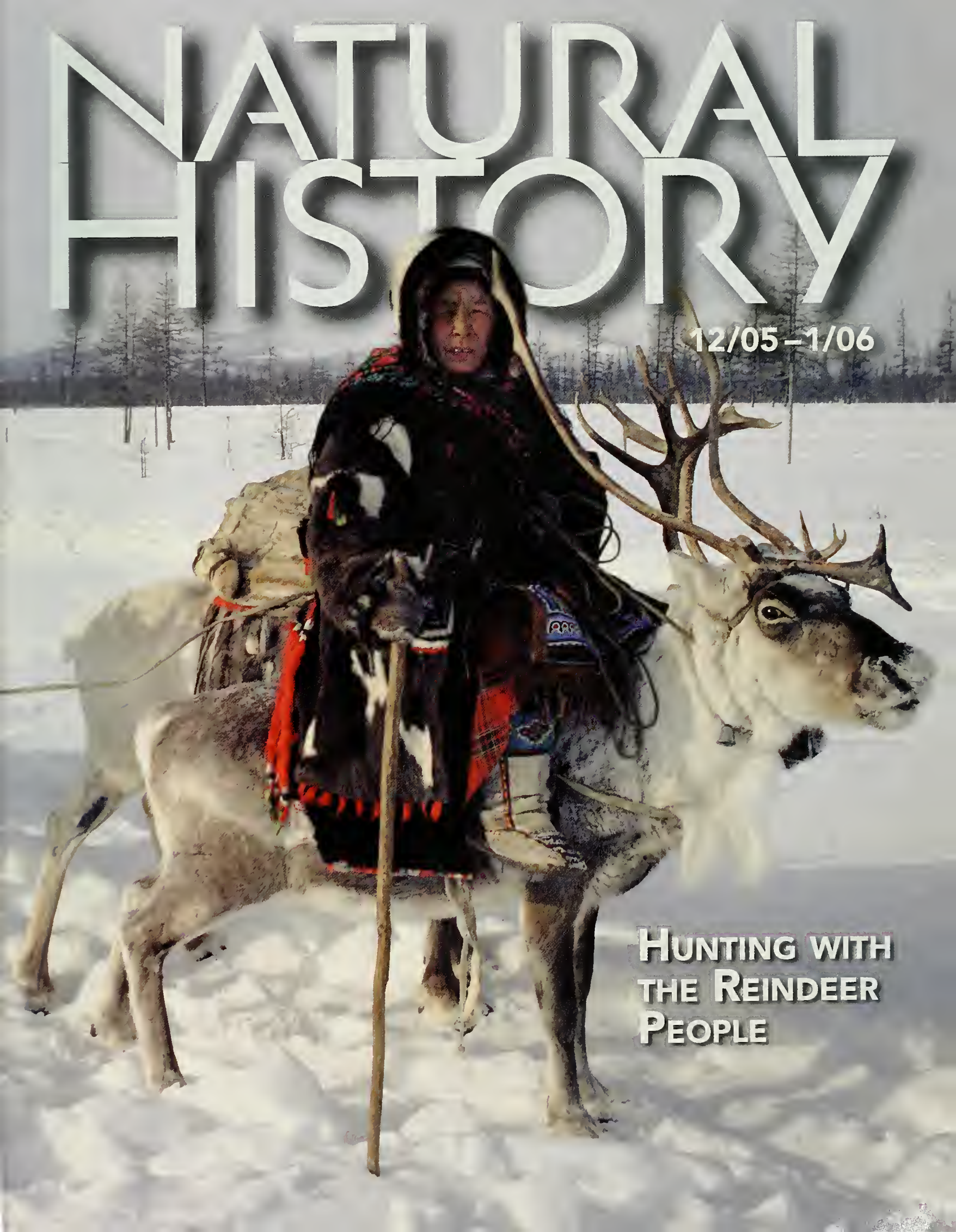
NATURAL HISTORY

12/05–1/06



HUNTING WITH THE REINDEER PEOPLE

NATURAL HISTORY

DECEMBER 2005/JANUARY 2006 VOLUME 114 NUMBER 10

FEATURES

ON THE COVER:
Eveny woman and her reindeer in eastern Siberia. Photograph by Bryan and Cherry Alexander

NATURAL HISTORY

DEPARTMENTS

6

54

14

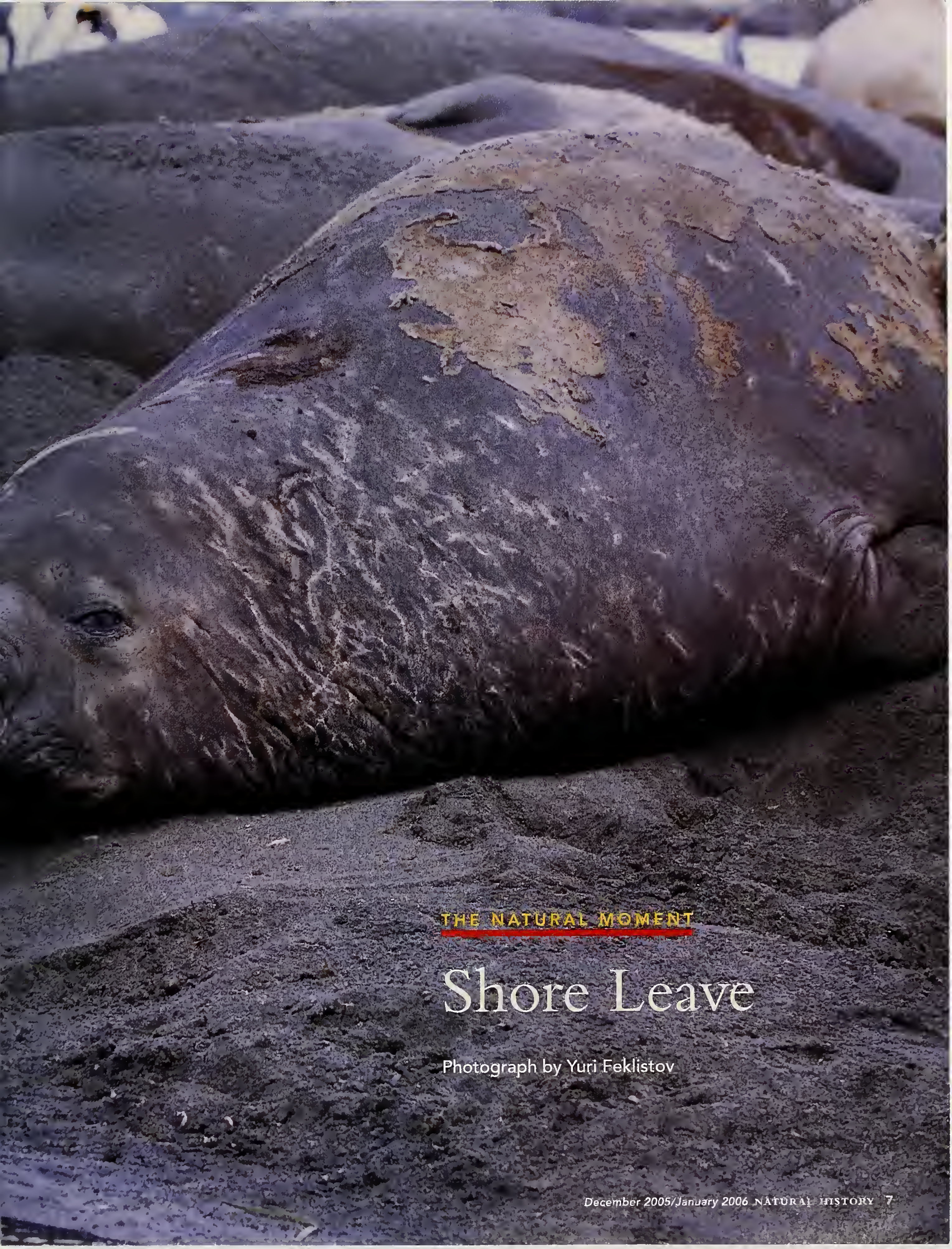
58

28

72

PICTURE CREDITS: Page 26

Visit our Web site at
www.naturalhistorymag.com



Shore Leave

Photograph by Yuri Feklistov

THE NATURAL MONEMT

◄ *See preceding two pages*

Every summer in the Southern Hemisphere, the islands around Antarctica attract millions of beachgoers, some with family obligations and some with a need to just vegetate. Both types appear in this scene on South Georgia Island.

King penguins (*Aptenodytes patagonicus*)—often mistaken for emperor penguins, which are featured in the recent documentary *March of the Penguins*—lay their eggs in December. Until early February the parents take turns being personal incubators, and whichever one is off duty can take a food break. In this photograph Yuri Feklistov captured a trio of king penguins—perhaps unattached, perhaps on break—ambling by, while several southern elephant seals (*Mirounga leonina*) caught some R & R.

A male southern elephant seal, like the juvenile in the foreground here, is unmistakable, with an inflatable nose and four tons of flesh. This juvenile is about seven years old; he spends his summers on land, molting and resting. He would have competed with other, stronger males for a mate five months earlier, going without food for many weeks. Then he would have made a grueling 1,200-mile journey to fishing grounds, spent a month or two fishing 24/7, and finally swum the 1,200 miles back to land. So it's no surprise that when Feklistov focused on this hulking seal, the only action was the fitful twitch of a flipper and the occasional belch. —*Erin Espelie*

UP FRONT

Improvise and Flourish

We had seventeen [reindeer] harnessed into one caravan to pull our sledges. . . . Seven pairs of reindeer alternated with six sledges; the remaining three animals were tied behind as spares. . . .

. . . I had crossed this area before on horseback, but now [in winter] we sought out paths of a new kind. We did not skirt laboriously around each lake, but instead cascaded down its embankment and flung ourselves onto its hardened surface.

The sudden speed and the spray of ice crystals flung behind . . . the reindeer's skidding hooves make it easy to feel that one is about to take off and fly into the air.

That's just a sampler of Piers Vitebsky's unforgettable portrait of life among the Eveny, a herding and hunting people of northeastern Siberia, where the legend of flying reindeer is alive and well ("A Winter Hunt," page 30). The Eveny live in the coldest inhabited place on earth; winter temperatures, even in this age of dramatic warming across much of the Arctic, fall to minus ninety-six degrees Fahrenheit.

The Eveny legend of flying reindeer can be traced to far earlier times than Dasher, Dancer, and other "tiny reindeer." "Reindeer stones" across northern Mongolia and Siberia, emplaced 3,000 years ago, portray antlers swept back to the animals' tails, as if in swooping flight. Eveny elders told Vitebsky of annual, traditional ceremonies that re-enact mythical flights to the sun on the backs of reindeer, purifying each rider and burning away the illnesses of the old year. Vitebsky's account of this remarkable people is the perfect cover feature for the coming winter holidays.

• • •

There's a big dose of bricolage in the development and evolution of life. That's the term, left over from the French art scene, for a work made from whatever materials happen to be lying around. (If you've ever thrown a meal together with whatever happens to be in the fridge, or improvised a stage set from an old bedsheet, a few scarves, and a kitchen stool, you'll know what I mean.) In their report from the cutting edge of evolutionary developmental biology ("The Birth of the Uterus," page 36), Vincent J. Lynch and Günter P. Wagner give an astonishing account of biological bricolage, centered about a group of genes known as *Hox* genes.

Hox genes occur so ubiquitously in plants and animals that the first *Hox* gene may have appeared before multicellular organisms emerged in the Precambrian era, some 640 million years ago. For most of that time, the genes have acted as master architects for the body plan along the long axis of an embryonic organism, determining where to grow an insect's leg, a fish's fins, a bird's wing, or a human's arms. Then, 180 million years ago, those same genes were recruited for an entirely new role. *Hox* genes became major players in the evolution of the uterus, the differentiation of the various parts of the female reproductive system, and the emergence of embryonic development inside the female body—in short, the birth of pregnancy.

• • •

With this issue, we close our publication schedule for 2005. We're getting lots of mail about "Darwin & Evolution," published last month, and you'll find a generous selection of readers' letters when we return to your mailbox with our February 2006 issue. Until then, we wish you a splendid holiday season and a joyous New Year! —PETER BROWN


JRV 603

CONTRIBUTORS

YURI FEKLISTOV ("The Natural Moment," page 6), a native of Russia, generally photographs people, but during a trip to Antarctica last year he found that the local wildlife offered a multitude of equally interesting subjects. Feklistov graduated from the All-Russian State Institute of Cinematography in Moscow in 1984. He works as a photojournalist, publishing widely in Russian magazines and newspapers such as *Ogonyok* and *Itogi*. More of his work can be seen on his Web site (www.feklistov.com).

Since 1988 **PIERS VITEBSKY** ("A Winter Hunt," page 30) has worked in the field among nomadic reindeer herders in the Siberian Arctic, where he was the first Western anthropologist in modern times to live long-term with a native community. He has also studied shamans and their communities in tribal India since 1975. His previous books include *Dialogues with the Dead: The Discussion of Mortality among the Sora of Eastern India* (Cambridge University Press, 1993) and *Shamanism* (University of Oklahoma Press, 2001). He is head of anthropology and Russian northern studies at the Scott Polar Research Institute at the University of Cambridge in the United Kingdom. Vitebsky's article is excerpted from his book *The Reindeer People: Living with Animals and Spirits in Siberia,* which is being published in December by Houghton Mifflin.

VINCENT J. LYNCH ("The Birth of the Uterus," page 36) was inspired by a tenth-grade biology teacher to study the deep evolutionary connections among all life-forms. Lynch earned his M.S. from Yale in 2004 and is currently working in **GÜNTER P. WAGNER**'s laboratory on his Ph.D. His other research interests include the evolution of snakes, their venoms, and the genetic basis for adaptive evolution and morphological innovations. Wagner, Lynch's coauthor, chairs the department of ecology and evolutionary biology at Yale University, where he is Alison Richard Professor of Ecology and Evolutionary Biology. His early work was primarily on mathematical population genetics. Beginning in 1991, Wagner collaborated with the biologist Frank Ruddle to study the evolution of *Hox* genes and their role in developmental evolution. That research remains Wagner's primary focus, though he directs student work on a variety of topics. He has published more than a hundred scholarly articles and has edited several books on developmental evolution.

What **KAROLINE T. SCHMIDT** ("Land of Plenty," page 44) likes most about working with red deer is the variety of their relations with people. The deer are considered "the epitome of game animals by hunters" and denounced "as a pest animal by foresters." Schmidt, who studied biology and anthropology at the University of Vienna in Austria, has investigated red deer in habitats ranging from the Austrian Alps to Scotland to Canada's Yukon Territory. She is the mother of four children, and she works as a freelance scientist for the Research Institute of Wildlife Ecology in Vienna. Schmidt's work focuses on sociological aspects of hunting and wildlife management, and on how attitudes toward deer vary from culture to culture.

NATURAL HISTORY

To contact us regarding your subscription, to order a new subscription, or to change your address, please visit our Web site www.naturalhistorymag.com or write to us at

Natural History
P.O. Box 5000, Harlan, IA 51593-0257.

Natural History (ISSN 0028-0712) is published monthly, except for combined issues in July/August and December/January, by Natural History Magazine, Inc., in affiliation with the American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024. E-mail: nhmag@naturalhistorymag.com. Natural History Magazine, Inc., is solely responsible for editorial content and publishing practices. Subscriptions: $30.00 a year; for Canada and all other countries: $40.00 a year. Periodicals postage paid at New York, NY, and at additional mailing offices. Canada Publications Mail No. 40030827.

If you would like to contact us regarding your subscription or to enter a new subscription, please write to us at Natural History, P.O. Box 5000, Harlan, IA 51593-0257. Postmaster: Send address changes to *Natural History*, P. O. Box 5000, Harlan, IA 51537-5000. Printed in the U.S.A


DA VINCI DECODED
Premiere Event
Da Vinci
& The Code He Lived By
Sunday, December 4th 9pm/8c
THE HISTORY CHANNEL
History.com

Sudden Collapse

Lee Siebert's article "Blown Away" [10/05] details how volcanoes can collapse. Last year, when Mount St. Helens reawakened, my colleagues and I at the U.S. Geological Survey (USGS) were asked whether the mountain's southern flank was unstable. We concluded that the volcano had been so eviscerated by the avalanche in 1980 that another large collapse was unlikely until the mountain rebuilt itself. Data showed that the current eruption was having little effect on the southern flank, except during a brief time when a new lava dome first reached the crater wall. The lava pushed the flank outward a few centimeters—nowhere near the 1.5 meters that the northern flank deformed each day before the 1980 collapse.

William E. Scott
U.S. Geological Survey
David A. Johnston Cascades Volcano Observatory
Vancouver, Washington

Lee Siebert mentions the controversial models of giant tsunamis that a collapse of island volcanoes might generate. We have calibrated our models with data from recent tsunamis caused by smaller, Mount St. Helens–size island-arc volcanoes. We were able to model the main features of an 1888 tsunami, caused by the collapse of the Ritter Island volcano, northeast of New Guinea, by assuming that a landslide traveled underwater at around ninety miles an hour.

Since then, our group has made sonar surveys and seafloor photographs of deposits made by the 1888 landslide, which show that the landslide left tracks similar to the ones left by the Mount St. Helens landslide at Johnston Ridge. Computer simulations of the 1888 landslide also show it must have been moving about ninety miles an hour to leave the traces it left. The agreement between landslide deposit data and tsunami data give us confidence that scaled-up models may predict what could happen when the flank of a volcano the size of La Palma, in the Canary Islands, heads for the ocean floor.

Steven Ward
Simon Day
University of California at Santa Cruz
Santa Cruz, California

Lee Siebert replies: Public reaction to the current eruption of Mount St. Helens was indeed colored by the catastrophic events of 1980. Data obtained by USGS scientists were important in demonstrating that the present eruption is not likely to lead to a 1980-scale landslide and ensuing lateral blast. Unfortunately, the title "Blown Away," which the editors of *Natural History* gave to my article, reinforces the incorrect per-

(Continued on page 65)


NEW ENGLAND ISLANDS
Boston
Plymouth
Fall River
New Bedford
Cape Cod
Providence
Bristol
Hartford
Newport
New London
Mystic
Martha's Vineyard
Nantucket
Block Island

Rio Negro, about sixty miles upstream from Manaus, Brazil

Holding Up the Amazon

Usually it's hard to imagine that the ground beneath your feet is anything but solid. In fact, though, the Earth's crust is elastic. In many places it moves up and down just a fraction of an inch, usually in sync with the varying amounts of water, snow, ice, and air pressure that weigh it down. Amazingly, Global Positioning System receivers are sensitive enough to detect the rises and falls.

One such GPS station has been operating since 1995 in Manaus, Brazil, on the bank of the Rio Negro, close to where it joins the Amazon River. Michael Bevis, a geophysicist at Ohio State University in Columbus, and a team of American and Brazilian colleagues report that the spot rises and falls by as much as three inches a year. That's a new world record: twice the size of the largest previously recorded oscillation.

The Amazon is a river of superlatives. It has the greatest discharge of any river—about 1,350 cubic miles of water a year, enough to deepen the Great Salt Lake by nearly a mile. And it swells impressively during the rainy season, from December through May. Near Manaus the water rises some thirty to fifty feet each year. Bevis's group determined that the Earth's crust sinks under the water load of the river and its tributaries as they course throughout the region within 125 miles of Manaus. In the second half of the year, as the flooding abates, the crust springs back up again. (*Geophysical Research Letters* 32:L16308, 2005)

—*Stéphan Reebs*

Can't Stand the Heat

A honeybee colony is a model of unity and selfless cooperation. Bees work together to tend their queen, forage for food, and maintain the colony. And when the colony's young are endangered by cold weather, worker bees come to the rescue. They form a cluster around the larvae and generate heat by vibrating their strong flight muscles. The core temperature of the cluster rises rapidly, incubating the youngsters.

But this act of sisterly care can also become a deadly weapon. Honeybee colonies are beset by predatory wasps and hornets, which prey on honeybees to feed their own young. When patrolling bees spot an approaching wasp, they surround it, creating a so-called heat ball. Inside the ball, temperatures can reach 113 degrees Fahrenheit—hot enough to kill the invader.

How do the bees survive the heat? Tan Ken, a honeybee specialist at the Xishuangbanna Tropical Botanical Garden and the Eastern Bee Research Institute of Yunnan Agricultural University in China, and his colleagues discovered that the lethal temperature limit for honeybees is about nine Fahrenheit degrees higher than it is for wasps—a small margin, but enough to do the job. (*Naturwissenschaften*, forthcoming)

—*Nick W. Atkinson*

Asian honeybees "cook" an invading wasp.

Great Leap

Genes that "jump" between closely related single-celled organisms are plentiful. But finding a gene that can jump between complex and distantly related species would excite any evolutionary biologist.

Charles C. Davis, a systematist and evolutionary biologist at Harvard University, and his colleagues at the University of Michigan and the Smithsonian Institution have discovered two such genes. The team had been trying to classify the rattlesnake fern (*Botrychium virginianum*), an exercise many biologists might find routine. Two gene sequences in the fern looked suspiciously similar to those of the Santalales, an order of flowering plants that includes parasitic mistletoes. The only reasonable explanation for the presence of Santalales genes in the fern was horizontal gene transfer—the passage of genetic material between organisms without sexual reproduction.

Most Santalales plants are parasites that can have intimate contact with fern cells, and so the investigators suggest the genes might have moved directly from flowering plant to fern. Another, more speculative hypothesis is that perhaps fungi, which live within the roots of many distantly related plants, served as a conduit for the jumping genes. (*Proceedings of the Royal Society of London* B 272:2237–42, 2005)

—*Graciela Flores*

The Lice and the Whale

Whale lice enjoy a meal of dead whale skin.

Whale lice—diminutive crustaceans that feed on dead skin—spend their lives attached to right whales (*Eubalaena* spp.). The benign parasites, also called cyamids, grow in thick masses, forming distinctive white patches on the whales' dark skin; marine biologists often use those living scars to identify individual whales. Zofia A. Kaliszewska, an evolutionary biologist at the University of Utah in Salt Lake City, and her colleagues have found that cyamids can also help track genetic changes and migration patterns in right whales.

Kaliszewska and her colleagues compared sequences of the mitochondrial gene *COI* in what they thought were three species of whale lice. It turned out that there were actually nine separate species. Three species of lice infected the three species of right whale, each of which lives in a different ocean: the North Atlantic, the North Pacific, and the Southern. The evolutionary divergence of the lice proves that the whales themselves diverged from a single species about 6 million years ago.

The study also shows that North Atlantic and North Pacific right whales, which are both highly endangered, might once have been as abundant as the more successful right whales in the Southern Ocean. Thus, the investigators suggest, the dramatic reduction in the whale populations in the past few centuries more likely results from intense whaling than from an original lack of genetic diversity. If so, there is reason to hope the two endangered species can recover. (*Molecular Ecology* 14:3439–56, 2005) —G.F.

Tale of a Two-Tailed Virus

With waters at least ten times more acidic than vinegar, and scorching temperatures as high as 200 degrees Fahrenheit, the hot springs of Pozzuoli, in southern Italy, are a special place to live. It's a good bet that any life-form that can survive in such conditions would have evolved some unique adaptations. Now Monika Häring, a molecular biologist at the Pasteur Institute in Paris, and several collaborators have discovered a remarkable adaptation in a virus from Pozzuoli: the organism can grow parts of its anatomy on its own, independent of its host cell.

Volcanic hot spring near Pozzuoli, Italy

No virus previously studied can grow or reproduce without the chemical building blocks and genetic copying machinery it commandeers from the cell it infects. But Häring's virus, dubbed *Acidianus* two-tailed virus, or ATV, is a bit more autonomous. The virus grows inside a member of the diverse and largely unexamined group of microorganisms called Archaea. ATV destroys its host cell after it has reproduced; once outside in the harsh spring water, it sprouts two tails all by itself.

Häring's group detected a gene in ATV that is also present in other organisms, where the gene codes for a filament-forming protein. The same filaments likely make up the virus's two tails. What the tails do is uncertain, however. They may stabilize ATV's structure in the hot, acidic water. Or, since ATV destroys its host, the tails may help the virus reach the few other, widely dispersed potential hosts that roam the hot springs. (*Nature* 436:1101–1102, 2005) —S.R.

Salt in the Wound

This winter, as you drive on ice-free roads flanked by drifting snow, ponder this: In winter, some streams in urban and suburban Baltimore have become one-fourth as salty as seawater. In areas where more than 40 percent of the ground is covered with structures that are impermeable to water, such as roads, parking lots, and buildings, surface waters are now saltier than recommended for the protection of sensitive freshwater life. Those conclusions come from a recently published study by Sujay S. Kaushal, an ecologist at the Institute of Ecosystem Studies in Millbrook, New York, and a team of collaborators.

