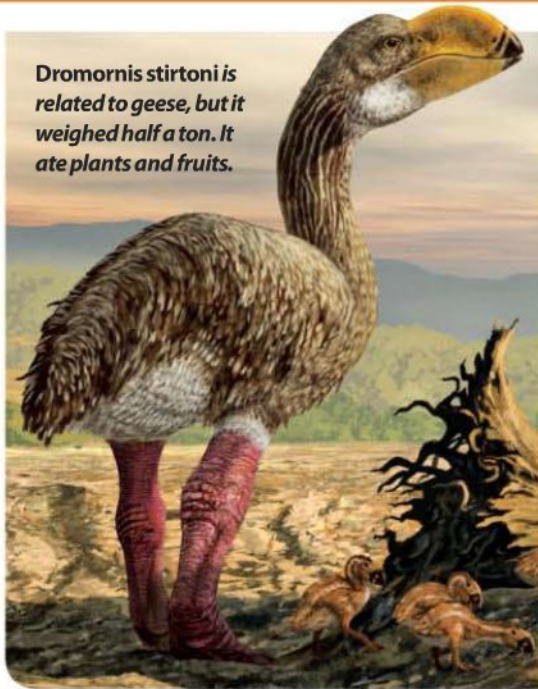
Gastornis lived 55 million years ago. It is one of the earliest giant birds known.



gists. Computer simulations by Texas Tech University paleontologist Sankar Chatterjee suggest that *A. magnificens* was a glider. Its wings were too weak for flapping flight, and it took off in a similar way to a hang-glider pilot—by dropping off a cliff or running down an incline and gliding from there.

Another of South America's mega-birds was *Icadyptes salasi*, a five-foot-tall penguin that lived 36 million years ago. In 2005, an international scientific team led by paleontologist Julia Clarke, now at the University of Texas at Austin, discovered fossils of the extinct penguin near the equator, in Peru's sunburned, coastal desert (an extension of the Atacama Desert).

Up north, the albatross-like *Osteodontornis orri* was the world's largest seabird. It had a 20-foot wingspan and unique toothlike projections on its beak, which may have helped it capture soft-bodied prey like squid off the California coast 15 million years ago. Roaming the North American



Dromornis stirtoni is related to geese, but it weighed half a ton. It ate plants and fruits.



Argentavis magnificens (wingspan: 23 feet) remains the largest bird ever to fly.

landscape were also birds thought to be from the *Gastornis* genus, and *Gastornis* birds lived in western Europe. Very little is known of these animals, but they are some of the oldest giant-bird species we are aware of.

MADAGASCAR

The elephant bird of Madagascar, from the genus *Aepyornis*, grew up to 10 feet tall and weighed as much as half a ton. The herbivore produced the biggest eggs known to be laid by any animal—three feet around.

NEW ZEALAND

Prehistoric New Zealand was home to two large bird species: the moa and its predator, Haast's eagle (*Harpagornis moorei*). The largest moa stood 12 feet tall and weighed a quarter-ton. The moa was an herbivorous grazer. It had to keep one eye on the sky, where *H. moorei*, the world's largest-known eagle, ruled. This bird had a 10-foot wingspan, and its talons were as large as a tiger's claws.

AUSTRALIA

This continent's thunder birds are thought to have evolved from smaller waterfowl ancestors, but the 10-foot-tall Stirton's thunder bird (*Dromornis*

stirtoni) was no ordinary goose. It had legs the size of tree trunks, a body the size of a wine barrel and a head the size of a horse's, sporting a huge beak. Despite its fearsome appearance, the thunder bird probably dined on plants and fruits, since fossil evidence shows anatomical structures like lateral eye sockets and hooflike toes, hallmarks of grazers rather than predators. Its close relative and the last thunder bird species to survive, *Genyornis newtoni*, went extinct about 50,000 years ago. It was over six feet tall and was also herbivorous. Like many of the other large animals, *G. newtoni* died out relatively soon after the arrival of humans in Australia.

How Did They Get So Big?

These birds didn't start big. The fossil record shows that they evolved from smaller ancestors. Several evolutionary mechanisms caused this change.

One such mechanism is called island gigantism. Animal life on certain islands has followed its own evolutionary path: Whereas in most areas mammals occupied the top spots in food webs after the disappearance of the dinosaurs, for some unknown reason giant birds occupied the top ecological niches on these islands.

Giant birds resulting from this process have been found in places like Madagascar and New Zealand.

For the elephant bird, the moa and Australian thunder birds, large size provided a competitive advantage. Their height allowed them to browse shrubs and trees that were out of the reach of shorter animals. Paleontologist Peter Murray of the Museum of Central Australia says that "large body size also made it possible for these birds to use hind-gut fermentation, which helps to break down coarse, low-nutritional vegetation for assimilation," like the process used by cows.

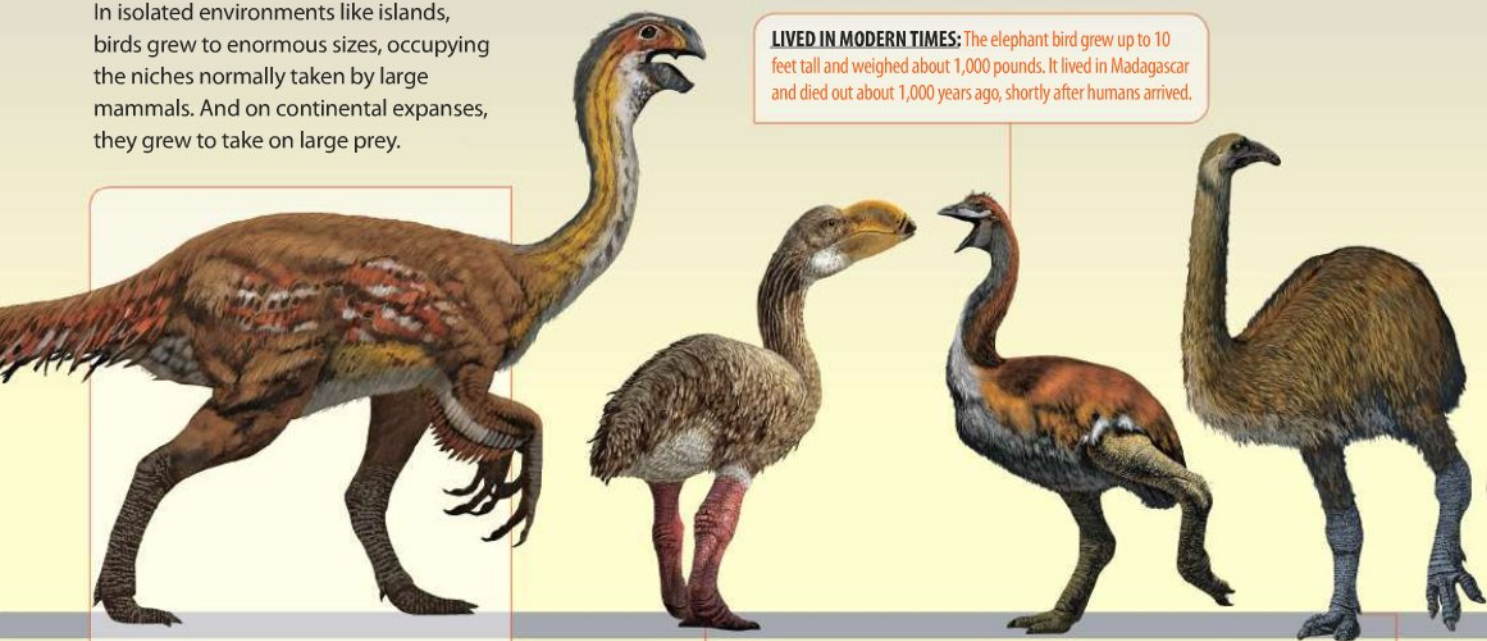
Predatory birds found on the continents, such as the North and South American terror birds, evolved body sizes to match their prey. In a carnivorous arms race, both the predator and prey evolved into larger sizes. The herbivorous targets did so to capitalize on hind-gut fermentation and to provide some insurance against predation, while the carnivores had to develop bodies large enough to take down the massive prey and to survive that prey's death throes.

Why Did They Die Out?

Paleontologists still debate which factor had a greater influence on the

Giant Birds Took Over after the Dinosaurs

In isolated environments like islands, birds grew to enormous sizes, occupying the niches normally taken by large mammals. And on continental expanses, they grew to take on large prey.



BIRDS' ANCESTORS: *Gigantoraptor* was a feathered dinosaur and a possible relative to birds. It lived 85 million years ago and was more than 25 feet tall.

RELATED TO GEES: *Dromornis stirtoni* grew up to 10 feet tall. It lived in Australia until about two million years ago. Its last relatives died out about 50,000 years ago.

RELATED TO OSTRICHES: The moa—10 species in the Dinornithidae family—grew up to 12 feet tall. They lived in New Zealand and probably died out in the 1500s.

giant birds' demise: climate change or humans. In some cases, such as North American terror birds and *O. orri*, abrupt climate change is the most likely culprit. In other regions, it was probably a combination of human influence and climate change.

In some areas, there is growing evidence that humans played a dominant role in the extinctions. The arrival of humans in New Zealand, Madagascar and Australia quickly brought about the destruction of the giant-bird populations there. Within 200 years of humans arriving in New Zealand between A.D. 1250 and 1300, the moa was gone; extensive archaeological findings show that it was intensely hunted and, as farming changed its habitat, it was unable to withstand the onslaught. The last moa probably died in the 1500s.

The elephant bird of Madagascar was driven to extinction—directly or indirectly—after humans arrived on the uninhabited island around 1,000

years ago. The reasons for its extinction are murkier than that of the moa. The most recent information suggests loss of habitat is the primary reason, but climate change may have played a small role. A team led by environmental scientist Simon Clarke of the University of Wollongong in Australia studied data on the carbon and oxygen isotopes in eggshell subfossils—the precursors of “true” fossils—to determine the elephant bird's diet. The analysis revealed that breeding females ate mainly trees and similar vegetation from the swampier areas near the coast, and as the area dried up, the bird lost a food source.

Climate was probably a stressor that exacerbated what scientists think is the main cause of the bird's extinction: the islands' inhabitants transforming the landscape when they cleared it for farming.

“If humans hadn't colonized Madagascar, would the elephant birds still be there?” asks Gifford Miller, a climate

scientist at the University of Colorado at Boulder. “The answer is yes.”

Habitat destruction also doomed Australian thunder bird *G. newtoni*. Like many of the other large animals, it died out relatively soon after the arrival of humans in Australia. Isotope analysis shows that the bird was a picky eater. This data was compared with that taken from the eggshells of the emu, another large bird that still lives in Australia today, which ate a far wider range of vegetation. A huge shift in the emu's diet occurred around the same time that the last thunder bird died out, Miller says, which indicates that *G. newtoni* was not able to adapt fast enough to the rapidly changing environment. There is no direct evidence, but Miller thinks the ecological changes were caused by slash-and-burn farming. His team has additional evidence, which they hope to publish next year, that human predation also led to *G. newtoni*'s extinction.



LARGEST WINGSPAN: *Argentinavis magnificens* had a 23-foot wingspan and weighed 155 pounds. It lived about six million years ago in what is now Argentina.



SERRATED BEAK: *Osteodontornis orri* had a 20-foot wingspan and a beak equipped with toothlike serrations. It lived 15 million years ago on the California coast.



CLAWS LIKE A TIGER: *Harpagornis moorei* sported tigerlike claws. It had a 10-foot wingspan and lived in New Zealand until the 1500s.



EARLY BIRD: *Gastornis giganteus* grew up to six and a half feet tall. It lived in Europe and North America 55 million years ago.



NORTHERNMOST TERROR BIRD: *Titanis walleri* weighed up to 350 pounds and stood about six and a half feet tall. It lived on the plains of present-day Texas and Florida—the only terror bird to live that far north—and died out about two million years ago.



LARGEST PENGUIN: *Icthyophaga alba* stood at least five feet high and lived in the coastal Peruvian desert 36 million years ago.



Large body size generally means lower reproduction rates and a diminished capacity to migrate over long distances—in addition to creating an attractive target for human hunting. So although large body size conferred advantages to the giant birds, in the end it proved their undoing. ■



Ancient Penguins Were Five Feet Tall

Paleontologist Julia Clarke, now at the University of Texas at Austin, and her team found fossils from a giant, desert-dwelling penguin that lived 36 million years ago in Peru.

The bird was at least five feet tall and had a spear-shaped beak—

unlike any other known penguin—which measured about seven inches, or two thirds of its total skull length.

This fossil of the giant penguin's beak was found in 2005 in Peru's dry coastal desert.



ROBOTS

on the Job

Robots are on the verge of replacing humans in a wide variety of tasks. As designers overcome ever-sophisticated challenges, automatons now make coffee, assist during surgery, and even teach schoolchildren. Meet the robot workers that are taking on the tough jobs we once thought only humans could handle



WORK 'BOTS



It's one thing to create robots that perform repetitive, unchanging tasks, such as assembling cars. It's another to build a robot that can interact with people in the workplace. If robots are to work alongside us, they'll have to seem empathetic, fit in the same spaces, move in familiar ways. But combining these complex capabilities into a single robot, and giving that robot the capacity to recognize and adapt to various social situations, is perhaps the greatest design challenge of all.

ロボ

Schoolteacher



NAME Saya

BACKGROUND Electrical engineer Hiroshi Kobayashi of the Tokyo University of Science originally developed a prototype of Saya in 1993 in an attempt to use facial expressions to allow robots to communicate emotions. Now the robot can teach class at a Tokyo elementary school, answer phones, and greet visitors in an office.

CAPABILITIES Saya behaves much like a real schoolteacher. In experiments at elementary schools, it gave children homework, observed and responded to their speech and behavior, called their names, and made eye contact with them. When prompted by an operator, the 'bot encouraged or warned them verbally or through its lively facial expressions. Saya can also use speech recognition and speech-synthesis systems to function as a receptionist. The robot speaks Japanese and English and could learn to speak more languages with voice-synthesis software.

CHALLENGES Saya's creators hope they can make its face even more lifelike. Today it can express surprise, fear, disgust, anger, happiness and sadness. The researchers' aim is to make its expressions more realistic using new mechanisms to move the muscles and new skin materials. Facial expressions aren't just important for communication between people, they're also important for a teacher seeking to get information across to a roomful of schoolchildren.

EMOTIVE BOOST



Engineers have put a lot of effort into giving Saya a lively face. They have provided it with artificial muscles that expand and contract with the aid of pneumatics. A mechanical system using blasts of air lies beneath the robot's skin and drives these muscles. As a result, Saya can, for example, lift its eyebrows while crinkling its nose or smile with its mouth and eyes. The robot's artificial skin (made of soft urethane resin) is cast in a mold and feels as soft and pliable as human flesh.



High-Precision Surgeon



NAME RIO

BACKGROUND The RIO robotic arm began with a 'bot developed at the Massachusetts Institute of Technology that could catch and throw a ball. The arm was adapted by MAKO Surgical Corp. in Florida, and RIO performed its first surgery in 2006.

CAPABILITIES In partial knee surgery, the arm uses a CT scan to help plan the size and placement of an implant and then aids the physician in precisely carrying out the surgery. The result should mean a less invasive and less traumatic surgery, with fewer complications and faster recovery for the patients.

CHALLENGES Designers want to make the arm capable of adjusting even if patients move, and they hope to eventually extend the technology to joints other than the knee.



Babysitter



NAME Rovio

BACKGROUND Launched in 2008, Rovio relays live video feeds to a user over the Web. It can also be taught to navigate through rooms by itself, inform users when its power is running low, and return to its charging station.

CAPABILITIES The little robot is equipped with a video camera, speakers and a wireless Internet connection. Users—say, parents running an errand—can control and communicate through Rovio remotely over the Internet. A clip-on headlight allows Rovio to capture video even at night.

CHALLENGES Rovio could make impromptu teleconferencing as natural as speaking to someone in the room. Rovio's designer, Hong Kong-based WowWee, is investigating adding high-resolution audio and video in future versions, as well as environmental, temperature and motion sensors.

Nurse's Aide



NAME GuiaBot

BACKGROUND Its designers at MobileRobots intended GuiaBot for face-to-face interactions with humans, and since its unveiling in 2008, it has been used for office and hospital work.

CAPABILITIES The 40-inch, 110-pound robot, equipped with a laser, a high-definition camera and a touchscreen, can navigate autonomously through a hospital (it even says "Excuse me") and act in the roles of receptionist, night watchman or guide.

