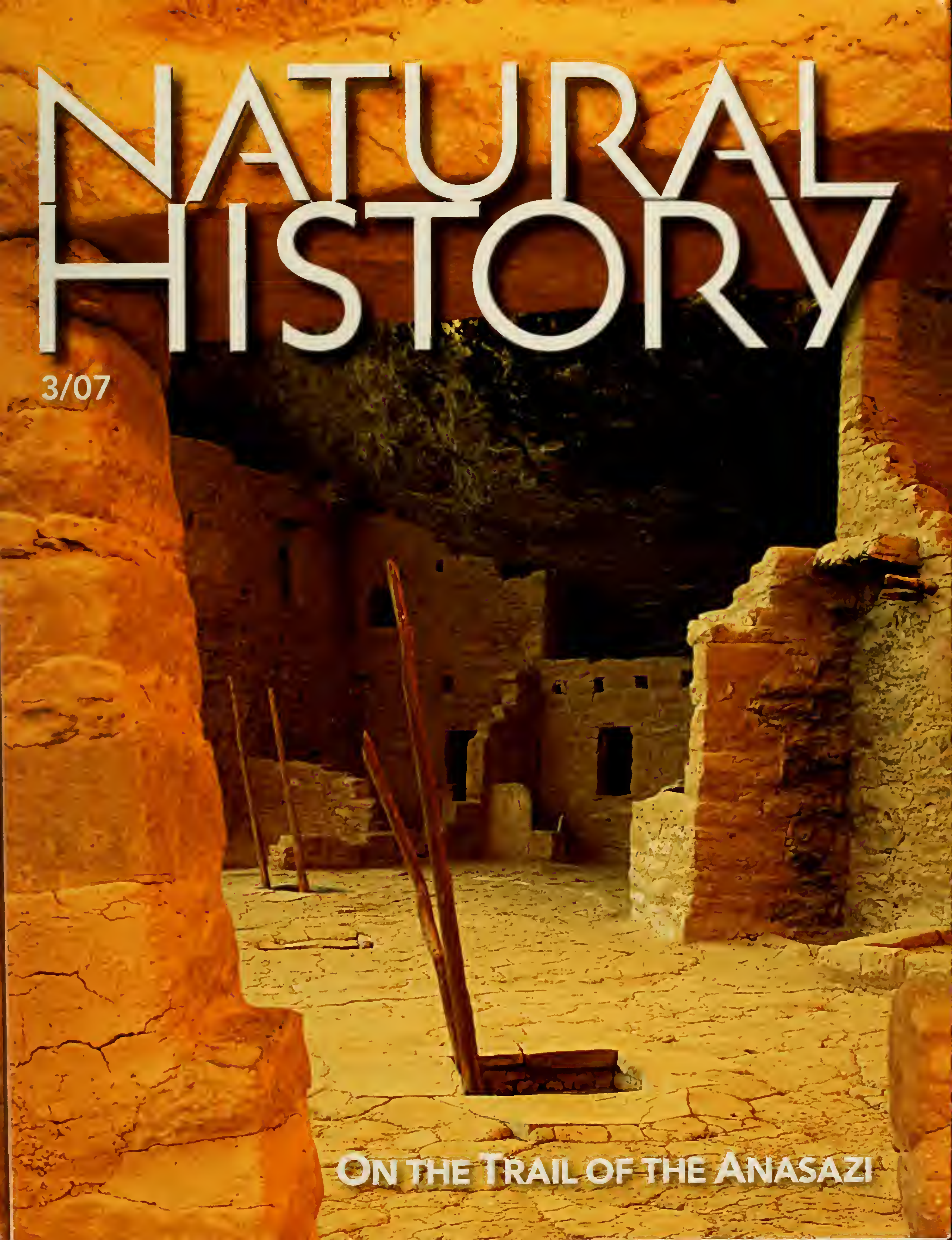
NATURAL HISTORY

3/07



ON THE TRAIL OF THE ANASAZI

NATURAL HISTORY

MARCH 2007 VOLUME 116 NUMBER 2

COMMENTARY

FEATURES

COVER STORY

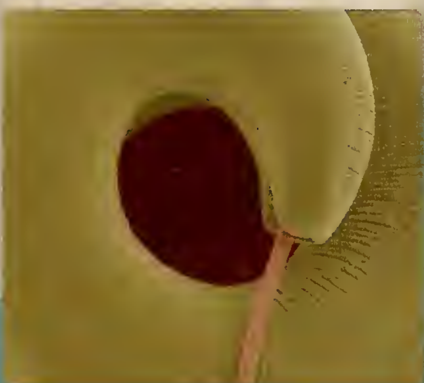
ON THE COVER: Doorway, with kiva and roof entrance, Mesa Verde National Park, Colorado. Photograph by George H.H. Huey

NATURAL HISTORY

4

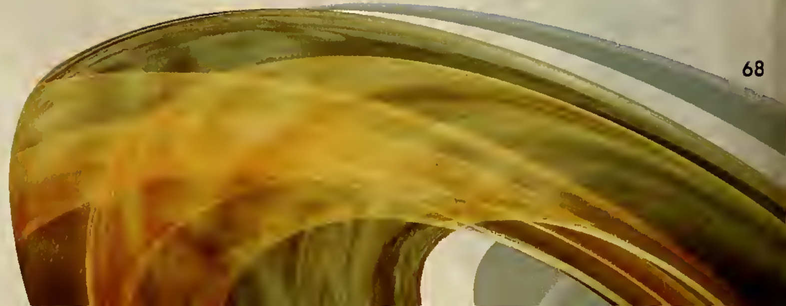
DEPARTMENTS

64



11

36



68

PICTURE CREDITS: Page 8

Visit our Web site at
www.naturalhistorymag.com

THE NATURAL MOMENT

Exit Strategies

Photograph by Tony Martin

THE NATURAL MOMENT

➤ *See preceding two pages*

Even from across a field of sea ice crowded with emperor penguins, Tony Martin was startled when he spotted a lone Weddell seal shoot through what looked like solid ice. Martin, a zoologist with the British Antarctic Survey, began walking toward whatever crack or hole had allowed the seal to emerge from the Ross Sea below. Before he arrived, the seal slid back under the ice, leaving Martin to wait.

The portal proved to be about three feet across, its inner edges serrated from the gnawing of the seals' front teeth, a process known as reaming. In the summer months intense reaming isn't needed, because the ice is thinner and has more natural openings the seals can use to surface. But whether under thick or thin ice, Weddells are far from hindered under water: they can sleep, mate, or, most often, hunt for fish and squid.

On a hunt, Weddells can descend a quarter of a mile under water and hold their breath for more than an hour. On such dives the seals slow their hearts, decrease blood flow, and use oxygen stored in their muscles. Physiologists dream that genes for low-oxygen tolerance might one day help treat people with heart and lung diseases.

Martin experienced the seals' diving stamina firsthand, as he waited at the lip of the hole. After an hour of keeping vigil, he got a big surprise when a 500-pound seal launched itself out of the water "like a missile out of a submarine," and landed on top of him. Fortunately, the next seal to come up for air simply poked out its deceptively petite head. —*Erin Espelie*

UP FRONT

Killer App

Kenneth M. Cameron ("Bar Coding for Botany," page 52) imagines that one day soon, "global flora scanners" will catch bad guys who smuggle endangered plants across international borders. My vision is more benign: You've taken the day off to hike the woods in the early spring. Wet snow still fills the forest with cool, damp air, but the sun is bright, and up ahead, at a break in the canopy, a blossom is bravely forcing the new season. The flower is unfamiliar.

You unclip your handheld GFS unit from your belt. Stoop. Snip. You take a tiny bite of leaf with the hole punch, press "ID" on the keypad, and wait for the Hypernet response. Sure enough, the blossom is a rare, endangered blue-eyed Mary *(Collinsia verna);* no one has recorded the flower in these woods for twenty years. Immoderately pleased by your sharp eyes and good luck, you press "Record"; the system clock marks the time and date, the GPS module remembers the location, and the flower is filed in your personal database. Before you move on, you take a digital photograph of the flower, and dictate a few remarks into the digital recorder.

Behind this new technological magic is one of the most exciting biological projects since the sequencing of the human genome. The project, known as DNA bar coding, is an international effort to create a universal genetic database of life by sequencing short, species-specific regions of DNA from every living species on Earth. Among botanists, Cameron says, the goal is to identify two or perhaps three genes that occur in all plants, yet in combination are distinctive enough from species to species to serve as reliable species markers. Between now and an international meeting this September in Taiwan, of the Consortium for the Barcode of Life (CBOL), Cameron and his colleagues in the Plant Working Group are seeking as much peer review as possible before a recommendation is made about exactly which genetic markers will serve as bar codes in the database.

How long will it take to build the database? "Lots of people are chomping at the bit to get into this," Cameron says. The bar codes for the vast majority of land plants could be ready within a couple of years of CBOL's decision, he adds. At the same time, electronics and nanotechnology circles are buzzing about how the relevant bar codes would be "read" in the field. Presumably, Cameron explains, once the plant matter is sampled and dissolved, its DNA would be channeled along micro-etchings on a chip-size glass surface, where a sequence of miniature chemical reactions and embedded logic circuitry would look for the relevant genes. No one knows how long Silicon Valley will need to make a usable product, but given the pace of change, several electronic generations (that is, five or ten years) doesn't seem unreasonable.

• • •

Our regular "Biomechanics" columnist, Adam Summers, reaches a milestone with this issue. His column, "No Bones About 'Em" (page 36), about the advantages of having a cartilaginous skeleton, is his fiftieth for *Natural History.* That's a remarkable achievement for a scientist and professor still young enough to have a seven-month-old child at home. Congratulations, Adam! —PETER BROWN

Legends of Fire Fighting

Average length of fire engine replicas: 5"

1924 AHRENS-FOX PUMPER
The classic Model A had a piston-powered pump which delivered 750 gpm, comparable to an A1 class pump of today.

Get the 1924 Ahrens-Fox N-S-4 for just $3.95

Incredibly detailed die-cast replica.

Hand painted in authentic colors.

SEAGRAVE TYPE-K PUMPER
Featuring cab-forward design, pioneered in the '50s, and the powerful deck-gun used by the County of Kentucky.

1939 BEDFORD This stalwart was especially active in England during the Battle of Britain. This one, from Liverpool, had a 500 gpm pump.

LEYLAND CUB FK7 Built in 1936, the FK7 had an 80 horsepower, 6-cylinder engine, a 49 feet extension ladder and a 750 gpm pump.

1907 SEAGRAVE AC53
Among the first motorized fire-fighting vehicles, the AC53 had a steel ladder, solid rubber tires and a 4-cylinder air-cooled engine.

Precision die-cast models, individually painted by hand.

FIRE! Terrifying blazes in the tall city buildings, devastating fires in remote areas. The need was for power, speed and versatility. And, from the '20s until the present day, the world's greatest auto makers have created innovative designs to deal with these demanding – and often life-threatening – situations.

Today, *The World's Great Fire Engines* brings together the most important trucks which have been re-created in the only officially authorized die-cast collection of its kind. Each classic has been intricately crafted, hand-assembled and hand-painted – so faithful to the original, it has been approved by experts.

Precision miniature reproductions and assured authenticity

Spanning almost a century, *The World's Great Fire Engines* includes the most celebrated machines in the history of fire-fighting from around the world. The 1924 Ahrens-Fox, whose pump could discharge 750 gallons per minute – equal to many modern fire trucks. The Leyland Cub, a life-saving "hero" in World War II London. Even a replica of the 1907 Seagrave AC53 from the L.A. Fire Dept.

These highly-detailed scale replicas capture the power of each original with extraordinary precision. Wheels made of metal and authentic paintwork…ladders, hoses and pumping devices … all reproduced in perfect miniature. Each bears the original operating fire company's insignia.

Each replica is accompanied by a colorful fact sheet containing data about its history prepared by experts. *To house these fact sheets, an attractive binder is provided free for subscribers.* Each collection comes with a certificate of authenticity.

Special Introductory Price: Just $3.95 for the first model!

You will receive the Ahrens-Fox Model A at the special introductory price of only $3.95. Subsequent models in the collection are priced at just $9.95 each…an extraordinary value! With this one-of-a-kind collection you will enjoy the history and excitement that surrounds these incredible machines. To subscribe, you need send no money now. Simply mail the order form today.

www.delpradocollections.com

ORDER FORM • Please mail promptly
Mail to: The del Prado Collection, P.O.Box 688, Holmes, PA 19043

The del Prado collection

YES. Please enter my subscription to *The World's Great Fire Engines Die-Cast Collection*, consisting of 25 models. I need send no money now. Bill me the special introductory price of just $3.95 (plus 95¢ for shipping) for the Ahrens-Fox model and then the regular price of $9.95* each thereafter. I will receive my collection at the rate of two models per month. I may cancel at any time.

*Plus $2.49 each for postage and handling.
NY and PA residents only, add state sales tax

FFT046

Name____________________
PLEASE PRINT CLEARLY
Address____________________
City____________________
State______ Zip__________
Telephone (______)____________

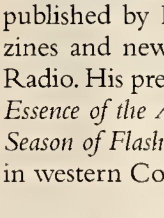
30-day Money-Back Guarantee

CONTRIBUTORS

TONY MARTIN ("The Natural Moment," page 4) is a zoologist with the British Antarctic Survey, specializing in seabirds, seals, and whales. He has spent most of his professional life studying aquatic mammals and birds in the polar regions and in the Amazon. Lenses and a camera in his backpack accompany him on all his fieldwork, ready to capture an image such as this month's Weddell seal. Martin enjoys writing and lecturing about wildlife, and he is completing his sixth book, *Albatross,* which will be distributed in the United States by Voyageur Press.

Born in Bridgeport, Connecticut, **BILL SHERWONIT** ("Bad News for Bears," page 38) is a nature writer who has made his home in Alaska since 1982. He has contributed essays to a wide variety of publications, and he is the author of ten books about Alaska. Since the late 1980s he has visited McNeil River State Game Sanctuary several times, and has written extensively about the sanctuary, McNeil's bears and their protection, and the legacy of Larry Aumiller, who was McNeil's manager for thirty years. His Web site is www.billsherwonit.alaskawriters.com.

KENNETH M. CAMERON ("Bar Coding for Botany," page 52) spends his working hours in the Bronx as Cullman Curator and Director of the Lewis B. and Dorothy Cullman Program for Molecular Systematics Studies at the New York Botanical Garden. In the evenings and on weekends, however, he retreats to a one-room cabin on a lake in the Hudson highlands. His most recent previous contribution to *Natural History* was an article about his research specialty, the evolution and classification of *Vanilla* and related orchids ("Age and Beauty," June 2004). His work has been featured in *The New York Times, The Wall Street Journal,* and on the PBS television series *NOVA*.



A native of the American Southwest, **CRAIG CHILDS** ("On the Trail of the Ancestors," page 58) has long been stumbling across traces of the Anasazi, a prehistoric people who once flourished there. Inspired as well by the work of archaeologists in the region to learn more about the Anasazi, he set out to gather the threads of evidence that would explain their fate. The result is his forthcoming book, *House of Rain: Tracking a Vanished Civilization across the American Southwest,* which is excerpted in this issue and is being published by Little, Brown and Company. Childs's writings appear in magazines and newspapers, and he is a regular commentator for National Public Radio. His previous books include *The Secret Knowledge of Water: Discovering the Essence of the American Desert* (Sasquatch Books, 2000) and *The Desert Cries: A Season of Flash Floods in a Dry Land* (Arizona Highways Books, 2002). He lives in western Colorado with his wife and two young sons.

PICTURE CREDITS Cover: ©George H.H. Huey; pp.4-5: ©Tony Martin/Woodfall Wild Images; p.9: Cartoon by Dolly Setton; p.11(top): The Granger Collection, New York; (middle): ©PHOTOTAKE Inc./Alamy; (bottom): Pierre Guezennec/Naturimages; p.12(top): NASA/ESA/Johns Hopkins University; (middle left):©Franco Banfi/SeaPics.com; (middle right): Richard Field; p.13 (top): ©Rolf Nussbaumer/npl/Minden Pictures; (bottom): ©DOC WHITE/naturepl.com; pp.14-15, 18: ©Art Wolfe/www.artwolfe.com; p.16: illustrations by Ian Worpole; pp.36-37: illustrations by Tom Moore; p.38-39, 41: Larry Aumiller; pp.39 & 59: Maps by Joe LeMonnier; p.40: Bill Sherwonit; p.42: ©Jim Oltersdorf/Accent Alaska; pp.52-53: illustration by Jac Depczyk; p.54: Lawson/EIA/telapak; p.55 (left): Rex Butcher/Garden Picture Library; (middle): Densey Clyne/Garden Picture Library; (right): Craig Jewell; pp.56-57: illustration by Frank Ippolito; pp.58-59, 60(left), 61(right), & 62: ©George H.H. Huey; pp.61-62: Gene Balzer/Museum of Northern Arizona; p.63: Regan Choi; p.64: Courtesy of the American Museum of Natural History; p.65: Courtesy of the Aldo Leopold Foundation Archive; p.66: Erich Lessing/Art Resource, NY; pp.68-69: DBIMAGE/Brand X Pictures/Jupiterimages; p. 80 (background): ©Alan Collins/Alamy; (top): ©Arco Images/Alamy; (bottom): ©imagebroker/Alamy

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.

Stars and Monuments

Donald Goldsmith's article on the "wandering" of the North Star ["Turn, Turn, Turn," 12/06–1/07] led me wonder, how did that wandering affect the orientation of ancient monuments, such as the Egyptian pyramids and England's Stonehenge, to astronomical features?
Ray Ortiz
Redwood City, California

Donald Goldsmith replies: Orientations would have differed, depending on the ancient builders' goals. The prevailing view about Stonehenge is that it was built primarily to mark sunrise at the summer solstice. To orient the structure, all the ancient builders had to do was note carefully the point on the horizon where the sunrise began its retreat southward. Precession does not affect that point.

In contrast, monuments built to orient toward a particular star would no longer point to that star after a few centuries. Only a complete cycle of precession would restore the original orientation.

A large literature deals with possible astronomical orientations of the pyramids. In my article I oversimplified, at best, in stating that the pyramid builders relied on Thuban as a north star (and I was apparently in thrall to a myth when I believed that a tunnel in the Great Pyramid aligns with it). K.E. Spence, an Egyptologist at the University of Cambridge, has argued that the pyramid builders used a combination of two stars, one on either side of the north celestial pole: Kochab, a bright star in the Little Dipper, not far from Thuban, and Mizar, one of the stars in the handle of the Big Dipper. According to her hypothesis, slight variations in the northward orientation of various pyramids arose from the way precession affected the Egyptian surveyors' ability to determine true north with that method. If so, those variations could help date the pyramids' construction.

Editor's Note: Donald Goldsmith's further reflections on precession and other motions of the Earth in space appear on page 14 ("Ice Cycles").

Soils: Alive!

One statement in Robert R. Dunn's delightful article "Dig it!" (12/06–1/07) deserves clarification. He writes: "When tunnels cave in, animals that are effective diggers can escape. Those that aren't, become part of the soil." Taken literally, that implies that animals and other organisms must be dead before they become part of the soil. But to soil scientists, both dead and living organisms are essential parts of the soil, and particularly of the "biomantle"—the upper layer in which most underground organisms live and dig. They collectively impart a biodynamic to Earth's soil that is probably unique in the universe, and totally unlike, we believe, Martian soil, lunar soil, and the like.
Donald L. Johnson
University of Illinois
Urbana, Illinois

"We don't mind visitors, as long as you don't eat our porridge."

Happy Birthday, Theophrastus

In his article, "Happy Birthday, Linnaeus" [12/06–1/07], Richard Conniff credits Linnaeus with being "the inventor of the system by which every living species gets its two-part scientific name." The actual origin of this binomial shorthand goes back more than 2,000 years, to Theophrastus, the original classifier of plants. When classical Greek knowledge was rediscovered in the fifteenth century, his convenient two-part naming system was revived. Thereafter a succession of botanists used it.
Tom Hoeber
Gold Hill, Oregon

Richard Conniff replies: Although I said in my article that none of the methods advocated in the Linnaean system was completely original, editorial space prevented me from elaborating on the antecedents. So I am grateful to Tom Hoeber for correcting the unintended slight to Theophrastus.

Shark Etiquette

R. Aidan and Anne Martin's amazing article on white sharks ["Sociable Killers," 10/06] prompts me to ask about shark behavior I witnessed on a scuba diving trip in Palau. At a seamount, one shark was hanging vertically in the water over the peak while so-called cleaner fish cleaned it. Off to one side, at the base of the seamount, ten or fifteen other sharks swam in a circle. As soon as the cleaned shark swam away, one shark peeled away from the circle and swam up to be cleaned. We never saw any sign of conflict among the sharks about taking turns. Did size prevent the conflict?
Jennifer McIntosh
Pacific Palisades, California

R. Aidan and Anne Martin reply: Cleaning stations are remarkable places on reefs, where many species of fishes suspend aggression and predation, and each individual waits its turn for tiny cleaners to pick off parasites or dead skin. Many species of sharks and rays queue and take their turn; size seems to have no effect on preferred access.

What intrigues us about Jennifer McIntosh's report is the vertical orientation of the sharks (which were most likely gray reef sharks). Many bony-fish clients adopt unusual postures while they are being cleaned, but sharks typically either lie on the bottom or swim more slowly so that the cleaners can keep up. Because sharks rely on dynamic lift to maintain position in the water column [see "No Bones About 'Em," by Adam Summers, page 36], it is not easy for them to reduce speed; where there are strong currents, it may be easier.

Froggy Went A-Hikin'

In "Living the High Life" [9/06], Kevin Krajick describes the discovery of tadpoles in ponds as high as 17,700 feet in Peru's Cordillera Vilcanota. Assuming they came from lower-elevation ponds, what could have led at least one reproducing pair to ascend to such suicidal heights? And how could they have survived the ascent?