Kaushal's group blames the accumulation of salt on the de-icer dumped on roadways in winter. During the five-year period of the study (1998–2003), Baltimore spread more than 82,000 tons of sodium chloride on its roads. By contrast, rural areas of Maryland, New Hampshire, and New York have long used less de-icer, and so the salt content of rural streams in these areas is less extreme. The ecologists found, however, that the

saltiness of rural streams has increased steadily for the past thirty years.

Perhaps "greener" ways of making roads safe in winter will someday be adopted. But if the current rate of annual winter salinization continues, Kaushal and his colleagues warn, much of the surface water in the northeastern United States will become toxic to freshwater life and unfit for human consumption in a century or two. (*PNAS* 102:13517–20, 2005) —*S.R.*

Deep Green

When most people think of photosynthesis, they think of sunlight. But most people aren't aware that black smokers—vents on the ocean floor that spew hot gases into the seawater—give off minute amounts of light, in addition to the heat and gas. Bacteria discovered near a deep-sea vent in the Pacific strongly suggest that photosynthesis can happen where the Sun doesn't shine.

J. Thomas Beatty, a microbiologist at the University of British Columbia in Vancouver, and his colleagues recently identified a new species of green sulfur bacteria off the west coast of Costa Rica, in water nearly 8,000 feet deep. Green sulfur bacteria make the food they need via photosynthesis, and, as a group, they have a knack of making do with exceptionally low levels of light. To drive photosynthesis, Beatty's bacteria absorb the faint geothermal light—also known as blackbody radiation—that emanates from active deep-sea vents. The photons are so scarce, though, that the bacteria must use the energy frugally: they don't move around (because they lack flagella), and they probably don't reproduce often.

The bacteria are the first organisms ever found that may rely solely on natural light that does not come from the Sun. Their discovery reinforces the likelihood that diverse life forms can live independent of the Sun—perhaps in such exotic habitats as beneath the ice on Jupiter's moon Europa—by relying on chemical, thermal, and alternative photic energy. (*PNAS* 102:9306–10, 2005)

—*Jennifer Evans*

Scramble for Milk

The pups of the European rabbit (*Oryctolagus cuniculus*) are on a strict diet from the moment they are born. Mom leaves them stowed in an underground nest, then visits only once a day for a three-minute feeding session. Worse, the pups have to get almost all their milk during the second minute of feeding. Rabbit mothers also frequently give birth to more offspring than they have nipples, which inevitably intensifies the competition for milk. So pups in small litters tend to gain weight faster, and are more likely to survive to weaning age, than pups in bigger ones.

Given the crunch of competition and feeding time, it wouldn't be surprising to find that rabbit pups slug it out for access to a nipple. But that's not what happens. According to Amando Bautista, a psychobiologist at the Universidad Autónoma de Tlaxcala, in Mexico, and his colleagues, the best strategy for a pup seems to be to find a nipple quickly and then hang on to it. (The technical term is "scramble competition.") Mom's visit just isn't long enough to waste time fighting your siblings. (*Animal Behaviour*, forthcoming)

—*N.W.A.*

European rabbit pups, waiting for Mom

Jonathan Hunt, *Fire Ball*, 2001

Fire and Ice

The Earth may be warming, but the cosmos is headed toward a very big chill.

By Neil deGrasse Tyson

Andy Goldsworthy, *Ice Star (Scaur Water, Penpont, Dumfriesshire)*, 1987 (detail)

When Cole Porter composed "Too Darn Hot" for his 1948 Broadway musical *Kiss Me Kate*, the temperature he was bemoaning was surely no higher than the mid-nineties. No harm in taking Porter's lyrics as an authoritative source on the upper temperature limit for comfortable lovemaking. Combine that with what a cold shower does to most people's erotic urges, and you now have a pretty good estimate of how narrow the comfort zone is for the unclothed human body: a range of about thirty degrees Fahrenheit, with room temperature just about in the middle.

The universe is a whole other story. How does a temperature of 100,000,000,000,000,000,000,000,000,000,000 degrees grab you? That's a hundred thousand billion billion billion degrees. It also happens to be the temperature of the universe a teeny fraction of a second after the big bang—a time when all the energy and matter and space that would turn into planets, petunias, and particle physicists was an expanding fiery ball of quark-gluon plasma. Nothing you'd call a thing could exist until there was a multibillionfold cooling of the cosmos.

As the laws of thermodynamics decree, within about one second after the big bang, the expanding fireball had cooled to 10 billion degrees and ballooned from something smaller than an atom to a cosmic colossus about a thousand times the size of our solar system. By the time three minutes had passed, the universe was a balmy billion degrees and was already hard at work making the simplest atomic nuclei. Expansion is the handmaiden to cooling, and the two have continued, unabated, ever since.

Today the average temperature of the universe is 2.73 degrees Kelvin. All the temperatures mentioned so far, aside from the ones that involve the human libido, are stated in degrees Kelvin. The Kelvin degree, known simply as the kelvin, was conceived to be the same temperature interval as the Celsius degree, but the Kelvin scale has no negative numbers. Zero is zero,

period. In fact, to quash all doubts, zero on the Kelvin scale is dubbed absolute zero.

The Scottish engineer and physicist William Thomson, later and better known as Lord Kelvin, first articulated the idea of a coldest possible temperature in 1848. Laboratory experiments haven't gotten there yet. As a matter of principle, they never will, although they've come awfully close. The unarguably cold temperature of 0.0000000005 K (or 500 picokelvins, as metric mavens would say) was artfully achieved in 2003 in the lab of Wolfgang Ketterle, a physicist at MIT.

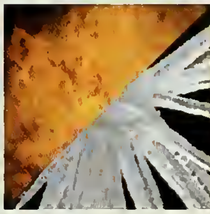
Outside the laboratory, cosmic phenomena span a staggering range of temperatures. Among the hottest places in the universe today is the core of a blue supergiant star during the hours of its collapse. Just before it explodes as a supernova, creating drastic neighborhood-warming effects, its temperature hits 100 billion K. Compare that with the Sun's core: a mere 15 million K.

Surfaces are much cooler. The skin of a blue supergiant checks in at about 25,000 K—hot enough, of course, to glow blue. Our Sun registers 6,000 K—hot enough to glow white, and hot enough to melt and then vaporize anything in the periodic table of elements. The surface of Venus is 740 K, hot enough to fry the electronics normally used to drive space probes.

Considerably further down the scale is the freezing point of water, 273.15 K, which looks downright warm compared with the 60 K surface of Neptune, nearly 3 billion miles from the Sun. Colder still is Triton, one of Neptune's moons. Its icy nitrogen surface sinks to 40 K, making it the coldest place in the solar system this side of Pluto.

Where do Earth-beings fit in? The average body temperature of humans (traditionally 98.6 degrees F) registers slightly above 310 on the Kelvin scale. Officially recorded surface temperatures on Earth range from a summer high of 331 K (136 F, at Al 'Aziziyah, Libya, in 1922), to a winter low of 184 K (–129 F, at Base Vostok, Antarctica, in 1983). But people can't survive unassisted at those extremes. We suffer hyperthermia in the Sahara if we don't have shelter from the heat, and hypothermia in the Arctic if we don't have boatloads of clothing and caravans of food. Meanwhile, Earth-dwelling extremophile microorganisms, both thermophilic (heat-loving) and psychrophilic (cold-loving), are variously adapted to temperatures that would fry us or freeze us. Viable yeast, wearing no clothes at all, has been discovered in 3-million-year-old Siberian permafrost. A species of bacterium locked in Alaskan permafrost for 32,000 years woke up and started swimming as soon as its medium melted. And at this very moment, assorted species of archaea and bacteria are living out their lives in boiling mud, bubbling hot springs, and undersea volcanoes.

Even complex organisms can survive in similarly astonishing circumstances. When provoked, the itsy-bitsy invertebrates known as tardigrades can suspend their metabolism. In that state, they can survive temperatures of 424 K (303 degrees F) for several minutes and 73 K (–328 degrees F) for days on end, making them hardy enough to endure being stranded on Neptune. So the next time you need space travelers with the "right stuff," you might want to choose yeast and tardigrades, and leave your astronauts, cosmonauts, and (Chinese) taikonauts at home.



Itsy-bitsy invertebrates known as tardigrades could endure being stranded on Neptune.

It's common to confuse temperature with heat. Heat is the total energy of all the motions of all the molecules in your substance of choice. It so happens that, within the mixture, the range of energies is large: some molecules move quickly, others move slowly. Temperature simply measures their average energy. For example, a cup of freshly brewed coffee may have a higher temperature than a heated swimming pool, but all the water in the pool holds vastly more heat than does the lone cup of coffee. If you rudely pour your 200-degree coffee into the 100-degree pool, the pool won't suddenly become 150 degrees. And whereas two people in a bed are a source of twice as much heat as one person in a bed, the average temperatures of their two bodies—98.6 and 98.6—do not normally add up to an under-cover oven whose temperature is 197.2 degrees.

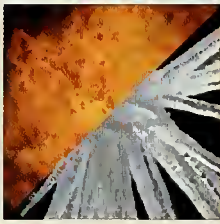
Scientists in the seventeenth and eighteenth centuries considered heat to be closely linked with combustion. And combustion, as they understood it, happened when phlogiston, a hypothetical earthlike substance characterized mainly by its combustibility, was removed from an object. Burn a log in the fireplace, air carries off the phlogiston, and the dephlogisticated log reveals itself as a pile of ashes.

By the late eighteenth century the French chemist Antoine-Laurent Lavoisier had replaced phlogiston theory with caloric theory. Lavoisier classified heat, which he called caloric, as one of the chemical elements, and contended that it was an invisible, tasteless, odorless, weightless fluid that passed between objects through combustion or rubbing. The concept of heat was not fully understood until the nineteenth century, the peak of the Industrial Revolution, when the broader concept of energy took shape within the new branch of physics called thermodynamics [*see "Energy to Burn," by Neil deGrasse Tyson, October 2005*].

Although heat as a scientific concept posed plenty of challenges to brilliant minds, both scientists and nonscientists have intuitively grasped the con-

cept of temperature for millennia. Hot things have a high temperature. Cold things have a low temperature. Thermometers confirm the connection.

Although Galileo is often credited with the invention of the thermometer, the earliest such device may have been built by the first-century A.D. inventor Heron of Alexandria. Heron's book *Pneumatica* includes a description of a "thermoscope," a device that showed the change in the volume of a gas as it was heated or cooled. Like many other ancient texts, *Pneumatica* was translated into Latin during the Renaissance. Galileo read it in 1594 and, as he later did when he learned of the newly invented telescope, he immediately constructed a better thermoscope. Several of his contemporaries did the same.



Anders Celsius set his freezing point at a hundred and his boiling point at zero—not the only time an astronomer got things backward.

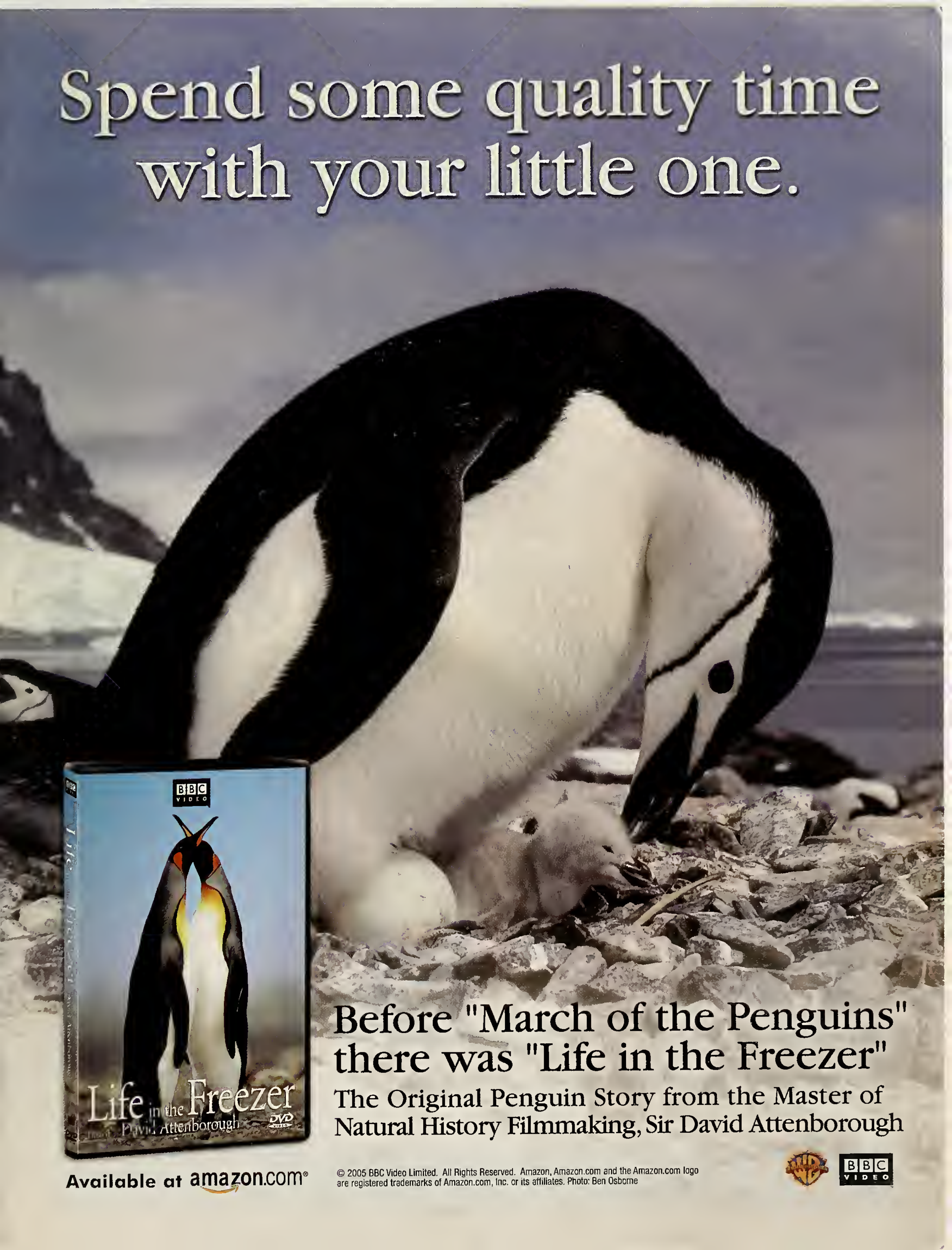
For a thermometer, scale is crucial. There's a curious tradition, beginning early in the eighteenth century, of calibrating the temperature units in such a way that common phenomena get assigned fraction-friendly numbers with many divisors. Isaac Newton proposed a scale from zero (melting snow) to twelve (the human body); 12 is, of course, evenly divisible by 2, 3, 4, and 6. The Danish astronomer Ole Romer offered a scale from zero to sixty (60 being divisible by 2, 3, 4, 5, 6, 10, 12, 15, 20, and 30). On Romer's scale, zero was the lowest temperature he could achieve with a mixture of ice, salt, and water; sixty was the boiling point of water.

In 1724 a German instrument maker named Daniel Gabriel Fahrenheit (who developed the mercury thermometer in 1714) came up with a more precise scale, splitting each degree of Romer's into four equal parts. On the new scale, water boiled at 240 degrees and froze at 30, and human body temperature was about 90. After further adjustments, the span from zero to body temperature became 96 degrees, another winner in the divisibility department (its divisors are 2, 3, 4, 6, 8, 12, 16, 24, 32, and 48). The freezing point of water became 32 degrees. Still further tuning and standardization saddled fans of the Fahrenheit scale with a body temperature that isn't a round number, and a boiling point of 212 degrees.

Following a different path, in 1742 the Swedish astronomer Anders Celsius proposed a decimal-friendly centigrade scale for temperature. He set the freezing point at 100 and the boiling point at zero. This was not the first or last time an astronomer labeled a scale backward. Somebody, quite possibly the chap who manufactured Celsius's thermometers, did the world a favor and reversed the numbering, giving us the now-familiar Celsius scale, with freezing at very near zero and boiling at very near 100.

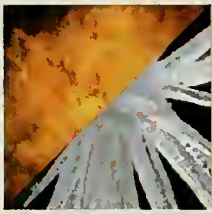
The number zero seems to have a crippling effect on some people's comprehension. One night a couple of decades ago, while I was on winter break from graduate school and was staying at my parents' house north of New York City, I turned on the radio to listen to classical music. A frigid Canadian air mass was advancing on the Northeast, and the announcer, between movements of George Frideric Handel's *Water Music,* continually tracked the descending outdoor temperature: "Five degrees Fahrenheit." "Four degrees." "Three degrees." Finally, sounding distressed, he announced, "If this keeps up, pretty soon there'll be no temperature left!"

In part to avoid such embarrassing examples of innumeracy, the international community of scientists uses the


Spend some quality time with your little one.
BBC VIDEO
Life in the Freezer
David Attenborough
DVD
Before "March of the Penguins" there was "Life in the Freezer"
The Original Penguin Story from the Master of Natural History Filmmaking, Sir David Attenborough
Available at amazon.com
© 2005 BBC Video Limited. All Rights Reserved. Amazon, Amazon.com and the Amazon.com logo are registered trademarks of Amazon.com, Inc. or its affiliates. Photo: Ben Osborne
BBC VIDEO

Kelvin temperature scale, which puts zero in the right place: at the absolute bottom. Any other location for zero is arbitrary, and does not lend itself to play-by-play arithmetic commentary.

Several of Kelvin's predecessors, by measuring the shrinking volume of a gas as it cooled, had established −273.15 degrees Celsius (−459.67 degrees F) as the temperature at which the molecules of any substance have the least possible energy. Other experiments showed that −273.15 C is the temperature at which a gas, when kept at constant pressure, would drop to zero volume. Since there is no such thing as a gas with zero volume, −273.15 C became the unattainable lower limit of the Kelvin scale. And what better term to use for it than "absolute zero"?



Travel halfway between the Milky Way and the Andromeda Galaxy, and the temperature will settle at 2.73 degrees above absolute zero.

The universe as a whole acts somewhat like a gas. If you force a gas to expand, it cools. Back when the universe was a mere half million years old, the cosmic temperature was about 3,000 K. Today it is less than 3 K. Inexorably expanding toward thermal oblivion, the present-day universe is a thousand times larger, and a thousand times cooler, than the infant universe.

On Earth, temperatures are normally measured by cramming a thermometer into a creature's orifice or letting the thermometer touch an object in some other, less intrusive way. This form of direct contact enables the moving molecules within the thermometer to reach the same average energy as the molecules in the object. When a thermometer sits idle in the air instead of performing its labors inside a rib roast, it's the average speed of the colliding air molecules that tell the thermometer what temperature to register.

Speaking of air, at a given time and place on Earth the air temperature in full sunlight is basically the same as the air temperature under a nearby tree. What the shade does is shield you from the Sun's radiant energy, nearly all of which passes unabsorbed through the atmosphere and lands on your skin, making you feel hotter than the air would by itself. But in empty space, where there is no air, there are no moving molecules to trigger a thermometer reading. So the question "What is the temperature of space?" has no obvious meaning. With nothing touching it, the thermometer can only register the radiant energy from all the light, from all sources, that lands upon it.

On the daytime side of our airless Moon, a thermometer would register 400 K (260 degrees F). Move a few feet into the shadow of a boulder, or journey to the Moon's night side, and the thermometer would instantly drop to 40 K (−390 degrees F). To survive a lunar day without wearing a temperature-controlled space suit, you would have to do pirouettes, alternately baking and then cooling all sides of your body, just to maintain a comfortable temperature.

When the going gets really cold and you want to absorb maximum radiant energy, wear something dark rather than reflective. The same holds for a thermometer. Rather than debate how to dress it in space, assume the thermometer can be made perfectly absorbent. If you now place it in the middle of nowhere, such as halfway between the Milky Way and the Andromeda Galaxy, far from all obvious sources of radiation, the thermometer will settle at 2.73 K, the current background temperature of the universe.

A recent consensus among cosmologists holds that the universe will expand forever and ever. By the time the cosmos doubles in size, its temperature will drop by half. By the time it doubles again, its temperature will halve once more. With the passage of trillions of years, all the remaining gas will have been used to make stars, and all the stars will have exhausted their thermonuclear fuels. Meanwhile, the temperature of the expanding universe will continue to descend, approaching ever closer to absolute zero.

So yes, our cosmos will die a slow and frigid death. And whatever meaning Robert Frost intended for his 1920 poem "Fire and Ice," to the astrophysicist the poem is about the cosmos itself, and the cryogenic fate that awaits us all:

Some say the world will end in fire,
Some say in ice.
From what I've tasted of desire
I hold with those who favor fire.
But if it had to perish twice,
I think I know enough of hate
To say that for destruction ice
Is also great
And would suffice.

Astrophysicist NEIL DEGRASSE TYSON *is the director of the Hayden Planetarium at the American Museum of Natural History. His* Natural History *essay "In the Beginning" (September 2003) is the recipient of the 2005 Science Writing Award from the American Institute of Physics. An anthology of his* Natural History *essays will be published in 2006 by W.W. Norton.*

PICTURE CREDITS Cover: ©Bryan and Cherry Alexander Photography; pp. 6–7: Yuri Feklistov/UNEP/Peter Arnold, Inc.; p.14 (Top): Claus Meyer/Minden Pictures; p.14 (bottom): courtesy of Tan Ken; p.16 (top right): Iain Kerr, Ocean Alliance/Whale Conservation Institute; p.16 (middle): ©Armin Maywald/naturepl.com; p.16 (bottom) Joe Viesti/viestiphoto.com; p.18 (top): AP Photo/Gerry Broome; p.18 (bottom): © NHPA/Michael Leach; p.20 (left): ©Jonathan Hunt; p.20 (right):©Andy Goldsworthy; p.28: Photograph by Sally Black; p.28–29 Illustrations by Tom Moore; pp.30 (left), 34–35: courtesy of Piers Vitebsky; p.30–31 (middle): Peter Carmichael/Aspect Picture Library; p.31: map by Joe LeMonnier; p.32; Thomas L. Kelly; p.33 ©Bryan and Cherry Alexander Photography; pp.36–37: Illustration by Khalil Younes; pp.38–39: Illustrations by Zang Media; p.41: Illustration by Mark A. Klingler/CMNH; pp.44–45, 46: courtesy of Karoline Schmidt; p.47: Illustration by Advanced Illustrations Ltd.; p.49: © Griffen, Gary/Animals Animals; p.50: Photograph by Sandy Carnival, courtesy of Tosohatchee State Reserve; p.51: Photograph by Scott Spaulding, courtesy of Tosohatchee State Reserve; p.51: Map by Joe LeMonnier; p.60: Alfred Pasieka / Photo Researchers, Inc.; p.72: Jerome Wilson/Painet

Spore Launchers

Ferns and fungi that explosively reproduce

By Adam Summers ~ Illustrations by Tom Moore

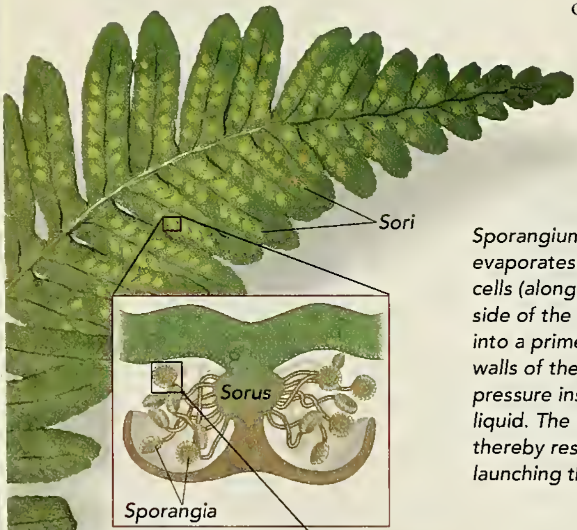
Reproduction usually involves routing very small particles—sperm, eggs, and spores—away from the site where they were created. Diverse solutions to the basic transport problem have evolved, such as sticky pollen that is picked up by insects, and moss gametes that are readily carried by water. The methods of transport that most intrigue me are ballistic: the catapulting of spores by ferns and the cannonlike firing of fungal spores.