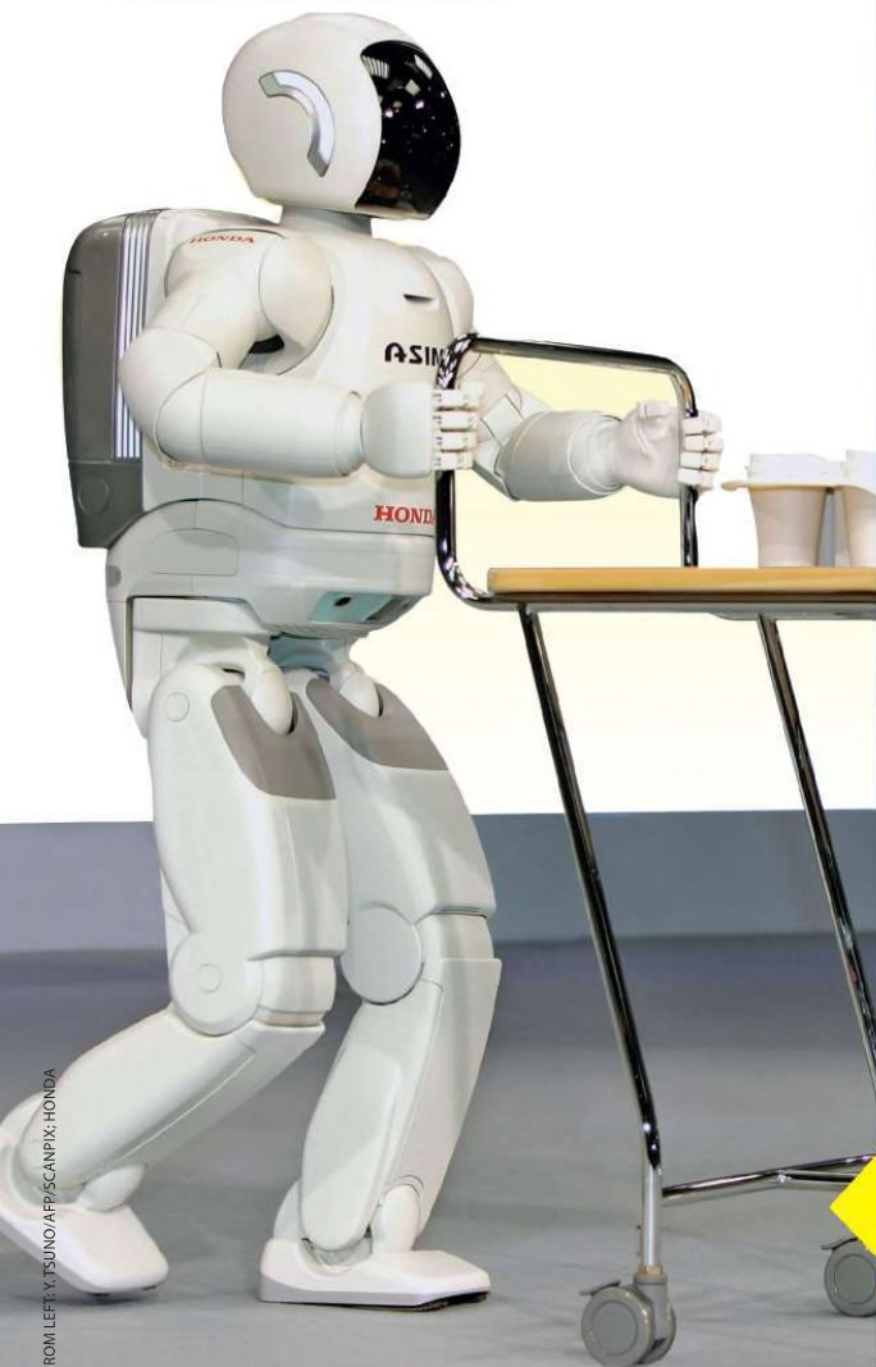
CHALLENGES Its designers hope to adapt it for use in hotels, airports and stores. Since users can extensively customize the robot and its interface, GuiaBot could soon have dozens of abilities and applications.



HOME 'BOTS



Robots are becoming part of the family. Today they can vacuum, shovel snow, and play with the kids, and in the next few years, the number of robots found in the home could rise markedly. Sensors and intelligence need improvement so that they can understand and interpret the world and then choose appropriate action. High on the list is facial recognition and the ability to identify emotions.



FROM LEFT: Y. TSUNO/AFP/SCANPIX; HONDA

Butler



NAME Asimo

BACKGROUND When the first version of Honda's Asimo was built in 1986, the robot needed five seconds to take a single step. Today the robot is capable of jogging. Several companies have made humanoid robots similar to Asimo, such as Mitsubishi's Wakamaru robot, which reminds patients to take their medicines, and Toyota's Partner Robot.

CAPABILITIES Asimo is one of the world's most advanced humanoid robots. It is 4'3" and 119 pounds, is able to climb stairs, and can run a mile in about 16 minutes. Asimo responds to voice commands, postures and gestures and can maneuver among people, moving aside if it encounters someone in an elevator or on the stairs.

CHALLENGES The newest model of this 24-year-old robot can cooperate with other Asimos to complete its tasks. The robots share information by wirelessly informing each other what they are doing and where they are located. They can, for example, work together to serve refreshments to humans. If one Asimo takes a break to get its batteries recharged, another will step in to take its place.

Additionally, Asimo can recognize up to 10 people's faces and address each by the correct name. The team that created it hopes to go further and make a humanoid robot that can behave completely autonomously and be truly intelligent, but such a feat will require a better understanding of the human brain.

MIND CONTROL

The Asimo design team has developed technology that allows a human to control the 'bot with his or her thoughts.

Helmet sensors gauge tiny changes in the brain's electrical impulses and blood flow—the first time these measurement methods have been combined for this purpose. The helmet's software assesses changes in the brain in real time and translates them into commands. They are transmitted to Asimo, which then lifts its arm, for instance, or takes a step.



Battlefield Extractor

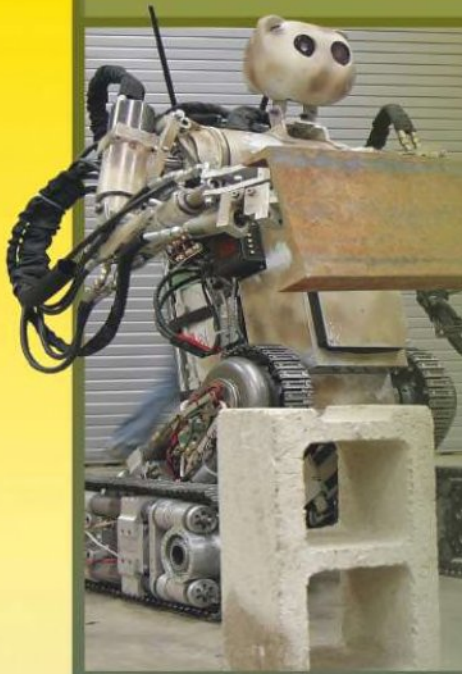


NAME BEAR

BACKGROUND Vecna Robotics created the Battlefield Extraction Assist Robot, or BEAR, with support from the U.S. Army. It could hit battlefields in six years.

CAPABILITIES BEAR can carry heavy cargo or tiny, fragile objects while crouching behind cover or traveling over obstacles. Its cameras and microphones allow for remote or semi-autonomous operation.

CHALLENGES Expected improvements include the ability to navigate complex environments, such as dangerous buildings, on its own.



Spybot



NAME T-Hawk

BACKGROUND This flying spybot was successfully battle-tested in Iraq and is on its way to having a permanent position in the American and English militaries. T-Hawk was a collaboration between the U.S. Department of Defense and the contractor Honeywell.

CAPABILITIES T-Hawk is equipped with an ordinary video camera plus an infrared camera for night vision. Soldiers can use the camera to find roadside bombs and other threats. The robot can fly for up to 50 minutes at speeds of up to 50 mph and, at 17 pounds, can be carried in a backpack. It takes off and lands vertically, and soldiers can either control it manually using a console or send it out on a preprogrammed route that the robot will navigate by flying from one GPS landmark to the next.

CHALLENGES Honeywell is looking to outfit T-Hawk with radar and other sensors to detect chemical, biological and radiation threats. Eventually, the robot may have interchangeable payloads. It is being tested for police use and could have commercial applications as well—inspecting pipelines and bridges, for example.

Rescue and Recovery



NAME RoboCue

BACKGROUND RoboCue was developed in 1994 in Japan for rescues where hazardous substances made the area too dangerous for firefighters. Tokyo's fire department uses a RoboCue half the size of the first model [below].

CAPABILITIES Operated by remote control, RoboCue retrieves and revives victims in dangerous circumstances. It can be fitted with as many as three cameras, a communication device for speaking with victims, an oxygen supply and a device to analyze the environment for firefighters.

CHALLENGES RoboCue had to be made as small as possible while remaining extremely strong and durable. Although it is more compact, the latest RoboCue can still use its arms to lift an adult man to its conveyor belt and drag him to safety.



DANGER 'BOTS



The number of robots found in the world's war and conflict zones is likely to increase in the near future. Both the American and English militaries are working with civilian companies to design and deploy robots for battle. One of the challenges is to develop robots that can move over rough ground—places four-wheeled vehicles would find hard to pass. Another challenge is to integrate delicate sensors and expensive devices into robots that will have to tolerate rugged, often dangerous conditions and operate day and night.

BigDog can carry up to 330 pounds of baggage and supplies through most terrain.

Beast of Burden



NAME BigDog

BACKGROUND For decades, engineers have sought to understand how people and animals move and maintain their balance. Researchers at Boston Dynamics developed a stable four-legged robot named BigDog that can function as a soldier's mule.

CAPABILITIES BigDog is about the size of a small donkey and weighs 240 pounds. It can walk at about 3.5 mph, cross mountainous terrain, and climb a 35-degree slope. It can carry 330 pounds of ammunition or supplies over a flat surface and up to 120 pounds through mud and rocks. The robot has four legs, a GPS receiver and a 15-horsepower go-kart engine that powers its movement. It is equipped with four hydraulic actuators on each leg, and 50 sensors, including some on the legs that monitor resistance encountered by each actuator. A computer processes input from the sensors and calculates where to place the next step. BigDog can maintain its footing even on slippery surfaces like ice and snow.

CHALLENGES The ultimate goal for a legged robot like BigDog is to be able to reach the same places as people and animals. This means crossing water, walking in deep snow, and climbing muddy hillsides. It is well on its way—a future BigDog model could soon have better balance and be able to cover harsher terrain and get back up if it falls. This would make it even more useful as a mule, especially for military transport.

BALANCE BREAKTHROUGH

Whereas a mechanical gyroscope maintains stability by spinning, BigDog uses a laser gyroscope to measure and maintain its orientation with beams of light. Laser gyroscopes are more reliable than mechanical ones, and combining information from this gyroscope with the robot's sensors and guidance system provides BigDog with a fantastic sense of balance. The guidance system adjusts BigDog's balance 500 times per second and directs the robot's movements, making even the present version very hard to tip over.



Broken Dreams

Brain regions involved in normal daydreaming don't light up in people with autism and Alzheimer's. Could this finding hold a clue to the disorders?

Daydreaming isn't just for starry-eyed loafers. For most of us, it's a fact of life. In one study, up to 96 percent of adults said they drift off at least once a day. Our minds tend to wander while we're engaged in mundane or repetitive tasks like driving home from work, digesting a meal, or taking a jog. Far from unhealthy, these mental vacations can relieve stress and boredom and help us prepare for the future. It's the people whose minds don't appear to do this that raise red flags among researchers. In fact, scientists have discovered that the brain regions that take over when our minds are left to drift don't function the same way in people with autism and Alzheimer's disease as they do in others, a finding that suggests that the same regions that govern our daytime reveries also have a part in certain brain afflictions.

Neurologist Marcus Raichle of Washington University in St. Louis uncovered one of those regions in 2001. When he and his colleagues scanned idle volunteers' brains using positron-emission tomography, they observed clusters of active cells among the inactive ones. The researchers dubbed these active cells the default-mode network because they appear to stay busy while the rest of the brain relaxes.

Raichle and others have found that when people engage in more-goal-directed thinking (such as math problems), default-mode-network activity decreases. This indicates a shift away from the default region to other cells thought to play a role in nonemotional

and nonsocial tasks. For reasons that are still unclear, this deactivation of the default-mode network doesn't happen in people with autism and Alzheimer's, possibly because the network never fully activates in the first place.

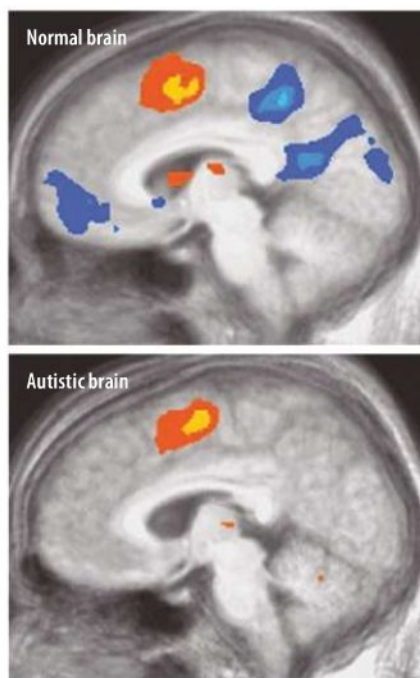
Active Thinkers

In 2006 Daniel Kennedy, a neuroscientist at the University of California at San Diego who specializes in autism, set out to find some answers. Kennedy knew that people with autism struggle to process emotions, recognize faces,

and concentrate their thoughts on other people, all activities associated with daydreaming and known to light up the default-mode network. So he and his colleagues devised an experiment to see how such tasks would change the brain activity of 12 volunteers with autism and 14 without. Volunteers were asked to take a tricky test often used to assess reaction times. The results showed that brain activity in healthy volunteers switched from the default mode to other regions of the brain to tackle the test, whereas in people with autism, brain activity remained constant, with the default region little used in both scenarios.

This is not to say that people with autism do not daydream at all. Rather, they may daydream about more-concrete things, perhaps related to an obsessive interest, and this could be why brain regions typically associated with daydreaming remain idle. "It's not like their mind is blank, but the idea is that there could possibly be a different interest," says Kennedy, now a postdoctoral candidate at the California Institute of Technology.

There may be an anatomical explanation of why those with autism don't show default-network activity. In people with autism, "early in development, there seems to be overgrowth of some brain structures, and particularly the frontal lobe seems to be affected," Kennedy says. Since the medial frontal cortex is a primary part of the default-mode network, differences in that area might be behind the differences in default-mode-network function.



Healthy people and subjects with autism show evidence of brain activation during difficult tasks. But those with autism don't show evidence of deactivation when idle.

The Wandering Mind

People with Alzheimer's also tend to have an underactive default-mode network. As with autism, the explanation for this is incomplete. One important factor, according to Jessica Andrews-Hanna, a postdoctoral research associate at the University of Colorado, is that Alzheimer's disrupts important components of the default-mode network such as the medial parietal cortex, the lateral parietal cortex and the hippocampus—all of which play a key role in remembering our past and planning our future. People with Alzheimer's tend to think less about the future, and the brain activity in their default-mode networks is lower during rest periods than in normal adults.

"The term 'mind wandering' has been given a bad rep," says Andrews-Hanna. "Mind wandering can be very adaptive and functional. When we daydream about the past, our brains may be consolidating these memories so that we remember them better later. When we daydream about the future, we may actually become better prepared to confront the event we're daydreaming about."

Amyloid plaques, fibrous protein deposits that are linked to Alzheimer's, also play a role. "What has been most stunning recently is PIB [amyloid marker] scans," Raichle says. "If you look at the deposition of plaques in the brain, it is an absolute mirror of the default-mode network."

But the idle brain doesn't rely only on the default-mode network. Michael Greicius, director of the Functional Imaging in Neuropsychiatric Disorders Lab at Stanford University, points out that it is one of several resting-state networks in the brain. "The interesting thing is it looks as though Alzheimer's tends to target this default-mode network," he says, "but then four other distinct neurodegenerative diseases target different resting-state networks."

Despite all the clues, no studies have proved conclusively that default-mode network deficits rob people with Alzheimer's and autism of the ability to daydream normally. Future studies may offer more insight into the causes and implications of these deficits. ■

Daydreams Take Place in Your Cortices

When most people daydream, the brain is particularly activated in three areas of the cortex. Combined, these areas form a network that communicates with the hippocampus, the center for memory. For people with autism and Alzheimer's disease, this cortical activation doesn't occur, which may disrupt normal daydreaming.

Medial prefrontal cortex

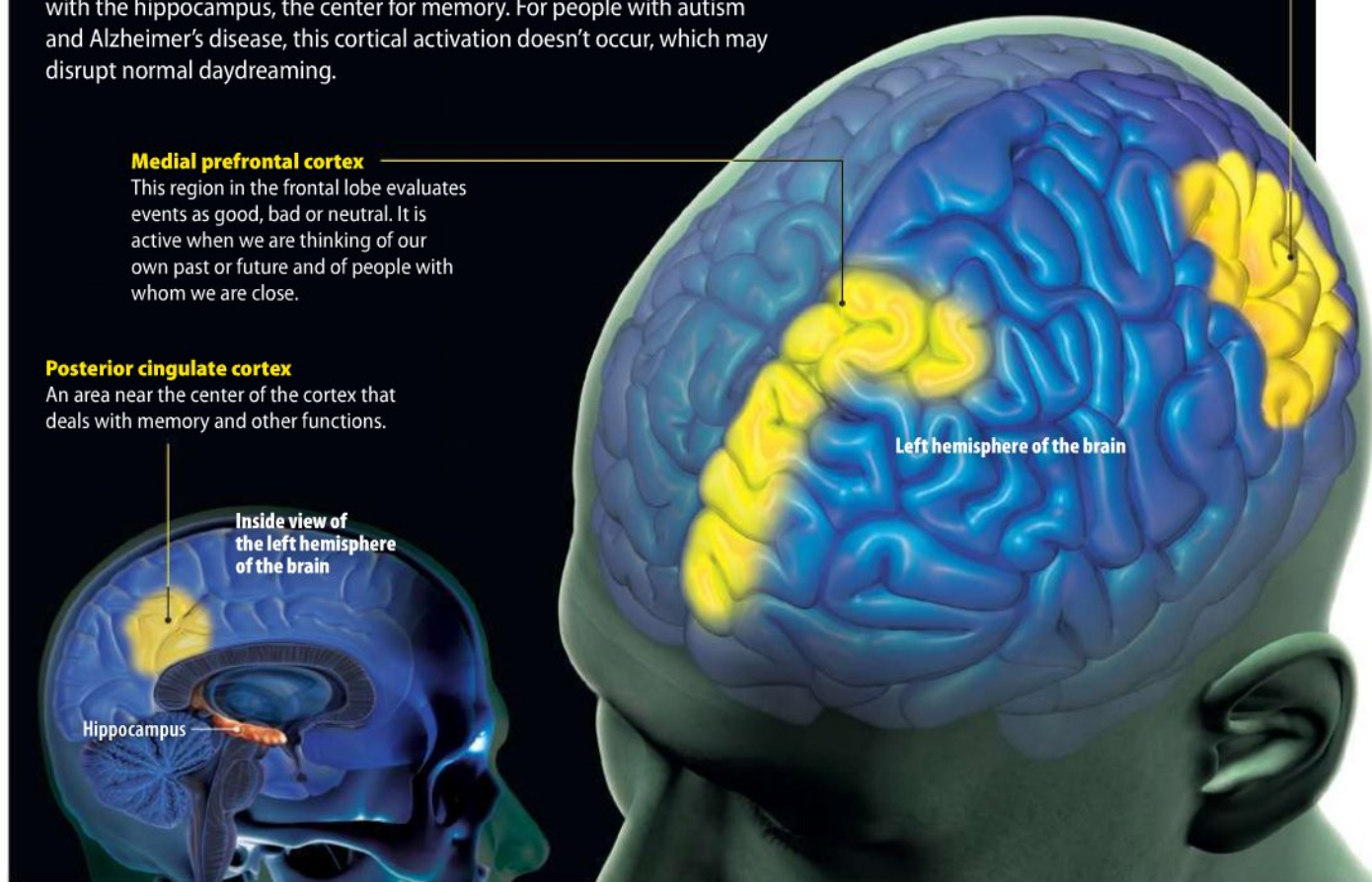
This region in the frontal lobe evaluates events as good, bad or neutral. It is active when we are thinking of our own past or future and of people with whom we are close.