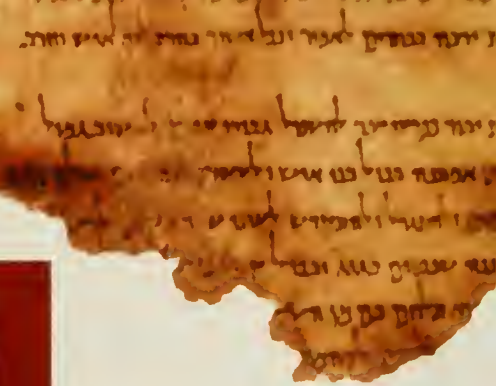
Norm Condit
Staten Island, New York

BIOLOGISTS TRACIE A. AND ANTON SEIMON REPLY: Three species of frog occur in the high alpine watershed of Sibinacocha, a large lake at 16,000 feet: the aquatic *Telmatobius marmoratus,* and two terrestrial species, *Pleurodema marmorata* and *Bufo spinulosus.* We have found the same three species at 17,200 feet in ponds that feed a small stream flowing into the lake. Thus the stream provides a conduit between the lake and the high ponds for all three species. No surface watercourses link those ponds to even higher ponds, and we have not observed *T. marmoratus* (the aquatic species) above that elevation.

In contrast, the two terrestrial species can migrate to higher ponds, and we have observed *P. marmorata* tadpoles at a cluster of small ponds at 17,700 feet. Because reaching those isolated ponds would require arduous traverses, it is plausible that they landed there by other means, perhaps as accidental passengers aboard birds or mammals.

Yet in two visits to the highest ponds we found no adults, which might indicate that adults only migrate to the high ponds seasonally to breed. The high ponds' isolation may reduce the threat of predation for the adults, and the intense midday solar heating may accelerate the metamorphosis of tadpoles into adults. A more speedy metamorphosis would also reduce the tadpoles' chances of being eaten, and enable them to leave the seasonal ponds before they dry out. In any case, no one should assume that these well-adapted species find their environments inhospitable.

Natural History *welcomes correspondence from readers. Letters should be sent via e-mail to* nhmag@naturalhistorymag.com *or by fax to 646-356-6511. All letters should include a daytime telephone number, and all letters may be edited for length and clarity.*



400-Yard Dash

The Dead Sea Scrolls, biblical texts written sometime before A.D. 68, were discovered in 1947 in caves near the ruined settlement of Qumran on the Dead Sea. But who were the scrolls' scribes? Most scholars think at least some of them were members of an ancient Jewish sect called the Essenes who, they argue, lived at Qumran. Newly discovered evidence—of a decidedly worldly nature—bolsters that view.

Two of the scrolls instruct religious adherents to build communal latrines some distance northwest of their city. Furthermore, Josephus, a Jewish historiographer of the first century A.D., wrote that the Essenes were adamant about defecating in "retired spots" and burying their feces. Evidence of buried feces a good distance northwest of Qumran, then, would connect the settlement, the Essenes, and the Dead Sea Scrolls.

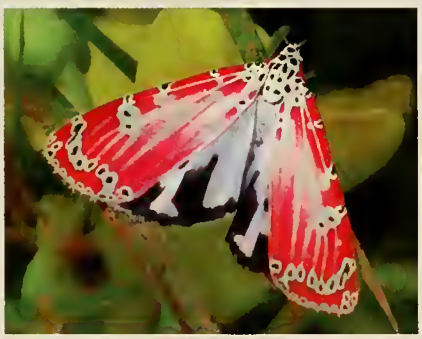
Feces can't normally remain intact in the desert for hundreds of years. But the dead eggs of intestinal parasites can—so long as they are buried and thereby protected from sunlight and wind. A team led by Joe E. Zias, a paleopathologist at the Hebrew University of Jerusalem, sampled the soil in and around Qumran. In only one area did they discover eggs from human intestinal parasites. As predicted, the site was about 400 yards northwest of the village (a nine-minute uphill hike, Zias determined) and hidden from view behind bluffs.

Zias believes that the sect members, their mission accomplished, immersed themselves in a bath on their walk back down to the settlement. That sounds like a healthy practice, but the bathwater was anything but fresh: Qumran relied for water on runoff collected during a brief annual rainy season. Skeletal remains indicate a population in extremely poor health, possibly because disease-causing organisms were repeatedly carried from toilet to bath, where they flourished and infected new hosts. *(Revue de Qumran)* —*Stéphan Reebs*

Fragment of Dead Sea Scroll (above); whipworm (left), an intestinal parasite, magnified 25X

Scent of a Moth

Female moths of the species *Utetheisa ornatrix* boost their chances of attracting a mate by pumping out sex pheromones in unison—the olfactory equivalent of chorusing frogs—according to new research. Hangkyo Lim and Michael D. Greenfield, both behavioral ecologists at the University of Kansas in Lawrence, tested females in the laboratory to find out whether they adjust their chemical signaling in the presence of other females. Females housed in groups began releasing pheromones sooner and continued to signal longer and with fewer interruptions than did isolated females. They also appeared to signal more vigorously: the group-housed females pumped their abdomens more rapidly, a behavior thought to enhance the release of pheromones.



Utetheisa ornatrix: *girls compete for boys*

Until now, biologists had described sexual communication in moths largely as a straightforward interaction between signaling females and responsive males, which fly upwind toward the source of the pheromones they detect. Lim and Greenfield's findings, however, show that female *U. ornatrix* moths also keep track of what their competitors are doing, suggesting that the story in that species is more complex.

Unlike the males of most other moth species, *U. ornatrix* males mate infrequently compared with females, because it takes the males several days to produce a spermatophore—a kind of insect prenuptial gift that carries nutrients, toxins to ward off predators, and sperm. That valuable gift entices females to mate multiple times, another behavior unusual in moths. Those quirks lead to a circumstance fairly uncommon in nature: the sexually receptive females outnumber the males. Lim and Greenfield suspect that the competitive signaling behavior of *U. ornatrix* females stems from the surplus. *(Behavioral Ecology)* —*Nick W. Atkinson*

The Chemistry of B.O.

Everyone has a special smell, often recognizable to other people and to dogs. New research, the most comprehensive study of human odor to date, shows that body odor is made up of a diverse array of volatile compounds. One's own distinctive scent, moreover, comes from a personalized blend of those chemicals.

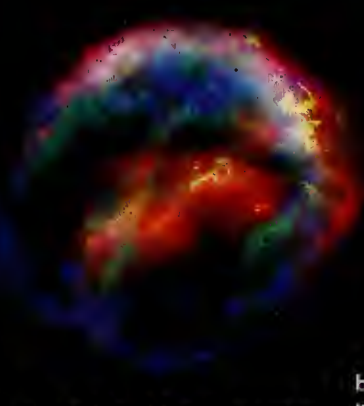
A team led by Dustin J. Penn, an evolutionary and behavioral ecologist at the Konrad Lorenz Institute for Ethology in Vienna, collected samples of saliva, armpit sweat, and urine from nearly 200 people living in an Austrian village. Sweat, the team discovered, includes the greatest number of volatile compounds; the team counted 373 such compounds that subjects consistently produced throughout the ten-week study.

Each person produced his or her own subset of the compounds. The subsets overlapped, yet individuals were readily distinguishable. Unsurprisingly perhaps, men and women tended to produce different mixtures—though no single compound differentiated the sexes. The study provides a new method for measuring a person's baseline odor. Because body odor can change with the onset of illness, the method could lead to new ways of diagnosing disease. *(Journal of the Royal Society Interface)* —*S.R.*

Cosmic Rain

Cosmic rays—charged particles emitted by supernovas and other highly energetic sources in space—continually strike the Earth's atmosphere. Most scientists, however, had assumed they could have little effect on terrestrial life. Then last year, Henrik Svensmark, a physicist at the Danish National Space Center in Copenhagen, published experimental evidence that cosmic rays could increase the formation of cloud droplets, with obvious implications for climate and thus for life. Now another study by Svensmark reveals a remarkable link between cosmic rays and the stability of biological productivity on Earth.

Two main factors, Svensmark assumes, have accounted for most of the changes in Earth's cosmic-ray exposure through geological time: the amount of shielding from cosmic rays afforded by the Sun's magnetic field, and the rate of supernova formation throughout our Milky Way. Svensmark estimated the Sun's shielding by studying other sunlike stars for clues to our star's history, and the supernova rate from straightforward astrophysical records. He also estimated changes in Earth's biological productivity through time by



Hot gas cloud from a supernova, a cosmic-ray source

measuring the ratio of the isotopes carbon-13 to carbon-12 in ancient sediments. Life processes, such as photosynthesis, preferentially use carbon-12, so the higher the relative amount of carbon-13 left behind in sediment, the greater Earth's biomass must have been when the sediment was deposited.

Svensmark discovered that when cosmic rays were most intense (between 2 billion and 2.5 billion years ago, for instance), life was particularly unstable: periods of high productivity alternated with leaner times. Thus a surprising connection exists between distant supernovas and life on Earth: intense cosmic rays appear to cause climate fluctuations that bring on alternating periods of feast and famine. *(Astronomische Nachrichten)* —*S.R.*

Double Trouble

Small fish on the coral reefs of the Red Sea face danger from all directions. Swimming in open water increases their chances of lethal encounters with hungry groupers, but hiding in a crevice exposes them to giant moray eels. It gets worse: a new study shows that the little fish's pursuers are in cahoots.

Redouan Bshary, a behavioral ecologist at the University of Neuchâtel in Switzerland, and three colleagues discovered that groupers shake their heads in a distinctive way to invite moray eels to leave their lairs and join the search for prey. The predators then set off together to patrol the reef; the eel sneaks through the rocks while the grouper waits to intercept fleeing prey. Similarly, the team found, if a grouper hunting solo chases its target into an inaccessible coral fissure, it sometimes gives a slightly different headshake to mobilize a nearby eel.

Hunting buddies: grouper (above) and giant moray eel (right)

Cooperative hunting between species had previously been noted only in humans hunting with dogs or dolphins. Even cooperative hunting among members of the same species is limited to a handful of mammals and birds, animals with relatively strong cognitive abilities. But Bshary's study shows that the active collaboration between groupers and eels increases hunting success—for the groupers, at least—by as much as a factor of five. Once caught, prey are never shared, but Bshary's group thinks the selfishness is actually the key to success because it eliminates competition for the kill. So long as both species benefit from the arrangement in the long run, it doesn't matter which hunter happens to catch a particular fish. *(PLoS Biology)* —*N.W.A.*

Basso Profundo

Blue whales, the biggest creatures on Earth, have the deepest voices: most of their vocalizations are pitched far too low for people to hear. Their songs repeat a series of eerie tones, blips, and creaks and may carry on for hours or even days. To human ears, the alien, barely audible songs are all but indistinguishable. A new study shows, however, that the leviathans sing several variations on the "blues," each correlated with a particular region of the sea.

Mark A. McDonald, an acoustician at Whale Acoustics, a company in Bellvue, Colorado, and two colleagues examined thousands of sound spectrograms computed from blue-whale songs recorded around the world since 1959. They found they could visually classify the spectrograms into nine distinct groups, each corresponding to a particular geographic region.

Blue whales of both sexes make short calls, but only the males are known to sing, suggesting the songs may enable them to attract mates or advertise their presence to other males. (Under certain conditions their songs can travel thousands of miles, communicating to other whales across vast ocean distances.) If so, each song group may be characteristic of a particular blue-whale population: after all, mating calls should attract compatible mates.

Songs, McDonald's team proposes, could become a convenient, noninvasive, low-cost way for biologists to keep track of blue-whale populations and subspecies—though distinguishing animal groups by their behavior instead of their physical or genetic characteristics remains controversial. *(Journal of Cetacean Research and Management)*

—*Rebecca Kessler*

Warm Down, Cool Up

Many satellites orbit Earth in the thermosphere, between sixty and 500 miles above the surface. Air is pretty thin up there, of course, but in the long run it's enough to make satellites slow down and fall to a lower orbit, a phenomenon known as orbital decay.

Orbital decay has been less pronounced in recent years, and that can mean only one thing: the thermosphere is thinning, which in turn means it's cooling. Here's where the story strikes closer to home. By burning fossil fuels people have been releasing ever more greenhouse gases—carbon dioxide (CO_2), in particular. And though CO_2 warms the lower atmosphere, it cools the thermosphere, because at those rarefied heights it converts the energy of collisions with other molecules to heat that radiates into space.

Liying Qian and Stanley C. Solomon, both atmospheric scientists at the National Center for Atmospheric Research in Boulder, Colorado, and two colleagues have taken advantage of satellite tracking to test a computer model of how the thermosphere responds to input energy. In their model, the investigators calculate how much the thermosphere has cooled in the past thirty years by estimating the contributions of two factors: variations in solar activity (which warms the thermosphere directly) and changing levels of CO_2. They found good agreement between their model and the temperature as measured independently by satellite orbital decay. Their model confirms that CO_2 has indeed cooled the thermosphere, and it predicts a further cooling of 3 percent by 2017.

If the useful lifetimes of satellites depended on physics rather than on budgets, maybe excess CO_2 would be good for something, after all. *(Geophysical Research Letters)* —*S.R.*

Northward Bound

Many bird species in the United States are shifting their breeding ranges northward, a new study shows. Similar northward shifts have been observed in Great Britain, so the cause of both is probably the same. Global warming is the likeliest suspect.

The new study comes from data gathered by the Breeding Bird Survey (BBS), a program run by the U.S. Geological Survey and the Canadian Wildlife Service. Each year, skilled birders spend a summer day driving or walking along more than 4,100 road segments of the U.S. and Canada, identifying the bird species they hear or see along the way. Because the survey has continued uninterrupted since 1966, its data enable ornithologists to analyze long-term population trends.

Alan T. Hitch and his graduate adviser, Paul L. Leberg, a conservation biologist at the University of Louisiana at Lafayette, report that out of twenty-six southern–U.S. species they studied in the BBS records, nine have significantly pushed the northern limits of their breeding ranges northward since the late 1960s. The northward shifts vary from twenty-six miles for summer tanagers to more than 200 miles for great-tailed grackles. At the same time, the northern limits of only two of the twenty-six species, Bachman's sparrows and Bewick's wrens, have retreated southward.

Great-tailed grackle

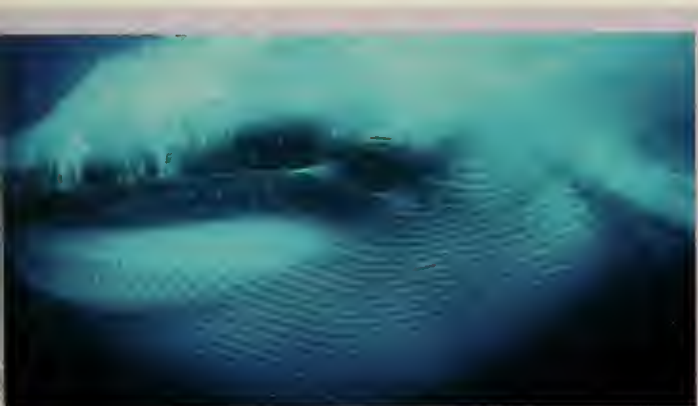
Hitch and Leberg say the diversity of the nine southern species shows they are not being drawn northward by some specific factor in the midlatitudes—more bird feeders, for instance. Nor are their ranges simply expanding. If that were the case, northern species should have expanded their ranges southward, too, and there was no systematic indication of that. Instead, rising temperatures seem to be nudging southern ecosystems northward. *(Conservation Biology)* —*S.R.*

Concrete Evidence

How the ancient Egyptians built the Great Pyramids of Giza nearly 5,000 years ago, using only manpower and copper tools, is one of Egypt's enduring mysteries.

Their most impressive creation, the pyramid of Khufu, stands forty-five stories tall and is made up of some 2 million massive, three-ton blocks, some of which fit together flawlessly.

Most Egyptologists think crews of workers cut the blocks from nearby limestone quarries, carved them with copper chisels, and hoisted them into place with immense ramps, levers, and wedges. But the absence of supporting evidence—no ramps, tools, or limestone waste piles remain—has given rise to alternative, and often controversial, explanations.

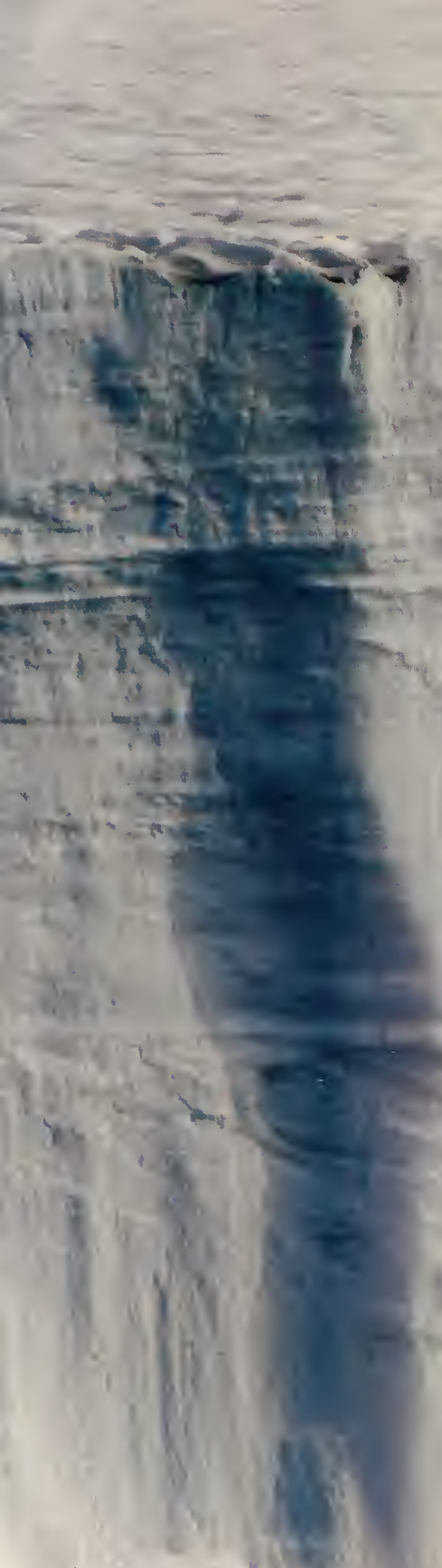


Now Michel W. Barsoum, a materials scientist at Drexel University in Philadelphia, and two colleagues have discovered evidence that could finally settle the issue—though in the meantime it has certainly fueled debate. The team examined samples from two pyramids at Giza and from local limestone formations with an electron microscope and analyzed the samples chemically. Their results support a two-decade-old idea: parts of the Great Pyramids were built not of carved limestone blocks but of concrete casts.

In ancient Egyptian concrete, Barsoum says, limestone particles were mixed with a silica-rich binder. The ingredients could be transported in manageable quantities, then poured on site.

If confirmed, Barsoum's discovery will burnish the already impressive reputation of Egyptian builders: they would get credit for inventing concrete. And their recipe may point toward a clean, inexpensive, long-lasting substitute for portland cement, which is widely used today but highly polluting. *(Journal of the American Ceramic Society)*

—*Graciela Flores*



PERSPECTIVES

Ice Cycles

Long-term fluctuations in ocean temperatures lend support to Milutin Milankovitch's theory of climate change. But can his theory account for the ice ages?

By Donald Goldsmith

People at war rarely focus on theories of climate change. During the first half of 1941, while the Second World War was raging in Europe, a little-known Serbian engineer and mathematician published a book about ice ages. Milutin Milankovitch was then living in the Yugoslav capital, Belgrade, shortly before the Nazis invaded the country. In his book, translated as *Record of Radiation on Earth and Its Application to the Problem of Ice Ages,* Milankovitch strove to connect the cycles of ice ages on Earth to small changes in our planet's motions in space. The world wasn't listening, arguably for good reason.

Historical bad luck caused Milankovitch's book to appear at the wrong time, in the wrong place, and in the wrong scholarly language. At first his book made little impression on climate scientists in England and the United States, where most of the action was in climatology. Several decades passed before many investigators took his ideas seriously, and several decades more before they had amassed enough data to verify that his planetary-motion cycles seem to agree with the overall record of climate change on Earth during the past few hundreds of thousands of years.

Yet today, as climate change caused by human activities is being recognized as one of the most pressing problems of our age, long-range climate studies of all kinds deserve scientific attention. And because the Milankovitch cycles in Earth's climate record appear to be real, they merit a closer look, if only to understand how to factor them into or out of predictions of what will happen climatically in the next few decades.

The concept of a linkage between periodic changes in the Earth's motions and the alternation of ice ages with warmer periods originated with James Croll, a Scottish amateur astronomer active during the third quarter of the nineteenth century. Although Croll lacked the more exact knowledge that later calculations would provide, he perceived that the Earth changes its orientation and orbit over periods of tens or hundreds of thousands of years, roughly the time (as then estimated) between ice ages. Milankovitch seized on Croll's ideas, performed extensive calculations of the changing amounts of solar heating that the cycles would produce, and claimed to have demonstrated a correlation between those celestial variations and changes in the Earth's climate.

Milankovitch concluded that the true causes of ice ages reside in the effects arising from periodic changes in three quantities that describe the Earth's motions in space. Those three quantities, each varying according to its own schedule, are: the angle by which our planet's rotation axis tilts from being perpendicular to the plane of the Earth's orbit around the Sun; the "eccentricity," or amount by which the orbit deviates from perfect circularity; and the timing of the seasons with respect to the point on the

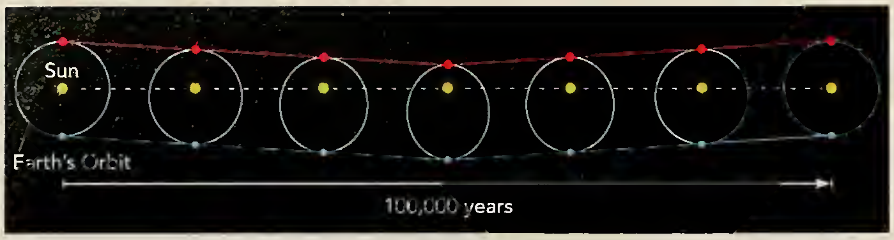
Earth's orbital path closest to the Sun, which slowly changes because of the precession, or wobble, of the Earth's rotation axis. All three changes arise from the gravitational effects of other planets in the solar system, among which Jupiter, by far the most massive, has the greatest effect.