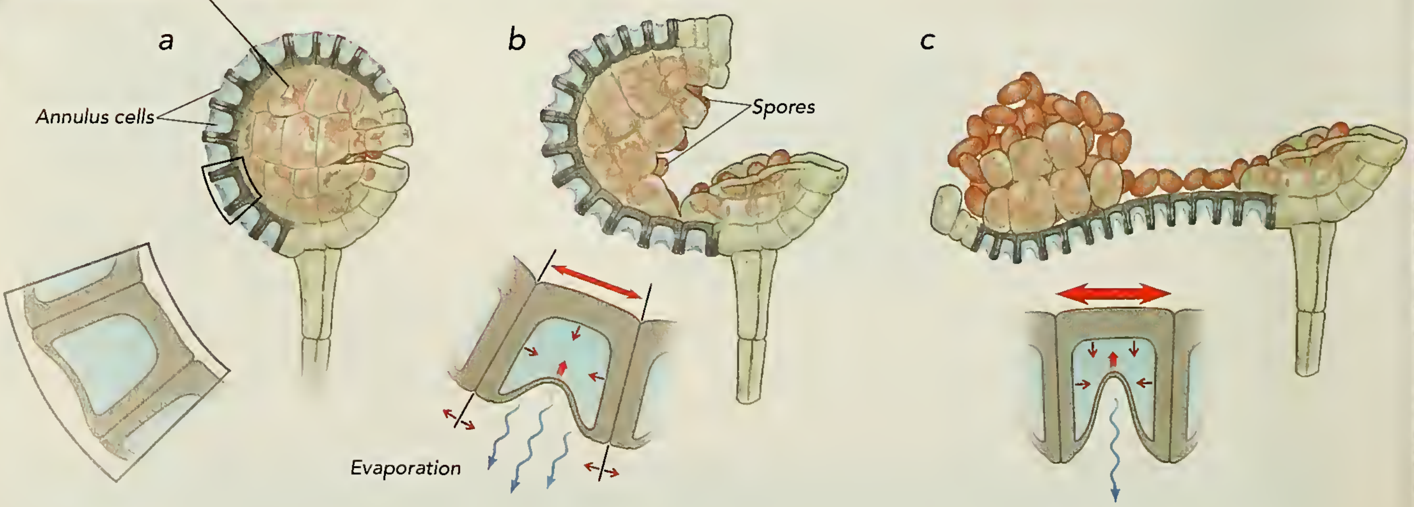
An object launched ballistically is accelerated to an initial velocity, and then drag acts to slow it, causing it to fall more steeply than it climbs. For heavy flying objects the effect of drag is minimal. But for small, lightweight ones, drag is hard to overcome. Roger Clemens has no problems pitching a baseball, but even his rocket arm could not get a dried pea from the mound to home plate.

Similarly, it takes tremendous muzzle velocity to shoot a spore—a speck just one-tenth the width of the periods on this page—the length of your thumbnail. The biomechanical mechanism that has evolved to do so resembles a catapult. Robbin Moran, the fern boffin at the New York Botanical Garden, knows the details of spore shooting, as well as some intriguing properties of water, the agent that both loads the catapult and triggers the launch.

A parental fern grows, protects, and ultimately ejects its spores from a stalked structure: the sporangium. To visualize its ballistic mechanism, imagine holding a small pile of peas in the palm of your hand and gently closing your fist. Further imagine that a thin, steel spring has been rigged along the inside surface of your bent middle finger. If some force were to pry open your fist, allowing the peas to roll to your fingertips, the force would stretch and load the piece of spring. Removing the force suddenly would cause your fingers to snap shut, flinging peas everywhere.

The fern equivalent of the spring and middle finger is the annulus, a row of cells that bisects the sporangium like a sturdy spine. The annulus has heavily reinforced inner walls and thin outer walls that are permeable to water. As the sporangium dries, evaporating water is drawn out from the cells of the annulus, causing the cells to shrink.





Sporangium encases the spores of a fern (a). Water evaporates through the thin cell walls of the annulus cells (along the spine of the structure), shortening one side of the sporangium's arm and ratcheting it back into a primed position (b,c). Because the thick inner walls of the annulus cells resist collapse, the water pressure inside the cells drops and bubbles form in the liquid. The bubbles pop the cell walls outward, thereby restoring the arm to its original form and launching the spores (d,e).

The thick, inner cell walls don't collapse, but the outer walls start to buckle. The process causes the curved surface of the annulus to shorten, thereby prying the sporangium open [*see illustration below*].

Now the spores are exposed, but they still cling to the surface of the primed sporangium. The column of water trapped in the annulus's cells is under progressively greater tension as water evaporates through the thin outer cell walls. But the thick inner walls continue to resist collapse, and so the water pressure inside the cell drops. When the pressure drops below a certain threshold, dissolved air or water vapor form a gas bubble in the liquid. The formation of such a bubble is called cavitation.

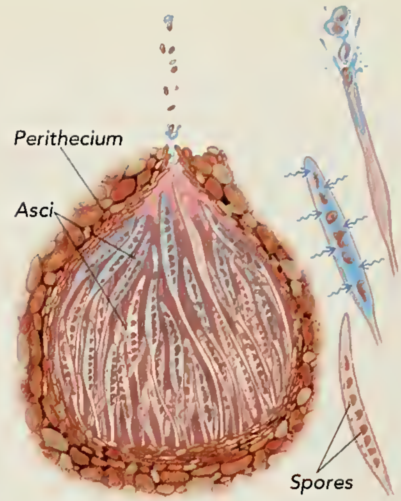
When one such bubble forms, it disturbs its neighboring cells enough to set off a chain reaction of bubble formation along the annulus. The fat air bubbles in the cells make the cell walls snap back into their pre-evaporation positions, firing spores in all directions.

That is a pretty slick solution to the problem of accelerating a small object quickly, but certain fungi have the fern catapult outgunned. Frances Trail and Iffa Gaffoor, both biomechanists at Michigan State University in East Lansing, teamed up with the biomechanist Steven Vogel of Duke University in Durham, North Carolina, to show how one fungus uses water in a different way to fire its spores. By their measurements, the fungus shoots with the highest relative velocity and greatest acceleration of any known biological entity.

Gibberella zeae, the new powerhouse spore launcher, is a fungal pathogen of wheat. Its spores are spindle-shaped and small enough that five of them would fit end to end across the cut tip of a human hair. Eight spores are packed into a pod-shaped, fluid-filled capsule called an ascus, and hundreds of asci are, in turn, crammed into a pimplelike organ called a perithecium [*see illustration at right*].

To begin the firing process, each ascus produces a high internal concentration of mannitol, a slightly sweet alcohol. The mannitol draws water by osmosis out of the surrounding tissue and into the ascus, causing it to swell. As it swells, the ascus elongates, so that it points toward the small central opening in the perithecium.

The "skin" of the ascus is now taut enough that a further influx of water will raise the internal pressure. And pressure is just what is needed to fire the spores from a pinprick-size pore in the ascus. But the ascus has a further osmotic trick to raise the pressure much higher: it pumps potassium and chloride ions from the outside to the inside, and the ions draw in yet more water. The pressure in the ascus rises as high as five atmospheres. Suddenly, the tip of the ascus bursts. Spores and fluid spurt into the air over a distance



Fruiting body, or perithecium, of the Gibberella zeae *fungus houses hundreds of asci, each containing eight spores. The asci pump themselves full of water by osmosis, eventually building up enough pressure to shoot spores out through their small openings and into the air.*

of . . . less than a quarter inch. The spent ascus retreats back down inside the perithecium and a newly bloated ascus comes up.

A quarter inch may not seem very far, but it is more than enough to launch the lightweight spores into air currents that can carry them to a new home. The force on the spores initially accelerates them at an astonishing 870,000 times the acceleration of gravity. They reach speeds of eighty miles an hour, or nearly 2 million spore lengths per second.

The instant the spores are fired, however, they hit the air as if it were made of concrete. A spore leaving the perithecium travels nearly straight up at first. Then, its forward momentum spent, it drops nearly straight down. And the smaller the spores, the less their flight paths look like a parabola, and the more they resemble the path of a marble falling off a table. Despite the temptations of superacceleration, though, it seems unlikely that the Department of Defense will go scurrying any time soon for ways to scale-up a spore launcher into a working gun.

ADAM SUMMERS (asummers@uci.edu) *is an assistant professor at the University of California, Irvine. He is a great fan of Robbin Moran's* Natural History of Ferns.

NATURAL HISTORY
DECEMBER 2005/
JANUARY 2006

A Winter Hunt

In Siberia, the reindeer really know how to fly.

By Piers Vitebsky

In the Verkhoyansk Mountains of northeastern Siberia, Eveny nomads are on the move. Teams of reindeer pull sledge caravans down the steep slide of a frozen mountain river. Bells tinkle on the lead reindeer while dogs on short leashes dive alongside through the snow like dolphins beside a boat. One man sits on the lead sledge of each caravan, his right leg resting forward for balance and his left foot set on the runner, ready to fend off hidden rocks and snagging roots. Passengers or cargo sit on the sledges be-

Cherski Mountains, right, where winter temperatures can drop to minus ninety-six degrees Fahrenheit, are among the harsh lands traversed by the Eveny, a hunting and herding people of eastern Siberia (see map at far right). Domesticated reindeer, which provide transportation and serve as a source of hides and furs for traditional clothing, enable the Eveny to survive in the forbidding environment. Inset photo, above: On the frozen Tumara River, in the Verkhoyansk Mountains, reindeer belonging to Vladimir Nikolayevich watch as a second caravan, led by his fellow hunter Manchary, catches up. In 1990 the author accompanied the two men on an expedition to trap fur-bearing animals.

hind. The passage of each caravan is visible from afar as a cloud of frozen reindeer breath.

This is the coldest inhabited place on Earth, with winter temperatures falling to minus ninety-six degrees Fahrenheit (minus seventy-one degrees Celsius). Water takes the form of ice for eight months of the year, and by January it is six feet thick. Throughout the winter, warm springs break through the surface of rivers and freeze into jagged obstructions. Caravan after caravan jolts over the last ridge of river ice and

skims across a great frozen lake. Deep lakes provide a more level surface, and the ice that forms from their still water glows black, marbled with milky white. The sudden speed and the spray of ice crystals flung behind the hypnotic flash of the reindeer's skidding hooves make it easy to feel that one is about to take off and fly into the air.

Thousands of years before the czarist empire taxed them or the Soviet Union relocated them into state farms, the ancestors of today's Eveny and of their cousins the Evenki moved from their homeland in northeastern China. They spread across forests and tundras, swamps and mountain ranges, from Mongolia to the Arctic Ocean, from the Pacific almost to the Urals, making them the most widely dispersed indigenous people on any landmass. Even today, elders can tell stories of journeys that make young people, tied to their villages and dependent on aircraft, smile with disbelief. The old people achieved this mobility by training reindeer to carry them on their backs and pull them on sledges.

The association between reindeer and flying is very ancient—much, much older than European or

American ideas about Santa Claus. Scattered across western Mongolia and some bordering territory stand the so-called reindeer stones, dating from about 3,000 years ago. The stones bear carved images of various animals, mostly reindeer. The earliest depictions were simple, but later ones became more ornate, the reindeer shown with neck outstretched and legs often flung out front and rear, as if not merely galloping but leaping through the air. Meanwhile the antlers grew until, fantastically, they reached all the way back to the tail, sometimes embracing the disc of the sun or a human figure with the sun as its head.

In Pazyryk, a Russian mountain valley west of Mongolia, burial mounds of chiefs from 2,500 years ago have been excavated by archaeologists, beginning in the 1920s. The graves contained food, fine clothing, gold ornaments, harps, combs, and mirrors. The artifacts are decorated with a range of animals. Three of the bodies—well preserved because they were originally mummified and later frozen—bear various tattoos, including the same reindeer as on the standing stones, with outflung hooves and exaggerated antlers. The imagery of flight is even more explicit because the branching of the antlers sometimes looks like the feathering of birds' wings; on some tattoos, each tine of the antler ends in a tiny bird's head.

The climate of Mongolia dried out toward the middle of the first millennium B.C.; today reindeer can no longer live there, except in one small, cool mountain region. But the association of reindeer with flight was carried by migrating peoples to lands where reindeer still existed, far to the north. When, as a child, I first read about the tattoos of Pazyryk, I did not imagine that one day I would live among people who, in their own childhood, had experienced reindeer flight as a living tradition.

Reindeer stone, dating from some 3,000 years ago, stands in northern Mongolia, where the climate was once favorable for both domesticated and wild reindeer. The original significance of such stones is an enigma, though the carvings appear to represent a kind of spiritual flight. The author found a tantalizing thread of the tradition of spiritual flight in the childhood recollections of elderly Eveny.

In the late 1980s I went to the village of Sebyan, in the Sakha Republic, to begin anthropological fieldwork. Sakha, home of the Eveny, was then still part of the Soviet Union [*see map on preceding page*]. My first friend was Tolya, a small, muscular man with an impish sense of humor. Together we rode from camp to camp, then crouched around darkened stoves at night, while I listened to him talking intently to nomadic elders in a language I could not yet understand.

The elders told Tolya that reindeer were created by the sky god, Hövki, not only to provide food and transportation on earth, but also to lift the human soul to the sun. From their childhoods seventy, eighty, or more years before, they remembered a ritual that was carried out each year on Midsummer's Day, symbolizing the ascent of each person on the back of a winged reindeer. During the white night of the Arctic summer, a rope was stretched between two larch trees; together, trees and rope represented a gateway to the sky. As the sun rose high above the horizon in the early morning, the gateway was symbolically purified with the aromatic smoke of the mountain rhododendron, which drifted from two bonfires. Each person passed around the first fire counterclockwise, against the direction of the sun, to symbolize the death of the old year and to burn away its illnesses. He or she then moved around the second fire in a clockwise direction, following the sun's own motion, to symbolize the birth of the new year.

It was at this moment, while the elders prayed to the sun, that each person was said to be borne aloft on the back of a reindeer. According to the tradition, the human passengers rode toward a land of happiness and plenty near the sun, where they received a blessing, salvation, and renewal. At the highest point in the flight, the reindeer transformed for a time into a crane, a highly sacred bird. I still do not understand how the Eveny of old acted out the experience of flying through the air, but they would mime their return to earth by sitting on their own reindeer as if they were arriving from a long journey. They acted tired, unsaddled their mount, pitched a tent, and lit a fire. When the ritual was complete, all joined in a circle dance in the direction of the sun, and enjoyed a feast of plenty.

The annual soul voyage recounted by the Eveny elders was an echo of the voyages made by shamans, whose souls, during a state of trance, were thought to leave their bodies and fly to other realms of the cosmos. Shamans enlarged the ordinary hunter's skills and intuitions by flying over the landscape to monitor the movements of migratory animals and by performing rites to stimulate the vitality of animals and humans alike. The word *shaman* itself comes from the language of the Eveny and the closely related Evenki, but all Arctic peoples have comparable figures, as do peoples in many parts of the world [*see "Worlds of the Shaman," March 1997*].

Eveny herder rides his mount in winter pastures near Verkhoyansk. As green plants become scarce, the animals turn to lichen as their main source of food.

The Eveny personality of bygone times was formed when people were scarce and precious on the landscape, and no village existed to exert a centralizing magnetism. It was only in the winter of 1990 that I began to appreciate this. I had gone back to England to teach classes for the autumn. But in late November I returned to Sebyan to take up an invitation from Vladimir Nikolayevich, a retired herder, to go hunting. We were to travel for two weeks in quest of ermine and sable, the small animals that had first lured the Russians into Siberia.

Reindeer fur was not fashionable, or needed, in Yakutsk, the capital of the Sakha Republic. Winter hats made from the lighter skins of fox, muskrat, marmot, otter, or wolverine were quite warm enough there. The Eveny, who had to endure a much more severe climate, wore these soft or fluffy furs in spring and autumn. In winter, however, the Eveny looked and smelled like reindeer, with their pungent mittens, hat, boots, and massive, all-enveloping outer coat. Reindeer hairs are hollow, and they have excellent insulating properties. If they didn't mimic the reindeer, the Eveny would die within hours.

During the coldest period, from November until February, one also needed to wear two pairs of thigh-length boots for wading through snow. The inner pair was made from a reindeer slaughtered in July, when the hairs were shorter; this fur faced inward toward one's body. The outer boots came from a reindeer slaughtered in autumn, when the hairs were longer. The bristly soles of the wearer's feet gripped the ice in a padded, silent walk, with just a slight crunch of impacted snow.

Reindeer trained as riding or draft animals are known as *uchakh*s. We had seventeen of them harnessed into one caravan to pull our sledges, which carried our tents and supplies, all tied down under furs and tarpaulins. Seven pairs of reindeer alternated with six sledges; the remaining three animals were tied behind as spares. The distribution of reindeer acted as a brake and prevented the sledges from careering out of control when going downhill.

Vladimir Nikolayevich sat on the front sledge, while I sat on the third. The platforms were made from larch planks, the struts from willow poles, and the runners from pliable strips of willow painstakingly bent over several weeks during the summer. There were no nails or bolts: the pieces were lashed together with strips of reindeer hide in loose, flexible joints, so that the sledge would yield as it banged into rocks.

Day 1, November 22, 1990. It was late morning when we left the village. The temperature felt cold, but had not quite reached the threshold of minus forty degrees F. Below minus forty, the school in Sebyan would be closed. Helicopters and biplanes were not supposed to fly. Saliva solidified before it hit the ground. If you threw hot tea up into the air, it froze and tinkled downward in a patter of tiny crystals.

That evening we joined up with Manchary, a young hunter equipped with his own sledges and uchakhs. Vladimir Nikolayevich had laughed when he warned me that Manchary would drive me crazy with his continual chatter. It took me a few confused minutes to get the joke: Manchary was the most silent person I had ever met.

Day 2. It would take two days to reach the headwaters of the Tumara River, the edge of our hunting ground. I had crossed this area before on horseback, but now we sought out paths of a new kind. We did not skirt laboriously around each lake, but instead cascaded down its embankment and flung ourselves onto its hardened surface. Instead of picking our way over stony beaches, we swooped along frozen river channels.

I found I could stay warm indefinitely in my clothes, but suffered as soon as I removed a reindeer-fur mitten and exposed bare skin to do anything that required dexterity. That was often, because we were constantly tying and untying the reindeer-hide thongs that hold a herder's life together. The paper of my notebook was so cold that it hurt like a burn to touch it.

By nightfall we had reached an empty hut. Manchary had already arrived, and we were guided by the faint glow of a candle through an absurd windowpane of torn polyethylene. It was minus fifty-eight degrees F, and the stove and candle had a hard time catching oxygen.

Day 3. A little way down the Tumara we pulled one of our tents off a sledge for the first time. Vladimir Nikolayevich shoveled two or three feet of snow to clear a rectangle of ground, while Manchary chopped down medium-size trees and I trimmed them into tent poles. "If we were proper hunters," said Vladimir Nikolayevich, "we'd carry our tent poles around with us. But we've got too much luggage!"

Travel to a meeting during the late summer in Sebyan, Siberia, begins as Kostya, a herding brigade leader, saddles up one of his reindeer.

Day 4. In the economy of the Soviet Union, reindeer were raised for meat, and Vladimir Nikolayevich had been a herder all his working life. This winter was only the third one he had been hunting. "It's the last year I'm doing this," he said. "It's too cold in a tent between November and February—I can't take it. I'm too old, nearly sixty."

Vladimir Nikolayevich warmed the underside of the saddle over the stove as a kindness to his uchakh. Then he crunched off, carrying saddle, stick, bridle, and a pouch of salt for calling his mount. Although they are distinct from their wild cousins, domesticated reindeer are only weakly attached to people; offerings of salt help reinforce the relationship.

Vladimir Nikolayevich and Manchary set off in different directions while I washed up by the hum of the glowing stove. It was the first time in my life I had been alone in an environment where I could not survive on my own. If my elderly friend and his taciturn companion did not come back, I would not get out alive. The remaining reindeer would not obey me, and I could not chop down trees, saw them, and split them fast enough to keep the stove going.

Day 5. Along our way Vladimir Nikolayevich stopped to point out the impressions of tiny paws. We hollowed out a snow cave a few inches deep on a rising slope, angled so that the sun would not throw up a relief of shadows where we had disturbed the snow. Then we laid a little trap with its jaws facing upward and pieces of meat and fish as bait, using a wooden spatula free of human odor to cover everything with fresh, soft snow and brush over all traces of our approach.

Day 6. No one issued bush radios, with their hand-cranked transmitters, to the hunters, but the awareness of who was where seemed almost paranormal. Everywhere there were signs: tent poles had been stacked, supplies had been cached, twigs had been bent to say, "I was here." Travelers made marks on cliffs or in snow or wrote a note on a piece of paper and left it wedged in a tree. A hunter could judge how recent each sign was and calculate how fast a person was moving and where he might be by now. I have seen someone gaze at a panorama of forest and mountain stretching for thirty miles, and find a traveler within a day.

Hunter and guide to the author's winter trek through Eveny hunting grounds, Vladimir Nikolayevich punishes a reindeer by sawing off its antlers. The reindeer had been behaving aggressively toward the others and had become intolerably disobedient. With its antlers gone, the reindeer became the target of the other animals, each of which came up in turn and kicked it, rearing up with hooves flailing.

Day 7. Every day followed a similar pattern: wake, light the stove, discuss the temperature, eat breakfast; dress moderately, gather the reindeer, eat an early lunch; dress heavily and go hunting near the same site, or else load the sledges and move on, setting traps as we go; arrive, unload and pitch our tent; supper, sleep. At any time the tasks might include repairing equipment, discussing the movement of animals—and drinking tea. We listened to the ordinary radio at least once a day, nursing our batteries and monitoring the temperature.

Day 8. In another week, I would be collected and transported by sledge back to the village, but Vladimir Nikolayevich and Manchary would stay on for five months, going farther down the Tumara. They would work their way several times up and down each tributary, checking for tracks, setting traps, returning to collect the deep-frozen little bodies. On the twentieth of any winter month, if they had collected enough furs to make the trip worthwhile, the hunters might travel to the state farm office to hand in their catch.

Tonight I stood outside looking at the moon, which cast an extraordinary blue light over the vast crust of snow. Inside the tent, by the yellow light of a candle, Vladimir Nikolayevich was bending something, cutting something, fixing something. The other hunters around us were surely asleep, their tents and huts thirty miles apart behind winding rivers, the embers fading in their stoves. An aviator or a shaman could have flown around these mountains all night without seeing another light.

The depth of silence was made all the sharper by the occasional snorting and scrunching of our reindeer on a darkened slope nearby—each of them named, trained, and bound to us by a loyalty that was ancient but could easily be lost.

Every time I fly over this land, I try to name the places I have visited and recall the events associated with them. When I flew back across the area where I had left Vladimir Nikolayevich to continue his midwinter hunt, I could trace the tracks of our journey together, and even work out some of the sites of our overnight halts. Half a mile above my friend and his uchakhs, the pilot dipped the wings of the little biplane in greeting.

From the air, to the attentive eye, winter reveals every step taken by human or animal. Sometimes a flight inches past a caravan of sledges, their movement almost imperceptible except for a slowly extending furrow in the virgin snow. There is usually someone on board the aircraft who can name the solitary figure on the lead sledge and say where he is going and why.

Once an animal's prints are made in early winter, they may remain until May or June. If one could follow them forever, as in a string maze, one would catch up with every single creature. □

This article is adapted from The Reindeer People, *by Piers Vitebsky, which is being published in December by Houghton Mifflin Company.*

The Birth of the Uterus

Genes that help determine what goes right or wrong in pregnancy also enabled early mammals to switch from laying eggs to bearing live young.

By Vincent J. Lynch and Günter P. Wagner

One hundred eighty million years ago, a small, hairy animal resembling a shrew or a vole evolved a new way to care for her developing offspring. Instead of laying eggs and incubating them in an uncertain outside world, she retained her embryos and allowed them to develop inside her body. Her evolutionary invention earns her the name ancestral therian, the common ancestor of all placental and marsupial mammals. Her innovation ranks with such evolutionary breakthroughs as the development of feathers in dinosaurs and the emergence of aquatic animals onto the land.

The ancestral therian is generally thought to have descended from a creature that had evolved the ability to delay laying her eggs. This still earlier animal could retain her developing eggs in her oviducts, while she chose the best time and place to lay them. The initial advantages of the added internal incubation would have been substantial. The mother would have had more time to find a suitable nest site. Her offspring would have gained a major protective advantage against drastic weather changes and other instabilities. And internal embryonic development would have freed the mother from most of the restrictions of sitting on the nest.

The shift in reproductive strategy begun by the ancestral therian was accompanied by a series of changes in the structure and physiology of the female reproductive system—as well as by radical changes in the way the organism's descendants would live and reproduce. Until the ancestral therian, nearly all animals developed from externally deposited eggs or, in the simplest organisms, from bud-

Khalil Younes, *Electronic Uterus*, 2005

ding directly off the parent. Egg-laying, in fact, was an amazingly successful method of reproducing, which led amphibians, fishes, and reptiles to dominate the world's ecosystems. The reproductive strategies of egg-layers were relatively simple, too: Organisms could lay millions of eggs, gambling that at least a handful would survive. Or they could lay only a few, doting on each one in the hopes that all would thrive.