Posterior cingulate cortex

An area near the center of the cortex that deals with memory and other functions.

Lateral parietal cortex

This area is involved in autobiographical memories, future planning, and thinking from other people's perspectives.



Continental IMPACT

Although we know that continents constantly move across the surface of Earth, we don't know why they first began to drift. A new theory proposes that violent impacts from celestial bodies could have kicked off the process 2.5 billion years ago

Earth's continents are always moving. This continental drift, part of the theory of plate tectonics, is so fundamental to geology that it's easy to forget that the concept was a fringe theory just a few decades ago. It's only recently that a majority of geologists accepted the idea that Earth's crust consists of plates that move in relation to one another and that this motion can explain earthquakes, volcanic eruptions and the formation of mountain ranges—some of the most important phenomena encountered in geology. Today the idea is largely undisputed. But there is a fundamental question about plate tectonics that has not been answered: How did the movement of continents begin?

Vicki L. Hansen, a geologist at the University of Minnesota Duluth, recently published her hypothesis that the movement may have started over 2.5 billion years ago. Hansen suspects

that powerful impacts in several places on Earth from so-called bolides—objects such as comets and asteroids that crash into planets and moons—could have caused large amounts of molten magma from Earth's mantle to flow to the surface. This would have set off subduction, a crucial process in plate tectonics in which one continental plate slides beneath another.

A New Movement

In 1915 German meteorologist, geophysicist and astronomer Alfred

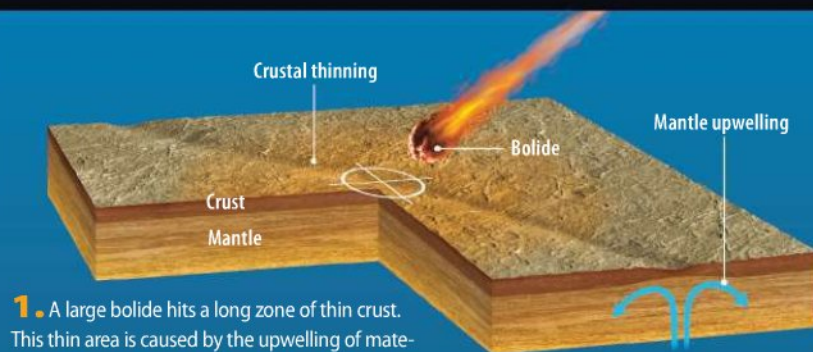


*Vicki L. Hansen
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of Minnesota
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objects impact-
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have set its sur-
face in motion.*

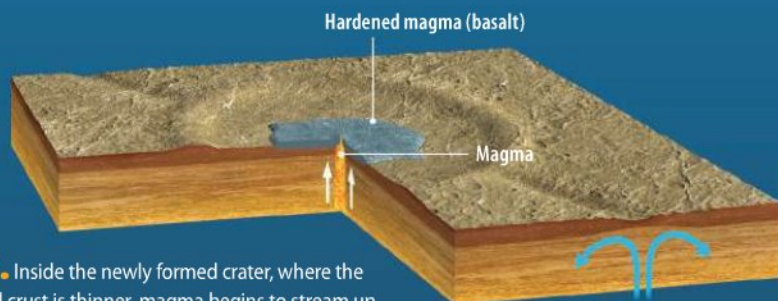


How a Bolide Sets Plates in Motion

More than 2.5 billion years ago, Earth was much hotter than it is today, and its crust could have been uniform. According to Vicki L. Hansen's hypothesis, a bolide—an impacting object—could have smashed a gigantic hole in the crust and let upwelling magma flow to the surface to kick off plate tectonics as we know it.



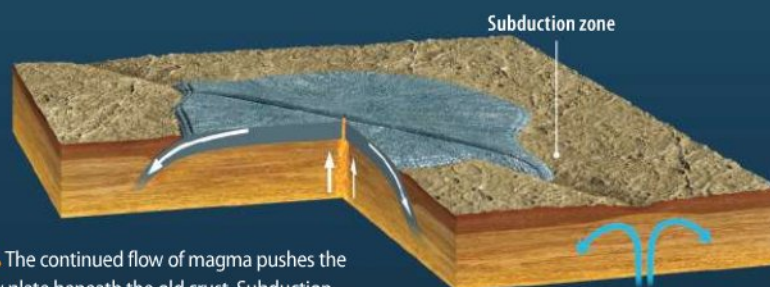
1. A large bolide hits a long zone of thin crust. This thin area is caused by the upwelling of material from the mantle below the crust.



2. Inside the newly formed crater, where the old crust is thinner, magma begins to stream up to the surface, where it hardens into basalt. This creates a new basalt plate, which spreads as magma continues to stream to the surface.



3. The upwelling of magma continues. The basalt plate continues to grow and push out to the sides until it hits the edge of the crater.



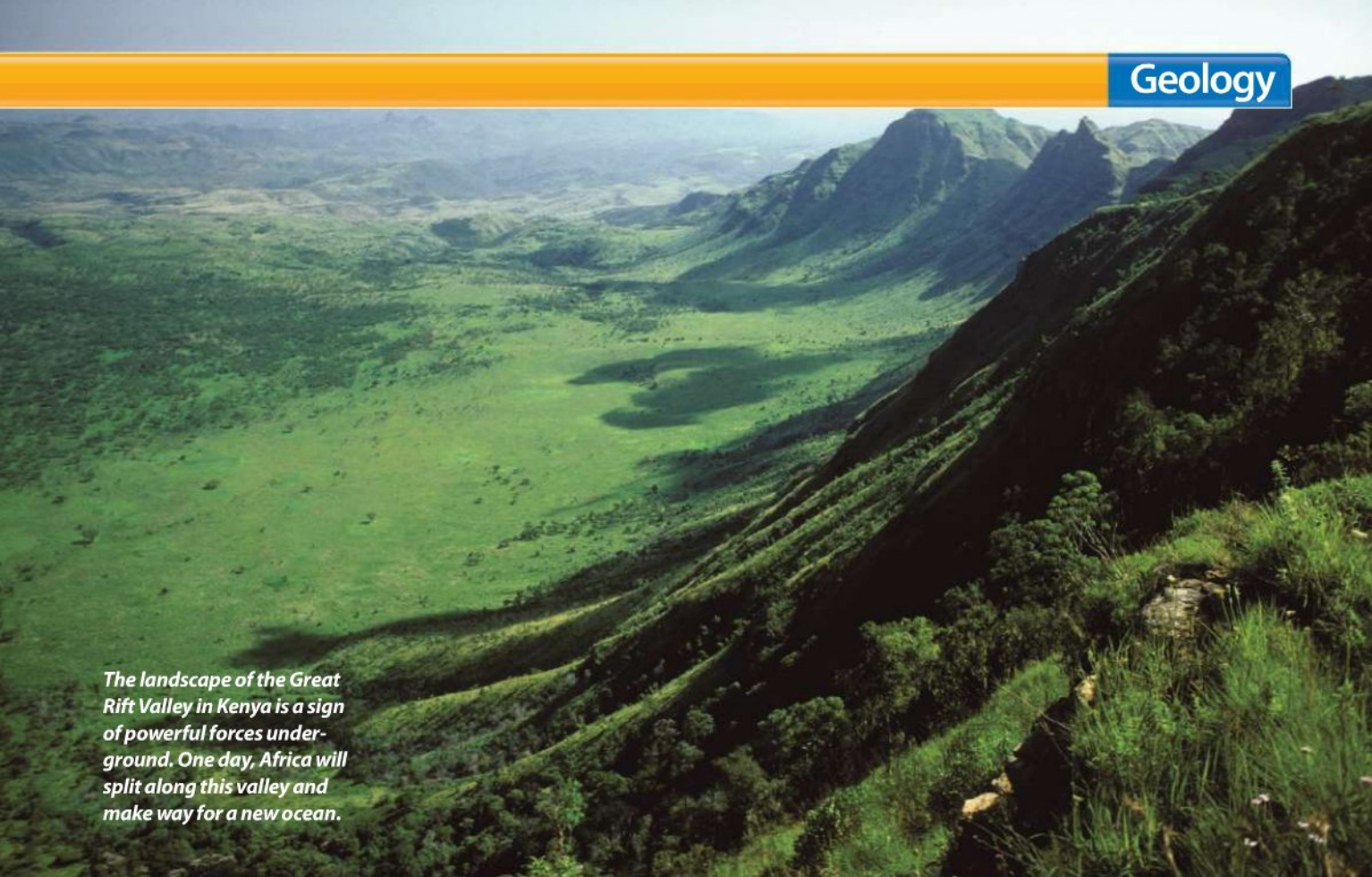
4. The continued flow of magma pushes the new plate beneath the old crust. Subduction—the process by which plates continually disappear back into the mantle—has begun.

Wegener presented his idea, now known as the theory of continental drift, that the continents are in motion and had once, in the distant past, formed a single supercontinent. Bringing together observations from several fields—the interlocking appearance of the African and South American coastlines, the identical plants and animals found fossilized on both sides of the Atlantic, the strikingly similar mountain ranges and rock formations on separate continents—Wegener asserted that the continents had once been a single landmass, which he dubbed Pangaea, and were now separate because they had broken and moved apart.

Wegener's contemporaries greeted his ideas with great skepticism. Although many scientists believed that the continents could have been connected, the reigning hypothesis was that they had been linked by land bridges, which had since sunk into the oceans. The idea that the continents moved seemed far-fetched, especially because Wegener couldn't explain how or why it happened. His suggestion that the continents plowed through the ocean floor as they moved was dismissed as impossible. And the explanations he offered for why the continents were moving—that the motion might be driven by centrifugal or magnetic forces—were similarly discounted.

Wegener worked on his theory right up to his death in 1930, but the notion of continental drift wasn't accepted during his lifetime. A turning point came in the decades after World War II. Because of military interest in submarine navigation, and with the aid of new sonar technology, geologists meticulously mapped the bottom of the oceans for the first time. The results astonished them. They discovered underwater mountain ranges extending for hundreds of miles across the globe.

In the centers of these ranges, dubbed mid-ocean ridges, geologists found evidence of new rocks forming from magma flowing to the surface and cooling. They also discovered undersea trenches, often where the



The landscape of the Great Rift Valley in Kenya is a sign of powerful forces underground. One day, Africa will split along this valley and make way for a new ocean.

continents met the oceans, and some of these trenches were more than six miles deep. At the same time that these discoveries were being made, seismologists were developing methods to more precisely locate earthquakes, which proved to be concentrated near the newly discovered mid-ocean ridges and

deep-sea trenches. Perhaps, researchers thought, the earth was moving most dramatically in these places where the deep ocean met the continents.

Another decisive breakthrough came in the 1960s, when research vessels were first sent out to drill into the seafloor. One important project started

in 1968, when the *Glomar Challenger* set sail on the first of 15 years of voyages for the international Deep Sea Drilling Project, which studied the seafloor below the ocean sediments.

Ocean research, such as that of the Deep Sea Drilling Project, gave scientists the pieces to assemble the



Alfred Wegener's theory was not accepted until decades after his death.

The Father of Plate Tectonics

German meteorologist, geophysicist and astronomer Alfred Wegener (1880–1930) was the first to propose, in 1915, that the continents had once been joined together as a single supercontinent and had broken apart and spread to create the continents as we know them. In his major work *The Origin of Continents and Oceans*, he based his theory on the geological and paleontological similarities among the continents and on the fact that their shapes fit together like puzzle pieces.

Wegener was a multitalented man. In 1906, together with his brother, he

broke the world record for balloon flights by staying up for 52 hours, and as a young man, he took part in several expeditions to the Greenland ice cap. Later, the ice killed him—he died on an expedition to Greenland in 1930.

One of Wegener's greatest challenges was his inability to explain the force behind continental drift (he believed that it was centrifugal or magnetic). Therefore, his hypothesis was not confirmed until 30 years after his death, when geologists discovered a mechanism by which continents could move.

modern theory of plate tectonics. The very bottom layer of the ocean floor is composed of a hardened magma known as basalt, which contains magnetic minerals. When the basalt cools and hardens, researchers discovered, these minerals line up with Earth's magnetic field, which periodically reverses its polarity. (The reversals are becoming more frequent. They once happened roughly every million years,

but in more recent times, they happen about every 200,000 years.) As a result, this deep-ocean basalt contains a record of the planet's magnetic field, and these reversals have been particularly useful for studying Earth's history. Geologists use them for, among other things, dividing the ancient past into periods. We now live in a period of magnetization known as the Brunhes chron. About 700,000 years ago,

however, during the Matuyama chron, north-south magnetization was the opposite of the way it is today.

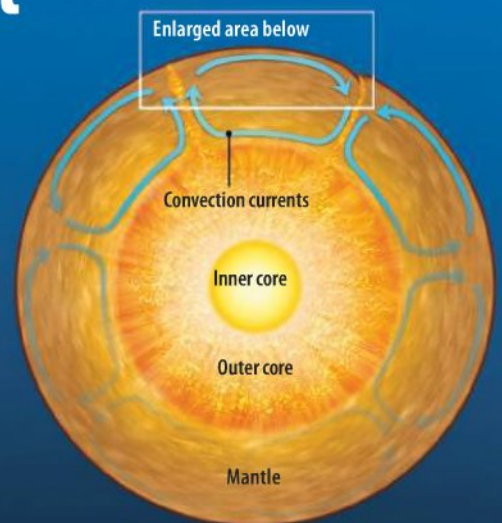
The Deep Sea Drilling Project found that the magnetic reversals form a very characteristic pattern in undersea basalt: The basalt located right next to a mid-ocean ridge contains the patterns of the most recent magnetic period. The farther away from the ridge, the older the patterns in the basalt.

Earth's Heat Fuels Continental Drift

The theory of plate tectonics, including continental drift, explains how the oceans came into being, why earthquakes and volcanic eruptions occur on Earth, and how mountain ranges arise. This central theory of geology is based on the idea that the outermost layer of our planet, the crust, consists of rigid plates, with the continents lying atop them. These plates move, carrying the continents with them as they drift over the surface of Earth.

Plate tectonics is powered by convection currents in Earth's mantle, which in turn are caused by heat being produced within the planet's

core and mantle. As material in the mantle warms up, it rises toward the surface of the planet. Some of this material escapes—the magma spilling out of the mid-ocean ridges is one example—but some remains trapped beneath the crust and moves laterally, cooling and sinking as it goes. These currents help push tectonic plates, causing them to diverge and free more magma in some places and to collide and begin subduction in others. It is at plate boundaries that most earthquakes and volcanic activity occur, and it is also at these boundaries that mountain ranges form.



MID-OCEAN RIDGE

Here new seafloor is created when magma from Earth's interior wells up at the sea bottom and then hardens into new plate material.

Ocean-bottom crust

Continental crust

Ocean

Plate

SUBDUCTION ZONE

An ocean-bottom plate glides here beneath another plate. Increased temperature and pressure melt some of the ocean-bottom crust and feed a volcano.

Volcano

Plate

HENNING DALHOFF

Scientists on the project also found that even the oldest areas of the seafloor are, geologically speaking, fairly young—200 million years old at most, as opposed to Earth itself, which is more than four billion years old.

These ongoing discoveries have led geologists to theorize that new seafloor must be constantly produced at each mid-ocean ridge, from which it spreads out to both sides.

Mid-Ocean Action

Today geologists know that Earth's 30-to-60-mile-thick oceanic plates and 60-to-160-mile-thick continental plates are rigid bodies consisting of the crust and uppermost layer of the mantle and that they move atop another layer of the mantle that is softer and more plastic.

Heat and pressure within our planet cause rock within the mantle to flow like a liquid. This forms an ocean of rock on which the plates move. When the plates resting atop the mantle diverge, the release of pressure can cause the mantle to melt and well up to the surface, where it hardens into basalt. This new basalt is constantly being pushed aside by new magma welling up from below, causing the plates to grow and move. When upwelling magma rises beneath a continent, the land will break in the middle and, later, an ocean will fill the gap—as occurred between Africa and South America and as is slowly under way today in the East African Rift System.

When a basalt plate in motion collides with a plate topped by a continent (which consists of more-buoyant rock, such as granite) or with a younger oceanic basalt plate, the basalt will sink under the other plate and eventually be reabsorbed into the mantle. This process, called subduction, explains why the seafloor is so young: The older seafloor is continually being pushed back into the mantle. Subduction occurs at the deep-sea trenches, where the seafloor plates on their downward path unleash powerful earthquakes. In addition, the plates partially melt and send magma



Drill samples from research ships can provide valuable information about the seafloor—including evidence of new seafloor being made.

back up to the surface. Behind the deep-sea trenches, this magma either forms volcanic mountain ranges on land (the Andes, for instance) or chains of volcanic islands in the sea (like the Philippines).

The continents, on the other hand, remain atop the plates because of their lower density and move with those plates. Sometimes the continents, too, can collide, as is the case with India, which rammed into Asia 40 million

to 50 million years ago, creating the Himalayas by doing so.

A Bolide Started It All?

Geologists now understand the processes that drive plate tectonics and know that it has been under way for billions of years. But its origin remains a mystery. There has especially been a lack of ideas to explain how subduction got started.

This is where Hansen's new hypothesis comes into the picture. Imagine a younger Earth, 2.5 billion years ago. At that point, the planet was significantly different. Judging by the impacts scientists have identified on the moon and Mars, Earth was probably under steady bombardment by bolides. Earth may also have been covered by a comparatively uniform crust, with few differences in density or strength from place to place. In the mantle beneath the crust, however, there could have been currents similar to those of today, and these currents could have caused areas of the crust to become thinner as it stretched over the slowly moving mantle. These



Vessels such as the Japan Agency for Marine-Earth Science and Technology's D/V Chikyu investigate the seafloor.

conditions—bombardment by bolides, a mostly uniform crust, and areas of localized thinning—serve as the starting point for Hansen's hypothesis.