An understanding of the possible effects of those changes on the Earth's climate begins with the ways in which they can affect the rhythm of the seasons, the cycle that causes the most fundamental, and the most obvious, variations in the Earth's climate. The cycle of the seasons arises from the tilt of our planet's rotation axis. Because the axis points in nearly the same direction in the sky (currently almost toward the star Polaris) throughout the Earth's yearly orbit, the tilt of the axis alternately exposes the planet's Northern and Southern hemispheres to more direct sunlight as the year progresses. As of the year 2000 this tilt was 23.44 degrees.

The first of Milankovitch's cyclical changes is a small oscillation in the tilt of the Earth's rotation axis. Over a period of approximately 40,000 years, the tilt varies between 21.5 and 24.5 degrees, with an average slightly less than its current value [*see lower diagram on next page*]. When the tilt gets smaller—and that's the current trend, which will continue until about the year 11,800—the difference between summer and winter in each hemisphere becomes less pronounced. The contrast makes little difference in the tropics, but at higher latitudes a smaller tilt leads to cooler summers and warmer winters. Cooler summers bring less melting of high-latitude snowfall, and that effect overshadows any reduced snowfall resulting from warmer winters. Hence the declining tilt tends to favor the onset of ice ages.

The second of Milankovitch's cycles deals with the eccentricity of the Earth's elliptical orbit. Eccentricity measures how much the shape of an ellipse deviates from being a perfect circle. The eccentricity of a circle is zero; as the eccentricity of an ellipse rises toward 1, the ellipse becomes progressively more elongated. (Formally, the eccentricity is equal to the distance between the two foci of the ellipse, divided by the length of the long axis.) All the planets of the solar system with the exception of Mercury (and Pluto, if you still count it as a planet) have orbital eccentricities less than 0.1. For the Earth's orbit, the eccentricity varies between 0.005 and 0.058, (with a current value of 0.017) [*see upper diagram on next page*]. The complete cycle takes about 100,000 years.

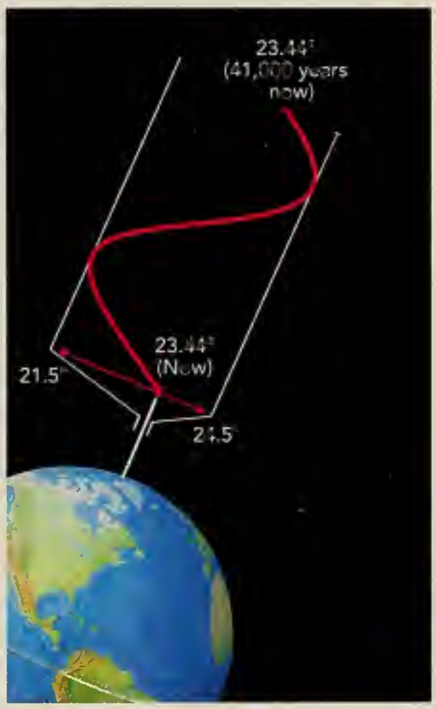
Although the changes in the Earth's orbital eccentricity do not alter the length of the year, they do change the distances to the Sun from the closest and most distant points along the Earth's orbit. The annual variations in the Earth–Sun distance are small—and they certainly don't cause the seasons—but they do have a marginal effect on the amount of solar heating received on Earth at various times of the year. Consequently, the changes in eccentricity produce subtle, but no-



Eccentricity of the Earth's elliptical orbit (its deviation from circularity) around the Sun changes periodically over a cycle of 100,000 years. At certain points in the cycle the orbit can barely be distinguished from a circle, but at others the orbit becomes more elongated (a change that is exaggerated here for clarity). The changes in shape cause small variations in the amount of solar heating on Earth.

ticeable, changes in the strength of the seasonal variation on Earth.

The third of Milankovitch's cycles arises from the combined effects of two kinds of precession. The first is the precession of the Earth's rotation axis, a slow wobble of the imaginary line through the Earth's north and south poles that extends against the sky. The wobble causes that line to trace a circle on the sky once every 26,000 years [*see "Turn, Turn, Turn," by Donald Goldsmith, December 2006/January 2007*], and so it slowly changes where the seasons fall with respect to the Earth's position in its orbit. For example, the summer solstice in the Northern Hemisphere now takes place when the night sky looks as it does on about June 21. But because of the precession of the axis, that solstice will arrive slightly "earlier," with respect to the stars, with each succeeding year.



Tilt of the Earth's rotation axis is responsible for the annual cycle of the seasons. The axis currently makes an angle of about 23.44 degrees from the perpendicular to the plane of the Earth's orbit around the Sun, but the amount of tilt regularly cycles to and fro over a period of 41,000 years. The variation is greatly exaggerated here for clarity.

The second kind of precession is vaguely reminiscent of an incredibly slow hula hoop gliding around the Sun. Astronomers call the hula-hoop motion "orbital precession"; it causes the Earth's perihelion, the point along our planet's orbit closest to the Sun, to slide around the Sun at a rate of about once every 110,000 years. The Earth now reaches perihelion in early January. But its orbital precession moves the perihelion in the direction opposite to that of the tilt-induced precession of the seasons. So the Earth reaches perihelion a few days "later," with respect to the stars, with each passing millennium.

The combined result is to speed up the rate at which the seasonal milestones are moving along the orbit with respect to the perihelion. The full cycle of the precession of the seasons through the perihelion is not 26,000 years—one cycle of the precession of the axis—but rather 21,000 years. That combined motion is the third of Milankovitch's cycles.

How could that third cycle make a difference to the Earth's climate? The difference arises from the fact that the Northern Hemisphere has far more land than the Southern, and land masses react much more rapidly to temperature changes than oceans do. As a result, subtle differences in the yearly cycle of solar heating arise from having first one, then another, hemisphere closer to the Sun during a particular season. Since the Earth now makes its closest approach to the Sun in the northern winter, and is farthest from the Sun in the northern summer, both winters and summers are somewhat milder in the Northern Hemisphere than they are in the Southern. The more severe seasonal swings of solar heating in the Southern Hemisphere, however, are mitigated by the temperature-stabilizing oceans.

At a time a bit less than halfway through the 21,000-year cycle, in about the year 11,700, the combined effects of orbital precession and the precession of the axis will bring the Earth closest to the Sun on the summer solstice in the Northern Hemisphere. Then the extremes of temperature will be hemispherically reversed. Winters and summers in the Northern Hemisphere will become more extreme, and those effects will be amplified by the temperature-sensitive landmasses. Meanwhile, the seasonal swings of solar heating in the Southern Hemisphere will be milder, and made milder still by the climatic inertia of the Southern Ocean. Overall, the differing proportions of land and ocean in the two hemispheres can subtly amplify or dampen how the precessional changes modify the Earth's seasons.

In short, three cycles, recurring approximately every 40,000, 100,000, and 21,000 years, could periodically alter the solar radiation that reaches various places on Earth. All three result from the combined motions of the Earth, Sun, Moon, and planets, as they tug at one another in a gravitationally induced ballet. Milankovitch's great question can now be explored: What do these three cycles imply for the Earth's climate?

If climatologists possessed a complete record of all climate change on our planet—temperature, rainfall, sea level, cloud cover, and other factors—they could, with an appropriate computer program, determine whether significant changes take place in sync with any or all of the three Milankovitch cycles. In reality, only partial and often uncertain records exist, primarily of the history of temperature changes in the world's oceans.

The most useful tool for obtaining the history of temperatures comes from the fact that oxygen atoms occur primarily in two isotopic forms, oxygen-16 and oxygen-18. Oxygen-16 is the commoner and lighter of the two, so when it binds with two hydrogen atoms in a water molecule, that molecule more readily evaporates. By contrast, when the heavier isotope, oxygen-18, forms a water molecule, it tends to fall as rain or snow more readily out of the sky.

Those differences become more pronounced as temperatures decrease. By the time water evaporated from the oceans is carried by the atmosphere to the cold, polar regions, it arrives deficient in oxygen-18. In a complementary way, seawater grows richer in oxygen-18, compared with oxygen-16, at lower temperatures.

Paleogeologists who seek to reconstruct the history of the oxygen isotopes in ice have secured mile-long ice cores from Antarctica, whose water molecules hold abundant oxygen. They have also measured the changing abundances of oxygen isotopes in the fossils of miniature creatures called foraminifera, whose shells incorporate the oxygen atoms from the water that the creatures inhabited. Sedimentary layers of rock sprinkled with fossils of foraminifera record the history of oxygen in the oceans.

With that data in hand, all that remains is to assign dates to the manifold layers in the ice cores (recorded in the seasonal alternation between greater and lesser snowfall) and in sedimentary rocks. The changing relative abundances of the oxygen isotopes in each layer can then reveal how ocean temperatures have changed with the march of time. By now, investigators have laboriously counted through the past few thousand years of ice cores and estimated the dates for even older ones.

To peer even farther back in time, paleogeologists date sedimentary rock layers, relying primarily on the history of reversals in the polarity of the Earth's magnetic field. That history has been independently determined from studies of other rock layers that record the same magnetic reversals, whose ages have been determined by radioisotope dating. By comparing ice cores and sedimentary layers from various places around the world, paleogeologists can verify that they are measuring global rather than local changes in climate.

Ice cores take the history of the Earth's temperature back through most of the past million years; the foraminifera in sedimentary rocks provide less accurate but still highly useful data back about 200 million years ago. Other techniques add to those results. For example, the geologists Paul

E. Olsen and Dennis V. Kent of Columbia University's Lamont–Doherty Earth Observatory in Palisades, New York, have reconstructed the history of rainfall changes over continental landmasses, supplementing the isotopic data for rainfall changes over the oceans. They discovered that the sedimentary records from ancient lake beds can serve as rain gauges, because dry and wet epochs left sediments of differing colors. Rainfall records in lake sediments, which stretch back 235 million years, offer the chance to find cyclical changes that should correlate with the temperature changes measured from ice cores and sediments.

In an ideal world, those approaches would combine to yield an unambiguous answer to the question of how much the changes in solar heating from each of Milankovitch's three cycles—tilt, eccentricity, and precession—affect the Earth's climate. In practice, the "signal" of any such effects, if it exists, is buried in the "noise" of the incomplete and imperfect climate record. To find any such signal, investigators rely on statistical methods, but the challenges are formidable. To their credit—and in accord with the finest traditions of science—the difficulties have not stopped them from making the attempt.

So far as climatologists can now discern, the prize for best-demonstrated Milankovitch cycle goes to the 100,000-year eccentricity cycle. That cycle—at least for the past million years—correlates best with the history of temperature changes. The other two, the 40,000-year and 21,000-year cycles, also appear in the temperature record, but with less certainty. To add to the confusion, when climatologists look back through the much longer, though less well established, record of the past few hundred million years, they find that this statement no longer holds true. Instead, a 400,000-year cycle of variation in eccentricity—a complication I had hoped to spare the reader—appears dominant.

Those results illustrate the basic challenge that climate scientists face: to understand, and thus to predict, whether climate will change, and by how much, as a result of the various influences on our planet. "Climate is the ultimate black box," Kent likes to say—meaning that climate experts still can't calculate the details of climatic "output" from "inputs" such as solar heating.

For example, the study of global warming in the past few decades has made climate scientists all too well aware that tremendous feedback effects can arise from even small changes in the amounts of greenhouse gases in the atmosphere. Consider methane: predicting its rise or fall in the atmosphere is a daunting task. The reason is partly that its sources are as diverse as bacteria in rice paddies and the digestion of bovines, and partly that it is such a strong greenhouse gas: twenty times as efficient as carbon dioxide at trapping heat from the Earth's surface in the atmosphere. Given such difficulties in understanding the present-day climatic effects of methane, reconstructing the methane budget of a million or a hundred million years ago seems nearly impossible. The connection between small changes in solar heating on Earth and the climate changes that they may induce remains a puzzle largely unsolved.

Given the difficulties of understanding present-day climate effects, reconstructing what affected climate a million years ago seems nearly impossible.

Similarly, even though the reality of the Milankovitch cycles seems well established, climatologists still don't understand exactly how our cosmic habitat affects our climate. Milankovitch's hypotheses stands in a position analogous to that of Alfred L. Wegener's "continental drift theory" in 1960, half a century after Wegener proposed it. At that time, the evidence for continental motions seemed intriguing (and had been noticed before Wegener proposed his theory). Once earth scientists realized that seafloor spreading can explain how and why the continents move, Wegener's theory gained relatively rapid acceptance.

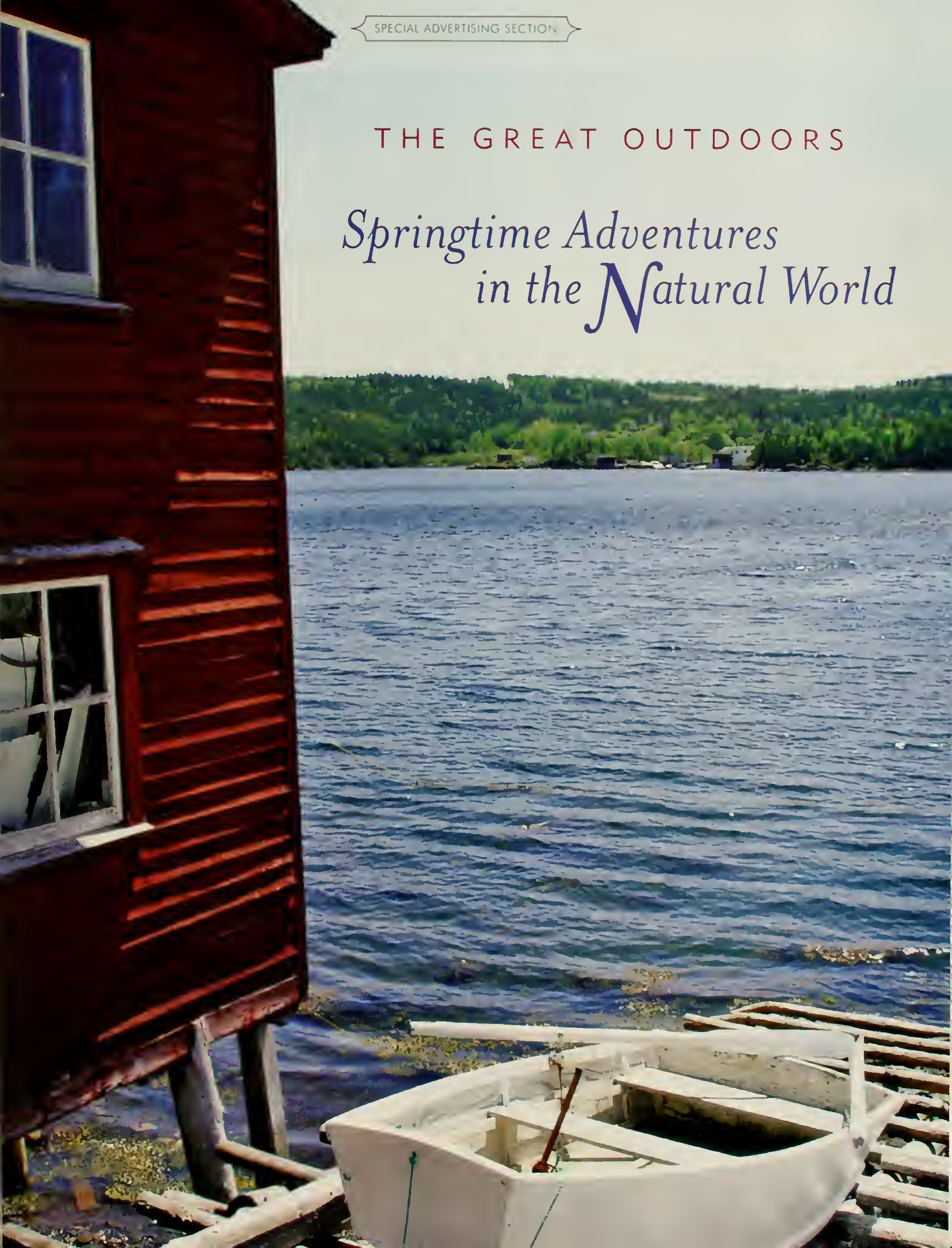
Like the geologists of Wegener's day, climate scientists can appreciate "bare facts" as well as anyone. Certainly climatologists are aware that small changes in solar heating arise from cycles of planetary motion; more precisely, they can calculate the small variations that arise from differences in solar heating throughout the Milankovitch cycles. But they cannot explain clearly enough how those variations can affect Earth's climate so strongly that an ice age arises or recedes. Some day, they may attain that understanding—or perhaps deeper insights into climate changes may lead to the rejection of Milankovitch's hypotheses.

Meanwhile, the theory of Milankovitch cycles has the virtue of making a definite prediction. Setting aside all effects of human activity on climate, Earth should be currently on a temperature downslope, growing ever cooler in the next 5,000 or 10,000 years. Sad to say, though, the present release of carbon dioxide, mainly through the burning of coal and oil, overcompensates for any cooling trend by several orders of magnitude. As clearly as anyone can peer into the future, human-generated global warming at today's rate will be enough to offset all the Milankovitch cooling of the next five or ten millennia in a single generation. It seems unlikely that nature will save us from ourselves.

DONALD GOLDSMITH *is the author of twenty books on astronomy, including* Connecting With the Cosmos *(published by Sourcebooks in 2002). He is the co-author, with Neil deGrasse Tyson, of* Origins: Fourteen Billion Years of Cosmic Evolution *(Norton, 2004).*

THE GREAT OUTDOORS

Springtime Adventures in the Natural World



Peru boasts ten thousand years of history and ancient cultures, a rich colonial tradition, and an extraordinary variety of wildlife

THINK OF PERU AND THE FIRST THING that comes to mind is the wealth of its age-old cultures and the legendary Inca empire.

The city of Cusco, the ancient capital of the Inca, is lined with narrow, cobblestone streets and Inca buildings. Cusco's Inca roots and colonial buildings placed it on UNESCO's World Cultural Heritage List in 1983. The Koricancha, the luxurious and sacred Sun Temple, just yards from the city's main square, was built in honor of Inti, the sun god, and its walls were once covered with gold. North of the square you'll find the palace of Inca Roca, which housed the sixth Inca governor. Some believe that the Incan city was built in the shape of a puma, or mountain lion, which squatted over the Saphi River; as evidence they point to street names that translate to "puma's spinal column," "puma tail," and other names designating parts of the animal's body. The Spanish conquistadors arrived in Cusco in 1533, and scattered amid the Inca sites you'll find Andean Baroque structures that preserve the legacy of this colonial period, such as the ornate Cathedral and the Church of the Company of Christ.

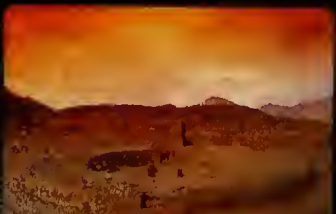
Don't miss the picturesque neighborhood of San Blas, where the best artisans in the city have set up their workshops. After hours, this magical city has an exciting nightlife with cafés, restaurants, and bars for all tastes. Just ten minutes away from the city, you can see the massive walls of the Sacsayhuamán fortress, and a few miles from there, you'll find the archeological sites of Qenko, Pukapukara, and Tambomachay, Incan buildings constructed completely with stone.

The most famous Inca site—and Peru's most visited attraction—is the Machu Picchu Historical Sanctuary. You can reach Machu Picchu via a scenic, three- to four-hour train

ride from Cusco, or better yet, get there by hiking the Inca Trail. This walking route through the mountains above the Urubamba River traverses ruins, a cloud forest, and rich subtropical jungle. The forty-five-kilometer trail, built along an old Inca roadway, takes about four days to complete. Machu Picchu (which means "old mountain" in Quechua, the Inca language) stands atop a mountain high above the Urubamba. A center of worship as well as an astronomic observatory, it was the private retreat of the Inca ruler Pachacútec and his family. The site has two major areas: an agricultural zone, made up of terraces and food storehouses; and an urban zone, with ornately carved temples, squares, and royal tombs. Stone staircases and canals are found throughout the city.

Because of its location in the cloud forest, Machu Picchu is home to unique species of flora and fauna, including the cock-of-the-rocks (Peru's national bird); the spectacled bear, the only bear species in South America; a rare dwarf deer called sachacabra; and the Huemal deer. In addition to more than 300 bird species (including the Andean condor and numerous hummingbirds), the site boasts some 200 recorded species of orchids. The best times to visit Machu Picchu are during the dry season, from April to September.

Don't leave the Cusco area without a visit to the Manu National Park, a nature lover's paradise in the Amazon Basin. Manu hosts more than a thousand species of birds, 1,200 butterfly species, over 20,000 plants, and innumerable insects, amphibians, and reptiles.


Citadel of Caral


Inca Uchabamba Doorway


Pyramid of the Sun and of the Moon

Chan Chan (Trujillo), the oldest mud city in the Americas
perú
Land of the Inkas
www.peru.info

Mountain goat reigning over Glacier National Park

Rodney Schlecht

Think of Montana as a giant, natural animal preserve

MONTANA HAS TONS OF FAMOUS SITES and sights you'll want to visit, such as Glacier and Yellowstone National Parks and numerous stops along the Lewis & Clark Trail. But off the beaten path, you'll find fantastic birding, one-of-a-kind dinosaur digs, remarkable scenic drives, and plenty of wildlife.

Montana has over 400 known species of birds, attracted by diverse habitats, from alpine zone at Glacier National Park to desert scrub, sagebrush steppes, and shortgrass prairie. Birdwatchers will appreciate the Bitterroot Birding and Nature Trail, one of the first completed trails in a planned statewide network, comprising 25 of the top nature sites between Lost Trail and Lolo Pass. The marshes of Red Rocks Lake National Wildlife Refuge are filled with the largest population of trumpeter swans in the lower 48 states. Along the Rocky Mountain Flyway, more golden eagles have been seen in one day than anywhere else in the country. And at the Kootenai River, you might see a profusion of bald eagles on a single autumn day.