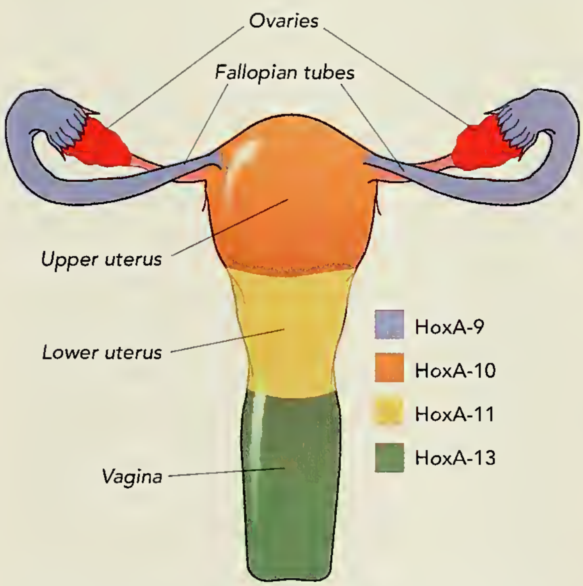
The female reproductive tract in egg-laying vertebrates was—and is—essentially a tube. Its upstream end is shaped like a funnel, which captures the unfertilized eggs after they are released from the ovary. The funnel-shaped section is followed by the oviduct, a muscular tube where the egg is covered with albumin, surrounded by membranes, and, in some organisms, encased in a hard shell. Farther downstream, beyond the shell-producing region, a short terminal segment opens into the cloaca, through which the eggs are laid. (Live birth has also evolved in some fishes, lizards, and snakes, but in those groups, where it occurs, the egg is not coated in a hard shell, and it receives no extra nourishment from the mother.)

The reproductive system of the therians (marsupial and placental mammals) is a complex variation on the egg-layer's basic tubular structure. In therians the muscular tube differentiated into the uterus and the vagina. The inner lining of the uterus developed into a highly complex tissue called the endometrium, which was able to grow and mature in response to hormones. It was supplied with a rich network of blood vessels and filled with various specialized glands that provide nutrients to the developing embryo. Finally, the placenta, which transfers nutrients directly from the mother to the fetus, evolved from membranes of the egg, which had enabled it to "breathe."

Many of the latest insights about the origins and natural history of the uterus and related reproductive organs come from the burgeoning field of molecular evolutionary and developmental biology. Such techniques as gene sequencing, the intentional creation of specific mutations in laboratory animals, and genetic labeling make it clear that certain genes, primarily the ones known as master developmental control genes, have repeatedly shaped the evolution of animal bodies, from the transition of fins to limbs to the origins of the female reproductive tract. But more, the genes that play a role in embryonic development are also active in the adult. They are closely connected with the implantation of the fertilized egg and with the formation of the placenta. They are even implicated in diseases such as endometriosis and in cancers of the various reproductive organs. Understanding their evolutionary history, in other words, may shed considerable light on disease as well as on complications of pregnancy.

Until recently, the genetic mechanisms underlying the evolution of live birth, the embryo's development inside the mother's body, remained elusive. In the effort to understand those mechanisms, evolutionary and developmental biologists took a particular interest in one class of genes, the so-called homeotic, or *Hox*, genes, also known as the master developmental control genes.

Hox genes were discovered through the study of the fruit fly *(Drosophila melanogaster)*. Soon after the discovery, geneticists began to look for *Hox* genes in other species. And remarkably, it soon became apparent that *Hox* genes occur in all animals, from the relatively simple to the most complex. *Hox*-related genes have even been discovered in plants and fungi. The broad range of life-forms that harbor the same, or closely related, genes suggests they originated before plants and animals diverged, and possibly even before the evolution of multicellular organisms in the Precambrian era, some 640 million years ago.



Female reproductive tract of placental mammals, such as the human one shown here, has a greatly enlarged uterus compared to the uteruses of marsupials (see diagram on opposite page). The color coding in the diagram shows the approximate region where various Hox *genes are expressed.*

Hox genes typically carry information about how embryonic cells are to be arranged in space and time, so that body cavities become organized, tissues differentiated, and organs formed, all in their proper places and in proper sequence. *Hox* genes determine the placement and timing for the embryonic development of insect antennae, thoraxes, and wings; worm segments; fish fins and vertebrae; even the arms and legs of human embryos. The recognition of the central role of *Hox* genes in shaping the basic body plan along the long body axis of so many organisms is one of the most important discoveries in evolutionary and developmental biology in recent years [*see "The Origins of Form," by Sean B. Carroll, November 2005*].

There is, of course, a downside to exerting such potent control on normal development. What happens when mutations occur in the control gene itself? The classic example of the effect was first described in 1915, a mutant fruit fly with two pairs of wings. It is now known that the cause of the doubled wings was a mutation in a *Hox* gene called *bithorax*. The mutation transforms the third thoracic segment of the fruit fly into the second thoracic segment, leading to the second pair of wings. A second mutation, this one in a *Hox* gene called *antennapedia*, gives rise to a particularly gruesome result, transforming antennae into legs.

Those two examples of mutations may seem to suggest that *Hox* genes direct cells to become a particular body part. What they really do, though, is demarcate positions in the embryo where the cells will develop into a particular body part. If a particular *Hox* gene is turned on, it activates other genes that control cell differentiation locally. Thus a *Hox* gene can be characterized as a kind of master architect that operates indirectly, through subordinate control genes.

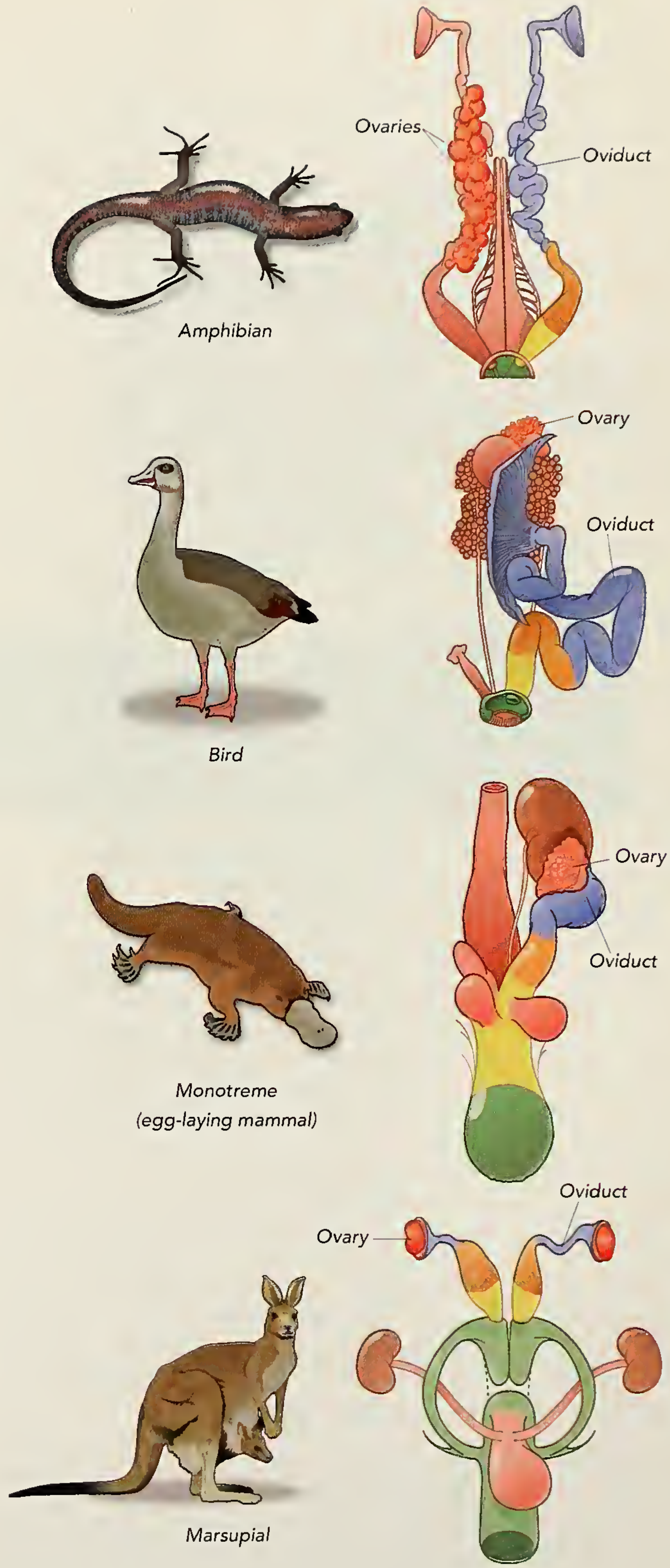
Why would *Hox* genes become the focus of research on the evolution of such a relatively "new" organ as the uterus—new, at least, when compared with the age of the *Hox* genes themselves, at least 640 million years? The answer grew serendipitously out of a discovery made in the late 1990s, when biologists were investigating the role of *Hox* genes in limb development. For their study, the biologists had devised a line of mutant mice that were missing certain *Hox* genes. Then, unexpectedly, they discovered a direct link between *Hox* genes and reproduction. The female mutant mice, lacking genes known as *HoxA-10* and *HoxA-11*, were infertile. Yet the eggs of the mutant mice were viable and could implant into a normal surrogate mother; they simply failed to implant into the uterus of a mutant mouse.

The observation eventually led to the experimental demonstration that some *Hox* genes function in new ways in shaping female reproduction in therians, both in the embryonic development of the reproductive organs and in the operation of those organs in the adult. Specifically, it has been shown that *HoxA-9* is active in the region that will become the fallopian tubes; *HoxA-10* is active in the upper uterus; *HoxA-11* in the lower uterus; and *HoxA-13* in the vagina [*see illustrations on this page and opposite page*]. Moreover, in addition to being active in the vagina, *HoxA-13* plays a vital role in the formation of umbilical arteries. It is worth noting that baby mice missing the *HoxA-13* gene die in utero.

Because "higher" mammals are the only animals with a uterus, those four *HoxA* genes must have acquired their role in reproduction after the marsupial and placental mammals diverged from the monotremes, or egg-laying mammals. (The only living monotremes are the platypuses and the echidnas.) That is not to say that *Hox* genes play no role in the reproductive systems of other animals. But whatever that role may be, it predates the specialized role *Hox* genes have developed in therian mammals. There the genes have evolved to do something truly unique: they establish the receptivity of the uterus to implantation by the developing embryo.

The emergence of an important new function for some very old genes suggests that the genes themselves may have been subject to fairly rapid evolution by natural selection. But what kind of evidence could show that *Hox*-gene evolution was taking place at about the same time as the uterus was differentiating and the internal development of the embryo was appearing?

Natural, or Darwinian, selection is the process whereby the individual organisms best adapted to their environments preferentially survive and reproduce. How Darwinian selection has acted on genes in the distant past cannot be read directly in the fossil record. The DNA of living organisms,



Form of the female reproductive system ranges widely among various animals, but the same genes are engaged in building each system. The color-coding in each diagram indicates where specific Hox *genes are active, according to the key in the diagram on the opposite page. Amphibians, for instance, have many ovaries connected by relatively long oviducts, for the hundreds of eggs deposited each time they reproduce. Birds have just one functional ovary; their oviduct equips the egg with a hard, calcium-rich shell. Monotremes have short oviducts and lay soft-shelled eggs; the platypus has only one functional ovary, the echidna has two. Marsupials produce no egg shell; instead, their developing young receive nutrients in modified oviducts. The animals are also unusual in having two uteruses. Each of them, though, is smaller than the one in placental mammals, because their young develop internally for only a few weeks before taking up residence in the pouch.*

however, preserves a living record of how and when genes changed.

DNA is made up of four chemical building blocks called nucleotides; they are designated by the first letter of their chemical names: *A*, C, *G*, and *T*. The nucleotides in turn combine in "words" of three letters—*ACT, ACG, GCT,* and so forth, $4 \times 4 \times 4$, or sixty-four possible words in all—to code for the formation of twenty distinct amino acids, the stuff of which protein is made. And protein does the major work of the cell.

Two main kinds of mutation, or changes in the spelling of a DNA word, can take place. Sixty-one words, matched with twenty amino acids (the other three words act as "stop" signals), implies that some of the DNA words, say *ACT* and *ACG,* may code for the same amino acid. So if a mutation causes *ACT* to become *ACG,* the amino acid is left unchanged—and the mutation is called a silent substitution. But if a mutation, say *ACT* to *GCT,* leads to the code for a different amino acid, the mutation is called a replacement substitution.

Once an organism evolved that retained its eggs, old genes took on novel roles to support the development of embryos inside the mother's body.

Molecular biologists are more likely to detect silent substitutions in living organisms, because changes in the amino-acid makeup of a protein are usually deleterious, and selected against. Sickle-cell anemia, for instance, results from a single amino-acid replacement in hemoglobin, the major protein component of red blood cells. That single change causes red blood cells to be stiff and pointed instead of soft and round, decreasing their ability to carry oxygen and thus causing the disease.

In rare instances, however, replacement substitutions are advantageous and selected for, a process called positive selection. One of the first examples of positive selection was identified in genes that code for the immune system. Replacement substitutions in those genes are often advantageous because they provide new ways to defend against attack from pathogens.

The aim of our research, then, was straightforward. We wanted to determine whether the *Hox* genes that are essential for uterine function and embryo implantation were undergoing positive selection in the ancestral therian during the evolution of the uterus, allowing the internal development of the embryo to evolve. To do so, we sequenced *Hox* genes from placental and marsupial mammals, from the platypus and the echidna, and from amphibians, fishes, and reptiles. When we studied all the patterns of amino-acid replacement and silent substitution, we discovered several replacements that all placental and marsupial mammals share. No other animals, however, have those same replacements. The evolutionary tree relating the mammalian species that share the amino-acid replacements dates back to the ancestral therian, 180 million years ago.

We then calculated that the number of replacement substitutions must have been significantly greater than the number of silent substitutions in the ancestral therian. In other words, there was a burst of positive selection in the relevant *Hox* genes. Then, after that initial burst of change, the rate slowed down; the *Hox* genes in placental and marsupial mammals are now evolving at the same rate as they are in other animals. To our knowledge, this example is the first in which the origin of a novel body part has been linked to the adaptive evolution of developmental control genes.

How did positive Darwinian selection on *Hox* genes lead to the evolution of the uterus? That question is only beginning to be explored. Nevertheless, important clues to the answer may emerge from the study of additional ways that *Hox* genes become active, notably in the menstrual cycle of mature adult females, as well as in pregnancy.

HoxA-10 and *HoxA-11,* for instance, promote the maturation of the endometrium, or uterine lining, in ways that are reasonably well understood. At birth, the uterus, unlike most other organs, is relatively undeveloped. During puberty, though, the blood concentrations of the sex steroids estrogen and progesterone increase, stimulating the *HoxA-10* and *HoxA-11* genes in the uterine tissue to direct the maturation of the endometrium. *HoxA-11,* for instance, determines how endometrial cells grow and develop in response to the changing proportions of sex steroids throughout the menstrual cycle. The gene also regulates how the endometrial cells respond during the implantation of a fertilized egg—or, more accurately, during the implantation of the pre-embryo. (The fertilized egg begins cell division even before the onset of pregnancy.)

Implantation of the pre-embryo in the uterine wall is a highly invasive process, akin to attack by a parasite. The outer embryonic cells, known as the trophoblast, bore into the wall of the uterus, secreting enzymes that dissolve away barriers to the maternal blood vessels. The properly matured endometrium both enables this invasion and acts as a shield for the mother, preventing it from going too far. The trophoblast eventually forms the placenta, through which the embryo proper receives dissolved nutrients and is cleansed of waste. The process does not stop there: hormones produced by the placenta mimic maternal hormones and cause the mother's blood pressure and sugar to rise and arteries to dilate, increasing the flow of nutrition to the growing fetus.

In response to this assault, the mother's immune system would quickly attack any other invader, but in a normal pregnancy the embryo is tolerated, even appeased in its quest for nutrients. On the surface of the matured endometrium are a half-dozen "sticky" proteins, which enable the pre-embryo to become attached. Recent investigations show that *HoxA-10* is responsible for turning on the production of one of those proteins. And the *HoxA-10* and *HoxA-11* genes turn down the immune system in the uterus at the time of implantation, enabling the pre-embryo to invade without retaliation.

Five-inch-long Eomaia scansoria *(Eomaia is Greek for "dawn mother"), a primitive mammal that lived 125 million years ago, is reconstructed from a fossil discovered in Liaoning Province, China.* Eomaia *is an evolutionary descendant of the ancestral therian, and the earliest known representative of the lineage that eventually led to placental mammals. The painting was made by Mark A. Klingler of the Carnegie Museum of Natural History.*

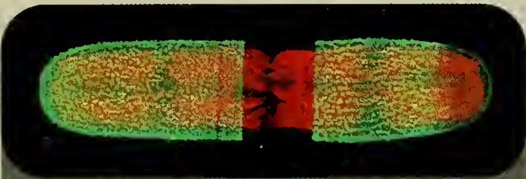
Hox genes that fail to function properly can also cause diseases of the female reproductive system. Endometriosis, for instance, is the growth of endometrial tissue on parts of the body other than the uterus—typically in cells that form the surfaces of the ovaries, intestine, and bladder. The abnormal tissue growth strikes about one woman in ten, and it causes pain, irregular bleeding, and infertility. The cause of the infertility that accompanies endometriosis is not known, but *HoxA-10* and *HoxA-11* fail to respond to sex steroids in the uterine endometria of affected women. *Hox*-related dysfunctions also cause ovarian cancers that are made up of cells resembling the cells that occur in the fallopian tubes, the uterus, or the vagina. Those cancers arise, respectively, from overactive *HoxA-9, HoxA-10* and *HoxA-11,* or *HoxA-13* genes in the ovary.

Evolutionary and clinical studies may have different goals and begin from different perspectives, but the cross-fertilization of the two disciplines offers great hope that both perspectives will benefit—in particular, that a means will be found to conquer such scourges.

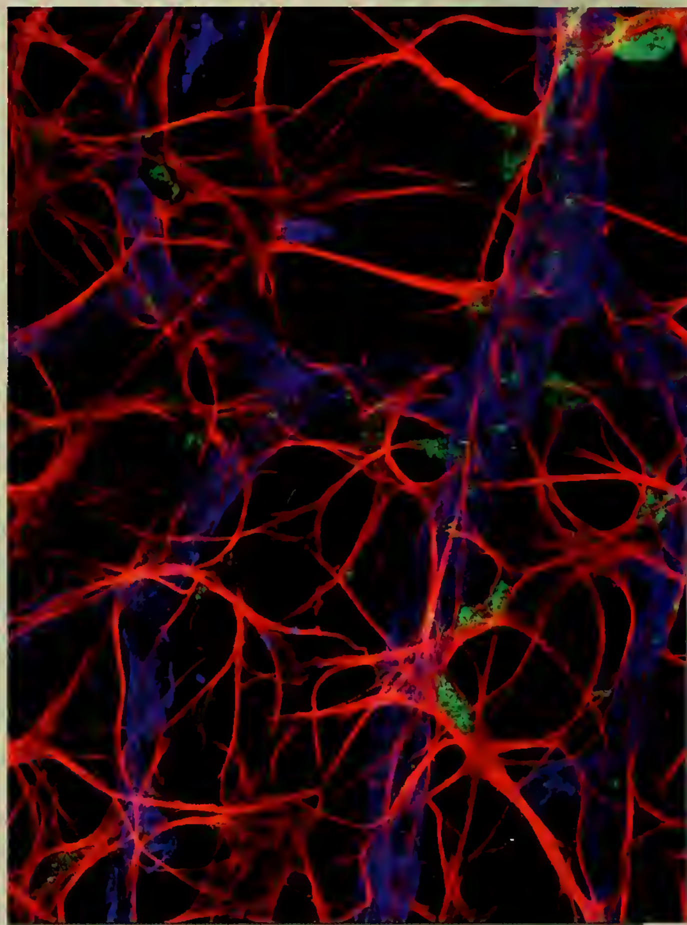
Meanwhile, the scientific picture of how the uterus, implantation, and internal embryonic development evolved is just beginning to emerge. Once the way was paved by the evolution of a precursor animal that retained its eggs and did not coat them with a hard shell, *HoxA-10* and *HoxA-11* apparently took on novel roles to support the development of embryos inside the mother's body. The initial changes may have involved thickening the tissue in the uterus and increasing the number of blood vessels serving it, creating a safe and well-oxygenated environment. Soon thereafter, the embryo developed the placenta, for direct access to maternal nutrients. *HoxA-13* was specifically involved in the formation of the blood vessels of the umbilical cord.

Those changes in early development were followed by further refinements. The attachment of the placenta to the wall of the uterus became more invasive, and it and the embryo began secreting hormones to extract more resources from the mother. To cope with these demands, *Hox* genes continued to adapt, giving the mother the ability to suppress her immune system without allowing the placenta to invade too far. The changes took place incredibly rapidly, perhaps in as few as 3 million years. But their effects can be seen in mammals the world around. ☐

Small Things Considered



Cell wall of a green alga was dyed fluorescent green and then allowed to grow for a day before being photographed. The filaments inside the algal cell are chloroplasts, and appear red independently of the green dye. Thus, the space between the two parts of the green cell wall shows a day of new growth, indicating that the cell grows from the middle outward. The image was made by David S. Domozych of Skidmore College in Saratoga Springs, New York; it is magnified ×380.



Retinal blood vessels surround local astrocytes—supportive cells of the nervous system—in the eye of an aged (two-year-old) rat. Blood vessels are shown in blue, astrocyte cell bodies in green, and extended portions of astrocyte cells are stained red. Changes in astrocytes as organisms grow older contribute to disease and degeneration. The image was made by Hussein Mansour of the University of Sydney in Australia; it is magnified ×25.

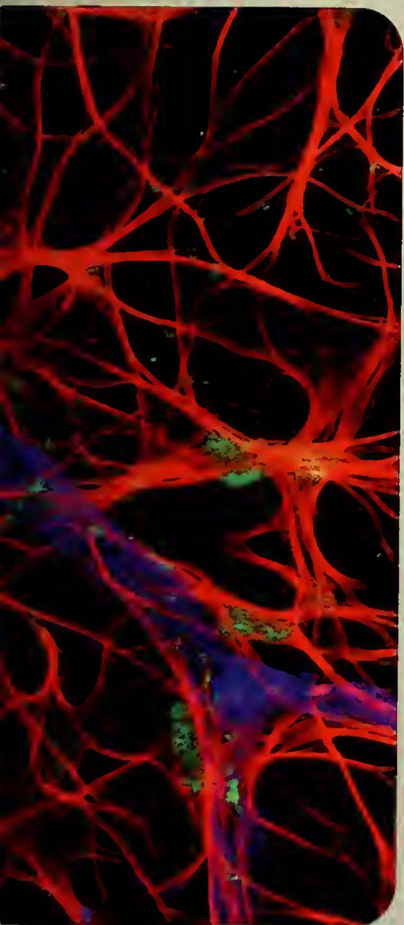
Microscopy has come a long way since the seventeenth century, when the English polymath Robert Hooke peered through a primitive compound microscope of his own design and realized that cork is made up of what he termed "cells." Today's techniques—live-cell imaging, fluorescent probes, the use of light beyond the visible reaches of the spectrum—have continued to open up worlds within worlds that Hooke could not have imagined.

But perhaps even more significant than the progress in microscopy itself are the advances in the ways of recording images—specifically by means of photography. Beginning with Hooke and continuing until well into the twentieth century, microscopists had to rely on verbal and written descriptions and drawings to describe the wonders they observed. Photomicrography changed all that. Photographic methods have become an essential part of scientific investigation, not to mention the vital role they play in making images that can be shared with one's colleagues.

The light micrographs here—among the top prizewinners in the Olympus BioScapes 2005 Digital Imaging Competition, organized by Olympus America Inc. of Melville, New York—represent an eclectic range of subject matter, as briefly detailed in the captions. Mostly, however, the pictures can stand on their own, as icons of technical scientific virtuosity, and as works of art.