If one of those many bolides had hit an especially thin part of the crust, and the impact made a crater more than 600 miles in diameter, Hansen believes that it could have started subduction, which has never stopped since. In addition to making the crust thinner where it struck, the bolide's impact would have led to local heating of the mantle, which would have caused magma to surge upward. This magma would have burst through the crust and up to the surface, where it

would have hardened into a dense, rigid basalt plate. As the process continued, this new basalt would have spread outward from the impact site, similar to the process by which the seafloor moves today.

Hansen goes on to imagine that continued spreading would force the basalt plate in the crater out to the sides. At some point, that plate would collide with the hard rim of the crater, which would not budge. The basalt plate would begin to sink beneath the rim of the crater, and subduction would be under way.

Hansen is not sure exactly when this process would have begun—she

says only that the most likely period was at least 2.5 billion years ago. But she does say that the combination of circumstances that she lists in her hypothesis could have occurred many times in different spots around the globe. So subduction could have started many times. And in every case, the die was cast: After the first impact occurred, the weakness would have expanded. Subduction is like a virus, Hansen says. Once it starts, it can very easily spread.

How It Will End

In another 250 million years, geologists predict, the continents could once again

An Undersea Map of Continental Drift

After World War II, geologists discovered chains of undersea mountains thousands of miles long. In the middle of these mid-ocean ridges are continual flows of hot magma coming from Earth's interior.

When this lava hardens, it becomes basalt, a volcanic rock containing magnetic minerals, and these minerals line up with Earth's magnetic field. (The orientation of the magnetic field reverses at regular time intervals.) Using the rocks' magnetic orientation at various locations, geologists were able to date those rocks' age. Seafloor sediments can also be dated, and the evidence was clear: At the mid-ocean ridges, the magnetized areas

and seafloor sediments from the ancient past spread out symmetrically from each ridge. The rocks are youngest adjacent to the ridge and get older the farther they are from it. These observations supported

the idea that new seafloor is continuously being created and that seafloor plates are constantly moving away from the mid-ocean ridges. Geologists had found the force that drives plate tectonics.



Extreme heat along the Mid-Atlantic Ridge creates hydrothermal vents.

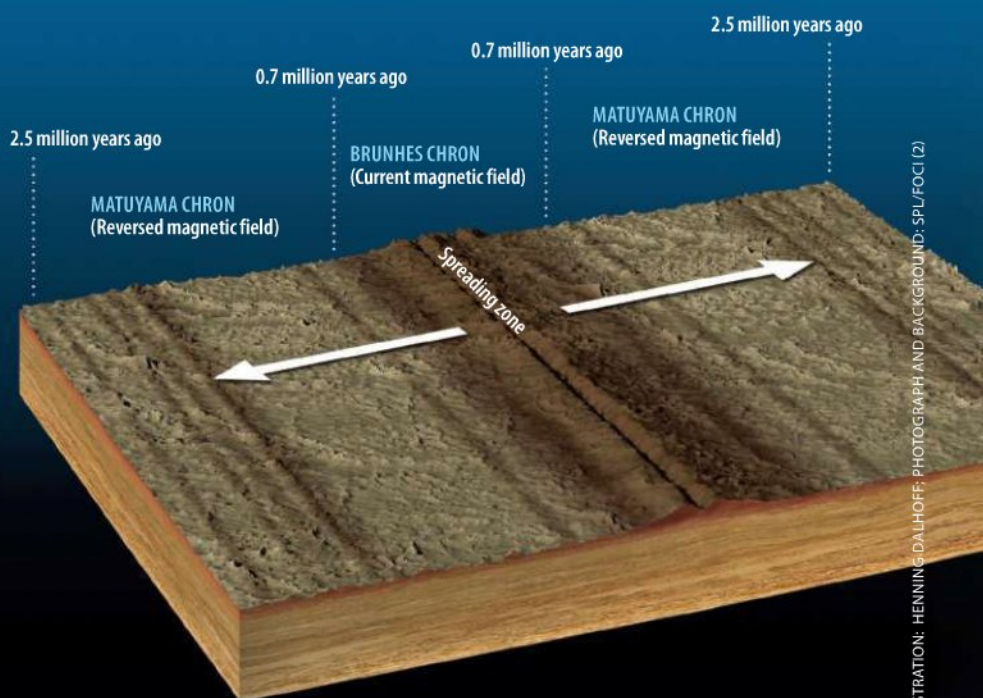


ILLUSTRATION: HENNING DALHOFF; PHOTOGRAPH AND BACKGROUND: SPL/FOCI (2)

come together into a supercontinent, only to break apart. But over the very long term—hundreds of millions or even billions of years—the plates could stop moving.

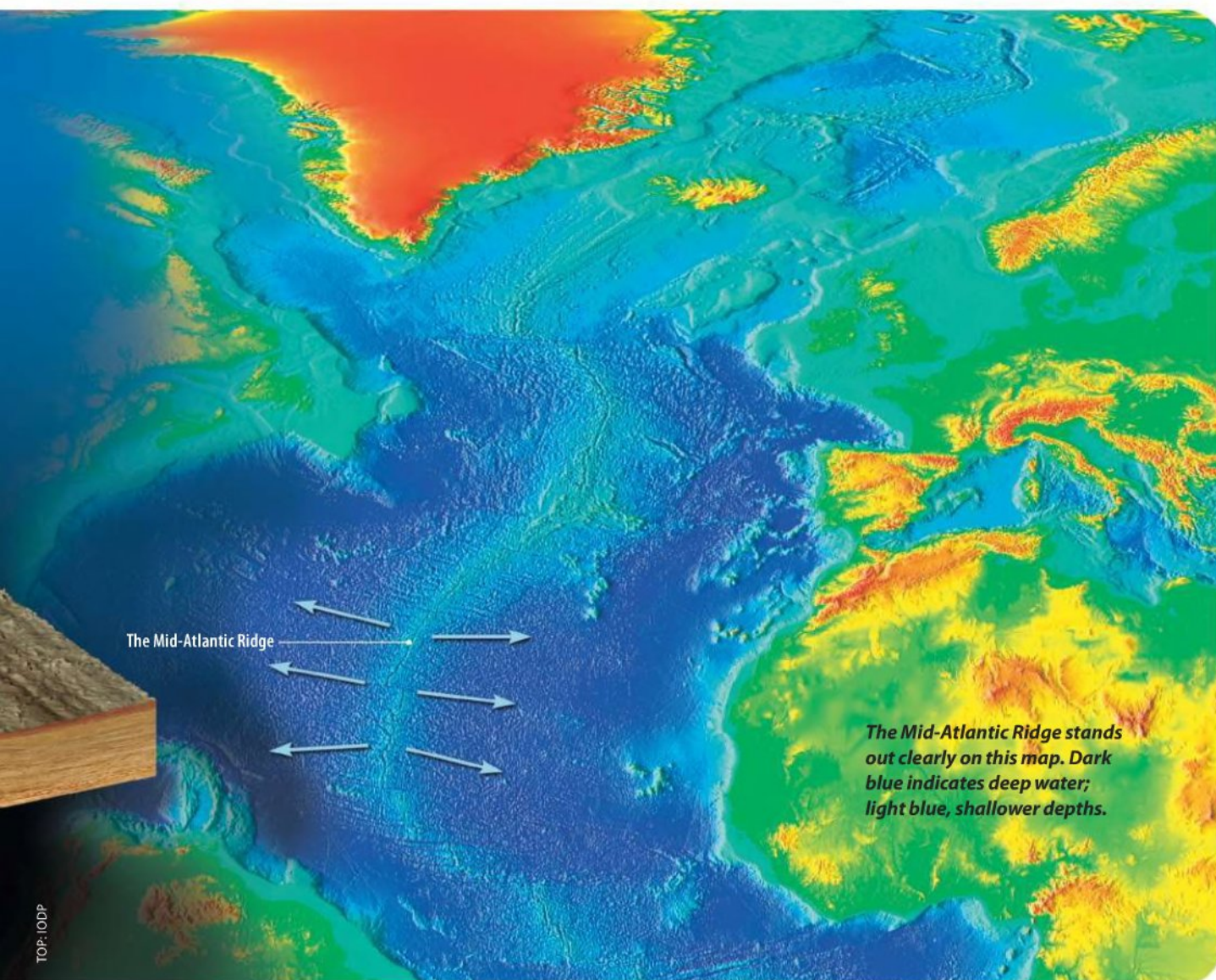
This is because, in the larger scheme of things, ever since Earth was formed 4.6 billion years ago, its core has been cooling. Very slowly, to be sure (partially because the decay of radioactive elements in Earth has continued to produce heat, thus delaying the process), but it is cooling nonetheless. The currents in the mantle are the planet's way of throwing off heat. And when they one day stall because heat production within the planet's



Volcanic material called basalt is shown here inside a research vessel's drill core.

core and mantle has dropped off, that will be the end of plate tectonics (and possibly all life on Earth).

For now, Hansen's hypothesis about the origins of subduction has been fairly well received by other geologists, but she points out that it must still be tested. She compares it with the theory that the moon was created by a collision between Earth and a heavenly body the size of Mars early in our planet's history. This hypothesis was put forth in the 1960s and '70s and at first was treated as absolute nonsense. But later, data appeared that supported it, and now it is the reigning hypothesis of how the moon came to be. Hansen's theory—like Wegener's before it—will have to undergo a similar process. ■



Who Will Survive?

Scientists say climate change is upon us, and a growing number of species—on the ground, in the water and in the air—are now facing its consequences. A look at how plants and animals are coping and the forecast for tomorrow

In 2007 the Intergovernmental Panel on Climate Change (IPCC) concluded with “very high confidence” that humans are in fact contributing to global warming, mainly through an increase in greenhouse-gas emissions. The panel estimated that if the global temperature increase exceeds between 2.7 and 4.5°F, 20 to 30 percent of species that were assessed in its studies are likely to face an increased risk of extinction. Meanwhile, the IPCC projects that the planet will warm by between 3.2 and 7.2° by the end of this century, compared with its temperatures in the late 1900s.

Earth’s history is riddled with climate-related extinctions. Near

the end of the last ice age, around 14,700 years ago, temperatures on the planet shot up 18° because of natural climate-change cycles. Around the same time as that warming, North America’s megamammals—a group that included mammoths, camels, mastodons and ground sloths—began to disappear. Some scientists say that climate change alone caused the die-off of these creatures; others maintain that humans overhunted and displaced the megamammals to the point of extinction. Still others say that climate change and the arrival of humans made a killer combo. More definitively, 56 million years ago—tens of millions of years before humans existed—many large ver-

tebrates, particularly mammals, disappeared as the world’s average temperature rose by about 13°, probably because of a huge increase in methane released by marine sediments.

Yet if all species disappeared every time the planet heated up or cooled down, there would be no plants or animals around today. Historically, many groups have shifted their habitat in response to climate change. During periods of warming, cold-climate species tend to move toward the poles, while those that flourish in hotter temperatures are able to expand their ranges. Today these patterns are emerging again, on all continents and most major oceans among well-studied plant and animal groups.►

*Sea-ice decline in Antarctica
is threatening some
polar bear populations.*





North America & the Arctic

A 2006 analysis led by biologist Camille Parmesan of the University of Texas at Austin found more than 800 studies documenting changes in species or ecosystems that could be attributed at least in part to climate change. So who will be the winners and losers this time around?

The Danger Zone

The complexity and interdependence of living creatures make it impossible to predict with certainty what will happen to any given species down the road, yet some are clearly more at risk of extinction than others. A report released last November by the Switzerland-based International Union for the Conservation of Nature says that the species in greatest danger are those possessing a high biological susceptibility to climate change. This vulnerability is determined by factors like the organism's ecology, behavior, physiology and genetics. An animal that can tolerate only a small range of cold temperatures, for example, would be at high risk during a warming period such as the one the planet is currently experiencing. The same report also found that 35 percent of birds and 52 percent of amphibians it assessed are climate-change susceptible.

Species that are well-adapted to urban as well as agricultural environments, such as sparrows, may be able to cope as humans continue to dominate more landscapes. Meanwhile, some plants and animals that



Pikas in Heat Shock

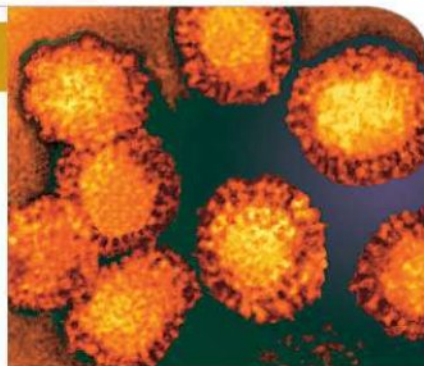
American pikas live at mountain altitudes of 8,000 to 13,000 feet in the western U.S. and Canada, sticking mainly to cool, moist areas. As temperatures rise, their habitat shrinks. Six to seven of the 25 known populations of pikas disappeared as of 2003.

According to climatologist Scott Loarie of the Carnegie Institution for Science, pikas are most threatened in the Great Basin region of the western U.S. Climate models predict a similar fate for the Sierra Nevada and Rocky Mountain populations.

THE FORECAST: There is a high probability that climate change will wipe out up to 59 percent of known American pika sites by the end of the century.

West Nile Spreads

Since 1999, the West Nile virus has spread across the U.S., killing more than 1,100 people. According to Paul Epstein of Harvard Medical School, climate change is one factor. Heavy rains linked to warming create new breeding sites for West Nile-carrying mosquitoes, while warmer air temperatures speed the virus's life cycle.



THE FORECAST: A broader distribution range and extreme weather, such as drought-like springs and heavy late-summer rains, will increase mosquito numbers, potentially multiplying the fatal meningitis and encephalitis infections that, in rare cases, West Nile can cause.



Beetles Kill Trees

As temperatures rise, the mountain pine beetle's life cycle speeds up, leading to more births in a shorter time span. The result: mass attacks on the lodgepole pines [above] that the beetles inhabit and feed on. The bugs most recently destroyed forests in the western U.S. and British Columbia, and they're now invading warming areas higher up the mountains and farther north.

THE FORECAST: According to Jacques Régnière, a research scientist at the Canadian Forest Service, many pines that did not co-evolve with the beetles, such as the whitebark pine, are defenseless against the insects. Whitebark trees shelter other plants and provide food for a number of species from squirrels to grizzly bears.



Polar Bears Lose Their Hunting Grounds

Up to 25,000 polar bears now live in the Arctic. Declining sea ice is affecting many of these populations, and in 2008 the animals were listed as "vulnerable" under the Endangered Species Act. They hunt their main food source, ringed seal pups, on

sea ice each spring. Kills during this period provide up to 80 percent of their yearly energy. But polar sea ice is breaking up an average of three weeks earlier in the spring in West Hudson Bay, Canada, which coincides with the bears' main feeding time.

THE FORECAST: According to biologist Ian Stirling, a researcher at Environment Canada, polar-bear populations could decrease by up to 70 percent by the middle of this century, surviving only in the northern extremes of Canadian islands and in northern Greenland. But the increase in temperatures in West Hudson Bay may bring in new food sources that will take the place of ringed seals in the bears' diet, which could help their chances of survival.

Spiders Fatten Up

During a recent 10-year period in West Greenland, higher temperatures caused the snow to melt 20 to 25 days earlier in the spring, giving wolf spiders more time to hunt. The average size of the female wolf spider has increased by up to 10 percent, and as a result, they are probably laying more eggs. Males might be reaching sexual maturity earlier, which could in time lead to a much shorter life cycle and even more spiders.

THE FORECAST: It's too early to say how the change will affect the surrounding ecosystem, but researchers speculate that the larger size difference between mothers and babies could lead to cannibalism among wolf spiders.





Europe

can shift habitats are nonetheless hemmed in by the ever-increasing spread of humans. Other species, such as old-growth woodland songbirds, have not adapted to human-altered environments and will face a greater risk of extinction.

So far, Parmesan's analysis found, tropical coral reefs and amphibians have suffered the biggest decline in numbers. At the same time, species with restricted ranges have lost the most habitat because of the effects of warming. These species include animals in the Arctic and Antarctic that depend on sea ice, such as certain populations of polar bears, ringed seals and some types of penguins, and those that are restricted to mountaintops and ridges in the southwestern U.S., including the American pika (a relative of the rabbit) and many varieties of birds and butterflies.

On the other side of the coin, "the winners are mostly pest species," says paleoecologist David Burney, director of conservation at the National Tropical Botanical Garden in Hawaii. Tree pests such as the mountain pine beetle, spruce bark beetle and pine processionary moth are booming in forests. Warmer winters have lowered the mortality rate of these insects, while a longer growing season between the last frost of spring and the first frost of fall has allowed them to increase their generation time. "A spruce bark beetle that used to take two years to mature in Alaska now matures in just one year,"



Spanish Invasion

Today some 800 breeding pairs of the trumpeter finch [top], a North African desert bird, have migrated into the increasingly dry regions of southeastern Spain. The bird has also expanded within Spain, moving 155 miles north over the past 25 years, says ecologist Andres Barbosa of the Supreme Council of Scien-

tific Research Arid Zone Experimental Station in Almeria. This expansion correlates with a reduction in rainfall, which has led to desertification. Since 1980, the African plain tiger butterfly [above], a distant relative of the monarch, has also moved north into southern Spain, where it developed large populations by the 1990s.

THE FORECAST: North African animals could increasingly invade southern Europe as temperatures rise. Birds and insects will probably be the first to arrive.

Songbirds Speed Up Migrations

In 2004 a team led by biologist Anders Tøttrup of the University of Copenhagen showed that, over the course of about 20 years, songbirds called willow warblers have shortened their spring migration from sub-Saharan Africa to their European breeding grounds by five days, perhaps by spending more

time flying each night. Tøttrup believes the birds' overall migration patterns are determined by genetics but that individual populations fine-tune their migrations based on local weather patterns. Willow warblers can sense that spring is coming earlier, he says, and adjust their flight time accordingly.

THE FORECAST: If the warming continues, willow warblers will have time for an extra brood each season, taking advantage of the warming.



Insects Change Their Ranges

At least eight European butterfly species have gone extinct in the southern boundaries of their ranges. Living near Barcelona up to the 1930s, the sooty copper butterfly [above] is now found only above 60 miles north in the Pyrenees Mountains. Warming may have affected plant cycles in the south, starving caterpillars. Thirty-four dragonflies and damselflies native to England and Scotland also shifted their ranges northward an average of 46 miles between 1960 and 1995.