Montana has yielded some of the world's most significant dinosaur discoveries. The

Biking in the shadow of the Rocky Mountain Front

Donnie Sexton

Montana's open land and majestic mountains make it a rare and special place

fifteen stops along the Montana Dinosaur Trail allow you to discover these paleontological treasures for yourself. Some of the dinosaurs were uncovered at the famous Hell Creek Formation, dating from the late Cretaceous period. This site in the badlands frequently produces finds, including those at the Makoshika Dinosaur Museum: a life-size Allosaurus, a Stegosaurus in combat, and Pterosaurs of all sizes. The first Tyrannosaurus Rex ever discovered, back in 1902, was found in Hell Creek near Jordan, which is now home to the Garfield County Museum. Find a dinosaur, or at least a dinosaur tooth, on your own: both the Garfield and the Makoshika, and many other sites along the trail, offer field digs to the public. And, don't miss the life-sized fleshed out model of Peck's Rex at the Fort Peck Dam Interpretive Center and Museum.


Donnie Sexton


Donnie Sexton

Top: Missouri River, northeastern Montana
Left: Buffalo roaming in Yellowstone National Park

Within Montana's 147,000 square miles of terrain, there are about 69,000 miles of public highways and roads, making it easy to get around Big Sky Country. Scenic drives such as the Lewis and Clark Trail and the Nez Perce Trail take you among prairies, mountain ranges, and ghost towns, with many glimpses of wildlife along the way. Perhaps the best known of the scenic roads is the Beartooth Highway, which Charles Kuralt deemed "the most beautiful highway in America." Now a Scenic Byway, the Beartooth offers skytop views of snow-capped peaks, glaciers, alpine lakes, and plateaus. The three-hour drive reaches heights of nearly 11,000 feet, transitioning from a lush forest to alpine tundra in the space of a few miles. You'll spot Rocky Mountain goats, moose, black and grizzly bears, marmots, and mule deer along the way.

In Montana, everyone has a few wild neighbors—not the kind who throw all-night parties but antelope, elk, moose, mountain goats, bighorn sheep, eagles, trumpeter swans, bears, wolves, and more. Montana has a greater variety of wildlife than any other state in the lower 48, and some of the best places for sightings are Yellowstone and Glacier National Parks and the National Bison Range. Also rewarding are Montana's many wildlife refuges, most of which offer self-guided opportunities for photography, wildlife viewing, scenic vistas, primitive camping, hiking, and other year-round outdoor activities. The Charles M. Russell National Wildlife Refuge in Missouri River Country is the third largest refuge in the continental U.S. It's home to elk, mule deer, red foxes, and coyotes, as well as an abundance of songbirds; look for ospreys, spotted sandpipers, and white pelicans along the boundaries of the reservoir.

To help you plan your Montana getaway, order a free travel kit including a 2007 vacation planner, packed with information, travel tips and calendar of events at **visitmt.com**.


+
PEACE
47:27.95N 112:36.02W
GPS


+
QUIET
Find what you're looking for in
MONTANA
visitmt.com
Sunrise on the Rocky Mountain Front
Call 1-800-VISIT-MT (847-4868), Ext. 771
for a free vacation planner.

Tumacacori National Historical Park

Copper Queen Mine

Arizona's rich and storied landscape is a treasure for intrepid travelers

San Xavier del Bac Mission

IN ARIZONA, GENUINE DISCOVERIES and off-the-beaten-path experiences await around every corner. From vast ranchlands to historic mining towns, from Native American ruins to fossils 225 million years old, this is a destination unchanged by evolution. Here, charming small towns—like Bisbee and Tubac—preserve their heritage and yet carve unique, and often artistic, niches in Arizona's present.

In its heyday the former mining town of Bisbee in southeastern Arizona was the region's mining, commercial, financial, and cultural center. Once known as the "Queen of the Copper Camps," Bisbee retains much of the flavor of yesteryear. Although its mines have closed, visitors still flock to Bisbee's hot spots, including its underground tours of the Queen Mine, the Brewery Gulch, Copper Queen Hotel, and the Lavender Pit.

Tubac, south of Tucson in Arizona's scenic high desert, is the oldest European-settled city in the state, established in 1752 as a Spanish presidio (fort). Artist studios now surround the grounds that once served as the home for a Spanish military garrison. Explore Tubac's origins at the Tubac Presidio State Historic Park (Arizona's very first state park), located in the Old Town. Nearby, the Tumacacori National Historical Park protects the ruins of three of the oldest Spanish colonial missions in the state.

San Xavier del Bac Mission, noted for its beautiful colonial architecture and colorful interior art, is nine miles south of Tucson. This brilliantly white structure rises from the desert floor of dusty green mesquite and sage; its imposing dome and lofty towers, rounded parapets and graceful spires are a seamless blend of Moorish, Byzantine, and late Mexican Renaissance architecture. It is acclaimed by many as the finest example of mission architecture in the United States.

Arizona's timeless discoveries can be found in every corner of the state. Venture off main roads and get to know the people and the land. The spirit of the legendary Old West continues to thrive throughout the state in small towns, guest ranches, and Native American nations. Bring an adventurous curiosity, leave your watch at home, and simply enjoy. You're in Arizona.

For your free Arizona travel packet, visit arizona**guide**.com or call 1-877-556-3733 toll free.


Traditional and contemporary art may look different, but they all share the same spark of inspiration.
Seize the Day
Grab life. Immerse yourself in a day full of adventure and a night full of fun. More to discover and definitely more than you expect, all waiting here for you. For your free travel packet, call 1-877-556-3733 toll-free or visit arizonaguide.com.
ARIZONA
GRAND CANYON STATE

In Tucson, take a walk on the wild side — and the urban side, too


Todd Brenneman

IF YOU'RE PASSIONATE ABOUT HIKING, climbing, or walking, Tucson is your dream come true.

In the beautiful parklands surrounding the city, you'll find a hiker's paradise of trails, ranging from leisurely strolls to challenging treks that can take you from desert floor to pine-topped mountain peaks. Sabino Canyon boasts spectacular views, a variety of wildlife, and dozens of marked trails ranging from easy to rugged, the easiest one that takes you up 3.8 miles up the spectacular canyon.

Saguaro National Park West also has many great trails, including the Sendero Esperanzo, which guides you to the top of 4,600-foot Wasson Peak in about two hours. Go north on Catalina Highway to Mt. Lemmon, thousands of feet above Tucson, to enjoy temperature averaging about 20 degrees cooler, and hike the

beautiful 6.5-mile Butterfly Trail.

Also in north Tucson, the Pima Canyon Trail—an exceptional hike for wildlife viewing and dramatic scenery—begins with a steep climb as you enter the canyon, then criss-crosses the streambed, offering a variety of short climbs and descents. Pima Canyon is a bighorn sheep preserve. Its steep climbs and rugged trails are for intermediate and advanced hikers. Finger Rock Trail is a highly visible landmark in the Santa Catalina Mountains—the climb is steep—you'll go from 3,000 to well over 7,000 feet. It's meant for intermediate to advanced hikers—but its rewards include plenty of wild and plant life, and stunning views of the city below.

For a more leisurely pace, take an urban hike. Follow the turquoise line along the Historic Presidio Downtown Walking Tour/Turquoise Trail, a path that leads to 23 numbered locations; plaques in English and Spanish detail colorful histories. You can pick up the trail anywhere, but we suggest starting at Church Avenue and Washington Street. This is the site of the Presidio San Agustín de Tucson, a fort established in 1775 that marked the northwestern edge of the Spanish frontier in Arizona.

Several splendid short trails run along the dry riverbeds near the city, including the mostly flat Santa Cruz River Park Trail. This route follows the banks of the normally dry Santa Cruz River west of downtown. To get to the trail, simply follow any major downtown street west to the river. The Rillito River Park Trail winds through the city along the north side of the Rillito riverbed. The asphalt trail is a favorite for walkers, joggers, skaters, and cyclists of all ages, and it's designed so you never have to cross any streets.

To start planning your Tucson vacation go to www.visitTucson.org.

Land of Fire and Ice: Iceland

WHETHER YOUR GOAL IS TO EXPLORE vast, untouched, and uninhabited expanses of landscape, or walk around town making friends, you'll feel free in Iceland. Throbbing with life by day and by night, all year round, Reykjavik, Iceland's capital city, is just as much a part of the Icelandic experience as the midnight sun or the magical landscapes forged by ice and fire. It offers a mix of cosmopolitan culture and local village roots, and best of all it's only a fifteen-minute cab ride from wild nature. In Iceland, you'll discover nature as you've never seen it before. The country has some of the world's most important nesting grounds for birds: near Latrabjarg is the world's single largest seabird-nesting cliff, while southern Iceland hosts the globe's biggest skua colony. Iceland is also home to some of the world's largest colonies of puffins. Head out to see the sights on fjords and peninsulas that branch out all over the country, explore a glacier, take a bath in a geothermal pool, or tee off at midnight when you play golf in the land of the midnight sun. When you visit Iceland, you'll enter a whole new realm of experience.

Fun in the Sun: Alabama's Gulf Coast

WITH THIRTY-FIVE MILES of white-sand beaches, magnificent resorts, and some of the friendliest people you'll ever meet, Alabama's Gulf Coast is a place not easily forgotten.

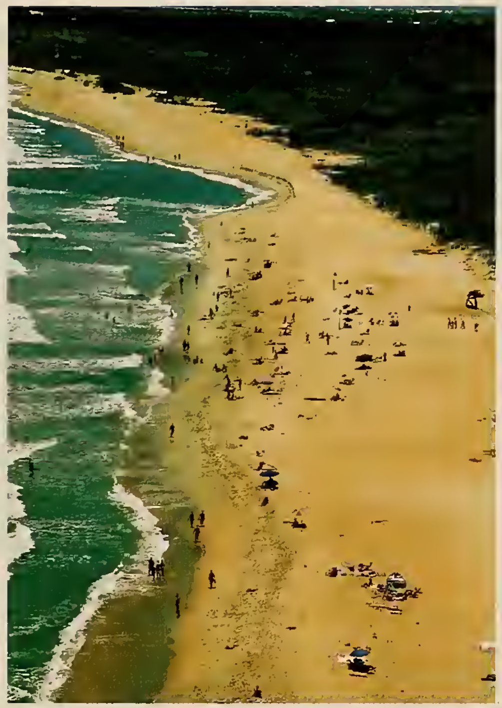
To explore the Mobile Bay area, bike or hike along the Eastern Shore Trail. This countywide network of trails begins at the USS Alabama Battleship Memorial Park, where you can see the mighty World War II battleship, a spy plane, submarine, and other military craft and weaponry.

Stop at the Weeks Bay Estuary Reserve, one of twenty-five national reserves protecting estuarine waters, marshes, shorelines, and adjacent uplands for research and education. Birders will enjoy the fifty-site Alabama Coastal Birding Trail, which *Audubon* magazine named one of the country's best bird-watching finds. This well-marked trail loops around delta bottomlands, Mobile Bay, and the sandy terrain bordering the Gulf of Mexico.

Feel like casting a line? Orange Beach boasts a fleet of more than a hundred charter boats ready to take you out fishing, or set out on a deep-sea expedition from Dauphin Island. Putter around on one of the area's championship golf courses. Travel back in history with a visit to Fort Morgan, the site of the Civil War Battle of Mobile Bay. Commune with nature as you hike through a wildlife area and gaze at gators and shorebirds. For outdoor fun, the Gulf Coast promises memories of a lifetime.

Photos: Alabama Gulf Coast Convention & Visitors Bureau

Outer Banks: Recreation and Reflection



MIDWAY ALONG THE ATLANTIC SEABOARD—SOUTH OF Norfolk and northeast of Myrtle Beach—you'll find a 100-mile chain of barrier islands known as The Outer Banks of North Carolina. With the Pamlico, Roanoke and Albemarle Sounds to the west and the Atlantic Ocean to the east, The Outer Banks has the third largest estuary system in the world, wildlife refuges, maritime forests, the Cape Hatteras National Seashore, and the highest sand dunes on the East Coast at Jockey's Ridge State Park.

The first national seashore in the country, Cape Hatteras extends more than 70 miles from South Nags Head to Ocracoke Inlet and includesw natural and historic attractions. A haven for recreation and reflection, the islands of The Outer Banks are prized for their sandy beaches, salt marshes, and maritime woods. The seashore is dotted with historic lighthouses, including the Cape Hatteras Lighthouse. Coined "America's Lighthouse", at 208 feet it's the tallest brick sentinel in the country. Built in 1871, this structure was relocated in 1999 to protect it from the encroaching Atlantic. The area claims the one time home of Blackbeard the Pirate at Ocracoke Island, which is also home to the oldest operating lighthouse in North Carolina.

Don't leave The Outer Banks without a stop at the Wright Brothers National Memorial, the site of the brothers' first controlled powered flight in 1903. The visitors' center features full-scale reproductions of the Wright 1903 Powered Flyer and interpretive presentations. And no trip is complete without a tour of Fort Raleigh on Roanoke Island, the site of the first attempted English colony in America dating back to 1585. The Lost Colony's disappearance of 116 men, women, and children is our nation's most elusive mystery.

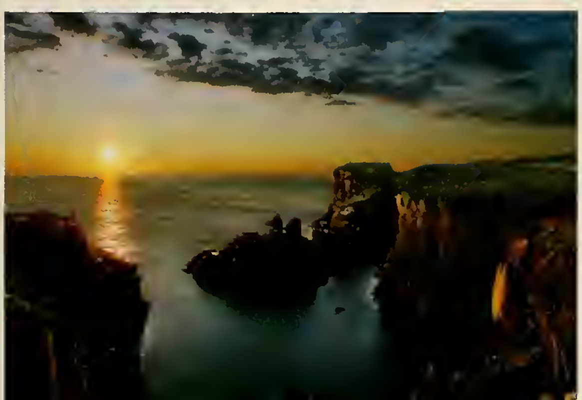
Do you seek adventure?
Or does it seek you?

AROUND EVERY CORNER, AROUND EVERY bend in Newfoundland and Labrador, there's an outdoor adventure waiting to happen. Whether it's a planned excursion or one that's anything but, it's hard to figure out what to experience first.

If you're a sailor at heart, you might want to try sea kayaking. There's everything from a gentle paddle around a sheltered bay to one alongside humpback whales and ten-thousand-year-old icebergs. Visit sea caves and remote pebble beaches for a boil-up, or ride the waves along the coast while you try to catch up with one of our millions of seabirds.

If you'd rather be below the surface, then scuba dive to one of the few accessible wreckage sites in North America, where German U-boats sank Allied ships.

If you consider yourself a hiker or a dedicated walker, there are literally hundreds of trails across the province, ranging from a short stroll through a park or along an abandoned railway line to multi-week-long treks through the wilderness. Our extensive hikes include the East Coast Trail and Gros Morne National Park.



Around here, you'll never have to go looking for wildlife. Over 22 species of whales grace our shores every year. And with over 35 million seabirds and 350 different species, this place is definitely for the birders. In the mood to cast a line? Try your luck at angling Atlantic salmon or brook trout.

When the snow comes, this place is a snowshoe and snowmobile paradise, complete with thousands of kilometers of winding, groomed paths of pure powder through the mountains and across the barrens. If you prefer to do your soul-searching at high speeds, there's Marble Mountain—a virtual adrenaline rush that comes with over sixteen feet of the white stuff, yours to carve as you please.

And at the end of the day, there's good food, lively music, and warm hospitality—the perfect combination to rejuvenate the senses for your next journey. With 29,000 kilometers of coastline, hundreds of hiking trails, and wildlife galore, Newfoundland and Labrador—Canada's eastern-most province—is a place that continues to live on inside of you long after you've travelled on.

To order your free 2007 Traveller's Guide call 1-800-563-6353, or visit us at www.NewfoundlandLabrador.com.

BIOMECHANICS

No Bones About 'Em

The biggest fishes in the ocean may have opted for cartilage over bone to bulk up without getting weighed down.

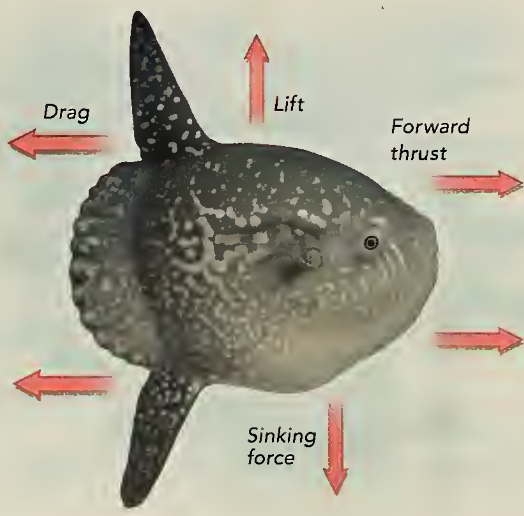
By Adam Summers ~ Illustrations by Tom Moore

Cartilage, the stuff most people associate with bendable ears and noses—or with career-ending injuries in professional athletes—seems a poor choice of material for the skeletons of the world's most formidable fishes. Nevertheless, sharks, skates, and rays have entirely cartilaginous skeletons—even their jaws are made of the soft material. Such scaffolding must work well, because the group boasts the largest and some of the fastest species of fishes in the sea.

Bone would have been a stronger and, one would think, more useful skeletal building block for sharks. In fact, bone predates them, and it played a role in the skeletons of some ancient, now-extinct sharks. So why did the ancestors of today's sharks and other cartilaginous fishes abandon bone in favor of a skeletal material that other large animals use only sparingly? I have recently come to think that cartilage gives sharks at least one important selective advantage: they can grow much bigger than bony fishes.

Now anyone who knows a fisherman also knows how hard it can be to pin down the size of fishes. Most people would agree that the gentle, planktivorous whale shark ranks as the largest fish in the sea. Some might even guess that second place goes to another plankton eater, the basking shark. Next in line, the scourge of Amityville, is the great white shark. After that, the ranking gets more nebulous and more prone to fishing lore. Still, the strongest contenders for numbers four through eight are all cartilaginous fishes: the Greenland shark, the manta ray, the sawfish, the six-gill shark, and the tiger shark (not necessarily in that order!).

All of them, each classified in a separate family, are larger than the two largest fishes classified as "bony": the beluga sturgeon and the ocean sunfish. And yet the sturgeon, which has reliably been weighed at just about a metric ton, and the ocean sunfish have skeletons made almost entirely of cartilage. The marlin takes the prize for being the largest bony fish that actually has a skeleton made entirely of bone, but its weight is less than 80 percent that of the sturgeon's.

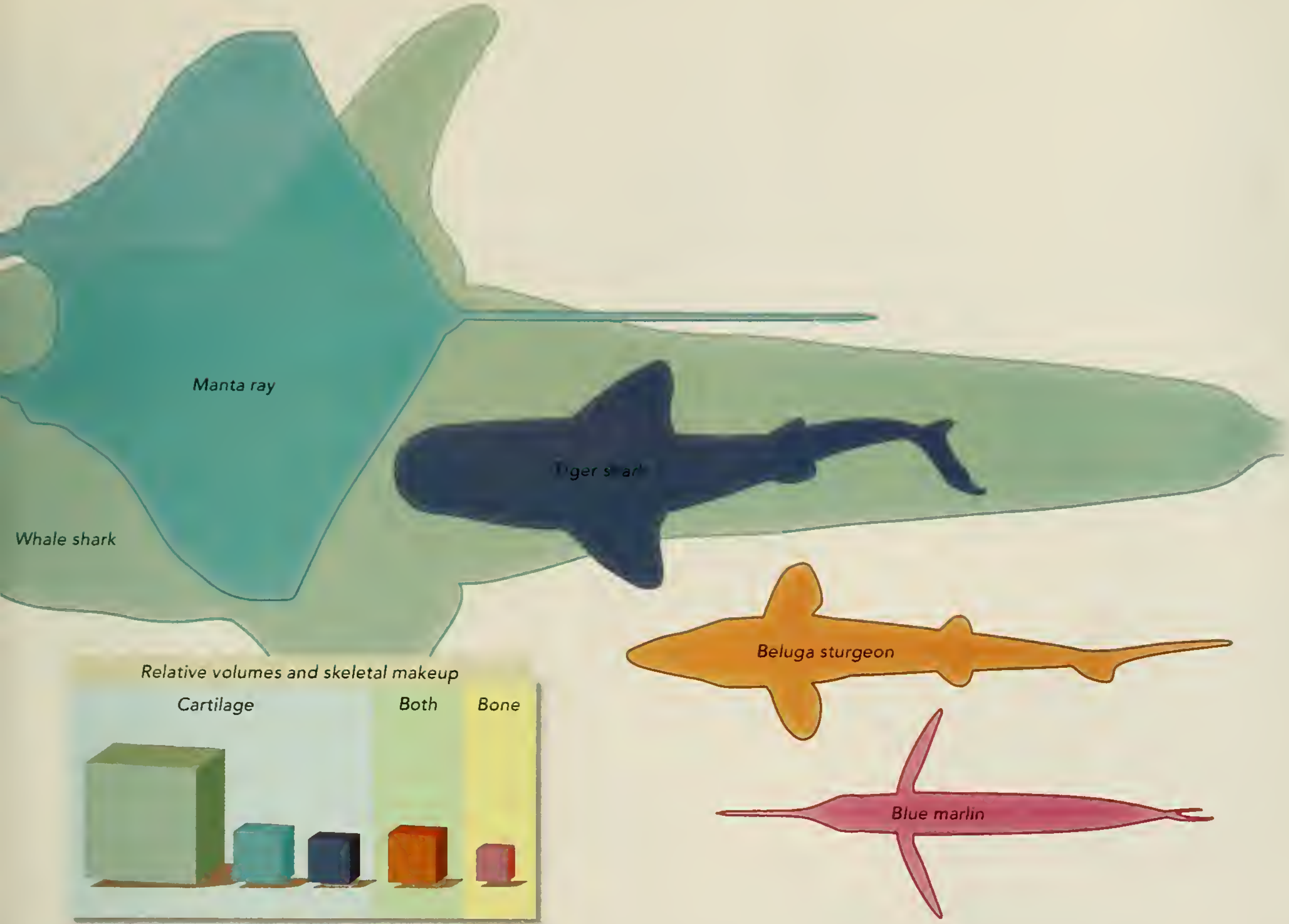


Ocean sunfish swimming level at a constant speed is subject to four forces—drag, forward thrust, lift, and sinking force (or "negative buoyancy")—that are paired, each pair in perfect balance. If a fish were to grow too large, the sinking force would overtake lift.