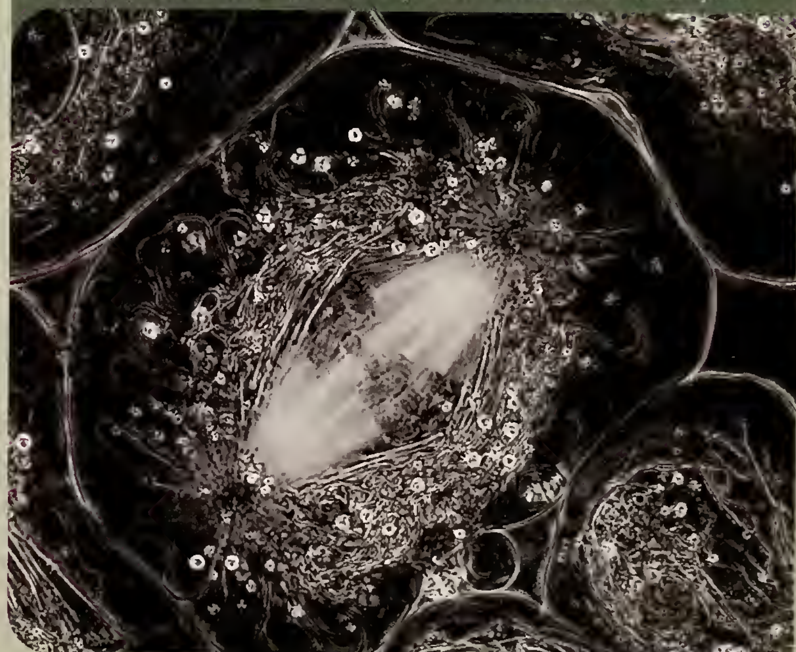
—THE EDITORS

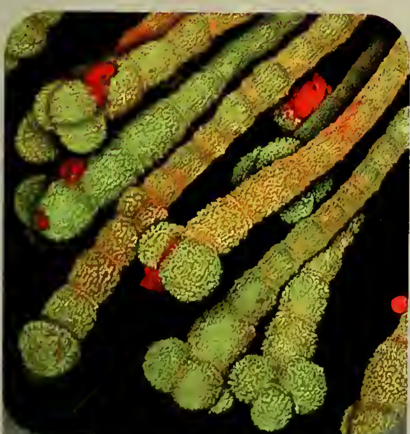
Tapering filaments of the cyanobacterium Gloeotrichia sp. arrange themselves in starlike spherical colonies. Large numbers of such colonies often collect in freshwater lakes, forming blooms. The image was made by Spike (M.I.) Walker of Penkridge, Staffordshire, UK; it is magnified ×20.



Filtering system known as the glomulerus (from the Latin for "little ball of yarn") is depicted inside the kidney of a living rat. The green tubes are the capillary loops of the glomulerus; the blue spots among them are cell nuclei. The image was made by Ruben M. Sandoval of the Indiana University School of Medicine in Indianapolis; it is magnified ×530.

Testis cell of a crane fly undergoes the first stage of meiosis, part of the process that produces sperm. The movement of chromosomes (center) during meiosis depends on spindle fibers (white contrast), which attach chromosomes to the spindle poles (where the spindle fibers converge). The image was made by Rudolf Oldenbourg of the Marine Biological Laboratory in Woods Hole, Massachusetts, and James LaFountain of the State University of New York at Buffalo. The image is magnified ×2,400; in reality, the spindle poles are only about a thousandth of an inch apart.





Fringed edge of an anther, or pollen-bearing organ, of the creeping vine Thunbergia is magnified ×250. The image was made by Shirley A. Owens of Michigan State University in East Lansing.

Land of Plenty

Austria's red deer feast on handouts and live half the year in fenced enclosures. Can they still fend for themselves?

By Karoline T. Schmidt

My first encounter with a rare herd of red deer wintering in the Austrian Alps came after a four-hour ascent on skis through snowed-in forests and steep terrain. The reward for my exertion was a perfect view of 160 animals, whose dark-brown bodies stood out sharply against the snow-covered pasture that spread before me. They picked their way across the concave meadow, grazing on odd bits of weathered vegetation that poked through the windswept snow. The sun shone in a glorious blue sky, while an icy wind whistled through the gaps in a pile of boulders behind which I had sought refuge. From that vantage, I could see another large herd loitering in the wintry meadows that rose on the far side of the valley, a mile away.

My search for red deer had been prompted by the tales of elderly hunters. Herds of several hundred animals, the hunters told me, had once roamed the harsh, alpine environment year-round. Yet by the time I began my quest, it was widely assumed that the alpine pastures had become summer-only grazing grounds. Come autumn the herds all supposedly descended to lower elevations for the shorter winters and the more plentiful food. Even more at variance with prevailing opinion was that any herd still lived completely independent of human care. Under Austria's game-management program, red deer are supplied with hearty meals throughout the winter—often inside fenced enclosures. So entrenched was the belief in the necessity of that program to the deer's

survival that several experienced hunters had tried to convince me that what I was seeking was absurd. A large herd could not winter above timberline without supplemental food. And yet, there they were.

But twenty years have now passed since that day, still so vivid in my mind. In 1985 I was just beginning four seasons of fieldwork for my doctoral dissertation in biology, studying survival mechanisms in one of the last of the wild alpine herds. When I returned to the alpine meadows ten years later, "my" group of 160 had dwindled to a few scattered individuals. It wasn't the harsh winters that had overcome this remnant wild population, but the very management regimen intended to ensure the species' survival and abundance.

High above tree line, this renegade group had survived nicely on a diet of heather, trailing azalea, tufted hair grass, and the leaves and stems of cowberries and blueberries. The wild herd had avoided the winter feeding stations that pepper the Austrian Alps, and the enclosures where most red deer spend more than half the year. For its insubordination, most of the wild herd was culled in the 1990s—standard practice for deer that decline to be "civilized." Today only 5 percent of Austria's red-deer population survives without any supplemental feed.

The goal of Austria's red-deer-management scheme—among the world's most intensive—is to keep deer populations large enough to guarantee hunting success without damaging commercial forests or farms. The objective is a worthy one, to be sure. But the program's sheer intensity has tamed the entire hunting endeavor; it now more closely resembles ranching than it does the primeval pursuit of prey. And in truth, it also threatens the long-term stability of red-deer populations.

The red deer *(Cervus elaphus)* has been the principal game animal in central Europe since the Bronze Age. Deer are abundant, gather in sizable herds, and are large enough to yield about 120

Red deer forage at a winter feeding station in the Austrian Alps (above). Game managers provide plentiful meals at such stations for as many as nine months of the year. In some areas the stations stand within fenced enclosures, where deer are confined for about half the year. The system is intended to keep deer abundant and healthy for hunters, while preventing them from browsing on commercial forests.

pounds of venison apiece. Hunters have long striven to influence the red-deer populations and the predictability of the animals' movements. By the twelfth century A.D., landowners distributed salt licks to attract deer, a technique so effective that the emperors subsequently forbade it except on sovereign hunting grounds. By 1500, landowners were putting out hay to attract deer, augment their numbers, and lower their losses in severe winters. To this day, supplemental feeding remains the hunters' most powerful management tool.

As firearms became increasingly available in the seventeenth century, noble hunters flaunted their marksmanship by shooting as many animals as possible. By the early twentieth century, hunters became interested in the quality—and particularly, the size of the antlers—of their quarry. Game managers developed an enticing cake of sesame, with equal parts calcium and phosphorus, to promote antler growth.

Small group of red-deer hinds and young stags traverses an alpine meadow in winter. In the past, large herds of several hundred red deer lived in this seemingly sparse environment year-round.

In 1910, at the First International Hunting Exhibition in Vienna, the term *antler* was replaced with *trophy,* a word that, until then, had been reserved for describing the spoils of war. Competitive trophy measurements were standardized in 1927, and a big, heavy, many-pointed rack mounted on a hunter's wall became a status symbol. Thus began the craze for antler size that persists to this day.

When Austria became part of the German Reich in 1938. German hunting laws were imposed. Hunters were required to provide the deer with supplementary food in winter. The intent was to redirect some of the hunters' energy from shooting game to caring for it, thereby preserving enough game to satisfy increasing numbers of hunters. Hunters have happily complied with those laws ever since. By the 1950s, as the Austrian economy was recovering from the Second World War, the duration, frequency, and abundance of winter feeding took off.

But the deer have not been universally adored. They have a relentless propensity to munch crops, strip bark, and browse new tree growth. Associations of exasperated farmers and foresters established zones from which the red deer were excluded through intensive hunting. These no-deer zones increasingly restricted the animals to forested, mountainous regions, where supplemental winter feed kept them from migrating to lower-elevation farmland.

As for many hunters, their goal for the deer can be summed up in a simple motto: "Stuffed—alive and dead." Today's red deer dine lavishly for as many as nine months of the year, from early autumn until late spring. The feeding stations dole out a buffet of high-energy feed that may include apples, bran, corn, grain, hay, oilseed pellets, silage, and turnips, along with minerals, sugar licks, worm treatments, and commercial supplements to increase antler size. What deer could resist? Of course, providing such a rich diet is expensive. In western Austria, where red deer are supplemented for about 180 days a year, costs average $250 per deer per year. Yet when you consider that a trophy stag can fetch as much as $18,000 for the landowner selling the right to hunt it, the investment in feeding may pay off.

In spite of their disagreements, Austrian farmers, foresters, hunters, and the public alike all seem to share the same erroneous belief about red deer: their survival depends on supplemental feeding. The main reasons cited are that deer have lost their winter habitat to human development, and that settlements and highways have disrupted their migration routes between the high altitudes of summer and the forested river valleys of autumn. That argument is certainly valid for some populations. By and large, though, feeding was as much the cause of the disruption of historic migration patterns as it was a response to it. Often feeding was done on the upper forested slopes expressly to break the cycle of migration and to keep deer on higher-elevation hunting grounds throughout the long hunting season.

Moreover, winter feeding is hardly necessary for the survival of the species: red deer are remarkably well adapted to wintertime food restrictions. Trig-

Red-deer habitat and traditional migration patterns are depicted in the composite schematic image of an Austrian alpine valley. In years past, most red deer summered in pastures above tree line (broken red line) and wintered in forested valleys—though some populations lived year-round in the upper mountains. Today, feeding stations and enclosures keep most red deer in mid-elevation forests during the winter. Human development has left only remnant forest pockets on valley floors, where a few deer still find shelter in winter.

gered by the shorter length of the day, various physiological systems cooperate to reduce the deer's need to eat in winter. The rumen, or first division of the deer's stomach, contracts. Less blood circulates to the digestive tract. The salivary glands shrink. As the animal takes in fewer calories, its body temperature falls, and its metabolism, heart rate, and activity slow to reduce the energy expenditure by more than 17 percent. When red deer are not restricted by an enclosure or a feeding station, they choose a winter habitat where they can survive food shortages through their various adaptations. Even in winter, natural forage is available around the clock, both in lowland areas near riverbanks and in alpine habitats. Such free-ranging animals follow their own feeding rhythms, which maintain an optimum environment in the rumen for microorganisms that aid digestion.

The feeding itself often makes feeding necessary. Feeding stations are typically situated for easy access by the manager, often in forested mountain valleys near roads. They draw the deer into a cold, moist, uncomfortable, and unsafe habitat that does not provide enough natural vegetation to sustain them through the winter. But the deer come for the smorgasbord, and they can come to depend on it. Food-supplemented red deer show less reduction in winter heart rate than wild deer do, and no decline in body temperature. With their engines running nearly full speed, they cannot slow down to winter pace on short notice. If, for instance, an avalanche blocks the roads, cutting off the feed supply for a few days, the deer simply go hungry. Ironically, then, food-supplemented red deer are at greater risk of starvation than naturally wintering herds.

Still, feeding stations are only half of the management picture. By the 1970s, more than twenty fat years of winter deer-feeding had left their mark on the forests—and upland commercial forests in particular. Stuffed with minerals and protein, food-supplemented herds searching for dietary fiber stripped tree bark and chomped twigs aggressively. Because rejuvenating forests offered dense foliage, heavy hunting during the long hunting season (from July through January) sent red deer into hiding in precisely those forests, compounding the problem. Individual trees had to be protected or entire plantations fenced off. Foresters labeled red deer a pest species and called for dramatic reductions in their numbers. In response, hunters took the next logical step, and fenced in some of the upslope feeding sites. That tactic kept red deer out of the downslope woods until late spring, when the new growth hardens off.

Ultimately, hunters and foresters are more dependent on the supplemental feeding of the red deer than the deer are themselves.

Today a network of feeding stations and enclosures covers most of the red deer's range. In some parts of Styria, Austria's most intensely managed province, there is one winter enclosure, on average, for every twenty square miles of territory, and one feeding station for every six square miles. In some areas the density of feeding stations is more than twice that high. Each enclosure encompasses some fifty to seventy-five acres, usually including a few small pastures and stands of trees.

Feeding inside the enclosures starts in late September or in October. The gates close in mid-winter, when most red deer are inside, and don't reopen until late June. Enclosing the deer has reduced the damage to adjacent forests, but only because red deer that do not enter are culled. Many a deer in the "wild" herds has paid with its life for this management measure.

Although deer feeding is common throughout Europe, by far the most intense feeding programs are in Austria, Germany, and Hungary. Only those three nations require deer feeding by law, and—no coincidence—they also have the highest deer populations and densities in continental Europe. Between 1950 and 2004, Austria's red-deer population nearly quadrupled, from 40,000 to 150,000 individuals. Winter feeding has lowered mortality among calves and old males—the herd members most vulnerable to harsh winters—and raised birth rates among yearling hinds (as the female deer are called). The feeding program has also been spectacularly successful in increasing the size of antlers.

All achievements come at a price, however. The most important consequence of the program is that red deer have abandoned seasonal migrations and lost traditional knowledge of their natural winter ranges, perhaps irretrievably. They have also become habituated to their feeding enclosures, an unsuitable habitat where they could not survive naturally in winter.

Austria's management program has other negative consequences, as well. Some evidence suggests that feeding sites, where deer gather in large numbers, may promote transmission of diseases and parasites. Furthermore, the competition for food at the feeding stations is paradoxically higher than it is in the wild. Normally, red deer spend November through September in segregated herds, the mature males in one herd, the hinds and youngsters in another. But at feeding stations the sexes mix, and the males inevitably dominate at the troughs, causing much social stress. Finally, when deer populations fluctuated more naturally, the native vegetation on which they fed may have had more time to regenerate before the herd passed by again.

For better or worse, the constant winter food supply also affects population dynamics by blunting the effects of natural selection. For naturally foraging red deer, winter and spring weather has a lasting effect on the weight, survival, and lifetime breeding success of all the animals born in a given year. Good weather provides pregnant mothers with abundant, high-quality food, and they bear strong, healthy calves. Bad weather has the opposite effect. For food-supplemented herds, however, the weather has little effect on calves' and yearlings' body weight. To take one example, consider what the data show about the annual variation in the average body weight of individuals of a given age. Because the quantity and quality of food remain roughly the same over time, the variation is less from year to year among the food-supplemented deer than it is among the deer that survive on their own.

Furthermore, because abundant food helps low-weight calves survive winters that would otherwise kill them, supplemental feeding also increases variation within the herd. In food-supplemented herds, red deer all born in the same year show 60 percent more variation in body weight than do the deer in nonsupplemented herds. Whether the dampening of natural selection affects other population dynamics is a question for further study.

Ultimately, it seems, hunters and foresters are more dependent on the feeding stations and enclosures than the red deer are themselves. The feeding program is critical to keeping hunters and foresters happy with large red-deer populations that do not interfere with timber.

And yet, Austria's management program has created a population of predictable red deer. The hunters' romantic image of themselves as top predators in the wilderness has become a bit ridiculous. Such intensive management kills the wildness in wildlife—and slays the spirit of hunting.

The answer is not to eliminate the management regimen all at once. That would immediately result in heavy losses of deer to starvation and severe damage to forests. There are simply too many deer and too many human interests to return to a totally unmanaged state of affairs. In the long term, though, a gradual shift to forestry practices that promote stands more closely resembling native forests would ease the way to a more natural balance. Such forests have thriving understories that provide natural forage for deer, and trees ranging broadly in age, making the forest as a whole less vulnerable to browsing. Realizing that vision, however, would require hunters to accept fewer red deer and more challenge from their sport by reviving the main thrill of hunting: unpredictability. □

Plenty of Deer

By James M. Peek

If the goal of Austria's red-deer-management program is to maintain high deer populations for hunters, the goal of many of the management programs for white-tailed deer in the United States is quite the reverse. Here the question is usually how best to reduce burgeoning populations of an animal that, in many suburban areas of the Midwest and East, has become an out-and-out nuisance.

Austria's red deer are fed like livestock in winter; in contrast, many U.S. white-tailed deer (*Odocoileus virginianus*) receive a human helping hand year-round, albeit often inadvertently. Across the country, residential areas have expanded into what was once the whitetail's natural habitat. Where people live in high densities, deer are often protected from hunting and predators. Couple that with the wealth of lush, tasty garden and ornamental plants of suburbia, and the ongoing explosion of deer—now an estimated 20 to 30 million animals nationwide—is virtually inevitable.

The whitetail population explosion has brought with it a dramatic increase in automobile accidents involving deer, damage to cultivated plants and crops, and, as in Austria, injury to commercial forests. Overbrowsing on wild lands often shows up as a decline in plant diversity and production. Dense populations of deer help spread Lyme disease among people and domestic animals, and, recently, chronic wasting disease among the whitetails themselves.

The management of suburban and exurban whitetails is almost always controversial. Many ways of controlling the deer have been attempted, and much depends on what the local human population prefers. Often the best choice is a well-managed hunt, targeted at the biologically appropriate sex and age classes. That can be combined with specified hunting seasons, which limit the hunter to one or another kind of weapon. Another way is to control deer depredations passively, with deer-proof fencing or the planting of ornamental plants unpalatable to deer.

Female white-tailed deer grabs a quick bite from a backyard in suburban New York.

A typical example of how the issues play out took place in the 1990s, in the communities near the Quabbin Reservoir in central Massachusetts. Wildlife officials documented extreme changes in local plant communities and rising bacterial counts in drinking water that were attributable to the deer. Local residents opposed to hunting suggested capturing and moving the deer. But that action would have been expensive, time consuming—and apt simply to shift the problem elsewhere. Finally, a well-managed hunt controlled the whitetails.

In recent years, several southeastern states have developed programs that keep deer populations at moderate levels and still provide hunters with large-antlered bucks. Hunters selectively cull the does to make more forage available for the bucks. Because the antlers are the last organ to receive nutrients, they are sensitive indicators of health: when bucks are healthy and well fed, they survive longer, and their antlers are larger as well.

European red-deer hunters have fewer opportunities for recreational hunting than do whitetail hunters in the United States. In Europe, the red-deer hinds are often culled, but managers often do the shooting. Fees for taking red-deer stags in Europe are high—as much as $18,000—compared to American fees for a hunting license and deer tags, which often amount to less than fifty dollars.

Unlike their European counterparts, American wildlife managers generally recommend feeding whitetails only during severe winters or prolonged droughts. Nevertheless, many private landowners maintain feeders and dole out mineral supplements to retain the deer and buttress antler growth.

For all their differences, Austrian and American game managers share a common goal: keeping deer populations at desirable levels, regardless of the way it's done.

James M. Peek is a professor emeritus at the University of Idaho, where he studied and taught conservation and management of wildlife resources, focusing on antlered and horned species, grizzly bears, and gray wolves. He continues to teach and conduct research on elk and mountain sheep.

Wet and Wild

Midway between Walt Disney World and the Kennedy Space Center lies a haven for Florida's natural delights.

By Robert H. Mohlenbrock

As much as I love southern Illinois, my native home, I must admit that I enjoy the relatively tropical vegetation in Florida. When I was teaching at Southern Illinois University, my family and I would pack off to Florida each spring break to enjoy tourist attractions and explore natural areas. Since my retirement I still travel to the state at least once a year to teach a class on wetland-plant identification. One of my favorite wild destinations is the William Beardall Tosohatchee State Reserve, about twenty-five miles east of Orlando.

At the edge of a flood plain marsh, cabbage palms rise amid blooms of Leavenworth's tickseed.

The property, covering nearly forty-four square miles, was acquired by the state beginning in 1977 under Florida's Environmentally Endangered Lands Program. During the first half of the twentieth century, much of it had been a cattle ranch; local sportsmen had also established a hunting club on the ranch back in 1922 (various kinds of seasonal hunting are still permitted in the reserve). Today's visitors may camp in "primitive" sites and explore a network of hiking, biking, and horse-riding trails, but a lot of vegetation and wildlife can be sampled just by driving the roads.

The reserve is bounded on the east by a nineteen-mile stretch of the Saint Johns River [*see map on opposite page*]. Two of the river's tributaries flow through the reserve: Tosohatchee Creek, which runs across the northwestern corner, and Jim Creek, which cuts all the way from south to north near the eastern side. Both are surrounded by swampy, heavily shaded woods dominated by cabbage palms and other tall trees, including species that occur as far inland as southern Illinois. The two streams are known as blackwater creeks because tannin, released from the breakdown of leaves in the woods, darkens their waters.

Various kinds of wetland appear throughout the reserve, including marshes, wet ditches that lie along the sandy roads, and isolated ponds. Hammocks—which are slightly elevated patches of land within a wetland—support slash pines and cabbage palms. And savannas, which are areas where scattered trees grow amid mostly lower-growing plants, are home to shrubby oaks that grow in the sandy soil.

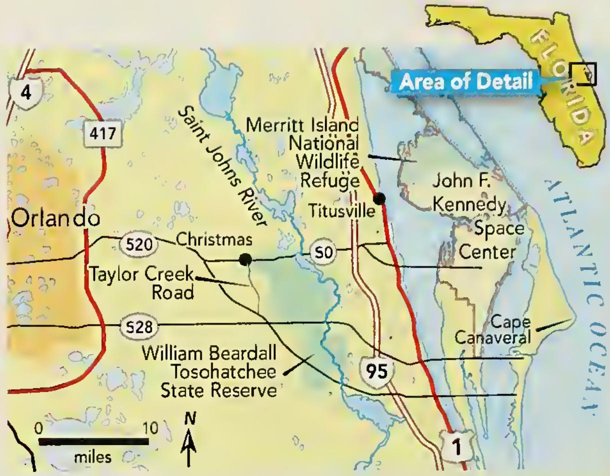
Animal life also abounds in the reserve. On our most recent visit, my wife Beverly and I were driving slowly along sandy, unpaved Long Bluff Road when, turning a corner, we saw an animal sauntering down the middle of the road, its back to us. It was only about a hundred feet ahead of us, and we drew even closer, finally stopping about twenty feet away. Only then did we realize we had come upon a bobcat. At first it ambled on, apparently unaware of our presence. Then, perhaps alerted by our whispering, it slowly turned its head. It was definitely surprised to see us! The bobcat immediately turned, raced a few feet to the side of the road, and leaped over two-foot-high vegetation, escaping into the adjacent forest. Farther along we saw a feral hog that was foraging within ten feet of the road—and so many armadillos we quit counting.

On other trips to Tosohatchee we

have seen alligators, snakes, squirrels, and turtles. Bird watchers will be treated to the sight of caracara hawks, Florida sandhill cranes, and numerous other species. Wading birds such as egrets, herons, ibises, and spoonbills, more commonly seen farther east, in the Merritt Island National Wildlife Refuge, feed in the marshes of Tosohatchee. The eastern indigo snake, which is on the federal list of threatened species, and the gopher tortoise also live here. We haven't seen a Florida panther, an endangered species that has been reportedly sighted in the reserve, but we are more than content with "our" bobcat.

Dusky pygmy rattlesnake

ROBERT H. MOHLENBROCK is professor emeritus of plant biology at Southern Illinois University in Carbondale.



FOR VISITOR INFORMATION, CONTACT:

William Beardall Tosohatchee State Reserve
3365 Taylor Creek Road
Christmas, FL 32709
407-568-5893
www.floridastateparks.org/tosohatchee

Habitats

Hammock Vegetation beneath the slash pines and cabbage palms comprises mostly nonwoody species. The undergrowth is often dense with dwarf palmettos and with such vines as earleaf, saw greenbriers (both very prickly), muscadine, and summer grape, all tough on hikers. Various species of beak sedge, crowngrass, lovegrass, and witchgrass are common. Among the attractive flowers are four-petal Saint-John's-wort, Leavenworth's tickseed, orange milkwort, shortleaf gayfeather, showy milkwort, sleepy morning, snow squarestem, and whitetop aster.

Epiphytes—plants that grow attached to other plants—live on the cabbage palms. They are not considered parasites because they have chlorophyll and so can manufacture their own food. At least six epiphytes are bromeliads: ball moss, Bartram's airplant, giant airplant, northern needleleaf, southern needleleaf, and Spanish moss. Others are ferns: golden polypody, long strap fern, and shoestring fern lodge themselves in the remnant bases of the old palm leaves. Resurrection fern and the rare hand fern live on the branches of some of the woody plants.

Swampy woods In addition to the cabbage palm, tall trees include American elm, laurel oak, pop ash, sugarberry, sweetgum, water hickory, and water locust. Blue beech, red maple, and swamp dogwood are among the shorter trees. Bald cypress is common in the wettest areas. Common buttonbush is the most abundant shrub, though bastard false indigo and silverling are also present. Savannah panicum, a large, broad-leaved grass, is scattered throughout the woods.

Many wildflowers in the habitat belong to the acanthus family, including branched foldwing, Carolina scalystem, Carolina wild petunia, looseflower water willow, and swamp twinflower. Acanthuses are not rare in the United States, but usually no more than one or two species occur in any given habitat.