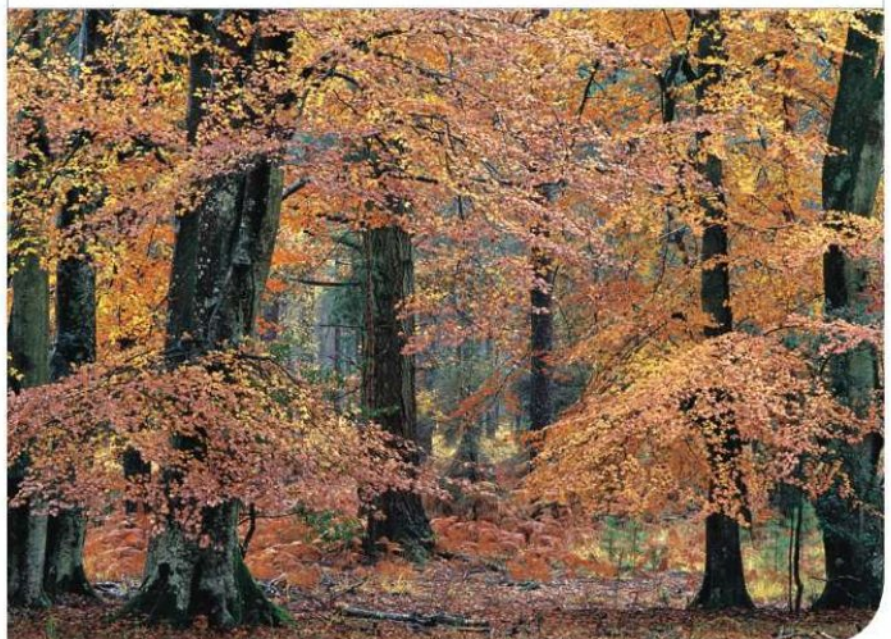
THE FORECAST: Many insect species may either greatly expand their ranges or move to the north entirely.

Spring Comes Earlier

Each of Europe's 78 International Phenological Gardens (IPG) contains genetically identical shrubs and trees, including beeches [below]. The dates on which the plants bud, blossom, and lose their leaves are entered into a database. Using this information, an IPG team determined that, between 1959 and 1996, the growing season

lengthened by almost 11 days—a trend confirmed in other locations across the world using satellite tracking and carbon dioxide concentrations. A 2006 follow-up, including data from the IPG, as well as agricultural and wild plant species, confirmed that spring is coming earlier across the board, advancing at a rate of two and a half days per decade.

THE FORECAST: If the trend continues, an earlier onset of spring and a longer growing season could alter interactions between plants and animals in these ecosystems, which could change competition between species and allow new pathogens to move in.





Australia and the Indian Ocean & Antarctica

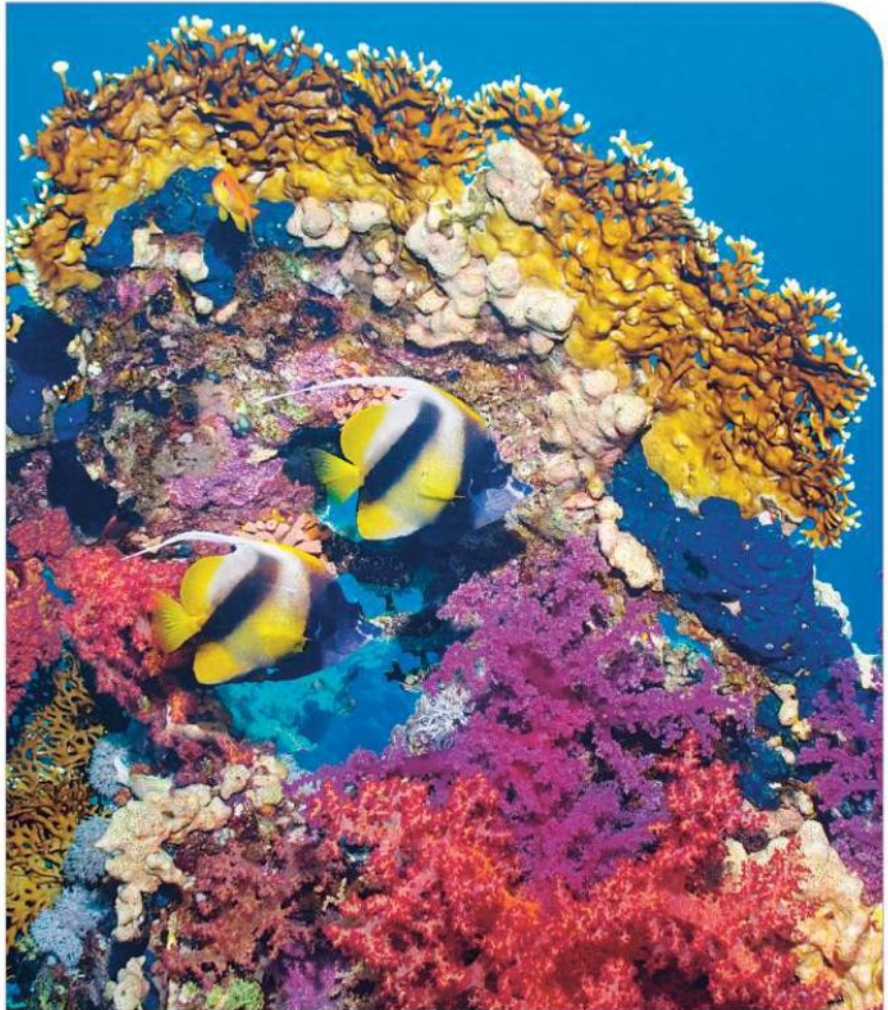
Parmesan says, “allowing a more rapid buildup of numbers.”

Fortunately, not all the species benefiting from the warmth are pests. “Many temperate species that are able to disperse long distances across human-dominated landscapes are doing fine,” Parmesan says. For example, both Sweden and Finland are seeing an increase in butterfly species as a result of colonization of temperate species from continental Europe that have moved north across the Baltic and into Scandinavia.

The Evolution Factor

Could some at-risk species adapt to the warming of the planet? In certain cases, small adaptations that allow species to expand their range are occurring in response to climate change. In Europe, for example, two types of crickets living at the northern range boundary of their respective species developed larger wings between 1982 and 2000. The adaptation happened when individuals that possessed larger wings were able to fly north into new territory and multiply there, while the crickets with smaller wings were left behind.

Biologists caution, however, that any evolutionary adaptations significant enough to allow a species to make its home in a formerly inhospitable environment are unlikely to take place as quickly as the planet is warming. Such a change would essentially create a new species—and that does not happen overnight. ■



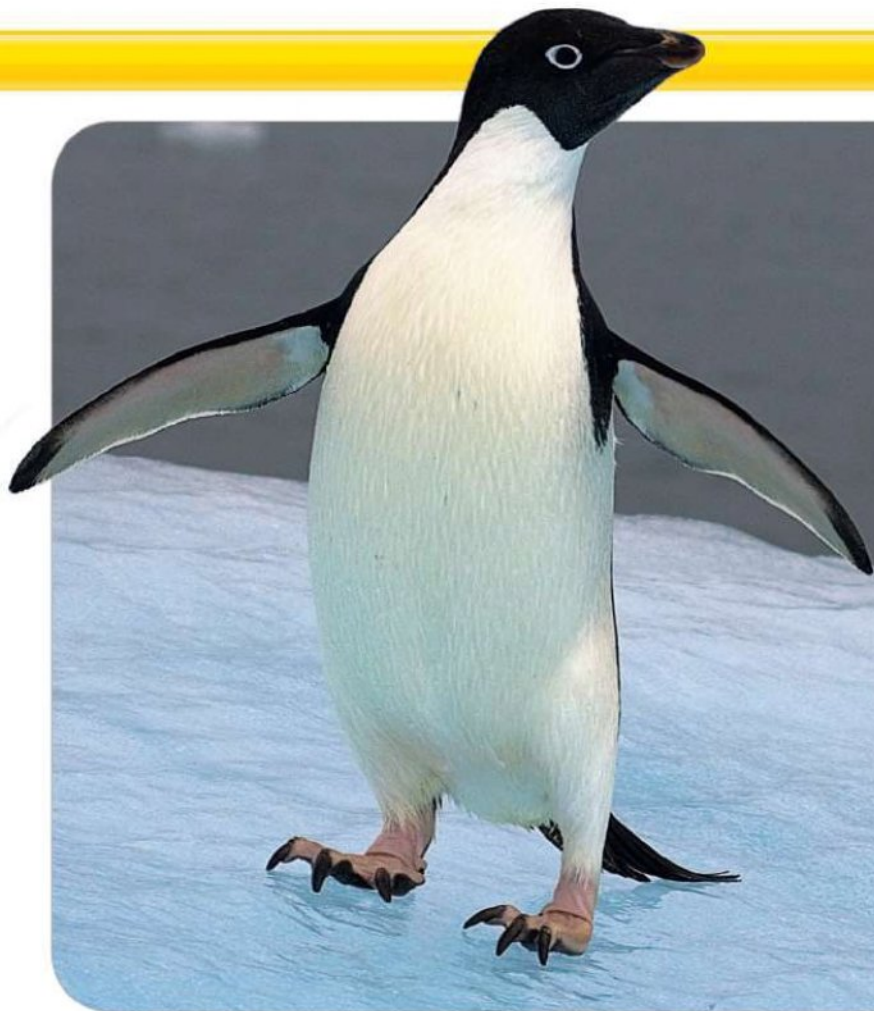
Symbiosis Breaks Down

Photosynthetic algae provide coral with nutrients, and together the two keep nutrients flowing in shallow, warm-water reefs. As sea temperatures rise, the symbiotic relationship falls apart: The algae leave and the coral die, disrupting the ecosystem.

Between 1997 and '98, unusually high sea-surface temperatures killed 90 percent of the Indian Ocean's shallow coral.

In the future, an increase in atmospheric carbon dioxide will also harm the reefs; the resulting ocean acidification depletes carbonate ions that are vital to building coral. Recent work led by Ove Hoegh-Guldberg, a coral biologist at the Global Change Institute in Australia, suggests that coral growth rates have decreased by 15 percent since 1990.

THE FORECAST: If current trends continue, says Hoegh-Guldberg, the world's tropical coral reefs could be a “distant memory” by 2040.



Penguins Make Way for Cousins

Most emperor penguins breed on pack ice off the Antarctic coast. Declines in sea ice in the northernmost region of the birds' range, the Western Antarctic Peninsula (WAP), have destroyed their numbers there. In 1970 a colony of 300 breeding pairs called the WAP home, but as of 2001, only nine pairs remained, and their fate today is uncertain. Adelie penguins [left] breed on land but spend the rest of the year on declining sea ice. During the past 25 years, two thirds of the Adelie penguin population of the WAP has disappeared.

THE FORECAST: Populations are stable outside the WAP. But inside this region, distribution of penguin species will change. Emperor and Adelie penguin populations will decline, and chinstrap penguins, which live in the open ocean, will thrive as a wider area of the ocean becomes habitable.



Less Ice Means Less Krill

Small crustaceans known as Antarctic krill [above] help feed a wide variety of animals, including penguins, fish, birds, seals and whales. Young krill live directly under sea ice, where they subsist on algae. As ice

continues to shrink, the crustaceans' numbers are declining alarmingly. Just 35 years ago, there were 70 percent more krill in the WAP and the southwestern Atlantic Ocean than there are today.

THE FORECAST: It is too early to say how krill will fare in the long run. For now, however, fewer krill means less food for many species of sea animals such as the crabeater seal [right], which feeds mainly on these crustaceans.



Teaching an Old Protein New Tricks

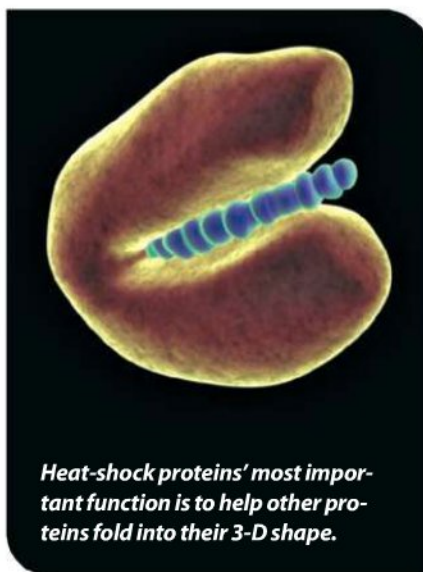
When a cell gets stressed, it brings in an army of fix-it men. These primordial proteins repair damaged cells using a wide variety of tricks. And now American scientists are giving heat-shock proteins a new assignment: fighting cancer

Heat-shock proteins, a curious class of molecules that help other cell proteins fold into their proper shape and keep cells healthy during times of stress, were once thought to exist only in fruit flies. They have since proved to be a vital part of all living organisms, from the most primitive bacteria to modern mammals such as humans. And they play an important part in the mammalian immune system's ability to recognize foreign invaders and diseased cells.

These discoveries have already resulted in new therapies that use heat-shock proteins to treat cancerous tumors, including a vaccine against kidney cancer that has completed clinical trials at more than 100 hospitals in Europe, Canada, Israel and the U.S. and that has been approved for use in Russia. No longer a lab curiosity, heat-shock proteins are poised to be a potent asset in the medical toolbox.

Cells' Anti-Stress Device

Heat-shock proteins were first discovered in 1962, when the thermostat on an incubator holding colonies of fruit flies at the Genetics Institute in Pavia, Italy, was inadvertently turned up overnight. Geneticist F.M. Ritossa examined the chromosomes from these flies and noticed that certain



Heat-shock proteins' most important function is to help other proteins fold into their 3-D shape.

areas of the DNA had puffed up. Scientists already knew that fly DNA puffs up during protein synthesis, but this was the first time anyone had seen protein synthesis in response to the heat shock the flies experienced. Research has since shown that heat-shock proteins exist in all cell lineages and are some of the oldest proteins in our evolutionary heritage.

Heat-shock proteins are, in fact, an entire class of proteins. They are produced not just when cells are subjected to high temperatures but any time the cells face stress. Other sources of stress can be chemicals, radiation, desicca-

tion (drying out), heavy metals or high pressure. All of these factors have one thing in common: They alter cellular processes by disrupting the normal functions of the proteins involved.

To function properly, all proteins must fold into a specific 3-D structure, which could contain, for example, a groove to facilitate chemical reactions or a specific shape for molecular recognition. When exposed to heat or chemicals, proteins lose this conformation, and can therefore lose their function. To rectify this, cells produce large quantities of heat-shock proteins, which fold themselves around the deformed proteins to induce them back to their correct shape.

A Fine Line between Good and Evil

But there's a catch: Heat-shock proteins indiscriminately help any cell in trouble—including the bad ones. Recent research shows that even cancer cells rely on them for survival. One heat-shock protein in particular, called HSP90, is especially useful to tumors. Cancer cells are under constant stress because of the many unusual molecular changes that let them reproduce quickly. HSP90 helps stabilize and correct the folding of proteins that, as a result of cancerous mutations, are more fragile than normal. HSP90 also seems to be acutely important in the

cell-signaling pathways that protect tumor cells. A new study, conducted by cancer researcher Harriet Kluger of the Yale School of Medicine, found that the higher the concentration of HSP90 in a breast cancer tumor, the lower a patient's chances for survival.

The good news is that now that scientists know how heavily tumors depend on heat-shock proteins, they have a new angle of attack in the fight against cancer. Pharmaceutical companies are currently testing drugs that target HSP90, rendering those types of cancers that exploit the protein more vulnerable to radiation and chemotherapy. Researchers are also considering strikes on a very powerful heat-shock protein, known as heat-shock factor 1, which controls the production of many other heat-shock proteins, including HSP90. A recent article by Luke Whitesell and Susan Lindquist, both at the Whitehead Institute for Biomedical Research in Cambridge, Massachusetts, suggests that suppressing the action of this protein (and thus the manufacture of many heat-shock proteins) has potent anti-cancer effects.

New Uses in the Immune System

Scientists keep turning up new ways in which heat-shock proteins help the body. Pramod Srivastava, an immunologist at the University of Connecticut School of Medicine who has spent

his entire career investigating these tricky proteins, recently showed that heat-shock proteins are a vital part of the immune system. He found that they help cells in the immune system recognize the molecular signatures of viruses or bacteria and diseased or cancerous cells. Certain heat-shock proteins, like HSP70, bind to peptides

Two Ways to Attack Cancer

Blocking heat-shock protein production: Scientists can block cancer cells' production of the proteins, making the tumor cells weaker and more vulnerable to chemotherapy.

Vaccine: Scientists can isolate heat-shock proteins and a molecular aggregate called MHC from tumors and inject them into the body again. This prepares the immune system to recognize and combat recurrences of the cancer.

(which are derived from larger proteins) found within infected cells and load these protein fragments onto a huge molecular aggregate called major histocompatibility complex (MHC). It is MHC's job to show these peptides (which are unique to the diseased cell) to the immune system's T cells, which recognize the cell as sick and destroy it. Another role heat-shock proteins

play involves delivering antibody generators to so-called antigen-presenting cells. These cells activate a variety of others within the immune system and provide the antigen that will serve as a mug shot for the infected cells.

Armed with this knowledge, Srivastava and his colleagues have developed a new strategy for cancer treatment. After removing a tumor, the scientists isolate complexes of heat-shock proteins and MHC from the cancerous tissue and inject it back into the patient's body. Any further cancerous cells of the same type will be recognized by the immune system and destroyed. Clinical studies have found that the risk of death from kidney cancer in patients treated with this vaccine was reduced by 50 percent and those receiving treatment lived up to a year and a half longer than patients who received no treatment (currently this type of cancer is not treatable). The vaccine was approved for clinical use in Russia in March 2008. The company that produces the vaccine, Antigenics (founded by Srivastava), anticipates approval in the European Union as early as this fall and by the U.S. Food and Drug Administration in about two years.