Patricia Hernandez of George Washington University in Washington, D.C., James A. Strother at the University of California, Irvine, and I have constructed a model that attempts to explain why cartilage became the skeletal material of choice for the giant fishes of the ocean. Picture a fish swimming at a constant speed. The swimming muscles generate thrust that exactly offsets the drag of the body as it moves through the water. (If the offset were inexact, the fish would speed up or slow down until a new constant speed was reached.) Similarly, as long as the fish moves forward, the fins and body generate lift that exactly counteracts the fish's tendency to sink [*see illustration on this page*]. That sinking tendency is known as negative buoyancy, and all fishes (and overweighted scuba divers) have it—all fishes, that is, except dead ones, which tend to float. Yet most fish tissues, from muscle to guts to nerves, are almost neutrally buoyant. Not so the skeleton, which is largely responsible for that slight sinking tendency.

So consider what would happen to the fish's physical dimensions if, magically, it doubled in size. Three aspects come to mind: length, area (the shadow cast by a light shining from above), and weight. Double the fish's length, and, presumably, the animal also doubles in width. The new fish has not twice its former area, but four times as much. As for weight, it is tied to volume, which is equal to the length times the width times the "height." When length and, presumably, width and height are doubled, weight goes up eightfold.

So what would happen to the nega-



The world's largest fishes, as seen from the perspective of a snorkeler looking down, all have enormous profiles. Each profile and the lift generated by each of the creatures' forward swimming motion would grow fourfold if the creatures doubled in size, but their volumes (see inset above) and their weights would grow eightfold. Because lift grows more slowly than weight, the biggest fishes conserve weight with skeletons made of cartilage, not bone.

tive buoyancy of a fish as it increases its length? Well, the weight of the skeleton should directly correlate with the weight of the fish, so the skeleton's negative buoyancy should cube when length is doubled. But the lift force needed to counteract the negative buoyancy scales quite differently. The key to lift is the "profile" of the lifting surface—another way of describing the shadow cast by the fish. Lift, therefore, should grow with the square of the length rather than the cube.

That sets up a fundamental problem. Because lift grows more slowly than the negative buoyancy acting against it, a growing fish species eventually runs out of lift; thereafter, it would be doomed to a life of squirming along the bottom. Of course, cartilaginous and bony fishes are in the same bind, but the cartilaginous skeleton weighs considerably less per foot of fish than the bony one. The propensity to sink kicks in at a longer length and a greater weight. It seems that one advantage of the cartilaginous skeleton is something of a reprieve from a size limit [*see illustration above*].

The skeptical reader is no doubt wondering how whales—not to mention extinct animals such as the plesiosaurs and Steller's sea cow—avoided the sinking trap. Those animals are (or were) all larger than the largest bony fish; in fact, the blue whale is the largest animal on the planet. But they have one thing in common: they all come from lineages that have returned to the sea after an evolutionary stint on land. They no longer swim as fishes, gliding through the middle depths in dynamic equilibrium. Instead, their lungs act as flotation devices, and they remain tied to the surface by positive buoyancy, which, to descend, they must swim against.

The motto of the early sharks that wanted to get bigger was not "bone stinks" but rather "bone sinks."

ADAM SUMMERS (asummers@uci.edu) *is an assistant professor of bioengineering and of ecology and evolutionary biology at the University of California, Irvine. This column is his fiftieth for* Natural History.

COMMENTARY

Bad News for Bears

For thirty years the wild Alaskan bears that visit McNeil sanctuary have learned to trust the people who watch them. But this fall, despite a public outcry, those bears may be hunted.

By Bill Sherwonit

On a bright August morning, with gulls screeching and bald eagles picking at spawned-out salmon, I'm standing with ten other people in the shadows of an alder-topped bluff. Our backs are pressed tightly against a dank rock wall. Everyone's attention is drawn to the left, where the bluff ends abruptly in a blind corner.

Douglas D. Hill, who's guiding our group, had peeked around that corner only moments earlier, then ordered the rest of us to stand quietly against the wall and remain absolutely still. Several more moments pass. Now, hardly daring to breathe, we watch as an adult brown bear rounds the corner, as if in slow motion, and angles our way. Passing within less than twenty feet of our party, the 600-pound animal scarcely acknowledges our presence as she squishes through mud and wades into the stream that flows before us.

That in itself is enough to send adrenal glands into overdrive. Imagine the tension, then, when two small cubs step gingerly into view and turn our way. Unlike their mom, the cubs eye us intently and pick up their pace, clearly anxious. But not so anxious that they run or cry or give us a wide berth. Barely larger than the teddy bears awarded as carnival prizes, the dark-chocolate spring cubs scoot

Dozens of brown bears come to McNeil Falls in southern Alaska from June until August during the annual chum-salmon run. A strict limit is imposed on the number of visitors allowed into the area: ten per four-day period. They watch from two gravel pads a hundred feet away. The bears treat their audience as part of the scenery, focusing instead on each other and on catching fish.

past our wall-pinned bodies, no more than ten feet away. Several yards beyond us the cubs wrestle with each other, perhaps a release of tension. Then they lope toward their mother, intently hunting salmon in the swirling, muddied water.

Anyone passionate about brown bears will instantly guess where our encounter took place. It can only be McNeil River State Game Sanctuary, a 200-square-mile parcel of coastland situated on the upper Alaska Peninsula, some 250 miles southwest of Anchorage. McNeil is the standard against which all other bear-viewing sites are measured. Established in 1967 and managed by the Alaska Department of Fish and Game, the sanctuary protects the world's largest gathering of brown bears—the coastal cousins of the grizzlies. As many as a hundred bears come to McNeil River Falls every summer to feed on chum salmon. It's not uncommon for visitors to see dozens of brown bears at a time congregating by the falls.

The McNeil bears are now threatened. The Alaska Board of Game, which has jurisdiction over McNeil and several surrounding areas, has voted to allow hunting in the Kamishak Special Use Area, adjacent to McNeil to the east and south [*see map above*]. Both before and after the salmon return to McNeil River, the bears fan out throughout the region, often far beyond the McNeil sanctuary. Tagging and radio-collar studies in this area have shown that some bears travel hundreds of miles in a year and that many McNeil bears venture into the Kamishak Special Use Area. So if open hunting there remains legal, it is only a matter of time before trophy seekers kill some of McNeil's most tolerant and approachable bears.

Protecting the McNeil bears is the stated mission of the Alaska Department of Fish and Game, which is why it established a permit system to keep human visitors at the site to a minimum. A state-run lottery attracts as many as 1,400 applicants, but permits are granted to just ten people at a time for consecutive four-day periods from early June through late August. Visitors take their seats on folding chairs placed side by side on two gravel pads within a hundred feet of the falls. The bears eat, nap, nurse, or even mate not far from the pads where the viewers sit transfixed by the action for as long as eight hours a day.

Many people are surprised by the bears' neutral attitude toward their fans. "Think about it," says Larry Aumiller, McNeil's former manager. "You've got this group of people standing in the middle of dozens of bears. You're very close to where they want to be. And they tolerate you."

Before the McNeil "experiment," many bear experts thought that habituated bears, particularly browns and grizzlies, were extremely dangerous because they had lost their natural shyness of humans. But Aumiller showed that habituated bears that have not learned to associate humans with food treat people as "neutral objects, maybe as innocuous as rocks or trees." Still, habituated bears remain wild; they should not be confused with tamed animals. As Werner Herzog's widely released documentary film about Timothy Treadwell, *Grizzly Man*, made clear to a worldwide audience, carelessly approaching any bear in the wild can have fatal consequences.

Larry Aumiller, pictured here in a photograph taken in 1988, never once had to use his shotgun in his thirty-year tenure as the manager of the McNeil sanctuary. If a curious adolescent bear got too close to a visitor, Aumiller would clap loudly until the bear moved away.

Because of the precautions that Aumiller and his staff have taken, no McNeil bears have attacked or injured anyone in more than three decades of close association with people. And no bears have had to be killed because they presented a danger. Those facts demonstrate that these bears are safe to be around if people are willing to adjust their behavior. "What goes on here is still news to a lot of people," Aumiller says. "They don't think it can happen. But it does. McNeil shows that if you learn about something that's different from you, and begin to appreciate it, then you'll figure out a way to keep it in your life. You'll learn to peacefully coexist."

When he first came to McNeil, Aumiller didn't think he'd stay more than a season or two. But two years became three, then five, and he found himself in love with both the landscape and its ursine residents. Here was a place he could stay forever.

By the mid-1980s, the "Bear Man of McNeil" was something of a local legend. And by the early 1990s, he had become widely recognized as one of the world's leading authorities on brown bears. Aumiller himself always pooh-poohed such acclaim. He humbly insisted (while adapting another cliché) that the more he learned about bears, the more he realized just how little he knew.

Yet as two decades at McNeil turned into three, Aumiller was beginning to contemplate what he once imagined impossible: resigning his position. Married, with a young daughter, he found it harder to spend his summers in the wilderness. An even bigger issue, though, was wildlife politics.

In 2002 Frank H. Murkowski, a Republican, was elected governor of Alaska, bringing new threats to McNeil's bears and heartache to Aumiller. No friend of bears and wolves, the governor was strongly endorsed by the Alaska Outdoor Council, a self-styled "sportsmen's group." AOC's leaders are strong advocates of hunters' rights and predator control, and for years the group has pushed for increased opportunities for bear hunting on state lands near McNeil. By the time of the spring 2005 meeting of the Alaska Board of Game (BOG), Murkowski had appointed enough AOC allies to it to make that wish come true. The BOG, which reports to the governor, determines whether hunting is allowed on federal, state, and private lands.

At the same time, McNeil's bears were receiving a huge outpouring of public support, expressed by thousands of written comments, as well as in public testimony of dozens of Alaska residents, including many hunters. Yet despite the outcry, and despite a substantial drop in the population of McNeil's bears since the late 1990s, the board voted to approve a new bear hunt in the Kamishak. (The details of the hunt, scheduled for fall 2007 and spring 2008, have yet to be worked out.) The population decline was most likely caused by diminished salmon returns and by increased brown bear hunting in Katmai National Preserve, another tract bordering McNeil, which is managed by the federal government. In fact, the number of bears legally killed in the areas surrounding McNeil has jumped to forty-five in 2005, more than double the number in the early 1980s.

Disheartened by the BOG's actions, Aumiller chose to leave his beloved job after the 2005 season, his thirtieth at McNeil. In an opinion piece for the *Anchorage Daily News*, he explained his action:

> More than any other single person, I am responsible for habituating McNeil bears to humans. That means that through every single interaction for over 30 years, we have done everything humanly possible to get bears to accept our benign presence. And guess what? It has worked incredibly well. . . . Because we have cultivated their confidence, we have more responsibility to protect them. The very bears that trust us the most are the most vulnerable to hunting, which will be occurring literally a one-hour walk away from McNeil Falls.
>
> To purposely and knowingly kill these habituated animals for trophies is beyond any definition of reasonable ethics or fair chase and, I believe, is morally wrong. I've always envisioned that I'd be at McNeil River until I couldn't physically do it anymore. But I can't continue to remove the bears' only protection—their natural wariness—knowing that even more of them will soon be exposed to hunting.

Doug Hill, Aumiller's replacement, has worked around bears before, but he is completely new to McNeil. Furthermore, many people who visited McNeil in 2006 already knew about the hunting debate. Many visitors wanted to know what they could do to protest the BOG's actions and ensure the protection of the bears.

"It's gotten to the point where I don't want to talk about it anymore. I've tried to stay clear of the politics," Hill admits. "At the same time, it's our job to protect the bears. It doesn't make sense that we'd be neutral about hunting near McNeil."

One staff member, Thomas M. Griffin, says his approach is "to tell people, 'It's up to you to decide what's right or wrong.'" Away from visitors, Griffin is less hesitant to share his opinions. "Are we setting these animals up? Oh yeah. It's a no-brainer. Where's the sport in hunting habituated bears? Where's the fair-chase ethic?"

In recent years, the BOG and other hunting advocates have consistently argued that hunting and killing a few bears won't harm either the McNeil experience or threaten the sanctuary's gathering. Ronald J. Somerville, a member of the BOG and one of the chief proponents for increased bear hunting near McNeil sanctuary, advanced that argument at the 2005 meeting that approved the Kamishak hunt set for 2007. "There is no mutually exclusive conflict between viewing bears and hunting them," he said then.

In fact, however, Somerville also suggested making hunting legal in McNeil River State Game Refuge, a 188-square-mile block of land just north of the sanctuary, where bears were afforded additional protections beginning in 1993. All bear hunting has been prohibited in the refuge since 1995. But the board agreed at the spring 2005 meeting that Somerville's proposal to allow hunting in McNeil refuge would be on the BOG agenda for its meetings this month from the 2nd through the 12th. In spite of the agenda vote, the board did not file Somerville's proposal by the required deadline. But the board could still bring the McNeil refuge into the discussion of the scheduled hunt in the Kamishak Special Use Area, which is formally on the agenda. Somerville, appointed chairman of the BOG in 2006, did not respond to repeated requests by *Natural History* for comment.

Visitors to McNeil sanctuary can watch for as long as eight hours a day, from chairs set up on the two viewing pads. The bears nap, nurse, and even mate as close as twenty feet from their human audience.

Ted H. Spraker, another board member and a former state wildlife biologist, says that the compatibility of viewing with hunting was not uppermost in the minds of board members when they approved the Kamishak hunt: "People need to understand that we weren't targeting McNeil's bears when we reviewed the Kamishak area's bear-hunting closure. It was simply part of a long-overdue review of hunting closures statewide."

The reasons for approving the Kamishak hunt were largely political, Spraker adds, a tactical response to a long-standing dispute between the state and the National Park Service (NPS) over lands—including the Kamishak Special Use Area—that the two parties agreed to trade years ago. Spraker and other board members argue that the NPS reneged on the deal once the Kamishak area was closed to hunting, a charge the NPS denies. By reopening Kamishak to bear hunting, Spraker says, board members hoped they would force the NPS back to the negotiating table.

"The board had good intentions, but it looks like [its tactic] may backfire on us," Spraker admits. "We puffed up our chests, played our cards. Now we may have to fall on our swords.

"We still could postpone any hunt [at the board's meeting this month]. I can't speak for the entire board, but I'd push for a delay in the hunt, and give the park service more time to deal with us."

Hunters killed forty-five bears in 2005 in the areas surrounding McNeil sanctuary. The decision to open a new area to hunting adjacent to McNeil may lead to the killing of some of McNeil's most approachable, human-tolerant bears.

Benjamin F. Grussendorf, a former state legislator and one of two board members to oppose the new hunt, refuses to speculate on the motives of the five who approved it. But Grussendorf has no doubt that "it was an unnecessary thing to do, to rile people up and create a huge public outcry, simply to allow for two or three more bears to be harvested. It just isn't worth it."

But like Spraker, Grussendorf suspects the BOG will "take a second look" at the Kamishak hunt during its March meeting. "I think you'll have some board members looking at things differently."

Whether he's had a sudden change of heart or not is hard to say, but Spraker now essentially agrees with Aumiller: "To be honest, I would hate to see [the Kamishak area or McNeil refuge] opened; I'd like to see a continuous area protected." To approve a hunt, he adds, "would cost both the board and hunters a lot of credibility. I don't think the opportunity to take a few more bears is worth the black eye it would give to either hunters or the state."

Spraker was the only board member who voted to open the Kamishak area to hunting who could be reached for comment.

In November 2006, voters elected a new Republican governor who is an avowed advocate of hunting. Sarah Palin, like her predecessor, was strongly endorsed by the AOC when she ran for governor, and is a member of the organization, which in recent years has largely gotten its way.

When asked about the bear-hunting controversy, Palin's deputy press secretary, Charles Fedullo, responded this way via e-mail: "The governor said she is a hunter and that . . . some of her best memories growing up are of hunting with her dad to help fill the family freezer. She wants Alaskans to have access to wildlife [to hunt]. However," he added, "she does not support bear hunting in the McNeil River State Game Sanctuary."

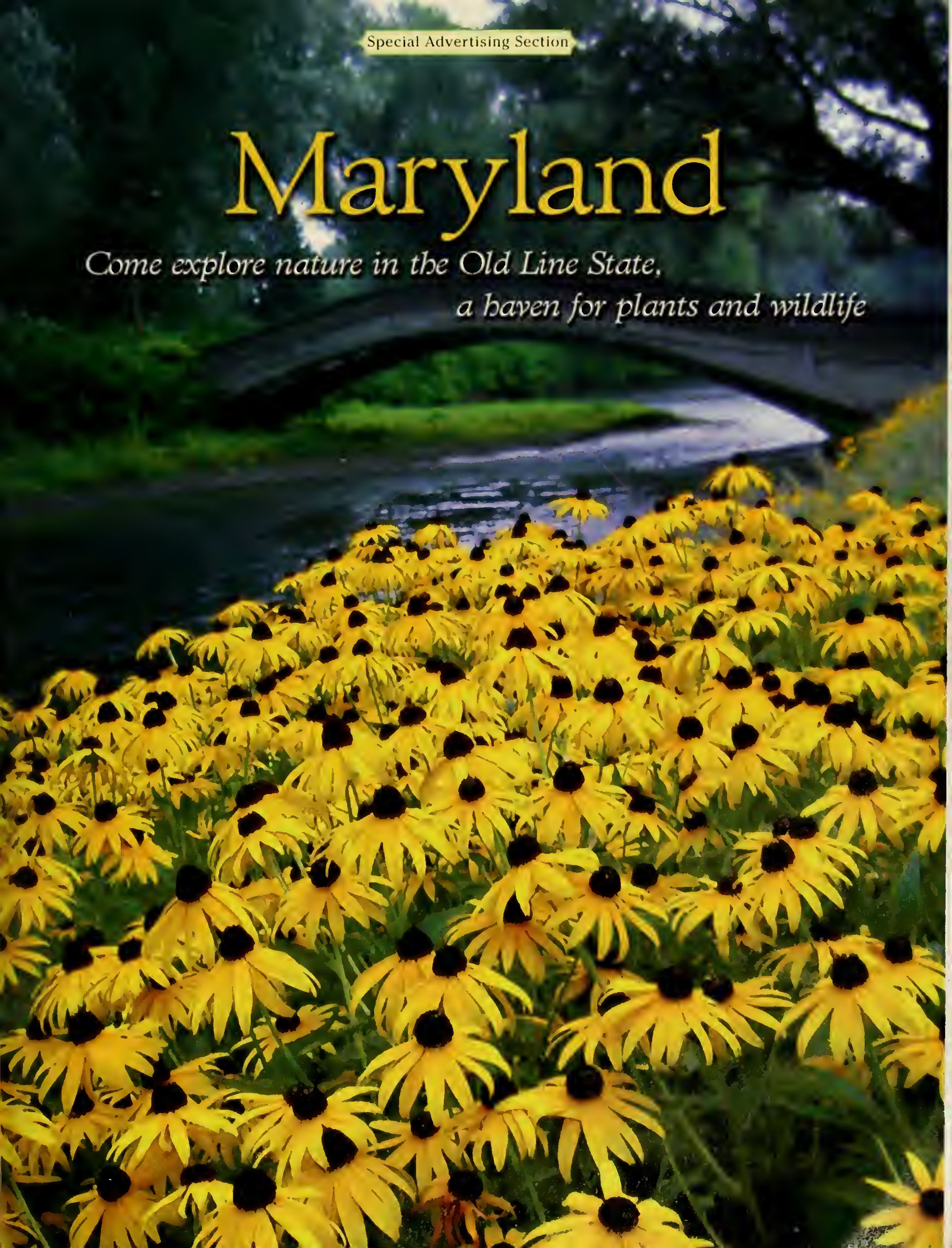
Beyond that, including on the issue of increased hunting around the sanctuary, Palin was more evasive. "The governor wants to wait till she, along with the fisheries and game boards, names a Fish and Game Commissioner to delve further into the issue," said her spokesman.

Palin knows she must tread lightly. She is surely as aware as the members of the BOG that any attempt to open McNeil refuge even to a limited hunt (as it was in fall 1995 and spring 1996) is likely to meet with intense and widespread opposition—even among many hunters and big-game guides. Those 1995 and 1996 hunts inspired hundreds of hunting opponents to swamp the real hunters by applying for the eight available permits; largely because of that protest effort, only one bear was killed.

But neither she nor the BOG can continue to dodge the looming question for long: Will the BOG again ignore overwhelming public sentiment and follow a path that, as Aumiller puts it, introduces new risks to the world's most famous and successful brown-bear sanctuary? Or, as Spraker has suggested, will it adopt a more moderate course: admit that opening the lands adjoining McNeil to hunting is a big mistake and make it clear that in McNeil, perhaps more than anywhere else in the world, the bears do indeed come first? □

Maryland

Come explore nature in the Old Line State, a haven for plants and wildlife



Idyllic shores, majestic mountains, and big-city thrills lure travelers to Maryland

"America in Miniature," as *National Geographic* once called the state, Maryland boasts mountains, seashores, cities, countryside, and everything in between—all within a three-hour drive of Baltimore.

In **Western Maryland**, the Allegheny Mountains serve as the stunning backdrop to rolling countryside, fast-moving rivers, and scenic Deep Creek Lake, the centerpiece of Western Maryland's resort area. With 65 miles of shoreline and covering nearly 3,900 acres, the lake is perfect for boating, swimming, and fishing. At Wisp, a year-round resort, learn to fly-fish, kayak, or golf. The mountains, as well as scores of forests and parks, offer well-marked hiking trails through undeveloped, scenic settings. History buffs should seek out such sites as the C&O Canal and Antietam National Battlefield.

Central Maryland is home to the state's capital, Annapolis, and to its most vibrant city, Baltimore. But the region also offers the pleasures of the Chesapeake Bay shoreline, serene wilderness, and charming small towns. Baltimore, a natural deep-water port that has been attracting ships since the 1600s, is today a modern seaport. Maritime history is everywhere but best seen around the city's Waterfront Peninsula. In addition to its celebrated Inner Harbor, Baltimore has fascinating neighborhoods, intriguing museums, and a wealth of restaurants where you can try out Maryland's famous blue crabs and fresh seafood. Annapolis—America's sailing capital—is celebrating its 400th anniversary in 2007. Since it became the state's capital in 1695, much of Annapolis has remained intact, with more surviving colonial buildings than any other place in the country.