Open wet habitat Roadside ditches, marshy terrain, and small ponds provide habitats for numerous wetland plants. Sedges abound, including a large number of beak sedges, and there are several kinds of yellow-eyed grass, some short and slender, others stout and nearly three feet tall. The pipewort family, whose plants put forth a single flower head on one stem, is well represented by three kinds of pipeworts, at least two kinds of bogbuttons, and one species of hatpins. Numerous species of arrowheads and bladderworts occur.

Savanna By definition, a savanna is a grassy habitat with scattered trees. But the trees that grow here—dwarf live oak and running oak—are shrubby species that often grow no more than a foot tall. Other plants include blackroot, two tiny-leaved species of blueberry, blueflower butterwort, early blue violet, fringed yellow stargrass pineweeds, pink sundew, queen's-delight, semaphore thoroughwort, and small butterwort.

FYI READER SERVICE

1. ADVENTURE CANADA
Travel on the 104-passenger, zodiac-equipped M/S Explorer and discover the art, culture and wildlife of Arctic Canada and Greenland with our team of artists, scientists, and culturalists.

2. ADVENTURE LIFE JOURNEYS
Small group travel in the Andes, Amazon, Galapagos, Patagonia, Antarctica, and Central America. Expert local guides lead our cultural and ecological explorations and naturalist cruises.

3. ADVENTURESMITH EXPLORATIONS
Small ship cruise and adventure travel experts. Explore nature up close and in style aboard luxury yachts, small ships and wilderness lodges. Our experienced staff knows the best ships and trips for every ability and budget.

4. ALABAMA GULF COAST
Spectacular beaches. Outstanding accommodations. And warmed by sunshine, history, culture and unspoiled natural beauty.

5. AMAZONIA EXPEDITIONS
Award-winning Jungle Lodge in the Tamshiyacu-Tahuayo Reserve, shown to have the greatest diversity of mammals in all of the Amazon.

6. AMERICAN CRUISE LINES
Enjoy scenic and culturally enriching 7-night cruises through the smooth waters of the inland passages along the eastern U.S. seaboard.

7. ATHENA PUBLICATIONS, INC.
Athena Review, journal of archaeology, history and exploration, invites you to send for more information on a free issue.

8. BELIZE TOURIST BOARD
Catch the Adventure! From rainforest resort to Barrier Reef. Belize is only 2 hours from the USA. Belize. Mother Nature's best kept secret.

9. CANON USA
Canon USA offers a full line of consumer imaging products from 35mm, APS and Digital Still cameras, Analog and mini DV camcorders, Image Stabilization Binoculars and Direct Photo Printers.

10. CHARLES COUNTY, MD
It's for the birds! Take a hike! Hunt for fossils, golf, fish, shop. Experience the wild side of the Potomac where eagles soar.

11. CROW CANYON ARCHAEOLOGICAL CENTER
Small-group cultural adventures led by world-renowned scholars explore some of the world's most interesting locations.

12. DELAWARE
Discover Delaware! Discover our beautiful beaches, rich history, culture and tax-free shopping.

13. DELTA QUEEN
The Delta Queen, Mississippi Queen and American Queen are the only genuine overnight paddle wheelers still plying America's rivers.

14. DORCHESTER COUNTY, MD
Destination Dorchester - Home to world-renowned Blackwater National Wildlife Refuge, excellent paddling, cycling, fishing and hunting; explore the heart of Chesapeake Country on Maryland's Eastern Shore.

15. EARTHJUSTICE
Earthjustice is a nonprofit law firm dedicated to protecting the magnificent places, natural resources, and wildlife of this earth by enforcing and strengthening environmental laws.

16. ECOTOUR EXPEDITIONS
Take a Walk on the Wild Side: Explore nature with our small groups and skilled naturalist guides in the Amazon, Galapagos, Costa Rica, Peru, and Brazil. Since 1989. Free Brochure.

17. FREDERICK COUNTY, MD
Maryland's Crossroads of History. Antiques, Battlefields, Covered Bridges, Parks, Wineries and more close to Gettysburg and DC.

18. GALAPAGOS TRAVEL
Specializing in comprehensive, educationally-oriented, professionally-led natural history tours of the Galapagos Islands. Spend 11 or 15 days touring all the significant outer islands.

19. G.A.P. ADVENTURES
Small group adventures, safaris and expeditions to all 7 continents, with a focus on culture, nature and sustainable tourism. We offer authentic, grassroots travel experiences.

20. ICELAND
Where else can you experience an ancient heritage, pristine nature, and modern lifestyle that coexist in harmony? Enjoy yourself in a pure, natural, and unspoiled place-Iceland: The Way Life Should Be.

21. INDIA
From the snow covered Himalayas to the tropical rain forests, India offers incredible experiences and adventures. Come visit India for an experience that is truly incredible!

22. INCLINATOR CO. OF AMERICA
Inclinator's Elevette® residential elevators provide convenience for people and add value to homes. They can be designed into new construction or added to existing homes.

23. ISLAND PRESS
Island Press is a leading publisher of books about the environment for professionals, students, and general readers.

24. JOHNS HOPKINS UNIV. PRESS
Celebrating 150 years of publishing for the world. Books about nature and science.

25. L.L. BEAN
L.L. Bean is the name you know and trust for quality clothing and gear. Make the most of the outdoors. For a free catalog of the best values direct from Maine, circle our number.

26. MARYLAND VACATIONS
Beaches, mountains, big cities, small towns. Maryland has so many things to do, so close together.

27. MELANISIAN TOURIST SVCS.
Luxury expedition cruising throughout the Sepik River and Trobriand Islands

For free information from the advertisers listed below, circle the corresponding numbers on the attached postage-paid card. Mail card, fax it to 856-380-4101, or visit us at www.naturalhistorymag.com. If the card is missing, mail your request to: P.O. Box 9000, Maple Shade, NJ 08052.

aboard the "MTS Discoverer." Customized land arrangements.

28. MONTGOMERY COUNTY, MD
Experience transportation history along the C & O Canal and the National Capital Trolley Museum. So many things to do with easy access to the nation's capital.

29. NEW BRUNSWICK, CANADA
Walk on the ocean floor along the Bay of Fundy, home of the World's Highest Tides!

30. NEWFOUNDLAND & LABRADOR
We offer our visitors the natural wonders of whales, icebergs and seabirds framed by our dramatic seascape and landscape and unique culture.

31. NEW MEXICO
Where unparalleled scenic beauty, outdoor adventure, world-renowned art and cultural diversity rest under the same magical sunset.

32. NORTH CAROLINA OUTER BANKS
The Outer Banks of NC-Immerse yourself in culture and history. Here anytime is quality time.

33. NORWAY
Norway is nature at its most spectacular. A land of cosmopolitan cities, charming towns, ancient Viking ships, and breathtaking coastal voyages.

34. NOVA SCOTIA
Yes, please send me my FREE 400 page Nova Scotia Doer's & Dreamer's Travel Guide - packed with everything I need to plan and book my vacation.

35. ORIENT LINES
Explore Scandinavia and Russia. Cruise to the Mediterranean's most glamorous playgrounds. Enjoy luxury at sea, aboard the elegant mid-sized ships sophisticated travelers prefer.

36. POCONO MOUNTAINS, PA
Free Pocono Mountains Outdoors Discovery Map. Information on state parks, forests, game lands, and the Delaware Water Gap National Recreation Area.

37. PRINCE EDWARD ISLAND, CANADA
Come experience our unique red cliffs and parabolic sand dunes and hike or bike the Confederation Trail across our Island.

38. PROMPERU
Peru has it all. Fascinating history, as the land of the Incas, incredible nature with more than 1,800 species of birds and colorful traditional culture. Come to Peru.

39. QUEBEC CITY
Discover the magic of North America's most European City! Only 40 minutes from the Old City, go birdwatching, hiking and enjoy yourself.

40. QUEBEC MARITIME
Nature destination par excellence, Le Quebec Maritime is a vast land whose shores are washed by the Gulf St. Lawrence and the St. Lawrence River.

41. SOL INTERNATIONAL
We specialize in South America, offering exceptional nature and cultural programs to areas where wildlife abounds and indigenous communities are unspoiled. Small groups, customized itineraries, personalized service.

42. ST. LAWRENCE CRUISE LINES
Canadian River Cruise Vacations. Spend 5 or 6 nights aboard a classically designed riverboat cruising the calm waters of the St. Lawrence and Ottawa rivers.

43. SWAN HELLENIC CRUISES
Ocean and sea cruises, expedition and river cruises all with the accent on discovery. Exotic destinations and distinguished guest speakers.

44. TALBOT COUNTY, MD
Talbot County's five beautiful rivers, 602 miles of shoreline, unique charming hamlets St. Michaels, Oxford, Tilghman Island and Historic Easton offer a timeless treasury of natural beauty and history.

45. TARA TOURS
Tara Tours specialize in travel to Central and South America since 1980. Free brochures and quotes.

46. TERRA INCOGNITA ECOTOURS
For trips that make a difference to you and to the places we visit. Trek Mountain Gorillas, snorkel on Barrier Reefs, rainforest hikes, whitewater rafting, and more.

47. TILLER INT'L TOURS INC.
Southwest China small group or private 3-week tours to Biospheres, Ethnic Tribe Town and Unique Architecture, Historic Cities, Major Archaeological Finds. Tiller Int'l Tours CTS#2022826-40

48. TOYOTA
In the U.S., Toyota is more than the cars we sell here. Together with our dealers and suppliers, Toyota is responsible for creating over 200,000 good jobs across the U.S. Learn more about our eight manufacturing plants, design, and R&D facilities, and how we invest in local communities.

49. TRAVEL CONCEPTS INT'L
Expand your horizons. Cultural tours. Small groups. Exotic destinations. Also "Between Weekends" and craft tours. Libya, Iran, India, Faroes, Apulia, Tibet, and much more!

50. TUCSON
Tucson, Real. Natural. Arizona. Discover a whole new side of nature in our fascinating desert landscape. And the weather's perfect for exploring our spectacular scenery any time of year.

51. WILDERNESS TRAVEL
Trekking Expeditions, Wildlife Safaris, Inn to Inn Hiking, and Sea Kayaking throughout the world. 27 years of experience, superb itineraries, expert leadership, small groups. Free catalog.

52. WORCESTER COUNTY, MD
Maryland's only seaside county. Visit Assateague Island National Seashore. Kayak, canoe, bird watch or golf. Stay in one of our many Bed & Breakfast Inns.

53. ZEGRAHM EXPEDITIONS
Offers small-group expeditions to remote locations around the world. Expertly led and staffed, our programs provide the finest adventure travel experience imaginable.

Best Books for Young Readers, 2005

By Diana Lutz

FOR THE VERY YOUNG

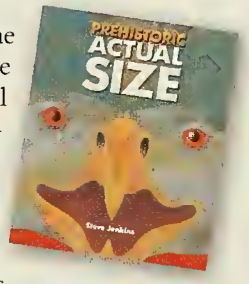
Why?, written and illustrated by Lila Prap (Kane/Miller; $14.95)

Reading *Why?* is a bit like visiting a kindergarten class on a day when the kids are as lively as Mexican jumping

beans. "Why do walruses have mustaches?" the teacher asks. "To tickle babies," one kid answers. "To look handsome," another says. "To hide their big mouths," adds a third. When the children finally hush, the teacher explains that walruses actually use their whiskers to comb the mud at the bottom of the ocean for mussels and clams. The question-and-answer format is old as the hills, but *Why?*'s silly answers, mock-childish drawings, and uproarious high spirits will appeal to young readers. It's a giggle.

Prehistoric Actual Size, written and illustrated by Steve Jenkins (Houghton Mifflin; $16.00)

Within its two covers, *Prehistoric Actual Size* tries to contain as much of a thirty-three-foot-long *Baryonyx* and an eight-foot-tall terror bird as will fit—which is not much. But the claws or beak that do fit are all the more impressive for being actual size. The bright, intriguingly wrinkled, cut-paper illustrations are works of art, but it is Steve Jenkins's playful sense of pacing and scale that will get the kids to squeal. A modest-size velociraptor is followed by the fly-speck image of a protozoan, which is followed by a six-and-a-half-foot-long sea scorpion. A big reptile's dinky head appears just a few pages before a gigantosaurus's enormous teeth. In the center of the book, in a big, foldout spread, lurks a yellow-orange flying *Dsungaripterus*. Cool!



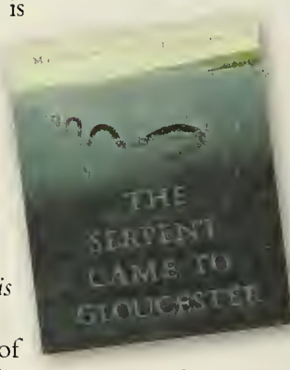
Leaf Man, written and illustrated by Lois Ehlert (Harcourt, Inc.; $16.00)

Leaf Man, a chance assemblage of colorful fall leaves, two acorns, and a sweet-gum fruit, appears briefly at the beginning of Louis Ehlert's book and then is scattered by a gust of wind. The wind blows over marsh, field, and lake, where leaf ducks waddle, leaf cows graze, and leaf turtles paddle—until it finally blows Leaf Man (and his Leaf Lady companion) together again.

Ehlert creates her characters with color photocopies of the serrated shapes and mottled colors of found leaves, which she considers "the most beautiful art supplies in the world." Overlapping die-cut horizons at the tops of the book's pages nudge the reader onward: What lies over the next ridge? The end papers and dust jacket present a miniature field guide to fallen leaves, and even include a few mystery leaves as well.

FOR INTERMEDIATE READERS

The Serpent Came to Gloucester, by M.T. Anderson; illustrated by Bagram Ibatoulline (Candlewick Press; $16.99)



Turning a historical incident into a moving environmental allegory, M.T. Anderson tells the story of a serpent that visited Gloucester, Massachusetts, in the summer of 1817. Initially terrified, the villagers soon become charmed by the serpent's playfulness. When bounty hunters arrive the following summer to slay the serpent, the villagers conceal its playground, and the hunters ignominiously land a mackerel instead.

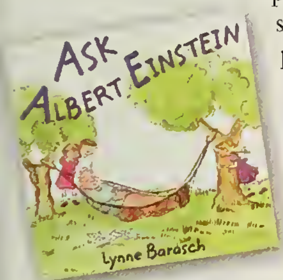
The Serpent recalls Coleridge's famous poem, "The Rime of the Ancient Mariner." When the ancient Mariner, watching the water snakes as they coil and swim, "blessed them unaware," the albatross he had "inhospitably killed" drops from his neck. In Anderson's sadder children's story, there is no redemption. The now-elderly narrator tells his grandson that he fears the serpents have gone and will never come again.

Math Potatoes, by Greg Tang; illustrated by Harry Briggs (Scholastic; $16.95)

When Greg Tang visited his daughter's first grade class, he noticed that every dot on every domino had a pencil mark on it, which meant the kids were counting the dots the hard way—one by one. In this cleanly designed book, sixteen clever visual puzzles coax kids to count the easy way—by recognizing patterns and groups. The idea may seem trivial, but the kids who enjoy math are the ones who collect tricks as industriously as apprentice magicians. *Math Potatoes* is part of an ongoing series that will extend from counting to calculus. A calculus book? . . . now that should be interesting.

Ask Albert Einstein, by Lynne Barasch (Farrar, Straus and Giroux; $16.00)

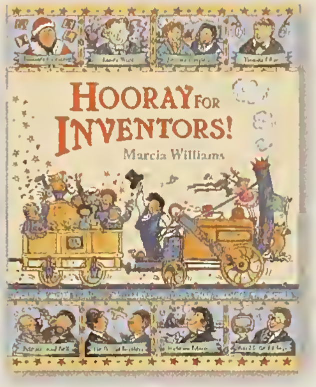
In this fictionalized account of an actual event, a seven-year-old girl writes to Einstein on behalf of her older sister, who must solve a geometry problem or fail a math class. Like good teachers everywhere, Einstein replies with a hint, not the solution. Happily, the sister solves the problem and passes the course.



Lynne Barasch movingly tells this parable about perseverance from the point of view of a younger sister who thinks her older sister can do anything—except perhaps solve this math problem. Quotations on the endpapers present Einstein as a comfortably rumpled man who has self-doubts of his own. But only adults and children who have taken geometry will be able to understand Einstein's hint, which is reproduced at the end of the book, and solve the math problem. That's a shame, since matching wits with Einstein is a lot of fun.

Hooray for Inventors!, written and illustrated by Marcia Williams (Candlewick Press; $16.99)

In rambunctious good-humored comic strips and single-panel cartoons,



Marcia Williams celebrates inventors both famous and forgotten—Johannes Gutenberg, inventor of the printing press, as well as the likes of Frances Gabe, who invented the self-cleaning house. *Hooray for Inventors!* is quite a departure for Williams, whose earlier books are condensations of literary classics, but her training in storytelling pays off here.

Like a Dickensian novel, *Hooray* is crammed with larcenous investors, doubting fathers, the boredom of day jobs, the weight of public skepticism, and the indifference of bureaucrats. In twelve small comic-strip panels, office workers at "the Great Western Union telegraph company" stall an early inventor of the telephone with twelve bogus excuses for not returning his prototype. For two years he visits their offices almost every week to ask for it back.

Birds, owls, and turtles inhabit the margins of the pages and make saucy remarks questioning the notion that every advance in technology is an advance in civilization. One turtle is a mild-mannered Luddite. "If the future is that way," she rants, "I'm going this way!" Her baby, however, is a budding consumer. "Can I have a TV?" she asks. "Can I?"

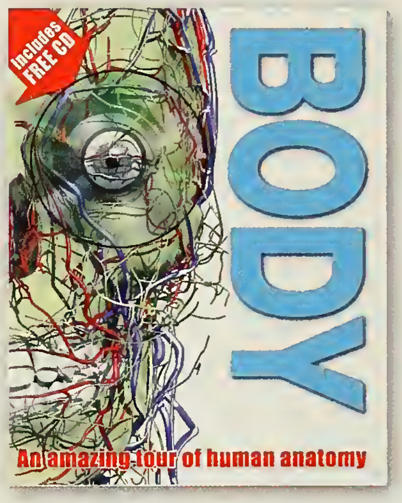
FOR ADVANCED READERS

Body: An Amazing Tour of Human Anatomy, by Richard Walker (DK Publishing; $19.99)

In 1994 a prisoner executed in Texas was steeped in liquid plastic, sliced thin, and scanned into a computer. Those images were then reassembled by a computer, making the prisoner the first "see-through human." Ever since, publishers have been offering lively computer-generated anatomies that make Gray's and Netter's autopsy-based classics seem, well, pickled.

Body is a superb example of the genre, one that brings to bear all the impressive craft of the DK publishing house. And despite its grim origins, *Body* is a cheerful book; its jaunty skeletons wear their brightly colored veins and muscles with style. Richard Walker, who has a Ph.D. in physiology and biochemistry, is also the author of the *DK Guide to the Human Body,* which won the prestigious Junior Aventis prize in 2002.

But as always with a DK book, it is the design that grabs you. When DK



shows you the six kinds of skeletal joints, you actually see how each one works. *Body*'s designers are so completely at ease they even play around a bit, using a pull-quote to make a nose for a disembodied brain and posing a skeleton on its back, arms behind its head. The book is spiral-bound, so that the pages lie flat for reference. Its covers open to reveal a grinning skull with overlying blood vessels and a CD covering one eyeball like an outsize monocle. Someone had fun thinking that one up.

Photo by Brady: A Picture of the Civil War, by Jennifer Armstrong (Simon & Schuster; $18.95)

In this engrossing photo essay, Jennifer Armstrong tells the wrenching story of the Civil War through the photographs taken by Matthew B. Brady's operators. Because the photos were stamped "Photo by Brady," many people think Brady himself made them all. In fact, he hired "a small army" of men to follow the troops in mysterious wheeled carts called What-Is-It Wagons, which were really portable darkrooms.

Armstrong, who has written three novels about the Civil War, summarizes its campaigns so deftly that it becomes a compelling story rather than the usual depressing jumble of facts. Each photo is given the context it needs to be understood. A picture of a row of dead bodies is not just a photo of "Civil War casualties," but Confederate soldiers who were trapped in a sunken road at Antietam and mowed down by Union troops.

Ever aware that to the modern eye, Civil War photos seem oddly airless and posed, Armstrong explains that the technology of the day required long exposure times. Photography was simply too slow to capture action. In any event, Brady's photographers were prohibited from going forward until the battles were over. When they got to the battlefield they were following scavengers, which explains the shoeless corpses. To make the most of their time, operators sometimes photographed the same bodies from different angles, and posed bodies to create a more tragic composition. With Armstrong as a guide, the reader may truly see these famous, moving photographs for the first time.

A Dangerous Engine: Benjamin Franklin, from Scientist to Diplomat, by Joan Dash, illustrated by Dušan Petričić (Farrar, Straus and Giroux; $17.00)

Benjamin Franklin, says Joan Dash, was "speckled"—he was several personalities rolled into one. *A Dangerous Engine,* which is really two books in one, describes two Franklins: the amateur scientist and the diplomat. Franklin the scientist possessed the omnivorous curiosity needed to become a first-rate investigator, and he poked his nose into everything from ocean currents to ant communication. He was particularly good at understanding electricity, a science then at such an early stage that a man with no training could make a meaningful contribution.

Franklin's experiments on electricity demonstrated that it was made up of two kinds of charge. Famously, he also showed that lightning is just a massive electrical spark. He and his friends, the Franklinists, also had fun inventing electrical entertainments, such as a dancing spider and a shocking picture frame. Apparently they had *too* much fun. After just six years, Franklin decided that such pursuits were self-indulgent and gave them up to spend the rest of his life being "useful."

The second half of the book describes Franklin's seventeen-year career as a diplomat in England and in France. This half is filled with intrigue and incident—in France, Franklin's group is infiltrated by a British spy who leaves bottled messages for his handlers, written in invisible ink and stuffed into a hole in a tree. It is also amusing to hear the familiar events of the War of Independence described by someone dining with the enemy. Still, seeing the war from an unfamiliar angle is a fairly adult pleasure. Most children would probably rather read about the man who chased a turkey with a Leyden jar, than about the figure who exchanged sarcasms with that ultra-sophisticated French foreign minister.

Poor Ben. Until the end of his life, he carried "a little Oil in the upper hollow joint" of his bamboo cane. That way, he reasoned, if he went for a walk in the countryside, he could pour oil on water and observe the effect. The man should have been a scientist.

DIANA LUTZ keeps an eye on children's literature for her daughter, Emily, and her roundup of the year's books for children on science and nature is a regular feature of our end-of-year issue. She is also the editor of Muse, *a science magazine for young people ages ten and older.*

STATEMENT OF OWNERSHIP

Statement of Ownership, Management, and Circulation (required by 39 U.S.C. 3685). Publication Name: Natural History. Publication Number: 374-800. Filing Date: October 31, 2005 Issue Frequency: Monthly, with combined issues in December/January and July/August. Number of Issues Published Annually: Ten. Annual Subscription Price: $30. Complete Mailing Address of Office of Publication and General Business Office: Natural History Magazine, 36 W. 25th Street, New York, NY 10010. Publisher: Charles E. Harris; Editor in Chief: Peter G. Brown, 36 W. 25th Street, New York, NY 10010. Owner: Natural History Magazine, Inc., 36 W. 25th Street, New York, NY 10010. Stockholders: Peter G. Brown, 36 W. 25th Street, New York, NY 10010; Exeter Capital Partners IV, LP, 10 E. 53rd St., New York, NY 10022; Todd Happer, 36 W. 25th Street, New York, NY 10010; Charles E. Harris, 36 W. 25th Street, New York, NY 10010; Robert E. Marks, 5 Greenwich Office Park, Greenwich, CT 06831; David W. Niemiec, 535 Madison Ave., New York, NY 10022. Known bondholders, mortgagees, and other security holders owning or holding 1 percent or more of total amount of bonds, mortgages, or other securities: None. Tax Status: N.A. Publication Title: Natural History. Issue Date for Circulation Data Below: October 2005. Extent and Nature of Circulation. Average number copies of each issue during preceding 12 months: A. Total average number of copies printed: 268,972. B. Paid circulation: 1. Paid outside-county mail subscriptions: 234,376. 2. Paid in-county mail subscriptions: 0. 3. Sales through dealers and carriers, street vendors, counter sales, and other non-USPS paid distribution: 14,214. 4. Other classes mailed through the USPS: 100. C. Total paid circulation: 248,690. D. Free distribution by mail: 2,300. E. Free distribution outside the mail: 3,230. F. Total free distribution: 5,530. G. Total distribution: 254,220. H. Copies not distributed: 14,752. I. Total: 268,972. J. Percent paid circulation: 97.8%. Number copies of single issue published nearest to filing date (October 2005): A. Total number of copies printed: 262,975. B. Paid circulation: 1. Paid outside-county mail subscriptions: 243,416. 2. Paid in-county mail subscriptions: 0. 3. Sales through dealers and carriers, street vendors, counter sales, and other non-USPS paid distribution: 5,300. 4. Other classes mailed through the USPS: 100. C. Total paid circulation: 248,816. D. Free distribution by mail: 2,006. E. Free distribution outside the mail: 1,966. F. Total free distribution: 3,972. G. Total distribution: 252,788. H. Copies not distributed: 10,187. I. Total: 262,975. J. Percent paid: 98.4%. I certify that all information above is true and complete. Charles E. Harris, President & CEO.