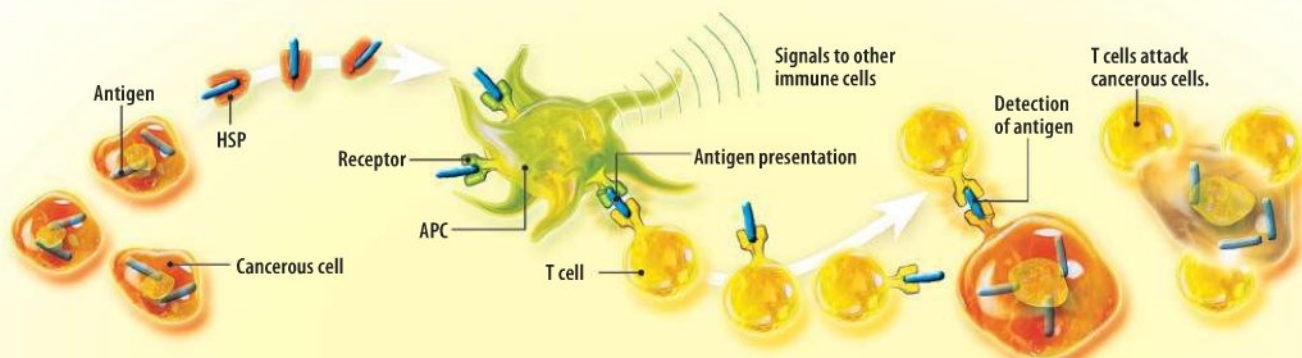
As scientists tease out the roles heat-shock proteins play in our cells, the possibilities for better, more-targeted drugs against cancers and other diseases could soon reveal themselves. ■

Heat-Shock Proteins Help the Immune System Destroy Diseased Cells

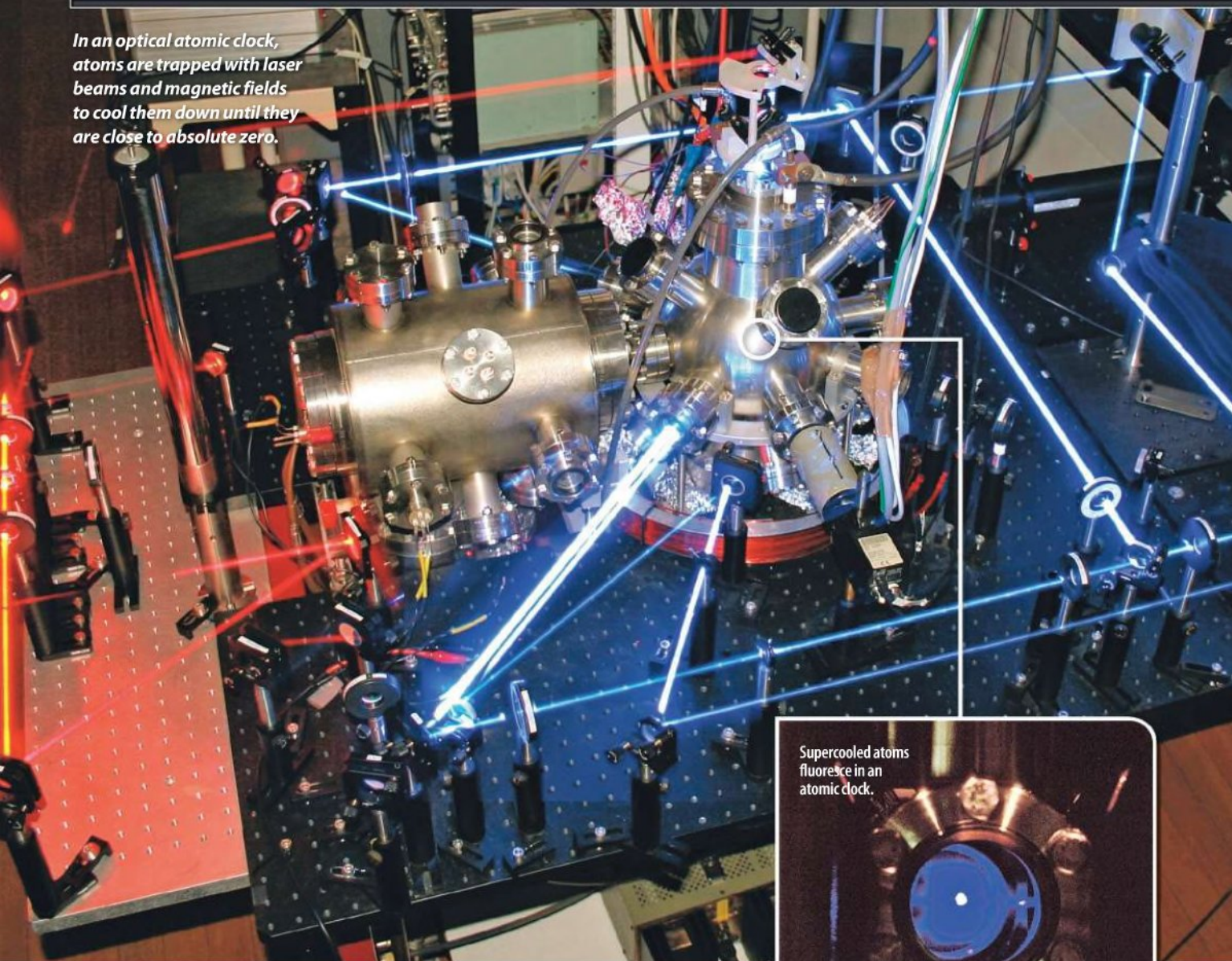
1. Find the cancer markers: All cancerous cells produce antigens, or proteins that are unique to the cancer and can spark an immune response. Heat-shock proteins inside the cell bind to pieces of these antigens as a part of their routine cleanup.

2. Tell the immune system: The heat-shock proteins (HSPs) meet up with antigen-presenting cells (APCs). HSPs and antigen bind to the APCs and enter. Then the APCs secrete signaling molecules that activate other immune cells.

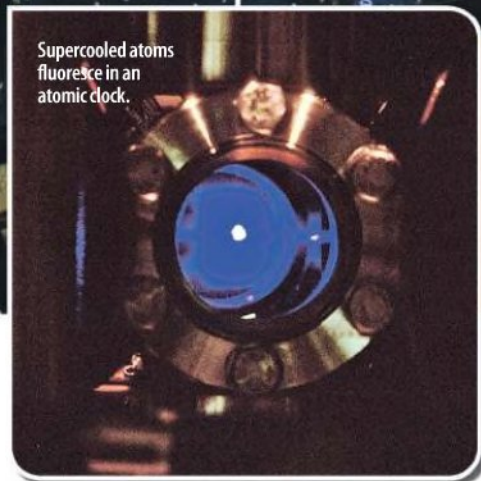
3. Send in the cancer-killers: The APCs present antigens on their surface, showing these to the immune system's T cells so that the T cells know how to recognize the cancer cells. Large numbers of T cells then seek out and kill the cancerous cells.



In an optical atomic clock, atoms are trapped with laser beams and magnetic fields to cool them down until they are close to absolute zero.



Supercooled atoms fluoresce in an atomic clock.

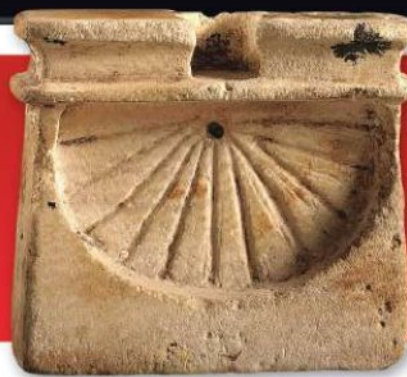


Clocking in with Atoms

Visible light makes new optical atomic clocks so precise that if they had been keeping time since before the extinction of the dinosaurs, they would not have lost even a quarter of a second. But the clocks do more than just keep time. They could solve some of the lingering mysteries about how space and time interact

Measuring Time Has a Long History

Since the Egyptians began measuring time 5,500 years ago by looking at how a stick cast a shadow on the ground, tremendous progress has been made. We can now measure time so accurately that clocks lose just one second in one billion years.



◀ 3500 B.C.

The Egyptians begin measuring time. Eventually, they divide the day and night into 12 hours each and track time using sundials. Unlike our system today, their hours are not all the same length.

You may not have seen one, but every time you turn on a light, pick up your cellphone, or use GPS to find your way around a traffic jam, you're relying on an atomic clock. These clocks help manage electrical loads in the power grid without frying the transformers, ensure that cellphone towers coordinate their signals so that you get your calls and texts without interruption, and make sure that GPS systems can accurately pinpoint your location on the globe.

The standard atomic clock keeps time using microwaves and atoms of elements like cesium or rubidium. These clocks are pretty darn good, losing one second only every 100 million years. But by switching to lasers, scientists have set new standards for precision. Researchers at the National Institute of Standards and Technology (NIST) have developed a mercury-atom-based optical clock that's 10 times as accurate—it loses one second every *billion* years.

Having ever more fine-tuned clocks won't just help improve GPS. The next generation of clocks may be precise enough to detect subtle shifts in Earth's gravitational field, helping scientists to more accurately map it. The optical atomic clocks may also be able to tell scientists about fluctuations in space and time, opening up exciting new possibilities in cosmology and physics.

Defining the Second with Atoms

All clocks rely on something that oscillates at a fixed time interval. The most familiar of these oscillators is the pendulum. In a grandfather clock, the pendulum swings once per second, ticking 60 times per minute. Atomic clocks function according to the same

principle. Their oscillators are individual atoms, and each "swing" is the time it takes for an electron in the atom to hop between specific energy levels. Atomic clocks have two main advantages over mechanical clocks. First, whereas mechanical clocks depend on the skill and technique of the clockmaker (which means their accuracy can vary from clockmaker to clockmaker), atomic clocks are governed by the rules of atomic physics—the behavior of a hydrogen atom doesn't vary from lab to lab. Second, atomic clocks "tick" far faster than a mechanical clock ever could, making the determination of a given time frame more precise. Today's cesium clocks tick nine billion times a second.

How are these ticks measured?

So-called cesium fountain clocks rely on a collection of laser-cooled cesium atoms. Laser cooling of atoms can be compared with slowing a rolling billiard ball by bombarding it with millions of ping-pong balls, which represent photons in laser light. Once the atoms are cooled, the lasers are turned off. Then another laser is used to toss them upward about six feet. During this toss, microwaves excite the atoms' electrons, causing the electrons to jump to a higher energy level. By measuring which frequencies excite the highest numbers of cesium atoms—by observing the reemission of energy as atoms' electrons drop back down to their normal levels—scientists can precisely determine the frequency of cesium's oscillation and use it to define exactly what "one second" is. Unfortunately, cesium fountain clocks are expensive and difficult to run; there are only a handful of them in

operation, and they are mostly used to calibrate the more common rubidium atomic clocks found in everyday technology such as cellphone towers.

In the U.S., millions of power plants, transformers and power lines work together to transmit electricity, pushing electrons along wires toward homes and businesses. These movements are precisely coordinated using rubidium-based atomic clocks. If the electrons are pushed at different times, or in different directions, power levels might drop or equipment could be damaged. Likewise, the stations in a cellphone network must be synchronized within a millionth of a second to properly transmit calls, and many cellphone stations are equipped with their own rubidium clocks.

GPS satellites, too, have rubidium clocks. GPS relies on a network of 24 satellites, all of which send out signals about where they are and when. A GPS receiver, such as the one in your car or cellphone, calculates its own location by timing how long it takes to receive those signals. If the time stamp on a satellite's signal isn't accurate, the calculation will be incorrect, leaving you at Home Depot instead of parked in front of your favorite diner.

Visible Light Ups the Ante

The faster the oscillations in an atomic clock, the more accurate the clock will be. "It's like a ruler," says Tom O'Brian, chief of NIST's Time and Frequency Division. "If you have a ruler that only has inch marks, you might be able to guess lengths to one fourth of an inch. But if you have a ruler with marks [denoting] each $\frac{1}{64}$ of an inch, you can measure things much more precisely."

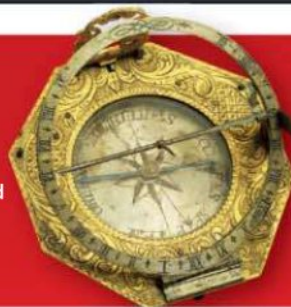


1400 B.C.

In addition to sundials, the Egyptians use water clocks to track the passage of time by observing water slowly dripping out through a hole at the bottom of the pot. Marks on the inside of the pot show how many hours have elapsed.

600 B.C.

The Babylonians divide the hour into 60 minutes and each minute into 60 seconds.



A.D. 1400

Large mechanical clocks emerge and measure time fairly accurately. Pictured here is a combination pocket compass and sundial made of brass.

To speed up those ticks, scientists are replacing the microwaves in atomic clocks with light waves. The frequencies of visible light and the surrounding spectrum are about 10,000 times as fast as the frequencies of microwaves. The switch is possible because of the optical frequency comb, a device developed in the late 1990s by scientists from NIST and the Max Planck Institute for Quantum Optics in Germany that can “count” the ultrafast oscillations of visible light emitted by atoms within a clock.

The optical frequency comb is a special laser. “If you look at the laser light coming out of an optical frequency comb, it would look like white light,” O’Brian says. “But if you put it through a prism, you would see the colors of the rainbow. And if you looked

closely at those colors, you would see thousands of sharp, evenly spaced lines like teeth on a comb.” Those “teeth” allow us to count the oscillations of visible light waves [see “Comb of Light Makes Counting Easy,” facing page].

Time Keeps On Slippin’

In the future, the international standard—the official designation of how long a second is—will almost certainly be based on an optical atomic clock, and more precise clocks will mean even bigger improvements in the technologies we use daily. But optical atomic clocks can be used for more than timekeeping.

Clocks that are moving through space actually tick more slowly from the perspective of a stationary observer, and an increase in gravity can

also slow a clock’s tick, although most clocks would have to move pretty quickly—at speeds approaching the speed of light—or be under the influence of incredibly strong gravitational fields for us to see an effect. But clocks that measure time as precisely as optical atomic clocks can detect this distortion at much slower speeds and at much smaller increases in gravity. “As you start measuring time more precisely, you’re no longer just measuring time,” O’Brian says. “You’re measuring how time and space interact.”

He predicts that, in the future, optical atomic clocks will be used as sensors to measure changes in gravity. Because the composition of the ground in a given location will affect the strength of gravity fields there, these ultrasensitive sensors could help researchers find

The Most Accurate Clocks Tick Billions of Times per Second

1 The Atomic Heart

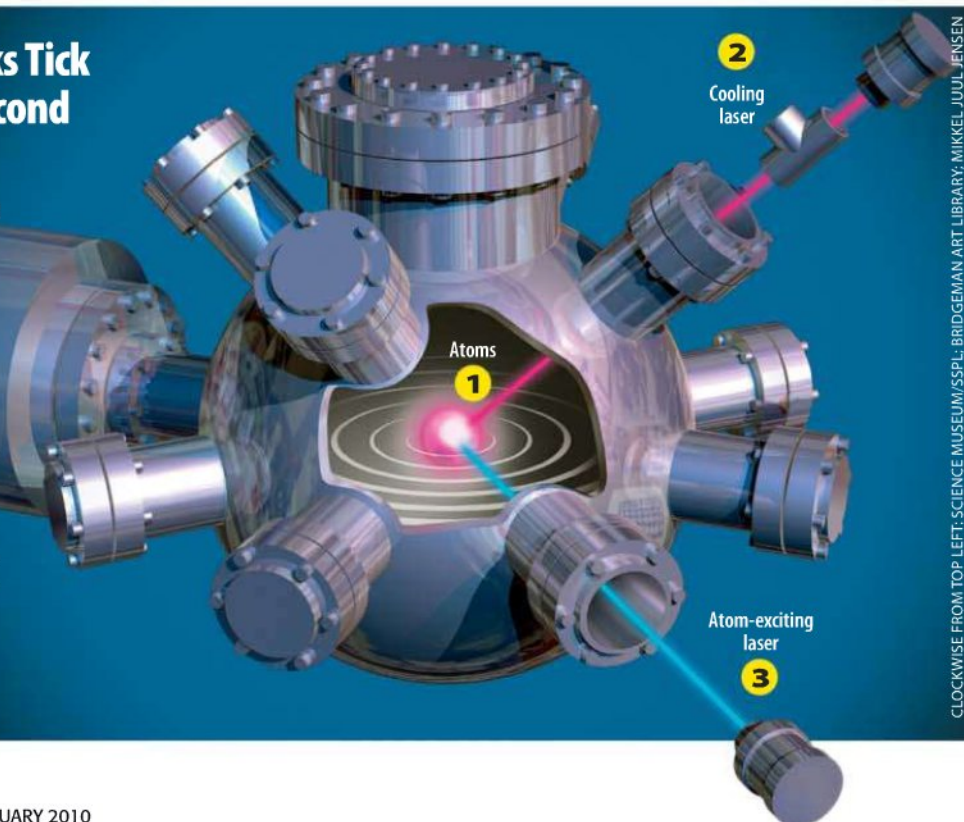
Optical clocks can use either collections of cold atoms (similar to those in the cesium fountain clock) or a single charged atom to generate the oscillations.

2 The Light Cage

In some optical clocks, an infrared laser traps and cools the individual atom or atoms within lattices of light, holding them as still as possible.

3 Creating the Clock’s Ticks

A second laser sends pulses of light through the lattices, exciting the atoms. By observing the interactions, and with the help of an optical frequency comb, scientists can determine the exact frequency of the oscillations.



CLOCKWISE FROM TOP LEFT: SCIENCE MUSEUM/SSPL; BRIDGEMAN ART LIBRARY; MIKKEL JUUL JENSEN



1656

Dutch astronomer Christiaan Huygens builds on Galileo Galilei's work with pendulums to create the first pendulum clock. Early versions are powered by weights; battery-operated ones are in use by 1906.



1927

The first quartz clock is developed. Time is measured by counting vibrations of a quartz crystal. The most accurate quartz clocks lose one second every 10 years.



▲ **1955** English physicist Louis Essen develops the first cesium atomic clock. Cesium clocks eventually help to define the second.

1958 Continuing improvements to cesium atomic clocks allow scientists to establish atomic time, an extremely precise timescale.

1967 The second is defined as "9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom" at the 13th General Conference of Weights and Measures.

1977 The U.S. launches a cesium clock into orbit on a satellite. This launch is the first step toward the Global Positioning System.