In 1634, the first European settlers arrived in what is now known as **Southern Maryland**. Here you'll find unique communities of watermen and farmers living between the Chesapeake Bay and the Atlantic Ocean. The state's original capital, Historic St. Mary's City, is preserved as an outdoor, living history museum on the banks of the St. Mary's River. In addition to quaint waterside towns, you'll find some of the best bass fishing on the East Coast, and boating opportunities on the Chesapeake Bay and the Patuxent and Potomac rivers.

Known as the **Capital Region**, the three Maryland counties that border Washington, D.C. offer convenient, hassle-free access to D.C.'s museums and monuments. But there are plenty of reasons to stay on the Maryland side of the border: a plethora of historical sites, state and national parks, and an array of restaurants, theaters, and cultural attractions. Perhaps unexpectedly, the area also attracts wildlife—species found here include deer, wild turkey, various reptiles and amphibians, and birds. It boasts the largest concentration of Canada geese on the Chesapeake Bay's western shore.

The **Eastern Shore** is known as "the Land of Pleasant Living" because of its quieter pace. During the day, you may run into a farmer or waterman bringing produce or fish to the restaurant where you'll be dining at night. You'll find immaculately preserved waterfronts and a maritime tradition unique to the area. Explore the majestic lighthouses that dot the seashore and have shown the way to centuries of seafarers—postcard-pretty reminders of the state's maritime heritage. The Eastern Shore also has superb national wildlife refuges—Blackwater and Eastern Neck—featuring major nesting populations of bald eagles, flocks of migrating waterfowl, and hundreds of other bird species.

With such a wealth of diversity in geography, attractions, and wildlife, Maryland makes it easy to plan an unforgettable getaway. Read on to learn more about the state's travel opportunities.


Seize the day off.
travelocity

Discover the unspoiled beauty of Calvert County, on the western shore of the Chesapeake Bay

In summer 2007, a crew of explorers, historians, naturalists, and educators will reenact Captain John Smith's 1608 expedition. Traveling in a 28-foot reproduction of Smith's shallop, and living much as Smith and his men did 400 years ago, the crew will voyage to almost every tributary of the Chesapeake Bay. Calvert County will host two stops. On June 9–10, the shallop will stop at the Calvert Marine Museum in Solomons to commemorate Smith's exploration of the Patuxent River and his encounter with the Patuxent Indians. On Sunday, August 5, the shallop will arrive at Jefferson Patterson Park and Museum to participate in its annual American Indian Heritage Day. The day will feature a re-created Indian village, dancers and drummers, traditional arts, and skilled demonstrations of flint-knapping, basketry, and pottery and fire making. Come learn about this important episode in the history of the Chesapeake.

Rich in history and tradition, Carroll County is a haven for Civil War buffs

Carroll County has so many things to do and see. Walk or drive along the scenic roads where Civil War troops trekked and camped on their fateful march to the Battle of Gettysburg. Learn about life on a 19th-century farm at the Carroll County Farm Museum, or explore the great outdoors at the Piney Run and Bear Branch Nature Centers. With an old-fashioned swimming lake, as well as parks for fishing and hiking, it's easy to get close to nature. The county also boasts an operating grist mill, quaint Main Streets lined with art galleries and antiques shops, a small family winery, and local theater. For a free information packet to help you plan your trip to the county, call 1-800-272-1933 or visit carrollcountytourism.org.

Charles County claims the wildest wildlife this side of the Potomac

Located twenty miles south of Washington, D.C., Charles County is the gateway to historic Southern Maryland. It has first-class fishing (in both the Potomac and Patuxent rivers), an abundance of undeveloped forests, 150 miles of spectacular Potomac shoreline, sumptuous fresh seafood, and top-flight golf. Purse State Park, a reserve of gently rolling hills, woods, and marshlands, is the perfect site for fossil hunting. The county is a haven for birds, with 231 bird species and the second largest bald eagle population in Maryland. It also has enough history to fill several books. Tour the Dr. Samuel A. Mudd House Museum, the home of the country doctor who set the broken leg of President Lincoln's assassin. Explore the numerous historic churches, some among the oldest in the nation.

Come see eagles soar at Blackwater National Wildlife Refuge in Dorchester County

Plan an Eastern Shore getaway with a trip to Dorchester County in the Heart of Chesapeake Country. Boasting 1,700 miles of shoreline, this unspoiled countryside offers many opportunities to enjoy nature. A major stop on the Atlantic Flyway, Blackwater National Wildlife Refuge has more than 27,000 acres of significant wetlands and woodlands with hiking, biking and paddling trails. The refuge boasts more than 250 bird species, including the largest nesting population of bald eagles north of the Florida Everglades, and huge flocks of ducks, geese, and swans in the peak migratory periods. The newly updated visitor center offers exhibits, an observatory, a butterfly garden, and an enlarged gift shop.

Scenic Frederick County is home to many Civil War sites, rolling farmland, and covered bridges

Less than an hour away from Washington, D.C., Frederick County has a wealth of Civil War history and heritage. You'll find the Monocacy National Battlefield, site of an 1864 battle that played a pivotal role in defending Washington, D.C., and the South Mountain Battlefield State Park (includes Gathland State Park and Washington Monument State Park, where you can hike on the Appalachian Trail).

The Barbara Fritchie House and Museum is a replica of the house where 96-year-old Barbara Fritchie confronted General Stonewall Jackson when Confederate forces marched into Frederick in early September 1862. The National Museum of Civil War Medicine, located in the heart of Frederick's fifty-block historic district, dating from 1745, is dedicated to patients, caregivers, and medical innovations during the war; soldiers were embalmed in the very same building that now houses the museum.

Frederick is also home to the National Shrine of St. Elizabeth Ann Seton, in Emmitsburg, honoring the first American-born canonized saint, and is the birthplace of Francis Scott Key. But even if you're not a history buff, this scenic county nestled in the Appalachian Mountains and Piedmont Plateau is well worth a visit. Frederick has more farms than any other county in Maryland, and is dotted with vineyards, covered bridges, and old railroads. The town of New Market is "The Antiques Capital of Maryland," and you'll find the largest water garden in the U.S., the Lilypons, in Buckeystown.

The County of Kent, Maryland's Upper Eastern Shore

Situated on a scenic peninsula where the Chester and Sassafras rivers meander into the Chesapeake Bay, the County of Kent has retained its serene beauty. Maryland's smallest county claims a coastline sprinkled with historic waterfront towns and stretches of low, rolling farmlands broken only by the tidewater tributaries of the Chesapeake. This quintessentially rural area also is home to a profusion of aquatic birds including ducks, geese, kingfishers, herons, ospreys, and other creatures that make their homes along the reeds and rushes, as well as bald eagles. Eastern Neck National Wildlife Refuge is a haven for waterfowl, wildlife, and fish and offers seven walking trails, many with observation decks. Rock Hall, a small fishing village, is celebrating its 300th birthday this year, with special events throughout the year. Other historic towns of the County are Chestertown, Galena, Betterton, and Millington.

Base your visit to the Capital Region in nearby Montgomery County, with fascinating attractions of its own

Bordering Washington, D.C., Montgomery County is a quick shuttle ride from the airport or Union Station. Visit the Chesapeake & Ohio Canal National Historical Park in Potomac and see an original lock house. Hike or bike on the 185-mile tow path, or take in the spectacular view of the Great Falls of the Potomac River from the Olmstead Bridges. Boyds Negro School House, open by appointment only (301-972-0484), is a restored one-room schoolhouse dating from 1896 to 1936. Glen Echo Park offers year-round dance and theater performances; near Glen Echo, take a free tour of the Clara Barton National Historic Site, home to the founder of the American Red Cross and headquarters of the organization from 1897 to 1904. At the 1,300-acre Black Hill Regional Park, in the northern part of the county near Germantown, follow the trail to Little Seneca Lake, a popular bird breeding area, or meander through oak and hickory forests. Historical markers along the trails identify a former mill site and recount the area's gold-mining history. Spring blooms are showcased at the county's public gardens including the Brighton Azalea Gardens, with more than 20,000 varieties of azaleas; the fifty-acre Brookside Gardens and its conservatory; and the McCrillis Gardens, featuring azaleas and rhododendrons. Also in the northern area of the county you can take a driving tour to see sites that showcase historical landscapes, recreational opportunities, and the agricultural heritage of the County. Visit www.heritagemontgomery.org for information.

red line it to DC on METRO!

STAY WITH US

AND SEE THE BEST OF THE NATIONAL CAPITAL REGION

Make the most of your trip by staying with us in Montgomery County, Maryland. Here, you'll enjoy value and quality in our wide selection of lodgings and restaurants as well as the opportunity to visit our many historic sites and national parks. Our 13 METRORail stations will transport you to Washington, DC's many attractions. Call for our Visitor Guide at 800-925-0880 or by visiting www.visitmontgomery.com

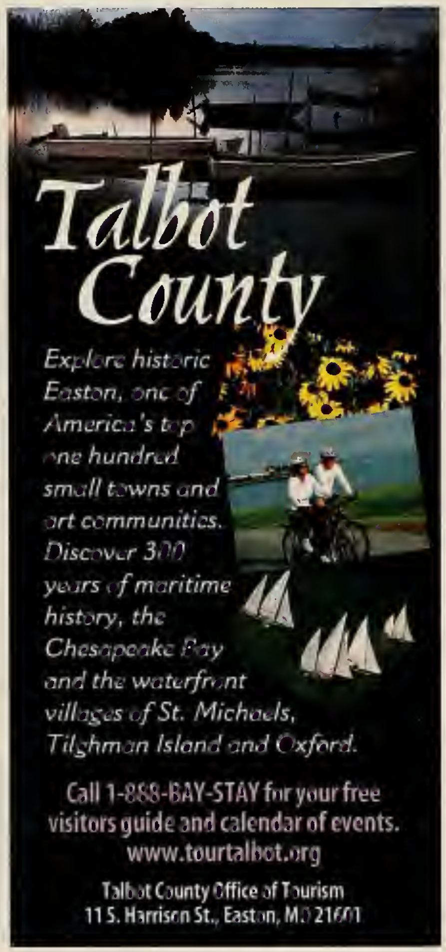
MONTGOMERY COUNTY MARYLAND

WELCOME

CONFERENCE AND VISITORS BUREAU OF MONTGOMERY COUNTY, MD, INC.
11820 PARKLAWN DRIVE, SUITE 380 • ROCKVILLE, MARYLAND 20852

St. Mary's County—Maryland's oldest—invites visitors to relax on the serene Chesapeake shore

Shaped by the Chesapeake Bay and its tributaries, the Patuxent and Potomac rivers, St. Mary's is Maryland's oldest county, settled in 1634. The first battle of the Revolutionary War occurred on low-lying St. George's Island. Now a quiet fishing community, the island is home to the Chesapeake Bay Field Lab, where you may cruise the Bay aboard the authentic skipjack *St. Mary's Dee*. Once an oyster packing plant, the Lab runs a shore-side program for visitors who want to learn to tie a bowline, tong an oyster, or test the water. Nearby Piney Point features the first lighthouse on the Potomac, which began operating in 1836. Exhibits at the Piney Point Lighthouse Museum include several historic wooden vessels that once sailed the Bay. This area of beach grass and tall pines has a campground and several marinas. Nearby attractions include Historic St. Mary's City, on the site of the state's original colonial capital, and is one of the nation's premier archaeological parks and living history museums, as well as Point Lookout State Park, which has fishing piers and campgrounds.



Talbot County's uniqueness belongs to its quaint towns and their treasury of history, heritage, culture, and architecture

Escape to Talbot County and explore historic Colonial towns and Chesapeake Bay watermen communities accented with the traditions of the Eastern Shore. Bustling with art galleries and antiques, Easton is rated among the Top Ten Best Small Towns in America and one of the Top 100 Small Arts Communities in America. Oxford was featured in James Michener's *Chesapeake*, and St. Michaels is the picture-perfect historic waterfront town. Unionville is a historic African-American community settled by former slaves and free blacks, many in the Union Army during the Civil War. And Wye Mills is one of the oldest towns in Maryland, filled with such historic gems as the Old Wye Grist Mill and Museum, the Wye Church, and the Little Red Schoolhouse, just fifteen miles from the Bay Bridge.

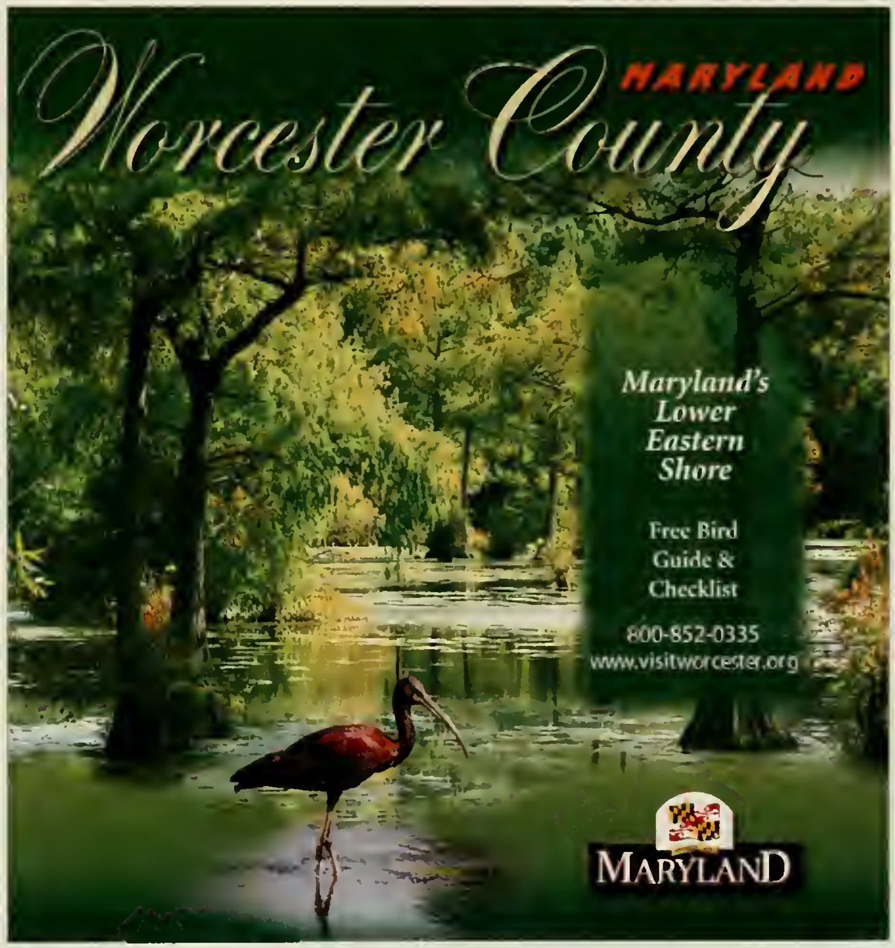
Your Chesapeake Bay experience begins here

Situated on eighteen waterfront acres in the historic town of St. Michaels, the Chesapeake Bay Maritime Museum tells the story of the Bay and the people who have shaped their lives around it. Explore ten exhibit buildings, the world's largest collection of traditional Bay boats, and the 1879 Hooper Strait Lighthouse.

Rediscover the fun of playing on the Bay, learn about the heritage of oystering and waterfowling, and get a new perspective on the Chesapeake through a schedule of changing exhibits. You can get your hands dirty pulling up a crab pot or nippering for oysters on Waterman's Wharf or trying your hand at building a wooden boat in their working Boat Shop, where you may talk with the shipwrights, apprentices, or a visiting captain or boat builder.

Worcester County is Maryland's prime destination for birdwatching

Located on the Eastern Shore, Worcester County is Maryland's only seaside county, known for Ocean City's sandy beaches, steamed crabs, and the famous wild pony herd on Assateague Island State Park and National Seashore. Worcester also has more than a dozen championship golf courses—enjoyable practically year-round thanks to the mild temperatures near the shore—and a hundred miles of marked bicycle trails on flat country roads. Explore history, architecture, and an easier pace of life in the Victorian-era town of Berlin, with its bed-and-breakfasts, or in Snow Hill, with its more than one hundred century-old homes and proximity to the Pocomoke River. Birders know Worcester as the county with the best birding in the state: almost 300 species have been identified in the county's diverse habitats of barrier islands, coastal bays, tidal wetlands, cypress swamps, upland fields, and primeval forests. Come spring, Worcester's birds are busy nesting, and northern migrants flock to the county's large unbroken tracts of woodlands. The county has extraordinary fishing in the tidal banks of the Pocomoke River and the Atlantic Ocean. Ocean City is the White Marlin Capital of the World and offers both bottom fishing in the inlets and deep-sea fishing offshore.



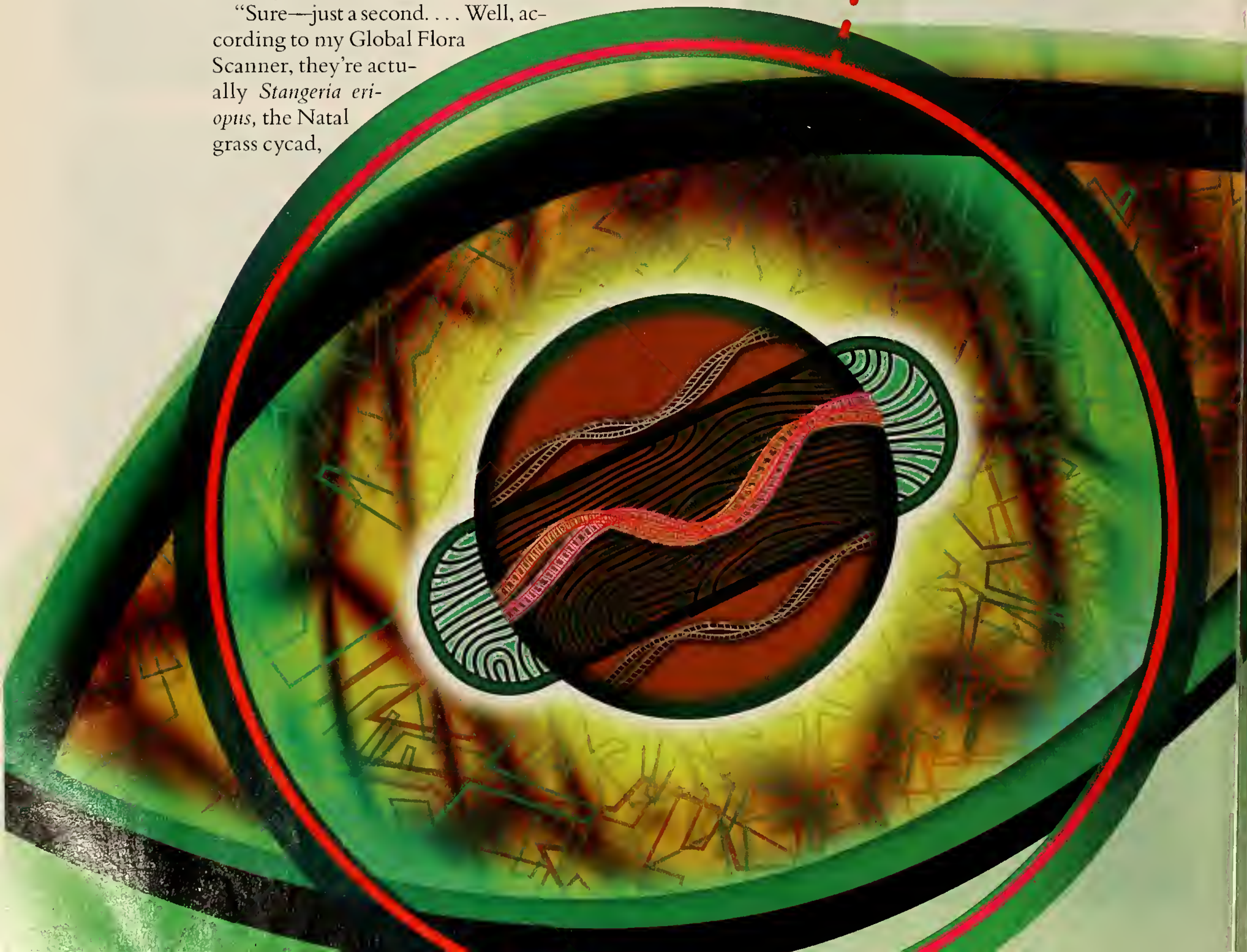
Bar Coding for Botany

A system modeled on commercial bar codes may soon enable anyone to identify any plant from a small fragment of its DNA.

By Kenneth M. Cameron

"What the heck are these? The documents for this crate say the contents are *Polypodium* ferns. Those are perfectly legal to import, but all the leaves have been hacked off these plants. I can't identify them from the stems alone. Jim, can you get a reading on them?"