NOUVEAU
1910
THE HERITAGE CONTINUES
BRENNY'S Fairhope, AL.
ED MARSHALL Scottsdale, AZ
JEWELS BY JOSEPH Newport Beach, CA.
MARDON Riverside CA.
JOHANN PAUL
COLEZZIONE
DI VITTORIO Montreal, CANADA
ROYAL GOLD
ROYAL GOLD Kailua, HI. 808-331-8818
JIM SAYLOR Kauai, HI.
JIM SAYLOR 808-826-2786
GOLDIN Chicago, IL.
SENG Louisville, KY
PEARLMAN'S Battle Creek, MI.
MAURICE New York, NY.
JUDITH ARNELL Portland, OR.
JEWERLY DOCTOR Vienna, VA. 703-255-1330
PRECIOUS GEM Williamsburg, VA. 757-220-1115
SOLOMONS Hamilton, BERMUDA 441-292-4742
ROSSIO PFISTER Cleveland, Ohio 216-621-4195
PAVLOS Jacksonville, FL. 904-641-2178
JOYERÍA RIVIERA San Juan Puerto Rico
KARATS Vail, CO. 970-476-4760

And for the Coffee Table

By Laurence A. Marschall

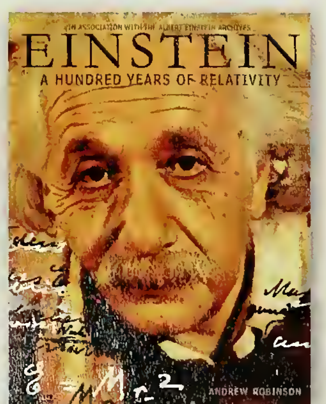
Encyclopedia Prehistorica: Dinosaurs, by Robert Sabuda and Matthew Reinhart (Candlewick Press; $26.99)

Talk about intelligent design! The creators of this unique volume are artists and graphic designers, not scientists, and they have put together one of the most diverting and attractive dinosaur books you'll ever see. Its conventional facade conceals six internal two-page spreads, each featuring a giant pop-up creature. Around the margins of each spread are smaller "books," which in turn contain more dino-related pop-ups. An archaeopteryx, feathers and all, spreads its wings as you open one page; a lumbering ankylosaur rises from the folds of another, its spiny tail raised threateningly. There's just enough text to help budding dinophiles understand what they are seeing, and to remind old fossils like me what we learned about these "terrible lizards" when we were young. To top it off, the authors promise at least two more *Encyclopedia Prehistorica* volumes to come, one on extinct mammals, and another on extinct sea creatures.

Einstein: A Hundred Years of Relativity, by Andrew Robinson, in association with the Albert Einstein Archives (Harry N. Abrams; $29.95)

The host of contributors to this centennial volume attests to the broad influence of Einstein's work since the publication of his first seminal papers in 1905. Physicists Philip Anderson, Stephen Hawking, João Magueijo, and Steven Weinberg, explain how the two major currents of twentieth-century physics, namely quantum mechanics and relativity, began with Einstein's work. They further show how current attempts to formulate a "theory of everything" are rooted in his yearning for a unified cosmology.

Andrew Robinson, an editor of the *Times Higher Education Supplement*, reviews Einstein's public persona, most notably his deep-seated pacifism, which coexisted, sometimes uneasily, with his support for the state of Israel. Even such personalities as Philip Glass ("Einstein and Music") and Arthur C. Clarke ("Einstein: Twentieth-Century Icon") have a few words to say about the man *Time* magazine named "Person of the Century."



So much has already been written about Einstein that there are few revelations here. But the writing is elegant, and the illustrations impeccable: among them are many seldom-seen letters and photographs from the archives at the Hebrew University of Jerusalem. Altogether, they make the volume a gift worthy of the great soul it celebrates.

Art of the Ancestors: Antique North American Indian Art, by George Everett Shaw, with Steven C. Brown, Benson L. Lanford, and Bill Mercer (University of New Mexico Press; $65.00)
Lascaux: Movement, Space, and Time, by Norbert Aujoulat (Harry N. Abrams; $65.00)

No one knows the identity of the artists whose work graces the pages of these showpiece volumes. Yet in a way, it seems, we know them well. In the first book, art dealer and collector George Everett Shaw has teamed up with three other experts to present an album of Native American artistry that, in his words, "approaches perfection." The noble visage on a Tsimshian headdress, inlaid with eyes and teeth of abalone, or a simple Iroquois drinking cup, bearing a stylized beaver carved in maple, express an aesthetic that speaks to a common humanity.

The second volume, *Lascaux*, written by a geologist and archaeologist, is a lavish and comprehensive record of the celebrated cave in southwestern France whose walls display polychrome images of bison, bulls, horses, and stags. In spite of their familiarity, the images remain remarkably dynamic and pack a surprising emotional punch.

Most of the Indian pieces in *Art of the Ancestors* date to the 1800s, by which time the Lascaux drawings were already 18,000 years old. But browsing through both books, you feel as if you're looking at precious legacies from venerable members of your own family.

A Dazzle of Dragonflies, by Forrest L. Mitchell and James L. Lasswell (Texas A&M University Press; $39.95)

Although their fossil ancestors, with wingspans of two feet or more, were among the largest flying insects in the history of the planet, dragonflies are the embodiment of delicacy. Tissue-paper wings bear their needle-thin bodies just above the surface of a pond or brook, while their legs form a basket to trap small prey for a meal on the fly. If they seem in a hurry as they dart from perch to perch, perhaps it's because life is so short: a typical dragonfly lives for less than a month after it emerges from the larval stage, even if it's lucky enough to escape being eaten.

Mitchell and Lasswell, both entomologists at Texas A&M, have stopped this action on the wing, as it were, compiling an attractive and accessible album of photographs of North American dragonflies, with enough intriguing facts to make anyone into a dragonfly buff. The most attractive illustrations were made with the help of a flatbed scanner, which seems ideal for creatures so thin they are almost two-dimensional. The authors even offer detailed instructions on how to catch, sedate, and pose your own neighborhood dragonflies before releasing them back into the wild.

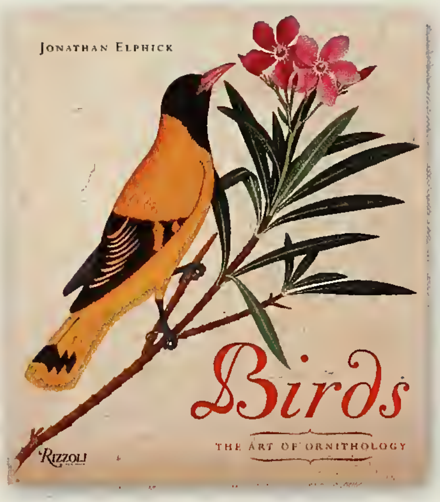
What's Out There: Images from Here to the Edge of the Universe, by Mary K. Baumann, Will Hopkins, Loralee Nolletti, and Michael Soluri, with a foreword by Stephen Hawking (Duncan Baird; $29.95)
Evolving Cosmos, by Govert Schilling (Cambridge University Press; $40.00)

The pace of astronomical discovery has been so rapid in the past two decades that it seems appropriate, as a yearly routine, to take stock of where the universe stands. These two colorful coffee-table books, however, are far from routine. *What's Out There* features a comprehensive gallery of color images from Earth- and space-based telescopes. The visual impact is extraordinary, though the organization (alphabetically from "aurora" to "WMAP") seems to defy common sense. It may take a bit of jumping back and forth for the reader to figure out what's out there within such a procrustean framework, but every leap will be enjoyable.

By contrast, *Evolving Cosmos*, lucidly written by the science journalist Govert Schilling, organizes its material according to the physical processes that govern the universe. Chapters deal with topics such as "creation" (highlighting the evidence for the big bang) and "moulding" (collisions that shaped the solar system). Lovely to look at, Schilling's book provides not only decoration for the coffee table, but food for thought.

Birds: The Art of Ornithology, by Jonathan Elphick (Rizzoli; $60.00)

It takes extraordinary technique to render the texture and iridescence of the plumage and contour of the avian form. Rarer still is the ability to breathe life into paintings of creatures that can be observed only as stuffed specimens,



or perhaps as distant flashes of color in the upper branches of trees. So it's not surprising that great ornithological illustrators such as John James Audubon bring to their subject both the ingenuity of a scientist and the soul of an artist.

Now Jonathan Elphick, a writer and zoologist with his own field guide to British and Irish birds to his credit, has brought the work of the great bird illustrators of past centuries together into one lavishly produced, thoroughly researched history of the art form. About a hundred pages are devoted to the works of Audubon's seventeenth- and eighteenth-century predecessors. Eleazar Albin, for instance, published his *Natural History of Birds* in 1738, featuring the first hand-colored illustrations of British birds. The work of artists such as William Ellis, John Latham, and Sarah Stone reflected the plethora of new species sent home by colonial naturalists around the world. And judging from the last 200 pages of the book, which showcase paintings by Audubon as well as by the finest bird artists of today, ornithological art continues to grow and flourish.

Frogs: A Chorus of Colors, by John L. Behler and Deborah A. Behler (Sterling Publishing Co.; $19.95)

Big-eyed amphibians peer out from nearly every page of this collaborative effort by the curator of herpetology at the Bronx Zoo and the editor-in-chief of *Wildlife Conservation* magazine. The gallery of close-ups includes dignified portraits of unusual species such as the Malayan horned frog, which resembles a miniature owl, as well as action shots of frogs leaping at insects, dining on snakes several times their size, or even, as in one scandalous photo of Costa Rica's Monteverde golden toad, engaging in a jaunty round of group sex.

But the book's title doesn't do justice to the accompanying text, which is hopping with delightful bits of frog lore. Did you know that frogs in the genus *Phyllomedusa* have opposable digits? Were you fully aware that some frogs in Europe and North America routinely freeze in winter and return to life with the spring thaw? The only downside to the book is frogdom's uncertain future. The Monteverde golden toad is already extinct, and a third of the world's frog species are now threatened by environmental toxins, fungal infections, and the indiscriminate draining of wetlands.

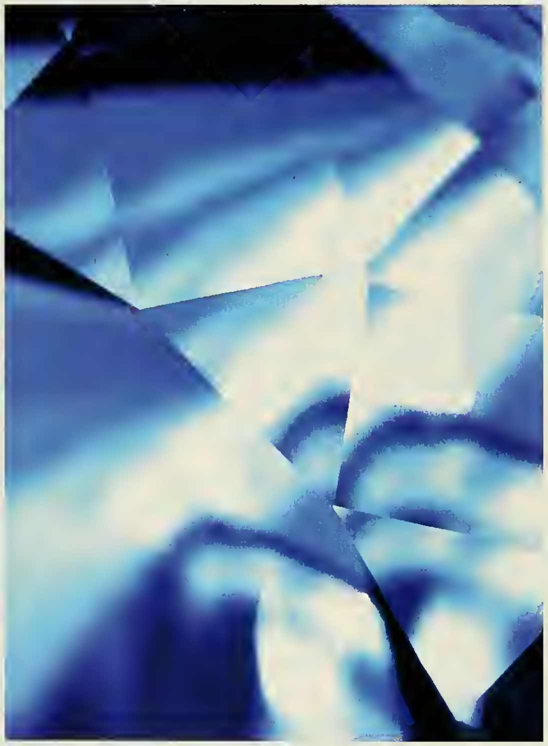
LAURENCE A. MARSCHALL, author of The Supernova Story, *is W.K.T. Sahm Professor of Physics at Gettysburg College in Pennsylvania, and director of Project CLEA, which produces widely used simulation software for education in astronomy. He is the 2005 winner of the Education Prize of the American Astronomical Society.*

Space Glitter

Cosmic nanodiamonds may steal some sparkle from a quasar.

By Charles Liu

Interstellar matter—the gas and dust that surround the stars—play all kinds of wacky tricks with light. Sometimes they change the light that shines through them from more distant objects. Sometimes they shine on their own. Some of their light appears to us on Earth in the form of colorful, ethereal nebulae, with equally colorful names: Carina, the Cat's Eye, Rosette, and the Veil.



Yet the same dust and gas that floats in the gaps between the stars—somewhat obscurely dubbed the interstellar medium, or ISM—can blur, distort, and even completely block our view of celestial objects. The interstellar medium comprises only about 1 percent of the mass of our Milky Way Galaxy, including "dark matter," and the bulk of the ISM drifts about in billowing clouds and wispy nebulae in a highly rarefied state, at a density of less than a thousand atoms per cubic inch. Even the best earthbound laboratory vacuums are millions of times denser. Nevertheless, the ISM makes it very hard for us astronomers to know exactly what we're looking at.

Frustrated but undaunted, we infer what lies behind the haze by assuming certain distributions of dust and gas, then modeling their effects on light radiating through them. If the models can be "tuned" to predict what we actually measure, we can cancel out the effects assumed in the model when we analyze the data we gather.

A research team led by Luc Binette, an astronomer at the Universidad Nacional Autónoma de México, in Mexico City, recently studied how the ISM would affect estimates of the energy output of quasars—distant, titanic, gravity-driven energy producers that are powered by supermassive central black holes. Binette's group suggests that a strange feature of the quasars' ultraviolet light, the so-called "big blue bump," could be explained if the light had to pass through a shimmering curtain of diamonds, each less than a millionth of an inch across.

To grasp how diamonds could explain the blue bump, think about what happens around noon on a clear day as the Sun shines through Earth's atmosphere. The air molecules preferentially scatter the blue, shorter-wavelength rays of sunlight in all directions, giving the sky a soft blue glow. Most of the other, longer-wavelength colors of the Sun pass directly through the air, giving the Sun a yellowish cast. At sunset, however, as the Sun moves closer to the horizon, sunlight shines primarily through the lower layers of our atmosphere, where a lot of atmospheric dust is suspended. The dust particles are much bigger than the various kinds of molecules in air, and they absorb much of the blue light and let through the longer-wavelength orange and red light. The combined effects of the air and dust turn the Sun orange and the sky red.

The ISM affects light in deep space the way gas and dust affect light on Earth, and then some. Even though the ISM is sparse compared to the particles in Earth's atmosphere, light that crosses the vast distances of interstellar space must often pass through great quantities—and a great many kinds—of material. When light from astronomical sources is analyzed, the effects of the ISM become evident: bright bands signal light being emitted, dark bands indicate light being absorbed, and the overall distribution of light is distinctly different from that emitted by the original source.

Even without the effects of the ISM, though, the light from quasars is a challenge to interpret. Their light comes not from stars, but rather from the glow of superheated gas swirling into a central black hole. Hence their spectra are quite different from those of ordinary galaxies, particularly at very short, nonvisible wavelengths. For example, quasars far outshine ordinary galaxies in ultraviolet and X-ray light.

One particularly prominent feature is that aforementioned big blue bump—a strong, broad enhancement of ultraviolet radiation at wavelengths of about a hundred nanometers (about 0.000004 inch). Most quasar experts think the bump is the result of physical processes


MASTERPIECES
OF THE MINERAL WORLD

around the black hole. Binette's team, however, wondered whether the ISM itself could be responsible: if dust grains a hundred or so nanometers in diameter filled part of the space between us and a quasar, could they transform a smooth source of ultraviolet light into a bumpy spectral signature?

By examining the properties of various kinds of materials, Binette and his colleagues found that dust grains of that size could indeed cause a big blue bump. The grains, however, would have to be made up of a crystalline form of carbon: diamonds. But the amount of "nanodiamond" dust needed to account for the bump is so great that the dust couldn't be evenly spread throughout space; the conditions in the universe have never been right to make so many diamonds. So the nanodiamonds would have to be produced near the quasar itself. A cloud of at least a thousand Earth-masses' worth of them—or, in jewelers' terms, 30 trillion quintillion carats—would have to be floating between the quasar and our viewing location here on Earth.

For the nanodiamond model to stand, some key questions need to be answered. The biggest question may be, can quasars make diamonds? Part of the answer may come, not from billions of light-years away, but from within our own solar system, in the form of primitive meteorites called carbonaceous chondrites. Older than our Sun, those objects contain nanodiamonds that are remnants of the ISM.

Laboratory studies of the nanodiamond grains have revealed some of their properties. Someday, it is hoped, their origins will also come to light. Knowing their origins could confirm whether it is possible for a shroud of glittering diamond dust to grow around a supermassive black hole. And it might suggest that the very ground we walk on once condensed in the midst of such a diamond-sprinkled cloud.

CHARLES LIU is a professor of astrophysics at the City University of New York and an associate with the American Museum of Natural History.

nature.net

Bonobo Watch

By Robert Anderson

I have nothing against scientific surveys scanning the heavens for signs of extraterrestrial intelligence. But given the odds, my bet is that the only nonhuman intelligence we'll ever really know is already here. On a recent visit to the San Diego Zoo, I spent several hours observing bonobo apes and decided that, for my money, they're the best candidates for that distinction. But if your schedule doesn't permit extended zoo visits, you can always turn to the Web.

The San Diego Zoo's site, for instance (www.sandiegozoo.org/animalbytes/t-bonobo.html), offers both video and photographic images of the zoo's denizens. And at the Great Ape Trust of Iowa online (www.greatapetrust.org/media/avclips.php), you can find archived video clips of a colony of eight resident bonobos (scroll down to the choices listed under "Bonobos"). The colony of apes now living at the Trust were once part of an experimental program at the Language Research Center of Georgia State University, near Atlanta. Kanzi, the colony's most famous member, is regarded by some people as the first ape to demonstrate real speech comprehension. You can see profiles and mug shots of Kanzi and his mates at www.greatapetrust.org/bonobo/meet/index.php.

Because of their resemblance to chimpanzees (*Pan troglodytes*), bonobos are often, misleadingly, called pygmy chimps, even though they are a separate species (*P. paniscus*). Bonobos, however, are more than an intelligent animal species. They and their chimpanzee cousins are our closest genetic relatives, at least on the basis of their DNA.

Some investigators argue that bonobos are a living window into the human evolutionary past. William H. Calvin, a neurobiologist at the University of Washington in Seattle who studies the evolution of the human brain, maintains an excellent site devoted to *P. paniscus* (williamcalvin.com/teaching/bonobo.htm).

Bonobos apparently evolved social structures quite unlike those of their chimpanzee cousins. The group dynamics of the two species of ape are compared in a video segment, "Why Sex?" from the PBS series *Evolution* (www.pbs.org/wgbh/evolution/library/07/3/l_073_03.html). You can also listen online to vocalization differences between the two apes (www.emory.edu/living_links/AV_library.html).

Studying animals in zoos has advantages, but it's no substitute for fieldwork. Unfortunately, bonobos occur only in the remote central rainforests of the Democratic Republic of Congo (formerly Zaire), and field studies have been limited. Still, some have yielded remarkable observations. E. Sue Savage-Rumbaugh, a primatologist at the Great Ape Trust, discovered that bonobos have fashioned plants into complex symbols to mark jungle trails (www.cnn.com/EARTH/9802/14/apes.ap).

The major threats to bonobo survival in the wild are rainforest destruction and poaching for the bushmeat trade. Alarmingly, late last year the Environment News Service (www.ens-newswire.com/ens/dec2004/2004-12-09-03.asp) reported that fieldworkers in some areas of the bonobos' range were having a hard time locating any bonobos at all. The World Wildlife Fund (WWF) provides a succinct profile of the bonobo as an endangered species, including its latest population figures, at www.worldwildlife.org/apes/projects/bonobo_study.cfm. Warning of the species' imminent extinction, Richard Carroll, a primatologist and the director of the WWF's Africa Program, says it all: "If humans allow our closest relatives to go extinct, we have failed as a species."

ROBERT ANDERSON is a freelance science writer living in Los Angeles.

By Joe Rao

On December 1 Mercury rises only an hour and fifteen minutes before the Sun and, at magnitude 1.2, is a bit hard to see. The planet rises earlier each day, however, and soon emerges from the glare of sunrise. By the 5th it is visible low in the east-southeast about forty-five minutes before sunrise, seventeen degrees below and to the left of the much brighter Jupiter. A slender crescent Moon appears to hover about seven degrees to Mercury's right on the morning of the 29th.

On New Year's Day, Mercury rises about an hour before the Sun and shines at magnitude −0.5. A week later, rising just forty-five minutes before the Sun, it is once again hard to see.

In December Venus makes its most magnificent appearance of 2005 and 2006. Look for it in the southwestern sky at sunset. As twilight fades, the planet seems to grow increasingly large and bright; to add to the drama, it pairs with the crescent Moon on the 4th to make an eye-catching sight. Venus reaches its highest altitude of the year early this month, coinciding with the night of its greatest brilliancy, on the 9th. On that night it appears to blaze eighteen degrees above the southwestern horizon forty-five minutes after sunset. By Christmas, Venus is plunging rapidly into the sunset glow.

In early January, Venus vanishes from the evening sky. On the 13th it reaches inferior conjunction, passing more or less directly between the Earth and the Sun. By the 19th Venus emerges as a new morning "star," rising in the east-southeast at mid-dawn. You may be able to spot it about six degrees above the horizon half an hour before sunrise. A week later you should be able to see it easily from any location with an open east-southeastern view, about an hour before sunrise.

Mars begins December shining in the constellation Aries, the ram, in the southeastern sky at dusk, and by 9:30 P.M. it has climbed to its highest point in the sky, due south. At the onset of December Mars shines at magnitude −1.6, but, having faded over the previous few weeks, it is only about half as bright as it was a month earlier. It continues dimming throughout December. Be sure to watch on the night of December 11–12, as the waxing gibbous Moon slowly glides above Mars.

In January the Red Planet shines orange-yellow in the south during early evening. At midmonth it sets in the west at about 2:15 A.M. By month's end it has lost half the brightness it had on the 1st; as a result, it appears about as bright as the bluish-white star Rigel, in the constellation Orion, the hunter. On the evening of the 8th Mars is to the right of a waxing gibbous Moon.

Jupiter is so prominent before sunrise in December that you hardly have to look for it. It's a steady silvery-white lamp that clears the horizon more than two and a half hours before the Sun does at the beginning of the month, and nearly four and a half hours before sunrise as the month ends. At dawn's first light, the gas giant hangs in the southeast. Jupiter is fourteen degrees below and to the left of the bright bluish star Spica, in the constellation Virgo, the virgin, as the month begins. The star and planet then separate as Jupiter drifts eastward. Jupiter appears to ride above and to the right of a crescent Moon on the morning of the 27th.

In January Jupiter continues to be visible before dawn. This month it rises after midnight and is high in the south-southeast by sunup.

Saturn, situated in the constellation Cancer, the crab, begins December rising out of the east-northeast shortly after 9 P.M.; by month's end it's rising two hours earlier. On the evening of the 18th Saturn is below and to the right of the Moon. By the end of December the planet shines brilliantly, even though it doesn't reach its closest approach to Earth until January 27. Saturn passes less than a degree to the south of an open star cluster called the Beehive, in Cancer, at the end of January.

The Moon is new on December 1 at 10:01 A.M. It waxes to first quarter on the 8th at 4:36 A.M. and to full on the 15th at 11:15 A.M. Our satellite wanes to last quarter on the 23rd at 2:36 P.M. It is new for a second time in December on the 30th at 10:12 P.M.

In January the Moon waxes to first quarter on the 6th at 1:56 P.M. and then to full on the 14th at 4:48 A.M. It wanes to last quarter on the 22nd at 10:14 A.M. and to new on the 29th at 9:15 A.M.

The Geminid meteor shower is one of the best annual showers. It is so named because the meteors appear to come from the constellation Gemini, the twins, which rises in the eastern sky during the evening. This year, however, a nearly full Moon during the predicted peak of the display—on the night of December 13–14—could make the shower hard to see. Try looking two nights before the peak, when there are short moonless intervals just before dawn.

A celestial holiday gift arrives on Christmas morning for those living in parts of the Pacific Northwest and the northern Rockies: the waning crescent Moon occults, or passes in front of, Spica. The star disappears along the Moon's bright limb, then pops back into view along the dark limb. In Seattle, Spica disappears at 5:21 A.M. Pacific standard time and reappears at 5:45 A.M. In Great Falls, Montana, the occultation begins at 6:16 A.M. mountain standard time and ends an hour later. Elsewhere, the Moon either barely misses Spica or the occultation takes place after sunrise.