▲ **2001** The first optical atomic clock achieves an accuracy equivalent to losing one second in 4.5 million years.

▼ **2009** With an accuracy of one second lost every billion years, optical atomic clocks surpass cesium atomic clocks as the world's best.



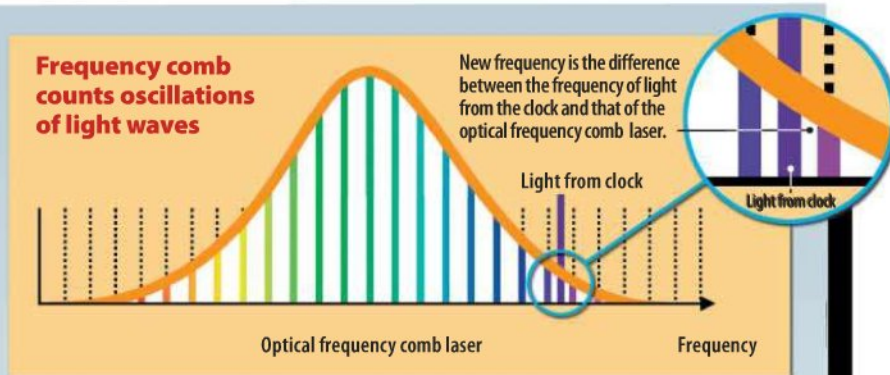
deposits of oil or minerals or create gravity maps of the ocean floor for submarine navigation.

Setting the Standard?

The future of optical atomic clocks looks bright, but there are still several challenges researchers will have to overcome before any clock can replace the cesium fountain clock as the international standard. One problem is synchronization. Right now, there are about 300 atomic clocks across the globe that are synchronized against the cesium fountain standard. This mi-

crowave signal can be beamed around the world by satellites, but accurately transmitting the optical signal needed to synchronize optical atomic clocks is much more difficult.

The biggest challenge of all might be choosing which clock will become the international standard. "They're all improving so rapidly that most scientists feel if we try to make a decision today, we might make the wrong decision," O'Brian says. "What we choose might be the most precise right now, but three years from now, something might surpass that." ■

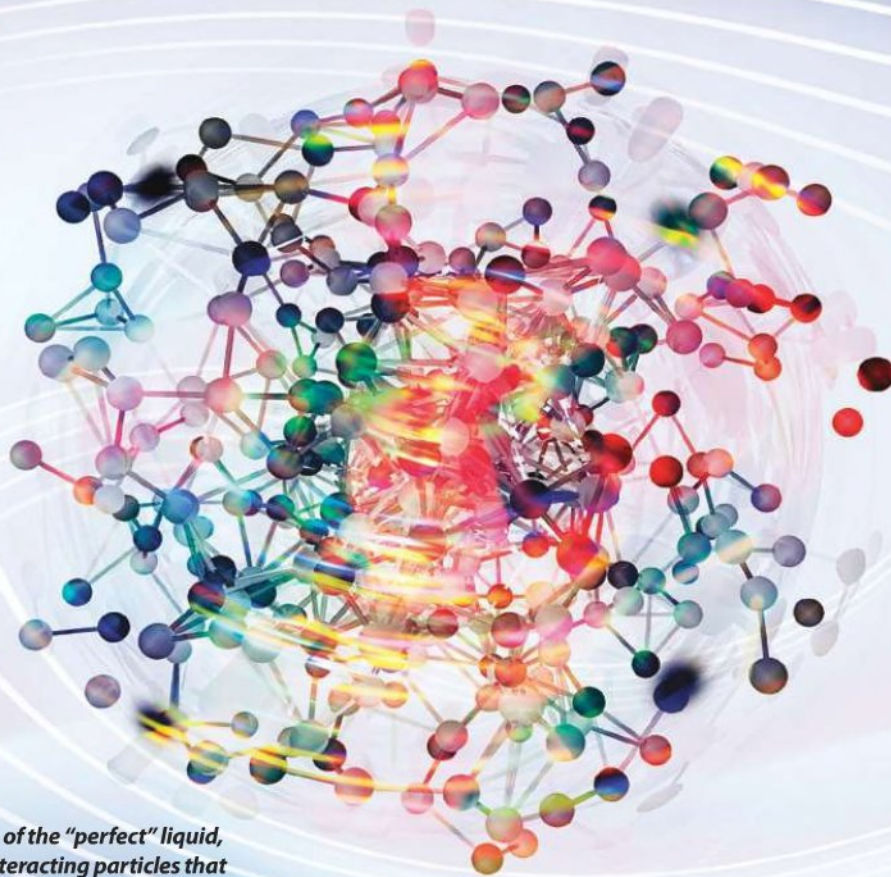


Comb of Light Makes Counting Easy

In an optical atomic clock, it is necessary to be able to count the lightning-fast oscillations in visible light—hundreds of billions of vibrations per second. This speed is too fast for electronic counters, so the light is funneled through an optical frequency comb.

The comb is created by a laser emitting one million ultrashort pulses per second. Each laser pulse contains a fan of different frequency lines, like the teeth on a comb. The precise frequency of

each of these "teeth" can be carefully determined and controlled. When a wave of unknown frequency (that is, the light coming from the optical atomic clock) is matched up with a tooth of known frequency, a new frequency is made. That new frequency is the difference between the unknown light wave and the known one—and it allows researchers to back-calculate the frequency of the light emitted from the atoms in the atomic clock.



An artist's rendering of the "perfect" liquid, made up of highly interacting particles that allow for zero viscosity.

A Liquid Beginning

Physicists simulating conditions right after the big bang have found that the universe started off as a "perfect" liquid. How does this change our understanding of the properties of matter?

All matter as we know it was created in the first few seconds of the big bang. But scientists don't know exactly how this happened. When researchers tested the leading theory by smashing gold ions into each other at nearly the speed of light in 2004, rather than creating conditions that mirrored a perfect gas, as predicted, the ions formed a nearly perfect liquid. Now physicists are amping up particle accelerators to use this surprising result to test string theory.

A First Glimpse

By the early 1930s, scientists knew that atoms consisted of a cloud of electrons and a nucleus made of smaller particles, called protons and neutrons. But it wasn't until the early 1970s that a new theory, quantum chromodynamics, described how these particles were bound together in atomic nuclei. This theory also predicted that under extreme conditions, protons and neutrons would melt, freeing smaller particles inside them called quarks

and gluons. The freed particles were expected to form quark-gluon plasma (QGP), a state of matter physicists believe to have existed microseconds after the big bang. It is only in the past decade, however, that new, higher-energy particle accelerators have created such plasmas for study.

The first hints of QGP emerged in 2000 at CERN, the European center for particle physics near Geneva, Switzerland. But the relatively low initial temperatures and short life span of

What Is a Perfect Liquid?

The matter formed at the RHIC is the closest thing to a perfect liquid ever observed. The thousands of particles emerging from a single collision of two gold nuclei move with a high degree of coordination, unlike normal liquids, in which individual molecules move randomly. The particles behave almost like a theoretical "perfect" fluid—a fluid with a high degree of interaction among particles and zero viscosity.

plasma made it difficult to study the possible QGP directly. It wasn't until 2004 that scientists at Brookhaven National Laboratory were able to use the more powerful Relativistic Heavy Ion Collider (RHIC) to detect QGP and measure its properties.

The RHIC, in operation since 2001, produces high-energy collisions of gold-ion beams traveling at near light speed within a 2.4-mile-long tunnel. The collisions yield temperatures of approximately 2 trillion degrees Celsius (3.6 trillion degrees Fahrenheit), recreating conditions found within about 10 microseconds of the big bang, when quarks and gluons still roamed free.

But the QGP detected in 2004 didn't behave exactly as physicists had predicted. According to Steve Vigdor, the associate lab director for nuclear and particle physics at Brookhaven, before the RHIC fired up, it was expected that particles in the QGP would barely interact, like atoms in a so-called ideal gas. Scientists found instead that the thousands of particles emerging from a single collision of two gold nuclei seemed to show a high degree of coordination of movement. In fact, QGP seemed to have all the properties of a nearly "perfect" liquid, one with extremely low viscosity (a perfect liquid would have zero viscosity). "Such ideal liquid flow requires exceedingly strong interactions among the constituents—

they need to remain in essentially instantaneous contact with one another," Vigdor adds. This behavior is in marked contrast to the predictions of quantum chromodynamics.

Understanding the Liquid

The discrepancy may be explained by string theory, an approach that models subatomic particles as tiny, vibrating stringlike entities. String theory has existed since 1970, but only as a mathematical construct; physicists have long been searching for some experimental confirmation. Now it seems like the RHIC's findings could be explained by an aspect of string theory that links the theories of strongly interacting particles and gravity. This has encouraged string theorists to try to predict other properties of QGP found at the RHIC, since testing these predictions would be a great way to validate the theory.



The RHIC's 2.4-mile-long concentric rings are made up of 1,740 superconducting magnets mounted end to end.

Scientists at the RHIC have discovered that some of QGP's characteristics, like its viscosity, seem to be fairly close to those predicted by string theory. The primary goal for the next decade is to procure more detailed measurements of QGP. But before they can do so, they will need more plasma samples, meaning more collisions per experiment.

An upgraded RHIC, dubbed the RHIC II, aims to increase collision rates 10-fold by next year. The improved collider will allow scientists to correct imperfections in the atom beam in real time. These imperfections will be measured at one point on the accelerator, and this information will be sent by a fiber-optic network or microwave link to a location ahead of the ion beam. Here, electric fields will automatically refocus the beam to prevent ions from missing each other on their collision course.

In the future, another upgrade will add a high-energy electron beam to the RHIC, which will make it the world's only electron-heavy-ion collider. Smashing heavy nuclei with electrons will give scientists a precise image of the nucleus and a better look at the strong force holding quarks and gluons together.

Any theory that seeks to explain the formation of the early universe must account for the different collision properties observed at different energies. So studying the characteristics of QGP using multiple accelerators can help develop a more comprehensive theory. Heavy-ion collisions at CERN's Large Hadron Collider (LHC) will produce matter at temperatures perhaps two to three times as high as those seen at the RHIC. Even though this matter is still unlikely to be at the ideal gas state originally predicted by quantum chromodynamics, it may be closer than that observed at the RHIC. And GSI, the German research center for heavy-ion physics, is currently building the Facility for Antiproton and Ion Research (FAIR). Scheduled to begin operating in 2016, FAIR will measure the properties of nuclear matter at lower temperatures than either the RHIC or the LHC.

The combination of the RHIC, the LHC and FAIR could provide the most complete picture yet of the contents of the nucleus and resolve many of the current mysteries surrounding quark-gluon plasma, bringing us closer to understanding the birth of our universe and the very nature of matter in it. ■

Island INVASION

Take a closely related family of languages spoken across far-flung islands, factor in bacterial DNA from a most unlikely source (our guts) and, researchers say, you end up with a map of one of humanity's greatest migrations

Five Ways to Say "Canoe"

By studying the evolution of cognates (similar words with the same meaning), linguists at the University of Auckland have attempted to map how speakers of the Austronesian family of languages peopled the islands of the Pacific. An analysis of 200 cognates, such as the words for "canoe" [see map at right], suggests that the languages—and people—originated in Taiwan 5,200 years ago. By the time the word for canoe reached New Zealand 800 years ago, linguists say, it had mutated from *qabang* to *waka*.



ON

Hawaiians say *lua* and Samoans, *e lua*. Bau-speaking Fijians say *e rua*. The Maori in New Zealand say *rua*, while Filipinos say *duha*. And for some Taiwanese natives, the word is *dusa*. Although many of these islands are separated by thousands of miles, the similar-sounding words all translate to the number *two*.

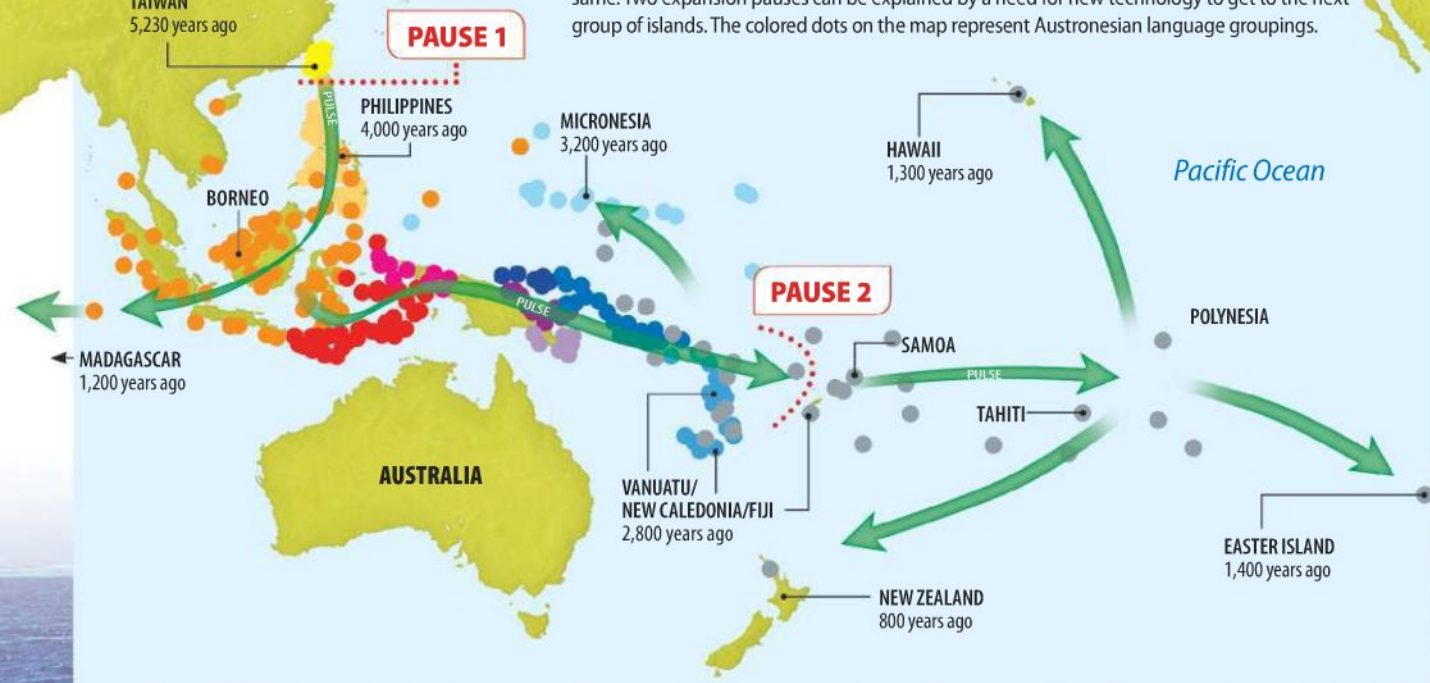
Linguists call such similar words cognates, and the Austronesian family of 1,200 languages, to which these tongues belong, is full of them. The Austronesian languages are spoken across the Pacific, from Taiwan in the north to New Zealand 5,800 miles to its south, and from Madagascar in the west to Easter Island 7,750 miles to its east. The languages' similarities are so striking, linguists believe, that their cognates could help explain how the Pacific was populated.

This area was the last in the world to be settled and is a major piece in the larger puzzle of ancient human migration. In addition to the language commonalities, archaeologists have found similar pottery, axes and shell ornaments, among other prehistoric relics, throughout the Pacific Islands—Melanesia, Micronesia and

ASIA

Pulse-Pause Pattern in the Pacific

Recent analyses suggest that migration happened in fits and starts as technology did the same. Two expansion pauses can be explained by a need for new technology to get to the next group of islands. The colored dots on the map represent Austronesian language groupings.



II PAUSE 1 5,200 to 4,000 years ago

The analysis indicates that proto-Austronesians came to Taiwan from mainland China around 5,200 years ago, arriving in simple canoes with no sails. They remained on the island for more than 1,000 years, marking the first major pause in the Austronesian Pacific migration.

► PULSE Invention of the Outrigger Canoe

Then, around 4,000 years ago, a huge wave of new languages emerged as Austronesians began to spread rapidly through the western Pacific, beginning with the Philippines, 400 miles south of Taiwan. The invention of the highly stable outrigger canoe [below] made it possible to cover far greater distances at sea than was previously possible.

II PAUSE 2 2,800 to 1,400 years ago

By around 2,800 years ago, Austronesians had reached Fiji in the mid-Pacific, 5,000 miles southeast of Taiwan. According to the University of Auckland analysis, a 1,400-year pause followed this major expansion pulse.

► PULSE Invention of the Double-Hulled Canoe

Starting around 1,400 years ago, another burst of new languages appeared when settlers arrived in the isolated islands of the eastern Pacific, including Hawaii and New Zealand. Double-hulled canoes [below], which offer even greater stability than outriggers, helped make these longer voyages possible.



Polynesia—indicating that a single culture known as the Lapita blazed a broad path through the region. But researchers disagree about exactly where and when the Austronesian migration originated, as well as the path and pace of its spread.

Anthropologists are divided into two camps. Most proponents of the so-called slow-boat scenario argue that a gradual and continuous migration originated on Wallacea, a group of islands in modern-day Indonesia, around 13,000 to 17,000 years ago. Maternal DNA from modern Austronesians indicates that the migration went in two directions from there—one branch moved north through the Philippines and into Taiwan, while the second prong spread east to the Pacific Islands. But such genetic studies of Pacific settlements have been hampered in part by problems in separating ancient DNA from recently incorporated lineages.

The alternative, known as the pulse-pause theory, says that Austronesians originated in Taiwan around 5,500 years ago. Pulse-pause theorists argue that language comparisons, archaeological finds and established arrival dates on certain islands all point to several bursts of expansion,

or pulses, followed by long periods of settlement, or pauses. Two recent, yet very different analyses—one that applies methods from evolutionary biology to linguistics and one that traces lineages of human gut bacteria—both give more support to this model.

A Tree Grows in Taiwan

Evolutionary biologists use a technique called molecular dating, based on the idea that gene mutations arise with a certain frequency, to calculate how long ago different species diverged. In 2008, Russell Gray of the University of Auckland in New Zealand and his colleagues employed the same principles to create an evolutionary language tree. But instead of DNA, they inputted words. The researchers analyzed more than 200 cognates from 400 Austronesian languages. Experts in Pacific languages compiled the database over the course of six years, choosing mainly basic vocabulary words.