"Sure—just a second. . . . Well, according to my Global Flora Scanner, they're actually *Stangeria eriopus*, the Natal grass cycad, which looks a lot like a fern. It's an endangered species from Mozambique—says here they're just about extinct in the wild. They're illegal to import, but collectors are just crazy about them. Apparently some cycads sell for as much as $20,000 on the black market. I've never intercepted *Stangeria*s here at the

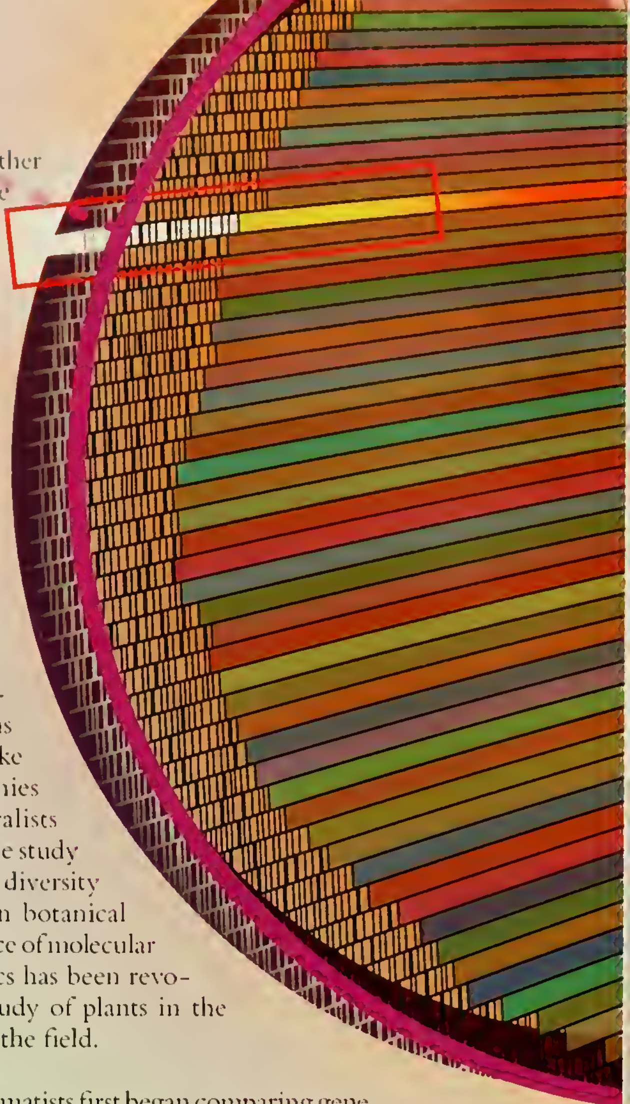


airport before. Good thing you spotted them—and that they were in the GFS database. We'd better investigate; this should mean a big fine or even an arrest for the importer."

The dialogue might sound like science fiction, but that kind of scenario could transpire sooner than you think. One of the great biological projects of our time will be to collect DNA sequences from every living species on Earth. The objective is to create a universal genetic database of life. Once it is mostly complete—perhaps a decade from now—the project will enable any plant, animal, fungus, or other organism to be identified simply by sampling its DNA and comparing that with the database of known DNA sequences.

That comprehensive approach to identifying species is called DNA bar coding. As the name implies, the idea is to develop, as explicitly as possible, the analogy with the universal product codes, or bar-code labels, that are attached to nearly every consumer product, from applesauce to zucchini bread. What makes the analogy such a good one? Just as varying the order of thin and thick black lines in the bar code of a product can distinguish one brand of cough syrup from another at the checkout counter, so the varying order of the four kinds of nucleotides that make up any fragment of DNA can make it possible to distinguish a bluebird from a blackbird, or a de-leafed *Polypodium* fern from a *Stangeria* cycad. Furthermore, a number of technological advances in DNA sequencing are on the horizon, making it conceivable that handheld bar-code readers—like my fictional Global Flora Scanner—will become available in our lifetimes. Such a device would extend to customs officials, scientists, and even members of the general public a skill that has long been reserved for specialized taxonomists.

DNA bar coding is the newest of several techniques that promise to make important contributions to the basic science of systematic biology. The discipline seeks to identify and classify organisms, reconstruct their evolutionary history, and map the extent of biological diversity—in other words, to build the family tree of life. The use of molecular tools in pursuing those goals has already transformed the way biologists understand the natural world. In particular, the wide availability of DNA bar coding in the future could enable specialists to make rapid, reliable identifications in the field, and make it possible for armies of amateur naturalists to contribute to the study of the range and diversity of species. Within botanical circles, the influence of molecular data on systematics has been revolutionizing the study of plants in the laboratory and in the field.



Botanists are on the verge of pinpointing a segment of DNA common to all plants, but distinctive for each species, that would make it possible to identify any plant by matching a small sample of its genetic material against a database of known DNA sequences.

Since plant systematists first began comparing gene sequences in the 1980s, their studies, more often than not, have simply confirmed classifications that botanists have accepted for centuries. For example, molecular evidence confirms that almonds, apples, cherries, pears, and strawberries are all closely related; all of them are best classified with roses in a plant family called the Rosaceae.

But nearly every study in molecular systematics has also led to its share of surprises. More than ten years ago, DNA data showed that, contrary to the accepted thinking of the day, a number of carnivorous plants that employ radically different methods of capturing animals share a common ancestor. A molecular phylogenetic tree showed that Old World pitcher plants of the genus *Nepenthes* [*see "Life and Death in a Pitcher," by Jonathan Moran, October 2006*] are closely related to sundews *(Drosera)* and to Venus flytraps *(Dionaea muscipula)*, even though the three plants evolved three distinct ways of catching prey: fluid-filled pitfall traps, sticky flypaper traps, and rapidly closing snap traps.

More recently, my collaborators and I demonstrated that *Aldrovanda vesiculosa*, the carnivorous waterwheel plant, is also a member of that highly unusual group. Like the Venus flytrap, *Aldrovanda* catches its dinner in snap traps. But unlike all other members of the group, it is aquatic. As if that finding were not strange enough, our studies also showed that the same carnivorous-plant group is related to buckwheat, cactus, carnation, jojoba, rhubarb, and salt cedar. Today botanists classify all of them in distinct but closely related families of the plant order Caryophyllales.

Perhaps the most dramatic example of a revised classification brought about by molecular systematics is *Nelumbo,* the water lotus. Cultivated for its beautiful flowers, distinctive seedpods, and edible underwater rhizomes, the lotus has been immortalized in Chinese paintings for centuries. Most people, including botanists, assumed it must be related to water lilies or to some other aquatic flowering plant. In fact, according to DNA-sequence data, the lotus is most closely related to *Platanus,* the sycamore or plane tree, along with the trees and shrubs in the family Proteaceae, which includes macadamia nuts and the showy-flowered members of the genus *Protea* [*see photographs on opposite page*].

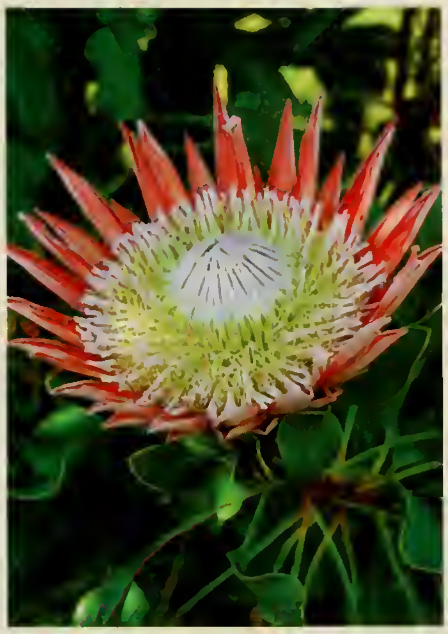
Illegal shipment of picture frames made from ramin, the common name for several species of protected hardwood trees in Southeast Asia, was intercepted in the United Kingdom in 2002 after arriving under a false species name. DNA bar coding could help customs officials verify the identity of imported natural products.

Superficially, the plants have nothing in common. But when the molecular evidence suggested taking a closer look, botanists discovered that lotuses, proteas, and sycamores share similar floral and vegetative features. Moreover, the group was widespread during the Cretaceous period and probably more diverse in form than it is today, suggesting that plants intermediary among the sycamore, lotus, and protea might once have existed. Examples of surprising relationships revealed by recent molecular analyses go on and on, and include the close kinship of fungi to animals, cucumbers and begonias to oaks, orchids to asparagus, and violets to poinsettias, among many other remarkable glimpses into botanical genealogy.

My sci-fi story of a customs bust is a good way to understand how all that botanical detective work may one day pay off. Trade in a number of plants has been banned or restricted under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Among them are species of cactus, cycad, ginseng, orchid, palm, and tree fern. Full-grown adult specimens of those plants are usually easy for customs inspectors to spot during a search. But to thwart the inspectors, smugglers have been known to chop off the plants' leaves, then illegally import the bare stems under false names. The plants remain alive, of course, and will produce new leaves the following season, but the practice makes it nearly impossible for officials to correctly identify the plants or to take legal action.

Identifying a plant from its DNA has several important advantages. First, the DNA of each species is distinct from any other; DNA is a unique identifier. Second, all nonreproductive cells of a given organism have the same complement of DNA. Testing any fragment of the organism—whether leaf, root, stem, or petal—is enough to identify the organism. Third, the DNA in each cell of the organism remains unchanged no matter what the current stage in the organism's life cycle—whether it be a plant in seedling or adult stage, a frog in larval or adult form, or a fungus in hyphal or mushroom phase.

The advantages of the bar-code project are even more pronounced. The bar code itself would presumably be just a unique indexing feature, one diagnostic part, of each cell's entire complement of DNA. A database of DNA bar codes for all species, if it were available, would simplify a customs


Strange sisters: studies of plant genetics show that the water lotus (left), which botanists once classified with the water lily (not shown), is in fact closely related to the protea (middle) and the sycamore tree (flowers shown at right). That reclassification, along with several others, is shown graphically in the illustration on the next two pages.

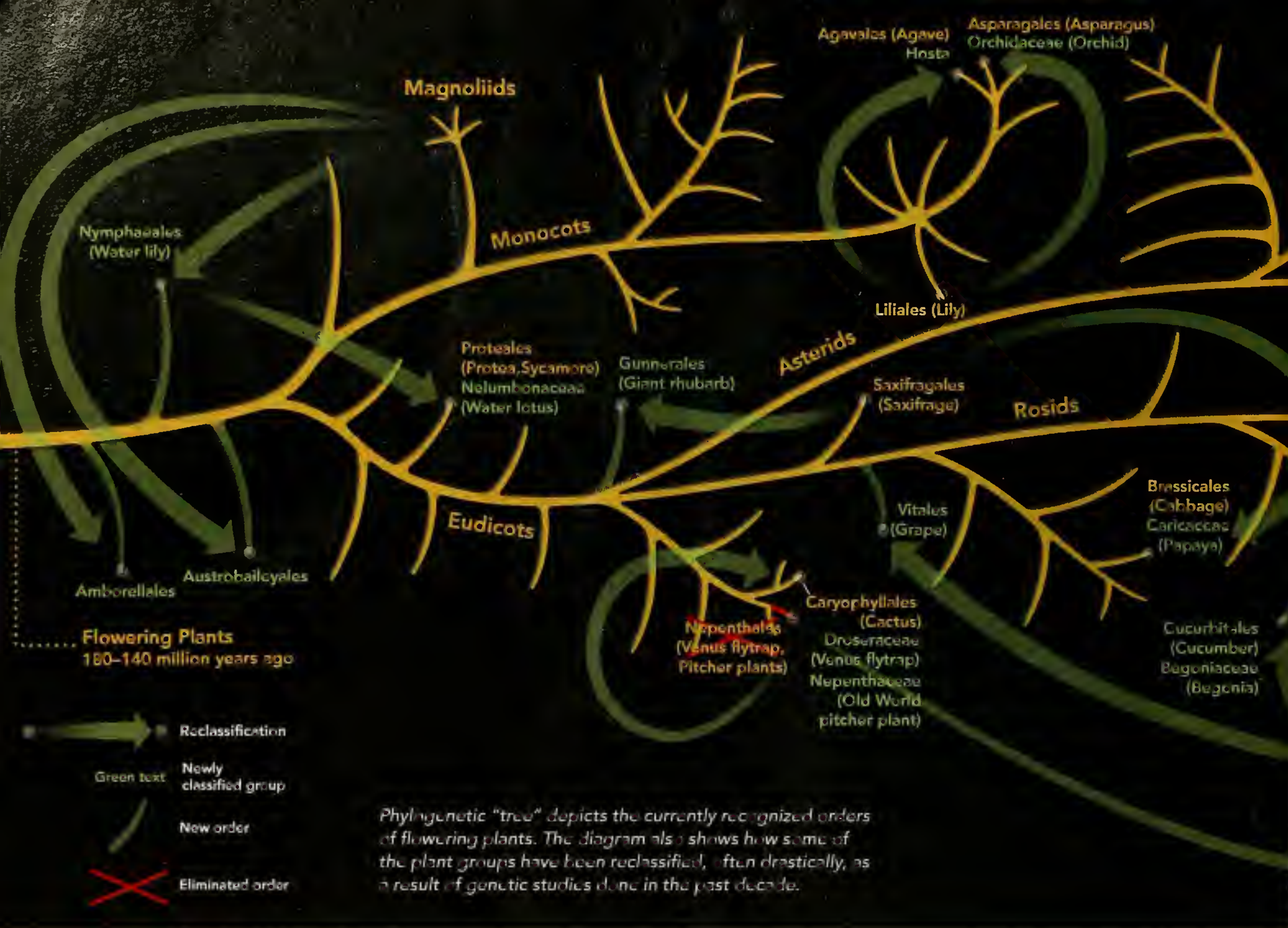
inspector's job. He or she would sample a few cells of virtually any plant or plant fragment that came through the inspection station. The inspector's handheld scanner would then sequence the bar-code DNA, submit the bar code for comparison with the universal database online, assign the correct name to the plant material, and link to useful information about the species.

But the practical applications of DNA bar coding for plants are hardly limited to catching smugglers. I have developed a genetic test to distinguish the vanilla beans of various species. The beans look similar, but they are quite different in quality. Inferior species are occasionally sold—either fraudulently or mistakenly—as premium-quality species to manufacturers of vanilla extracts, a problem DNA bar coding will help eliminate. Consumers will be glad to hear that dried roots, leaves, and stems from medicinal plants can be identified with DNA bar coding before being sold as herbal supplements. Ecologists, too, will find the technique valuable in field surveys, because they will be able to include all plants in an area—whether big or small, easy or hard to identify.

Two other, more universal advantages of DNA bar coding are worth mentioning: it could extend the reach of expertise and make sophisticated biological knowledge more accessible to everyone. It has been estimated that biologists may have discovered and cataloged no more than 10 percent of Earth's biota. Yet species are disappearing at an alarming rate. That leaves a lot of work to be done in a very short time by taxonomists. Yet taxonomy is a shrinking profession because of budget cuts at museums and academic institutions, and a trend away from organismal biology toward the study of life at the cellular and molecular levels. Moreover, the same taxonomists are asked all too often to devote substantial time and expertise to making routine identifications of well-known species.

With DNA bar coding, any organism could be identified by entry-level technicians. Experts could give up the time-consuming burden of making routine "dets," or determinations, and focus their energies instead on more substantial scientific tasks. No longer would just a few authorities have the skill and knowledge to distinguish all 600 species of *Amanita* mushrooms—some poisonous and some edible—from one another; instead, almost anyone could do it! Knowledge could be spread widely and available to all. Amateur field guides do a good job of guiding the nonspecialist, but portable bar-code readers, remotely linked to searchable databases of DNA bar codes, photographs, and species descriptions, could do even better.

So how far along is the scientific community in developing DNA bar-code databases? In zoology great progress has already been made. A single gene known as *cox1*, which occurs in the mitochondrial genome, has been chosen as the universal genetic



Phylogenetic "tree" depicts the currently recognized orders of flowering plants. The diagram also shows how some of the plant groups have been reclassified, often drastically, as a result of genetic studies done in the past decade.

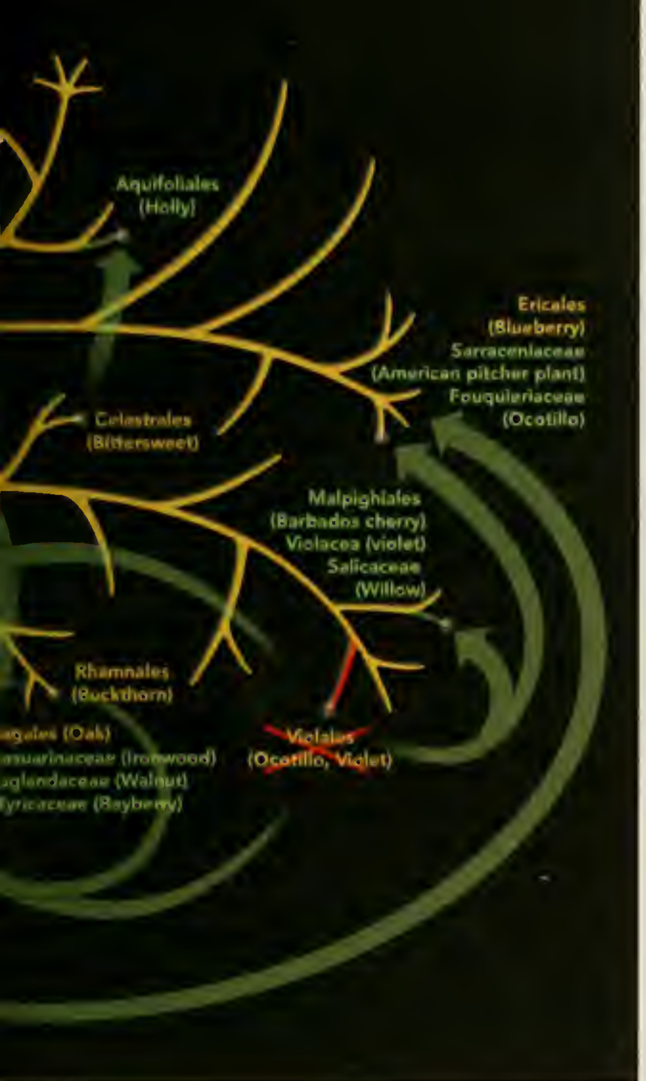
bar code for animals: nearly every animal species possesses a distinct version of *cox1*. Zoologists in laboratories around the world are sharing techniques for sequencing the gene, and are quickly amassing enormous numbers of *cox1* gene sequences from thousands of different species.

One of the best-publicized projects is the All Birds Barcoding Initiative, whose goal is to establish an archive of DNA bar codes for the approximately 10,000 known species of birds on Earth by 2010. Even more ambitious is FISH-BOL, aka the Fish Barcode of Life Initiative, which has already started to collect DNA bar codes for the world's more than 29,000 known fish species. FISH-BOL hopes to complete its collection within the next five years.

Unfortunately, the botanical community has not been as quick to jump into DNA bar coding as zoologists have. In part, the reason is that plants present unique challenges. Pressed and dried plant specimens in herbaria often yield their DNA less readily than do preserved animal specimens in museums. Moreover, animal species are most commonly defined by their reproductive isolation from one another, whereas many plant species can hybridize, thereby blurring their genetic boundaries. Finally, the mitochondrial genome has evolved quite differently in plants than it has in animals. The *cox1* gene is not practical as a universal bar-code marker for photosynthetic organisms.

To address those problems, the Consortium for the Barcode of Life, a body of scientists representing natural-history museums, universities, and botanical gardens around the world, formed a plant working group in 2005. That group, on which I serve as vice-chair, is actively engaged in a two-phase project to find a plant gene, or small set of genes, comparable to *cox1* in animals, that can act as a bar code for all plant life. The first phase, completed in early 2006, aimed to identify five or more candidate gene regions from a small set of plants. The second phase is devoted to testing those candidates across the entire plant kingdom. There is consensus among the two dozen scientists in the group that the gene or genes should meet several criteria. The genes should be present in all plants, easy to sequence, as short as possible, and highly variable from plant to plant.

After several months of testing during our first



phase, we identified six candidate genes by comparing gene sequences from 122 plants, representing sixty-one closely related species pairs from across the entire plant tree of life. The candidates are all chloroplast genes—known as *accD, matK, ndhJ, rpoB, rpoC1,* and *YCF5*—most of which happen to code for proteins that play a role in photosynthesis. Now, in the second phase of the project, those six candidate genes are being sequenced in a broader selection of plants, including various conifers, cycads, ferns, and mosses, as well as monocot and dicot flowering plants. For example, in my laboratory we are sequencing the candidate genes for almost every species of the tropical fern genus *Elaphoglossum*, the conifer genus *Cupressus*, and the Hawaiian flowering plant genus *Labordia*.

My laboratory is also overseeing a complementary project to sequence the six candidate genes in all the vascular plant species of a fixed geographic region, rather than in scattered lineages throughout the entire plant kingdom. And where better to start than in one's own backyard? Our goal is to bar-code every species of vascular plant—both native and exotic—within the fifty-acre forest at the New York Botanical Garden. The forest has never been cut for agriculture and thus includes a rich diversity of plants: approximately 343 species in 246 genera from ninety-eight families. Each species is being newly collected, identified by at least two staff botanists, and pressed, to serve as a new voucher specimen for the herbarium. A sample of leaf tissue is preserved in silica gel and frozen to serve as a source of DNA. Those DNA samples are then added to the garden's permanent DNA library.

Many other such projects are taking place around the world, and as a whole the plant working group is making excellent progress. Within the coming months we expect to announce our recommendation for the gene or genes that will enable plant DNA bar coding to proceed.

In spite of the rapid gains DNA bar coding is making, support for it in the biological community is not unanimous. The strongest objection is that the technique is not foolproof. In practice, though, as technology develops, reliability should improve dramatically, and the problem should largely go away.

Modern biology is built around two primary paradigms. One centers on evolution and embraces the disciplines of Mendelian genetics, natural history, and systematics. The merger of those disciplines during the first half of the 1900s was called the modern synthesis. The second paradigm centers on gene expression and is the foundation of biochemistry, cell biology, molecular biology, and physiology. Those areas of research were brought together during the second half of the twentieth century under the unifying framework provided by the structure of DNA; that paradigm has been termed the molecular synthesis.

Biology is on the verge of a great new scientific revolution that will unite those two separate paradigms into a single program of research: the final synthesis. That new paradigm will enable molecular biologists in their laboratories and organismal biologists in the field to begin to communicate across disciplines.

Within botany, the blending of disciplines is already well underway. The molecular revolution has forced botanists to look more carefully at plants as well-known as the Venus flytrap and the water lotus. DNA bar coding promises further progress by providing new tools for scientists, amateur naturalists, and the public at large. Our children, armed with handheld Global Flora Scanners made possible by the molecular studies in full blossom today, will undoubtedly see and hopefully respect the diversity of life on this planet in ways that none of us can now imagine. □

On the Trail of the Ancestors

Anasazi pueblos lie in ruins across the American Southwest. What became of their inhabitants?