The solstice takes place at 1:35 P.M. on December 21, ushering in winter for the Northern Hemisphere and summer for the Southern Hemisphere.

Earth reaches perihelion, its closest point to the Sun, on January 4 at 11 A.M., when our planet comes within 91.4 million miles of the Sun.

Unless otherwise noted, all times are given in eastern standard time.

 (Continued from page 12)

ception that volcanic explosions caused the destruction of the summit and the northern flank of Mount St. Helens. The dominant process was actually massive landsliding.

The new study of the 1888 collapse contributes to the understanding of the impacts that the collapses of much larger oceanic volcanoes could cause.

Wrong Poison

In his article "Toxic Treasure" [10/05], Robert George Sprackland writes that tetrodotoxin "also turned up in the feathers of two genera of birds. . . . The source of the toxin turned out to be bacterial." My doctoral research focuses on those two genera; the birds carry batrachotoxin, not tetrodotoxin, a very different chemical. Tetrodotoxin is produced by various organisms, including bacteria, but there is no evidence that bacteria produce batrachotoxin. In fact, no one yet knows where the birds get their toxins.

Daniel Levitis
Berkeley, California

Robert George Sprackland replies: Daniel Levitis is correct: the toxin that occurs in the two bird genera is batrachotoxin, which is commonly found in the skin of some Central and South American frogs. My main point remains, nonetheless, that many toxins can be found across a very broad and disparate range of creatures.

Stormy Waters

I was intrigued with Laurence A. Marschall's review [10/05] of *The Great Hurricane: 1938*, by Cherie Burns. I experienced that hurricane from the relatively safe confines of Watertown, Massachusetts, and I have studied many accounts of the storm.

Mr. Marschall states that a high-pressure system from the north caused the hurricane to stall. In fact, the hurricane accelerated as it approached Long Island, traveling at more than sixty miles an hour when it made landfall.

John R. Moyer
Sedgwick, Maine

Cherie Burns replies: John R. Moyer is correct in pointing out the error in the book review. I did not write in my book that the hurricane "stalled"; instead, I wrote, it gained speed and intensified throughout its assault on the eastern seaboard. Its ferocity grew even as it swept across Long Island and roared on to the Connecticut and Rhode Island mainland.

The Next Big One

I happened to pick up the February 2005 issue, and as I read Shea Penland's article, "Taming the River to Let In the Sea," I was amazed by its timeliness and accuracy. Six months after its publication, Mr. Penland's dire predictions—that a big storm could wipe out New Orleans's defenses—came true.

Mr. Penland points to the compression, and consequent subsidence, of the delta plain as a critical factor in the increasing vulnerability of New Orleans to flooding. As a structural and site engineer, I am intrigued that as recently as the 1930s, levees were being built on self-compressing silt, a poor foundation for such a critical defense system. Dams, sea walls, and levees must be founded on firm base material, preferably bedrock.

Now I am concerned that the levees are not being rebuilt according to proper engineering standards. The breaches in the levees are being closed with material that, once again, rests on self-compressing silt.

Vincent A. Ettari
Shrub Oak, New York

Shea Penland replies: New Orleans and southeastern Louisiana underwent unprecedented devastation and extreme changes to their coasts as a result of hurricanes Katrina and Rita. And the impacts of these storms on the Mississippi River delta are still being uncovered. The barrier islands are massively eroded, and chunks of marsh litter the coast.

What can we learn from these storms? People must learn to coexist with our coasts, live in practical areas, and, where feasible, build the necessary defenses to stormproof our society. To minimize future storm risks, coastal restoration and the rebuilding of the hurricane protection system must be integrated.

Misplaced Madison

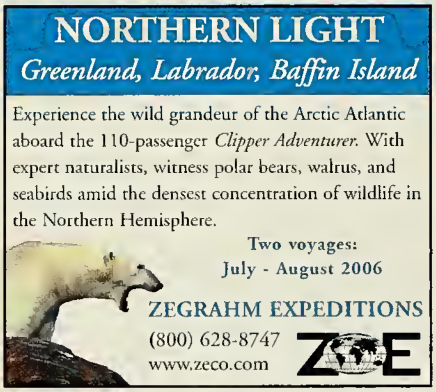
Robert H. Mohlenbrock may know *This Land* ["Where Glaciers Did Not Tread," 10/05], but the map that accompanied his article misplaced Madison, Wisconsin by about 100 miles.

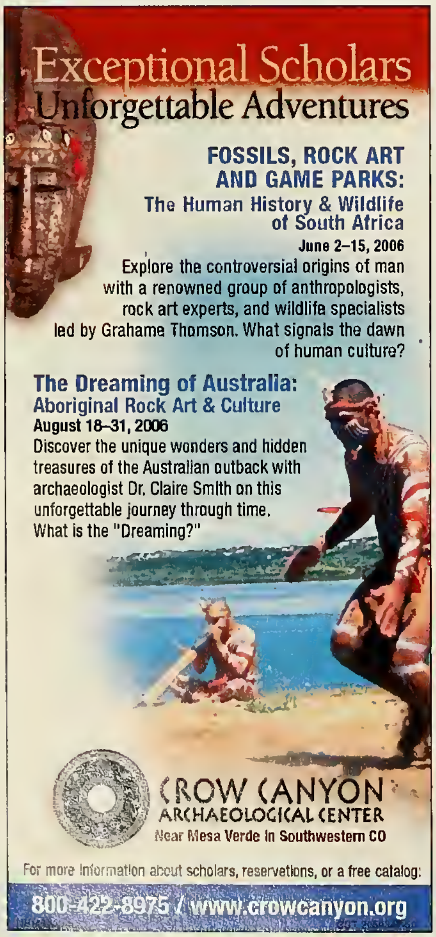
Matthew J. Courchane
Greendale, Wisconsin

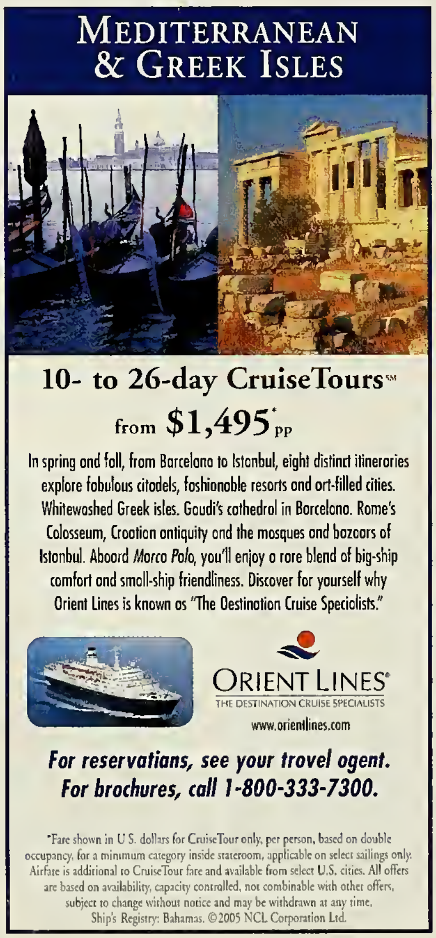
The editors reply: Matthew Courchane is correct, but the error was ours, not Mr. Mohlenbrock's.

Natural History *welcomes correspondence from readers* (nhmag@naturalhistorymag.com). *All letters should include a daytime telephone number, and all letters may be edited for length and clarity.*

EXPLORER GUIDE







EXPLORER GUIDE

Darwin

Darwin, the most in-depth exhibition ever mounted on this highly original naturalist and his theory of evolution, will remain on view at the Museum through May 29, 2006. It will offer visitors a comprehensive, engaging exploration of the life and times of Charles Darwin, whose discoveries, observations, and insights in the 19th century forever changed the perception of the origin and nature of our own species and launched—and remain central to—modern biological science. *Darwin* is the latest in a series of exhibitions the Museum has developed on great thinkers, explorers, and scientists such as Leonardo da Vinci, Ernest Shackleton, and Albert Einstein.

"This exhibition features the greatest collection of Darwin artifacts, specimens, and memorabilia ever assembled," said Niles Eldredge, Curator in the Museum's Division of Paleontology and curator of *Darwin*. "We have specimens Darwin collected on the *Beagle* reunited for the first time since the 1830s with some of his diaries full of notes and analyses of them. We will have critical correspondence, notebooks, and manuscripts revealing the development of Darwin's evolutionary ideas and his agony as he kept his ideas secret from a sure-to-be disapproving public for 20 years."


C. CHESEK/AMNH

Specimens collected by Darwin

Visitors will learn how Darwin arrived at the conclusion—a heretical one at the time—that life on Earth is not static, but changing, and how his theory of natural selection offered a mechanism to explain the production of the amazing diversity of life on Earth. These insights continue to have enormous relevance and importance today as Museum scientists and their colleagues worldwide apply concepts derived from his work to global inventories of life, conservation biology, reconstruction of the evolutionary Tree of Life, and the treatment of diseases ranging from AIDS to SARS.

Highlights of the exhibition include:

- An introduction to Darwin, the man, as well as the significance of his thinking at the time of its emergence and continuing through today. This section features the Darwin family magnifying glass, which the young naturalist likely used to closely examine his surroundings with the habitual curiosity that shaped his life.
- Some of the wonders Darwin witnessed on his five-year voyage on the HMS *Beagle*, which he called the most important event in his life. Visitors will see live Galápagos tortoises and an Argentinian horned frog, reminiscent of the species Darwin studied on his journey. Also on display will be fossils and mounted specimens of the uniquely American modern animal groups he saw, along with actual specimens he collected and some personal items he took with him on the voyage, including his pistol and his Bible.
- A video biography of Darwin, narrated by his great-great-grandson Randal Keynes, author of *Darwin, His Daughter, and Human Evolution*, which will introduce visitors to the political, social, and scientific climates of 19th-century England. The film will retrace Darwin's life via footage shot on location in England, giving insight into the place and time in which he conducted decades of research and wrote many of his 20 books, including the seminal *The Origin of Species*.
- Notebooks and letters charting the development of his thinking, which illustrate his growing reputation in London during those years and the social climate within which he conducted his research. This section will also include specimens critical to the development of his theory, such as the original fossil skull of a hoofed mammal, *Toxodon platensis*, that he collected on the *Beagle* expedition and later discussed with colleagues.


S. QUINN/AMNH

Blue-footed booby

"Since its inception, the American Museum of Natural History has been a pioneer and leader in scientific research that pursues and develops the incredible insights of Charles Darwin and the implications of his theory of evolution," said Michael J. Novacek, Senior Vice Presi-

Darwin (cont.)

dent, Provost of Science, and Curator in the Division of Paleontology. "I'm excited that this exhibition will relate the riveting story of the origins of evolutionary theory that paved the way for the state-of-the-art research that our exceptional curators and scientific staff at the Museum conduct today in the fields of biology, paleontology, and anthropology."

Darwin is the first exhibition to feature an extensive and in-depth array of material related to Darwin's life and works. The exhibition is mounted in cooperation with English Heritage, the organization that administers Down House, Darwin's long-time home; the Natural History Museum, London, one of the primary repositories, along with Cambridge University, of Darwin's writings and many of the specimens he collected during the *Beagle*'s journey; and some of Darwin's living family members. The exhibition is curated by Dr. Eldredge and is designed and produced by the American Museum of Natural History's Department of Exhibition.

The American Museum of Natural History gratefully acknowledges **The Howard Phipps Foundation** for its leadership support.
Significant support for *Darwin* has also been provided by Chris and Sharon Davis, Bill and Leslie Miller, the Austin Hearst Foundation, Jack and Susan Rudin, and Rosalind P. Walter.
Additional funding provided by the Carnegie Corporation of New York and Dr. Linda K. Jacobs.
Darwin is organized by the American Museum of Natural History, New York, (www.amnh.org), in collaboration with the Museum of Science, Boston; The Field Museum, Chicago; the Royal Ontario Museum, Toronto, Canada; and the Natural History Museum, London, England.

K. FREY/CBC/AMNH

A Galápagos land iguana

COSMIC COLLISIONS

NEW SPACE SHOW AT THE HAYDEN PLANETARIUM!

Opens January 14, 2006

On January 14, a new Space Show of cosmic proportions is hitting the Hayden Planetarium Space Theater! Immersed in a dazzling virtual reality simulator, you'll journey into deep space—well beyond the calm face of the night sky—to explore cosmic collisions, hypersonic impacts that drive the dynamic and continuing formation of the universe.

You'll witness the creation of our Moon some five billion years ago when a wandering planetoid struck Earth; the violent meeting of two stars in a dense globular cluster; and the future collision of our Milky Way galaxy with our closest neighbor, the Andromeda spiral galaxy, a cosmic crash that will produce a new giant elliptical galaxy billions of years from now.

Finally, you'll feel the ground shake beneath you as you bear witness to such high-energy events as the meteorite impact that hastened the end of the Age of Dinosaurs millions of years ago and cleared the way for mammals like us to thrive.

PEOPLE AT THE AMNH

Lauri Halderman
Director of Exhibition Interpretation
Department of Exhibition

D. FINNIN/AMNH

Lauri Halderman, Director of Exhibition Interpretation, admits that after months of working on a new exhibition, seeing the words come alive on gallery walls is both exciting and gratifying.

As head of the team that writes the text for all new exhibitions, Lauri collaborates with many different departments to determine not only what story to tell, but also how to tell it. She describes the Museum's exhibitions as "storytelling in three dimensions," and she and her team as the content translators. "We're not the subject-matter experts. We're the 'interface' between the scientific departments and the public." In *Darwin*, for example, the story is largely a human one, and visitors will be put in the shoes of a man who asked good questions and came up with amazing answers.

When she is not spending time with her family, Lauri is completing a master's degree in museum leadership. Before joining the Museum, Lauri worked on designing new museums including a presidential library and the Mashantucket Pequot Museum and Research Center in Connecticut.

After nearly a decade at the Museum, Lauri hasn't lost sight of the most rewarding part of her work: "Seeing kids walk around the Museum, knowing they've come for a big day and that when they go home at night, they'll still be thinking about what they saw here, is really gratifying."

Museum Events

AMERICAN MUSEUM ō NATURAL HISTORY

www.amnh.org

EXHIBITIONS

The Butterfly Conservatory: Tropical Butterflies Alive in Winter
Through May 29, 2006
A return engagement of this popular exhibition includes up to 500 live, free-flying tropical butterflies in an enclosed habitat that approximates their natural environment.

Dinosaurs: Ancient Fossils, New Discoveries
Through January 8, 2006
Discover the most current thinking on the mysteries of dinosaurs: what they looked like, how they behaved, and why—or even whether—they became extinct.

Dinosaurs: Ancient Fossils, New Discoveries and its accompanying education and public programs are made possible by **Bank of America.**
This exhibition is organized by the American Museum of Natural History, New York (www.amnh.org), in collaboration with the Houston Museum of Natural Science; California Academy of Sciences, San Francisco; The Field Museum, Chicago; and North Carolina Museum of Natural Sciences, Raleigh.
Major funding has also been provided by the Lila Wallace-Reader's Digest Endowment Fund.

Voices from South of the Clouds
Through March 12, 2006
China's Yunnan Province is revealed through the eyes of the indigenous people, who use photography to chronicle their culture, environment, and daily life.

The exhibition is made possible by a generous grant from Eastman Kodak Company. The presentation of this exhibition at the American Museum of Natural History is made possible by the generosity of the Arthur Ross Foundation.

Vital Variety
Ongoing
Beautiful close-up photographs highlight the importance of the immense diversity of invertebrates.

GLOBAL WEEKENDS

Kwanzaa 2005
Thursday–Saturday, 12/29–31, 1:00–5:00 p.m.
Festivities for the entire family, including performances, workshops, a marketplace, and Kwanzaa culinary delights.

R. MICKENS/AMNH

Microraptor gui appears to fly through the Liaoning Forest diorama.

Living in America: Celebrating Darwin's Voyages
Three Saturdays, 1/14–1/28, 1:00–5:00 p.m.
Performances, lectures, films, and activities introduce visitors to some of the cultures Darwin encountered during his travels.

Global Weekends are made possible, in part, by The Coca-Cola Company, the City of New York, and the New York City Council. Additional support has been provided by the May and Samuel Rudin Family Foundation, Inc., the Tolan Family, and the family of Frederick H. Leonhardt.

LECTURES

Encyclopedia Prehistorica: Dinosaurs
Sunday, 12/4, 2:00 p.m.
With masters of the pop-up book Robert Sabuda and Matthew Reinhart.

Darwin: Discovering the Tree of Life
Tuesday, 12/6, 7:00 p.m.
With Niles Eldredge, Curator, AMNH Division of Paleontology.

Our Inner Ape
Thursday, 12/15, 7:00 p.m.
With noted primatologist Frans B. M. de Waal.

The Science of Evolution
Thursday, 1/5, 7:00 p.m.
With Douglas Futuyma, Department of Ecology and Evolution, Stony Brook University.

Adventures in the Global Kitchen: Sake
Tuesday, 1/17, 7:00 p.m.
Learn about the history of sake and then sample some.

The Smaller Majority
Tuesday, 1/24, 7:00 p.m.
Get acquainted with the 99% of animal life that is smaller than a human finger.

FIELD TRIPS

Lunchtime Winter Bird Walks
Three Tuesdays, 1/31–2/14 12:00 noon–1:30 p.m.
With Paul Sweet, Collections Manager, Department of Ornithology.

FAMILY AND CHILDREN'S PROGRAMS

DR. NEBULA'S LABORATORY
Planetary Vacation
Saturday, 12/17, 2:00–3:00 p.m.

New! Voyage through the Stars
Saturday, 1/28, 9:30–10:30 a.m.

D. FINNIN AND C. CHESEK/AMNH

Niles Eldredge

DARWIN'S DOGS
Copresented with the American Kennel Club

Darwin and His Dogs
Sunday, 1/22, 12:00 noon–1:00 p.m.

Mapping the Dog Genome
Sunday, 1/22, 2:30–3:30 p.m.

More about Dogs: Ask the AKC
Sunday, 1/22, 3:00–4:00 p.m.

STARRY NIGHTS
Live Jazz

ROSE CENTER FOR EARTH AND SPACE
6:00 and 7:30 p.m.

Friday, December 2
The 7:30 set will be broadcast live on WBGO Jazz 88.3 FM

Friday, January 6

Enjoy jazz and tapas on the first Friday of every month. Visit www.amnh.org or call 212-769-5100 for lineup.

Starry Nights is made possible, in part, by Constellation NewEnergy and Fidelity Investments.

SPACE EXPLORERS

Voyage through the 3-D Universe
Tuesday, 12/13, 4:30–5:30 p.m. (Ages 8 and up)

Telescope Star Party
Tuesday, 1/10, 4:30–5:30 p.m. (Ages 8 and up)

COLLECTION OF THE AMERICAN KENNEL CLUB MUSEUM OF THE DOG, ST. LOUIS, MO

Fox terrier painted by Horatio Henry Couldery

HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME

Virtual Universe
Black Holes and Quasars
Tuesday, 12/6, 6:30–7:30 p.m.

The Grand Tour
Tuesday, 1/3, 6:30–7:30 p.m.

This Just In...
December's Hot Topics
Tuesday, 12/20, 6:30–7:30 p.m.

January's Hot Topics
Tuesday, 1/17, 6:30–7:30 p.m.

Celestial Highlights
Winter Skies
Tuesday, 12/27, 6:30–7:30 p.m.

Short, Small, and Stubby
Tuesday, 1/31, 6:30–7:30 p.m.

LECTURES

Frontiers in Astrophysics
Monday, 12/5, 7:30 p.m.
Visit www.amnh.org/hayden for details.

Roving Mars
Monday, 12/12, 7:30 p.m.
With Steve Squyres, Cornell University.

COURSE

Matter and Motion
14 Thursdays, 1/26–5/11, 6:30–8:30 p.m.

PLANETARIUM SHOWS

SonicVision
Fridays and Saturdays, 7:30, 8:30, and 9:30 p.m.
Hypnotic visuals and rhythms take viewers on a ride through fantastical dreamspace.

D. FINNIN/AMNH

SonicVision is made possible by generous sponsorship and technology support from Sun Microsystems, Inc.

The Search for Life: Are We Alone?
Narrated by Harrison Ford
Made possible through the generous support of Swiss Re.

Passport to the Universe
Narrated by Tom Hanks

LARGE-FORMAT FILMS

LeFrak IMAX Theater
Galápagos explores the unique fauna of the islands and the surrounding sea.
IMAX films at the Museum are made possible by Con Edison.

INFORMATION

Call 212-769-5100 or visit www.amnh.org.

TICKETS AND REGISTRATION

Call 212-769-5200, Monday–Friday, 9:00 a.m.–5:00 p.m., or visit www.amnh.org. A service charge may apply. All programs are subject to change.

AMNH eNotes delivers the latest information on Museum programs and events to you monthly via email. Visit www.amnh.org to sign up today!

Become a Member of the American Museum of Natural History

As a Museum Member, you will be among the first to embark on new journeys to explore the natural world and the cultures of humanity. You'll enjoy:

- Unlimited free general admission to the Museum and special exhibitions, and discounts on Space Shows and IMAX films
- Discounts in the Museum Shops and restaurants and on program tickets
- Free subscription to *Natural History* magazine and to *Rotunda*, our newsletter
- Invitations to Members-only special events, parties, and exhibition previews

For further information, call 212-769-5606 or visit www.amnh.org/join.

Cold Chisel

By Laurie Lawlor

Wind whips across the frozen lake, bends dried cattails, and sends a blast of sharp crystals skyward. It's a three-hat day. I wear ear warmers, a wool cap, and a hood in addition to a vest, coat, scarf, and mittens—and I'm still cold on this fierce grey morning. The skin on my face burns as I shoulder into the wind along the path leading to the stream. Newly fallen snow fills the tops of my boots as I shuffle around the iron-hard tussocks and sedges glistening with white beards. Not far off, the lake mutters in its icy bed. When I look out over the crushed bulrushes, weighted down by snow, I can imagine the glaciers that carved this place.

Slow-moving, massive sheets of ice and snow arranged and rearranged the land in my corner of southeastern Wisconsin. As the glaciers rumbled forward, they gathered up or crushed anything in their path—breaking boulders into cobbles, cobbles into gravel, gravel into sand. When the glaciers melted, they spewed torrents of water and dumped tons of soil, rocks, and debris. Hills, valleys, lakes, and rivers were destroyed, formed, and destroyed again. I'm dizzied contemplating so much creation and destruction—all according to the whims of water and temperature.

The landscape I'm standing in was formed between 25,000 and 14,000 years ago, during the last gasps of the Ice Age. I shut my eyes and try to picture how the terrain might have looked 25,000 years ago. It's a chilling thought. Everything around me would have been buried beneath ice hundreds of feet thick. I shudder and wrap my scarf tighter around my neck.

The most recent glaciation to invade Wisconsin moved south like a six-fingered hand shoved into a too-small mitten. Each finger eased along at a different speed as the glacier thawed, froze, and then pushed forward again over the millennia. When I glance downstream toward the frozen lake, I can hear the low moan and crack of growing ice. What did the glaciers sound like as they sideswiped each other and shoved debris along the surface—debris that included everything from clay, silt, sand, and pebbles to boulders as big as automobiles and blocks of sedimentary rock as vast as football fields? From how many miles away was it possible to hear the glaciers roar and rumble?

The collision of two adjacent glacial lobes—two fingers—helped set the stage for the creation of "my" wetland and its surrounding landscape. As the glaciers receded roughly 18,000 years ago, the lobes began to pull back and apart like the edges of an opening wound. As the ice thawed, a string of partly collapsed, outwashed fans of gravel and debris was left behind. Eventually it became a ninety-mile-long ridge of knobby hills.

This lake and wetland were born from the rushing meltwater of glaciers. The icy torrent formed braided rivers and streams that flowed across the place where I am standing. The raging current redistributed tons of gravel and silt. It dumped a layer of sand more than seventy feet deep. Water scattered rocks that had been smoothed and rounded like birds' eggs.

As time passed, some of the streams dried up. Others coursed along. Chunks of old ice buried deep underground melted slowly over many centuries. Sand and gravel basins gradually became sealed with finer silts. The wind buffeted clouds of dust across an unpromising landscape littered with glacial puddles, icy lakes, and cold, sediment-choked rivers. To the north there was nothing—not a tree in sight—to slow the blast of air from the Arctic.

Left behind was a landscape that seemed too cold, too rocky, and too poorly drained to be habitable. But those very conditions were ideal for creating something amazing: the terrain that would one day become a wetland.

Somehow it seems fitting on this freezing, gusty December morning to think that this snow-covered lake had its genesis as a wayward chunk of ice from a dying glacier.

Laurie Lawlor is the author of thirty-five books for children and adults. This essay is adapted from her book This Tender Place: The Story of a Wetland Year, *published by the University of Wisconsin Press in fall 2005.*