By comparing the geographical distribution of the cognates against differences between the words, the researchers could determine the words' origin and how they evolved. The number of changes were used as a kind of clock showing when new words arose.

Working from a supercomputing facility at the University of Reading in England, the researchers drew a tree that suggested a surprisingly clear sequence of events: The Austronesian family of languages appears to have originated in Taiwan some 5,230 years ago. A long pause followed before the first group of related languages arose about 3,800 to 4,500 years ago south of Taiwan in the Philippines, Borneo and Indonesia and east of Taiwan in the Pacific Islands of New Guinea, Vanuatu and New Caledonia. By 2,800 years ago, Austronesian languages—and the people who spoke them—had reached Tonga, Samoa and Fiji, 5,000 miles southeast of Taiwan.

After this first wave, linguistic analogies suggest, further migration paused until about 1,400 years ago. Over the next 600 years, Austronesians went on to inhabit the more-isolated islands of Polynesia, including New Zealand, Hawaii, Tahiti and Easter Island. During these migrations, Austronesians would have met people already living on some islands. Humans first reached Australia by way of Asia 40,000 to 50,000 years ago. To get there, they took a coastal route along a landmass known as Sundaland, which is now broken up into the Malay Peninsula, Sumatra, Java, Borneo and Bali. Just a few deep channels separated Sundaland from a giant landmass that later became Australia, New Guinea and Tasmania, and the early groups would have crossed them easily.

When the Austronesians spread out over the Pacific, bringing agriculture with them, there were hunter-gatherers on such islands as Sumatra, Java and New Guinea. (More isolated islands, such as New Zealand, were unpopulated until Austronesians arrived.) Gray believes that the Lapita cultural complex—an ancient group from which many native Pacific Island groups may be descended—emerged from the combination of these two peoples.

Gray's linguistic analysis is backed by research on a common bacterium called *Helicobacter pylori*. Different strains of the intestinal bug are associ-



Micronesian boat builders on Satawal Island still construct sailing canoes. The hull's planks will be bound together with coconut-fiber cords.

A. RYMAN/CORBIS/POLEOTO



The traditional outrigger canoe is equipped with a float on a long arm that functions as a counterweight to the sail. Such boats are still used for fishing and transportation.

ated with different areas of the world, so its gene mutations can be used to chart human movements.

An international team of researchers led by Yoshan Moodley of the Max Planck Institute for Infection Biology in Berlin did just this from 2003 to 2006, comparing *H. pylori* samples from Austronesians and native Australians with samples collected during previous studies on European Australians and other Asian populations. The analysis found a Maori strain that originated in Taiwan and went on to colonize the islands of the Pacific in a sequence closely resembling the one indicated by Gray's language tree. "It is nice that the words that come out of our mouths tell the same story as the bacteria in our stomachs," Gray says.

Putting a Finger on the Trigger

According to the fossil record left by these early cultures, Austronesians brought domesticated plants and animals with them as they moved. Historians have theorized that the development of agriculture, which allows groups to outcompete their neighbors and develop larger populations, drove the Austronesian expan-

sion. But the long pauses and sudden bursts suggest that other factors were involved. What kept the population on Taiwan for 1,000 years before it set out for the Philippines, and why was there a second pause before it branched out to the more-isolated Polynesian islands? Gray believes one possible answer is boats.

Archaeologists assert that the pulse-pause model's structure argues for a technology-driven expansion. Geneticists who support the slow-boat theory have resisted that concept, defending the gradual, consistent migration model against the idea that migration fundamentally hinges on technological innovation. Gray says that his language



Strains of *Helicobacter pylori* support the pulse-pause migration theory.

analysis, along with support from the bacteria study, gives a boost to the idea that innovation shaped a pulse-pause migration pattern.

From some points on the Chinese mainland, where proto-Austronesians originated, Taiwan is separated by just 100 miles of water; the first migrants, Gray says, could have easily paddled to the island in a primitive canoe. The Philippines, on the other hand, are located 220 miles south of Taiwan, separated by the strong currents of the Bashi Channel. Reaching this distance would have required more-advanced boats with greater stability.

Gray theorizes that the invention of the outrigger canoe, which features a sail and a long arm with a float to counterbalance it, enabled Taiwanese Austronesians to cross the channel. Once there, they were able to spread rapidly over the roughly 450 miles between the Philippines and western Polynesia. The idea is supported by Gray's linguistic analysis, which determined that the words for outrigger canoe can only be traced back to settlements that arose after the Austronesians left Taiwan. "Once they had an outrigger canoe that would allow them to cross the straight," Gray says, "they left, taking the words with them."

As for the second long pause, in western Polynesia, Gray believes the Austronesians needed to develop new technology and skills to travel to the farther-flung islands of eastern Polynesia. They had to invent double-hulled canoes (which have even greater stability and carrying capacity than outrigger canoes), learn how to use the stars in the night sky to estimate latitude, and learn to safely negotiate the strong easterly trade winds.

The Austronesian analyses have proved that linguistics and genetics are a powerful combined tool for mapping ancient human history around the world. Gray is now assembling a team of linguistic researchers and evolutionary biologists to map other great migrations in the Americas and Southeast Asia. For him, the Pacific migration was just the beginning. ■

Words Mutate Just Like Genes

Just as genes mutate over time, small changes occur in the way words are pronounced and spelled. When a language is isolated in a geographic region—like a remote island in the Pacific—over time these changes accumulate into a new language. By studying mutations among similar words with the same meaning, known as cognates, linguists can determine the relationships between languages and calculate when each one split off from its ancestor.

The chart at right shows four common words and how they are pronounced in five different Austronesian languages. The words in each column share a common ancestor and underwent a series of mutations. In the words for hand and skin, for example, we see a common sound shift: from an “l” sound to an “r.” Among the words for skin is the Samoan *pa’u*, which underwent a different set of mutations from the others.

By comparing thousands of mutation sets identified by researchers, a computer can draw the most likely language tree and calculate how rapidly development has proceeded in the various languages. The linguistic analysis can then be used to extrapolate human migration routes and timing.



Samoa



Hawaii



Tahiti



New Zealand



Easter Island

Hand	Skin	Bone	Woman
lima	pa’u	ivi	fahine
lima	’ili	iwi	wahine
rima	’iri	ivi	vahine
ringa	kiri	iwi	wahine
rima	kiri	ivi	bahine

Despite the enormous distances in the Pacific—the islands of Bora Bora [shown here] are 6,500 miles from Taiwan—there are strong similarities among the 1,200 Austronesian languages.



Extremes of Nature

Rainforest-Dwelling Dolphins

Not all dolphins live in the ocean—four species, known as river dolphins, make their homes in freshwater. One, the Amazon River dolphin, even inhabits seasonal floodwaters. The mammals reside in

the vast river system of northern South America, and during the wet season they move deep into the flooded areas of the Amazon rainforest. There, they use sonar to locate prey in the turbid waters.

Sensitive whiskers on their long snouts help them find crustaceans hidden in the mud at the bottom of the river.

River dolphins are toothed whales, a group that also includes the familiar bottlenose dolphins, porpoises and sperm whales. The Amazon River variety can grow up to eight feet long and 300 pounds (bottlenose dolphins, in comparison, can reach 13 feet in length and more than 400 pounds). This freshwater species is easily distinguished from others in part by the contrast of its pinkish-gray belly to its dark-bluish-gray topside.



River dolphins use their long snouts to find crustaceans and other prey in muddy river bottoms.

Research Footnotes

What Your Seat Says about You

Why do we sit where we do on the bus? Psychologist Tom Fawcett of Salford University in England observed the behavior of passengers on double-decker buses on London's Manchester-to-Bolton line to find the answer for a local transportation company. Although age and time of day are big factors—older people understandably prefer the bottom deck, for instance—personality may also play a part. People who

choose the front of the top deck tend to be energetic, forward-thinking individuals, as well as curious types who want to see where they're headed. People who want to feel important tend to choose raised seats, located in the back of the lower deck. Fawcett cautions that the research was more of a fun exercise than a rigorous scientific study, though, so don't start judging people on their seating preference just yet.



Where would you sit on this bus? Your answer may reveal your personality.

FROM TOP: T. PUSSER/NATURE PL; TERRY WHA

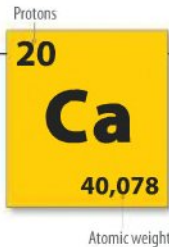
Elemental Secrets

Calcium

■ Pure calcium is a silver-gray metal soft enough to easily cut with a knife. It burns with an intense red flame, and in powdered form it reacts violently with water to release free hydrogen.

■ Calcium is one of the most common elements on Earth, but because it reacts readily with water and oxygen, it is never found in its pure form in nature. It combines with other elements to form such key rocks and minerals as chalk, limestone, gypsum and marble.

■ An adult human's body contains more than two pounds of calcium. Bones and teeth contain more than 99 percent, but the element is also important for the functioning of nerves and muscles.



Nature's Rarities

Ants Use Their Heads

In Australia's swamps, biologists have discovered ants that build nests in the hollow shoots of mangrove trees. But *Camponotus anderseni*, known as mangrove plug ants, face a daily complication: As the tide rises, water submerges the shoots. To keep her colony from drowning, the queen excavates an entrance hole only as wide as a soldier ant's



Soldier ants plug nests with their heads (and conserve air) at high tide.

head. For up to three hours, a soldier blocks water from seeping inside. No air reaches the nest during these periods, so the ants minimize their respiration.

Highs and Lows

World's largest flower . . .

Rafflesia arnoldi, known as dead-body flower for its rancid smell, grows up to three feet across and weighs as much as 24 pounds. A parasite of rainforest vines in Sumatra, it takes nine months to develop a bud, but the bloom lasts only a few days.

. . . and the shortest

Wolffia, called watermeal, are the world's smallest flowering plants. These tiny, rootless flowers float on the surface of lakes around the world. High in protein, they are commonly eaten in Asia.



Did You Know . . .



STRADIVARIUS VIOLINS

built in the late 1600s and early 1700s are known for having an especially fine tone, possibly because they were carved from slow-growing trees with extremely dense wood.



THE LARGEST CROSS-WORD PUZZLE

in the world covers a building's side in Lvov, Ukraine. Clues are scattered around the city, and at night the 100-foot-tall puzzle is lit up with the solutions.



SCORPIONS fluoresce in ultra-violet light. Of the 1,826 known species alive today, only around 20 have poison toxic enough to kill a person.



Earn more points by using fewer clues to answer each question.		5 points	4 points	3 points	2 points	1 point
BOTANY	Name this vegetable	This edible plant comes from the genus <i>Rheum</i> and is a member of the "smartweed" family.	Its roots were used as a laxative in China as early as 2700 B.C.	Its leafstalks and stems are edible, but its leaves are poisonous.	Its tart red stalks are used in jellies, pies, jams and wine, often paired with strawberries.	In Italian, its name is <i>rabarbaro</i> .
CHEMISTRY	Name this element	At room temperature, it is a greenish-yellow gas that irritates the eyes and respiratory system.	It made its appearance in World War I as the first gas used in chemical warfare.	Number 17 in the periodic table of the elements, it sits between sulfur and argon.	It is found in ordinary table salt, where it is bound to sodium.	It's commonly used as a disinfectant in swimming pools.
ARCHITECTURE	Name this building	This structure no longer exists, but the large square named for it still does.	After it was torn down, many of its stones were reused to construct the Pont de la Concorde, a famous bridge that crosses the Seine.	It was constructed in the late 1300s, and in the 17th century it turned into a state prison. The Marquis de Sade was one famous inmate.	France's national day is named after the building, which was stormed on July 14, 1789, marking the start of the French Revolution.	Its name means "fortress" or "castle" and comes from <i>bastir</i> , an Old French word meaning "to build."
MEDICINE	Name this disease	Usually contracted in childhood, it is extremely contagious: Just standing near an infected person can make you sick.	After about 10 days, patients develop fever, red and watery eyes, a runny nose, and sometimes bluish-white specks on the inside of the mouth.	After a vaccine was introduced in the 1960s, the disease mostly disappeared from the West, but it is still prevalent in the developing world.	About three days after symptoms appear, patients get a rash of red spots that can cover the whole body.	The MMR vaccine protects against it. The second M stands for mumps, and the R for rubella.
PERSONALITIES	Name this character	This man was mentioned as early as the 14th century, when his name appeared in William Langland's poem <i>Piers Plowman</i> .	Some claim that the character was based on the English Earl of Huntingdon.	Many actors, including Douglas Fairbanks, Errol Flynn and Kevin Costner, portrayed him, and he appeared as an animated fox in a 1973 Disney film.	According to pop culture, his hero was Richard the Lionheart and his enemies included the Sheriff of Nottingham.	He was renowned for stealing from the rich and giving to the poor.

What year was it?

January 5, Czechoslovakia

Alexander Dubcek is elected head of the nation's Communist party, ushering in the Prague Spring period.

June 5, U.S.

Presidential candidate Robert Kennedy is shot in Los Angeles [right]. He dies the following day.

December 24, Space

The three astronauts on *Apollo 8* become the first people to see the "dark side" of the moon when their spacecraft circles Earth's satellite.

Your guess Points

Correct year

5

± 2 years

4

± 4 years

3

± 6 years

2

± 8 years

1



Your score:

24-30

Good show, Sherlock

17-23

Not bad, Watson

9-16

Good enough, Paris

0-8

Hit the books, Homer!

Answers appear on page 82

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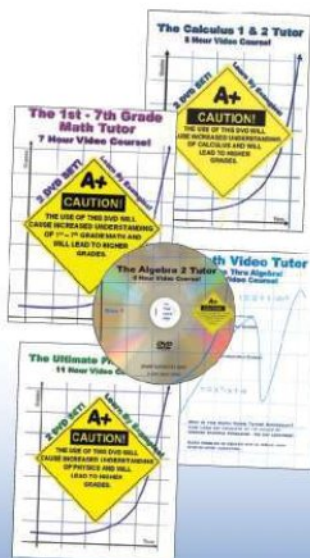
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Answer Key

$$\begin{array}{r} 10652 \\ + 1085 \\ \hline 957 \end{array}$$

telling the truth, witnesses 1, 2 and 3 are all lying. Thus, the number is an even, one-digit number that cannot be written with straight lines. The only possibilities are 2, 6 and 8. Neither 6 nor 8 is either a square or a prime, so the answer is 2, and witness 5 is telling the truth.

3. See equation below. $S = 9$, $E = 5$, $N = 6$, $D = 7$, $M = 1$, $O = 0$, $R = 8$ and $Y = 2$.

HEADBREAKERS ANSWERS

1. 2/9. Each blue circle has a diameter of $1/3$ of the big circle's, so its area is $(1/3)^2 = 1/9$ of the big circle. The blue area is thus $7/9$ of the total, so the red area is $2/9$ of the total area.

2. Hole 2. Witness number 5 told the truth. Witnesses 4 and 5 cannot both be lying, since no number is both a square and a prime. Because at least one of them is lying, the number is either a square or a prime. Because either 4 or 5 is

2. $(22 + 8) / 5 - 3 = 3$.

3. In each row, the sum of the first two numbers equals the product of the last two numbers. In the row D, $4 + 5 = 9$, so $3 \times X = 9$. $X = 3$.

4. Down.

5. $(4 - 4) \times 4 + 4 = 4$.

1	1	2	0	2	1	1
3						
0						
1						
1						
0						
2						

1. See diagram.

BRAIN TRAINERS ANSWERS

Botany: Rhubarb
Chemistry: Chlorine
Architecture: The Bastille
Medicine: Measles
Personalities: Robin Hood
History: 1968

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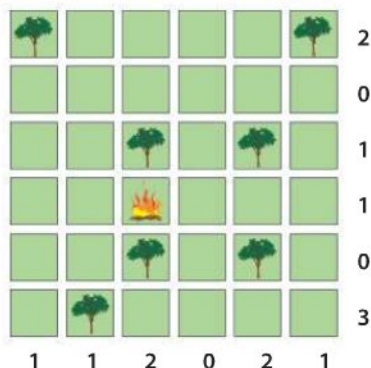
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1

Complete the diagram below by putting bonfires into empty boxes. Every tree must have at least one bonfire adjacent to it, and no bonfire can touch another vertically, horizontally or diagonally. The numbers outside the diagram show how many bonfires are in each row or column. How should they be positioned?



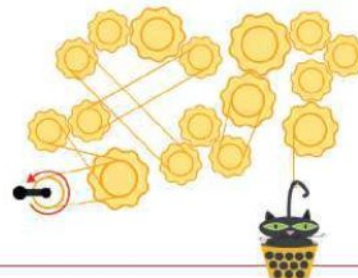
3

What number should replace the question mark in row D?

A	7	5	3	4
B	9	7	2	8
C	6	8	7	2
D	4	5	3	?

4

If the black handle is turned counter-clockwise, will the cat in the basket go up or down?



2

Insert "+", "-", "x" or "/" in place of the question marks to make a true equation.

$$(22?8)?5?3=3$$

5

Using arithmetic operations and four "4"s, make an equation similar to the examples below but equaling 4.

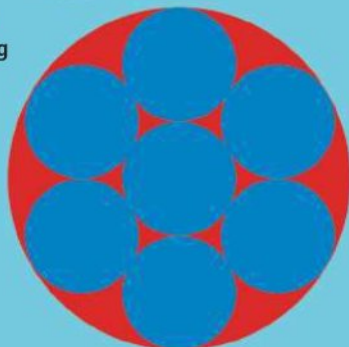
$$(4+4)/(4+4)=1 \quad 4/4+4/4=2 \quad (4+4+4)/4=3$$

Headbreakers



1

What fraction of the area of the big circle is red?



3

On the right, different letters correspond to different digits. Assign digits to the letters so that this becomes a correct addition problem.

$$\begin{array}{r} \text{SEND} \\ + \text{MORE} \\ \hline \text{MONEY} \end{array}$$

2

You are playing golf on an 18-hole course, and a friend hits a hole-in-one. Five witnesses tell you which hole it happened on, but at most one of the five tells the truth. They say:

1. It is not an even number.
2. It is a two-digit number.
3. The number consists only of straight lines.
4. The number is not a prime.
5. The number is not a square.

At which hole did the hole-in-one happen?

Answers appear on page 82

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