By Craig Childs

The Colorado Plateau is a 130,000-square-mile blister of land roughly centered on the Four Corners area, the dry confluence of Arizona, Utah, Colorado, and New Mexico. Its surface is incised with countless canyons and wrinkled into isolated mesas and mountain ranges that rise suddenly from the desert floor. The climate and the land are barely suited for scratching out a partial subsistence from agriculture. Yet the region is dotted with impressive ruins of pueblos, or towns, built of adobe and stone—often in the form of great communal blocks of apartments ensconced in valleys or tucked into cliffs. Some thousand years ago those dwellings, in such places as Chaco Canyon and Aztec, New Mexico; Mesa Verde, Colorado; and Canyon de Chelly, Arizona, housed a population numbering in the hundreds of thousands. The inhabitants, the so-called Anasazi, grew corn, traded pottery and textiles, and built great underground ceremonial chambers known as kivas.

Viewing the abandoned structures, most people assume this land must once have been better country to live in. But the climate was no different 1,000 years ago than it is today. Rainfall has always been unpredictable in the desert. It was just as dry at some times as it is now, and as wet at others; it was prone to the same scales of flooding. Farming seasons expanded and contracted like an accordion, leaving only slim margins for planting and growing. The secret of the Anasazi was that they had learned how and when to move.

For more than 10,000 years the Anasazi and their ancestors walked the climatic tightropes of the Colorado Plateau, chasing the rain, leaving their camps and settlements behind. Sporadic farming began some 4,000 years ago, as corn and other subsidiary crops slowly made their way northward from southern Mexico. But even with the onset of agriculture, the Anasazi remained a wayfaring people. Small family groups and clans readily skirted around climate changes, transferring their settlements to high, wetter mesas, or down to the sun-baked lowlands, as the need arose. Rarely would a person have been born, grown old, and died in the same place.

When farming became more widespread, a thousand years ago, the Anasazi rose with it, reaching the civilized heights of extensive housing complexes and public architecture. Then suddenly, about A.D. 1300 and well before Europeans invaded the Americas, an especially prolonged drought appears

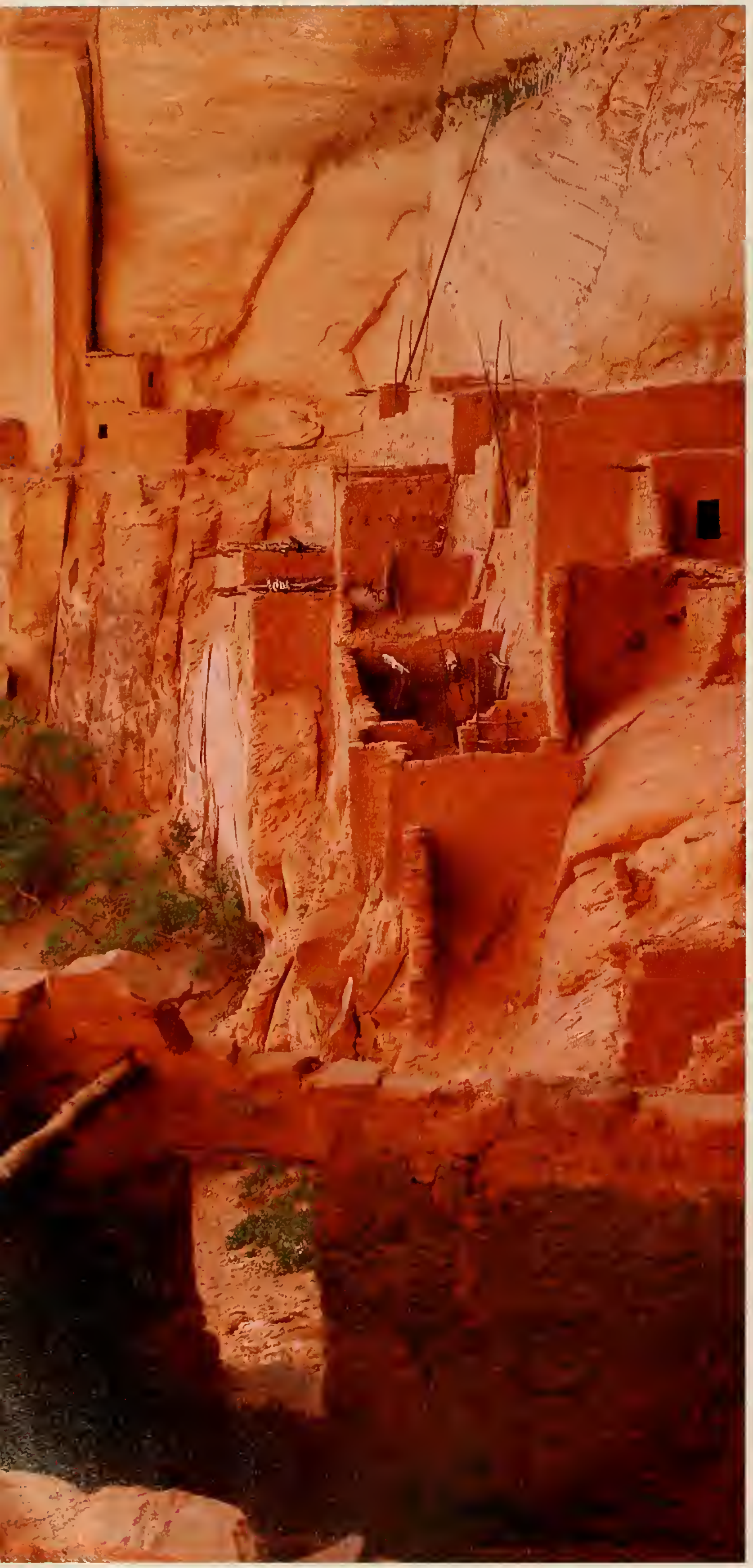
Cliff dwellings in Mesa Verde National Park, Colorado, right, were occupied by the Anasazi during the twelfth and thirteenth centuries A.D., but then abandoned. Top left: Anasazi potsherds and prehistoric corn cobs, Navajo National Monument, Arizona.

to have contributed to the social collapse of most of the pueblos in the Four Corners. But whether the great populations migrated away, fell victim to internecine warfare, or suffered some other fate remains a great mystery of the Southwest.

The truck tires gobbled at paprika-colored sand as we gunned our way across Antelope Mesa, in a corner of the Hopi reservation. The mesa is one of four principal ones spread over a thirty-mile stretch of northern Arizona, standing like castles in a moat of formidable desert. The other three are home to several thousand Hopi residents, but only a handful of isolated families live here, without phones, without postal addresses. It has not always been thus. In the fourteenth century, well after the Anasazi are commonly said to have disappeared, Antelope Mesa was a cultural center, bustling with trade, manufacture, and incoming migrants. By far the largest pueblos in the Southwest, each with as many as 4,000 rooms, were perched above its sharp edge.

Mike Yeatts, an archaeologist employed by the Hopi tribe, was driving me to one of those abandoned pueblos. "You see a lot of prehistoric pottery from this region traded throughout the Southwest," he explained as he drove. "I believe these people were involved in a major trade network, exporting their pottery down to the Phoenix Basin and over into the White Mountains." At the time, a distinctive irrigation culture known as the Hohokam farmed the Phoenix Basin, while part-time agriculturalists, the Mogollon people, lived in the White Mountains of east-central Arizona. Each group created its own version of puebloan architecture.

In the early fourteenth century, populations around Antelope Mesa exploded as migrants arrived from disbanded settlements to the north. People were coming from Kayenta, a region of forested mesas and desert basins to the northwest. Others arrived from Mesa Verde, to the northeast, which had come apart at the seams and was left empty, and from



whatever was left of Chaco, where a remnant population was camped out in a deteriorating shell of public architecture.

We drove through groundswells of dunes tied down at their edges by rabbitbrush and ricegrass. In a tuck between two large billows of sand Yeatts stopped the truck. From here, we would continue on foot. As we walked, the dunes shrank and bedrock appeared from under the sand, whales of reddish stone barely breaching the surface.

I began to notice potsherds—luminous yellow-orange pieces, like little suns rising out of the ground. I reached down and picked up a piece of a bowl. Its warm, egg-yolk hue was completely unlike the cherry-colored red of the pottery I knew from north of here, and a far cry from the sharp black-on-white pottery that dominated the entire Colorado Plateau from about A.D. 900 until 1350. This pottery marked the arrival of the fourteenth century.

As I studied the sherd, I commented to Yeatts on its luster, its solidness.

"You find prehistoric coal mines below most of the sites out here," Yeatts said. "They were using coal to fire their pottery. It was a technological shift that took them from red wares and black-on-whites to these yellow wares."

"The coal affected oxidation during firing?" I asked.

"Both oxidation and how long a high temperature was maintained," Yeatts replied. "Wood-burning reaches the peak just as the fuel is about to collapse and after you've lost your main flame. Coal holds its shape so you can get that heat and keep air going into it for a much longer time. That is what gives you this wonderful color. Potters were probably using the same clay as that used for white wares, but it's the technique that is different."

Yeatts picked up two pieces and clinked them together, producing a melodious chime.

"Nearly porcelain," he said.

It is no surprise that a new style of pottery appeared here. Antelope Mesa was the ultimate unification of the Colorado Plateau, two Anasazi

Elaborate complex of cliff dwellings in Navajo National Monument, Arizona, was built in the second half of the thirteenth century by the people of the Kayenta region, which lay across present-day southeastern Utah and northeastern Arizona. The complex encompasses 135 rooms and was occupied for only a few generations.

Jeddito black-on-yellow bowl, dated to the late 1300s, was discovered in Verde Valley, in central Arizona. The bowl came from Antelope Mesa, some 125 miles to the northeast, presumably through trade. The nearly ceramic-like hardness and yellow base color result from firing the clay with coal, which maintains a high temperature longer than wood.

halves—east and west—coming together. Heading south, the people of Mesa Verde and Kayenta no doubt mixed in their exodus. Where travelers mingle and cultures touch each other, imagination and invention flourish. As much as drought was a push, urging people out of Kayenta and the Four Corners, the lure of growing civilization here in the south must have exerted a strong pull. Even today the place is legendary among the Hopi for once having had high-quality textiles, beautiful ceramics, and busy ceremonies.

Yeatts and his colleagues had been working for years putting together a map of just one of the pueblos at Antelope Mesa, recording evidence for thousands of rooms within a series of perimeter walls. I walked to the top of the ruins, enthralled by how a village could have grown into such a massive pueblo, one that continued to prosper until as late as the eighteenth century before it was finally abandoned. Unlike most Anasazi settlements that have lain empty for many centuries, pueblos on Antelope Mesa and the Hopi mesas have been occupied well into historic times. The Hopi themselves are the direct descendants of ancient pueblo dwellers.

As Yeatts and I walked through the ruins, I asked him about ancestry—the relationship between Hopi and Anasazi. But when I used the word *Anasazi*, Yeatts put his hands in his pockets and looked uncomfortably at the ground.

"I'm sorry," I said. "I wasn't thinking." Here, I knew, *Anasazi* was an insult.

The word was crafted by the Navajo, who in the 1800s were paid by white men to dig skeletons and pots out of the desert. The Navajo probably did not arrive in the Southwest until the mid-sixteenth century, nomads from present-day southeast Alaska and British Columbia. Their reservation now dwarfs and surrounds the Hopi reservation. For a long time *Anasazi* was romantically and incorrectly thought to mean "old ones." It actually means "enemy ancestors," a term full of political innuendo and slippery history.

"You understand why it is an unpopular term," Yeatts said. "It is not a name the Hopi chose."

"I understand," I told him, aware that the word implies people are dead and gone, the land abandoned, available for anyone who wants it.

"But *Anasazi* is also a very rich term, full of history," I said.

"The Southwest has many conflicting histories to contend with," Yeatts admitted.

The bar was small and smelled of cigarette smoke. A few men played a slow game of pool in the back. On the trail of Anasazi who might have migrated south of the border, we had driven out of the desert and up the pine-bristled slope of the Sierra Madre of northern Mexico. A southern group of the Mogollon people once lived in this region. There were four of us, including my wife, Regan, and two college students, Darin and Eugene, both studying Southwest archaeology.

Sixty or so years old, the bartender standing across from us was gregarious. We had been talking with

Remnants of a thirteenth-century wood balcony at Mesa Verde have been exceptionally well preserved by the arid climate.

Ceremonial double mug unearthed at Mesa Verde is an unusual shape, but its black-on-white style dominated the Colorado Plateau from about A.D. 900 until 1350.

him for half an hour, drinking beer and exchanging news. We told him where we had been, a couple of weeks in the mountains, camping out beyond the roads, and spending some time at Paquimé, also known as Casas Grandes, the great pueblo ruin of northwestern Chihuahua.

With both hands spread on the bar, Gilberto the bartender asked what we were looking for out there in the *barrancas,* the canyons.

I told him we were travelers interested in wilderness—*"la tierra salvaje,"* the wild land.

Gilberto nodded and asked if we were looking for treasure, for Sierra Madre gold. We all laughed, a little uneasy.

Darin, sitting on the stool to my left, turned a cigarette in his mouth and leaned forward to meet Gilberto's outstretched lighter. "We're looking for the dead," Darin said, in Spanish.

"The dead?" Gilberto asked, suddenly reserved.

"We're interested in ruins, in prehistory," Darin said. "We're students of archaeology."

Gilberto studied us for a moment. He had a large brass belt buckle emblazoned with a leaping buck. He was a hunter. He would have known about the countryside, the farther places.

"People are nervous about archaeologists here," he said. "They fear the government might confiscate their land."

Eugene, brooding to my right, laughed darkly as he swiveled his beer bottle between his fingers. "We are not archaeologists," he said. He looked down the line of us and asked, "How do you say in Spanish that we're just glorified vagabonds?"

Regan explained that these two were students, and she and I were their instructors for a semester of field studies. But more so, we were friends, traveling companions.

"We are careful people," Regan said. Her voice was calm, its tone asking him please not to judge us for our boldness, or for our broken Spanish.

"We understand these places are very delicate, very personal," she said. "How do you say, sensitive."

Gilberto nodded slowly. *"Frágil,"* he said.

"Sí, frágil," Regan said.

The bar was quiet for a moment.

Gilberto smiled and said, "People around here call them the Anasazi."

I sat forward over my beer. "Anasazi?" I asked.

Gilberto laughed. "It is the incorrect term, of course. People here are ignorant when it comes to archaeology."

I was impressed that he knew enough about archaeology to know that *Anasazi* is a displaced word down here. He considered us for a moment, and then said he wanted to show us something. He excused himself and slipped out from behind the bar.

"Maybe we shouldn't have told him all that," Eugene said down into his beer. "Now we're going to have *federales* in here asking for papers."

"I think he has something to show us," Regan said, taking the bartender at his word.

Ten minutes later Gilberto returned, carrying a worn manila envelope. He lit a cigarette, then pulled a stack of photographs out and laid them in front of us. The photo on top, the size of an index card, showed Gilberto with a dead white-tailed deer. It was a buck, three points to each antler, and in the photo Gilberto held the head upright. We all nodded approvingly. A good kill.

"Through the heart," he said, pointing his cigarette at the deer.

He had gone hunting in the *barrancas.* The deer were deep in those canyons that run through the Sierra. He had traveled a long way on foot, following deer tracks into difficult places. He turned to the next black-and-white photograph.

It pictured a cliff dwelling, a bank of walls and dark roof beams tucked back into a cave. I had not seen any cliff dwellings of such stature south of those constructed in the fourteenth century just below the Mogollon Rim. Migrants from the Four Corners into east-central Arizona had lived in cliffs along that rugged escarpment, which forms the southern limit of the Colorado Plateau. I now believed I was seeing evidence of these same migrants even farther south. We leaned in from our bar stools as if Gilberto had just opened a treasure chest.

The site he had photographed had thirty rooms, maybe more. It was three stories tall at the back end, where adobe walls snuggled against a soot-blackened cave ceiling. It looked like the cliff dwellings of the Anasazi, similar in scale and design to the largest structures at Four Corners. T-shaped doors, a feature of many ancient Southwest pueblos, were strung across the buildings like standards.

The next photograph plainly showed a different site. "How many cliff dwellings are there?" I asked. Gilberto said they were everywhere.

Gilberto arranged five shot glasses along the bar. He pulled out a bottle of sotol he said was bootleg, and poured each of us a drink. Gratis.

I looked at Gilberto, who was smiling. I lifted the shot glass to him and then touched it to my lips. The sotol, the traditional highlands drink distilled from the heart of a saw-bladed, yuccalike plant, tasted smoky and as hard as gasoline.

If we wanted to know, he said, he would tell us where the ruins are.

Yes, we wanted to know.

Cliff dwellings with rounded storage chambers lie deep in a canyon of the Sierra Madre of northern Mexico. The author believes they may have been built in part by Anasazi migrants from the U.S. Southwest, though pueblo ruins in the region are commonly attributed to the Mogollon culture, which was contemporary with that of the Anasazi.

He explained that a maze of dirt roads leads into the Sierra, until finally there is only one road, in places hardly a road. There is a rancher named José who lives there, a lonely, strange man, but very hospitable. In the canyons beyond where José runs cattle are the cliff dwellings.

Gilberto placed his fist against his heart. "This is a very important place in my life," he said.

I told him we would be careful. He poured another round.

T-shaped doorway in the Sierra Madre of Mexico, constructed in about A.D. 1400, resembles many others that occur in the U.S. Southwest. The purpose and significance of the design are unknown.

We traveled across mountainous terrain with a couple of weeks' worth of supplies on our backs. The way was broken up by fathomless canyons, with no trails but the ones left by animals. Brushy forests of Mexican pines, walnut trees, and big-toothed maples grew along the drainages where we set camps. Unfamiliar bird calls spilled from the canopy like silver coins.

Just as Gilberto had said, cliff dwellings were everywhere in these canyons, packed into nearly every cave we spotted, biscuit-colored adobe walls notched with black windows and conspicuous T-shaped doorways. The number of T shapes was startling, crowds of them of many sizes, some as small as dollhouse doors.

We climbed to these towering cliff dwellings and walked awestruck through their rooms and hallways. Some buildings were three stories tall, cave ceilings black with wood smoke. With frayed parts of baskets on the floors and painted bits of murals peeling off the walls, they appeared not to have been touched for centuries. As we climbed through thickets of poison ivy, as we cooked meals at night, as we gathered water from springs, there was a constant sense that we were in someone else's house.

Even when we got drunk one night on a bottle of Gilberto's bootleg sotol we had packed in, two of us took off in the dark and found a ruin. Walking shoulder to shoulder through its rooms in the beam of a headlamp, we were suddenly sobered, hearing nothing but our own breath in the gaunt quarters. □

This article was adapted from Craig Childs's book House of Rain: Tracking a Vanished Civilization across the American Southwest, *which is being published by Little, Brown and Company.*

Chrysalis: Maria Sibylla Merian and the Secrets of Metamorphosis
by Kim Todd
Harcourt, Inc.; $27.00

Surinam, a steamy wedge of land on the northeast edge of South America, is no destination for the casual traveler even today. Imagine, then, what it was like in June 1699, when fifty-two-year-old Maria Sibylla Merian, her luggage packed with notebooks and art supplies, left Holland, bound for the New World. At a time in which most women her age with comfortable incomes and grown children looked forward to catching up on their reading or needlework, she abandoned the sedate townhouses of Amsterdam for the mangrove swamps of a virtually uncharted frontier colony. Odder still, Merian went in search of—of all things—caterpillars, not exactly the fabled hidden treasures of El Dorado.

Since childhood, this daughter of a prosperous Frankfurt publisher had been fascinated by wiggly creatures. Later she became interested most of all in the curious ways they changed form. She trapped them in boxes and brought them indoors, then kept careful records as they wove cocoons, worked mysteries inside silken shrouds, and re-entered the world, miraculously transformed. By the time she was in her thirties, she had published two books on caterpillars, as prized by nature lovers and bibliophiles in her time as they are today.

But it is her voyage to the New World that assured Merian's place in history. Assisted by her twenty-one-year-old daughter Dorothea, she spent two years in the Surinamese jungles and plantations, observing, collecting, and recording her observations in her drawings and watercolors. The lush environment dazzled her, and her sketchpads quickly filled not only with caterpillars, butterflies, and moths, but also with all kinds of unfamiliar animals: scarlet ibis (which she regarded as a species of flamingo), opossums, and even cockroaches.

In 1705, four years after her return from the tropics, Merian's magnum opus on the insects of Surinam was ready for the presses. It is remarkable not only for the beauty and skill of its artwork and its descriptive text, but also for the presentation of its subject matter. Contemporary illustrations of insects usually showed them as objects abstracted from their natural surroundings, as indeed the artists' models often were: portraits of butterflies, for instance, relied on dead specimens pinned to a board.

Engraving of Maria Sibylla Merian's 1705 painting of the life cycle of the white witch moth

In contrast, Merian's drawings show insects as she saw them in vivo. A caterpillar appears alongside the butterfly or moth it turns into, perched on the plants it eats, and among the branches on which it pupates. Most notably, her books express an ecological sensibility that place her, among naturalists, two centuries ahead of her time.

Biographer Kim Todd, author of the award-winning *Tinkering with Eden,* does more than just present such facts and spin a lively tale. Her prose imaginatively evokes the bustle of eighteenth-century Holland and the languid torpor of the South American rainforests, placing Merian in the intellectual, political, and social context of her times. A few color reproductions of Merian's watercolors give the reader a taste of her genius, though the small size of today's trade books only hints at the magnificent folio pages of the originals.

Aldo Leopold's Odyssey: Rediscovering the Author of A Sand County Almanac
by Julianne Lutz Newton
Island Press; $32.95

Aldo Leopold's career began at a critical time in the environmental history of the United States. In 1909, as a young man fresh from Yale University and newly minted as a forester with the USDA Forest Service in Arizona, he entered an America transformed by a century of progress. The last vestiges of frontier were disappearing. The prairies had been cleared to make way for cash crops. Family farming was giving way to agribusiness, and people were leaving the rural homesteads of their parents and grandparents for factory jobs in the cities.

What to make of all this was a matter of great public concern. Everyone knew that forests were thinning and wild animals were disappearing. The once-great herds of bison were no more, and the vast flocks of passenger pigeons, once seemingly inexhaustible, had been hunted to extinction in a matter of decades. If those losses were now cause for national remorse, what was to be done?

Under the leadership of outdoorsmen such as Teddy Roosevelt, the environment became a public issue for perhaps the first time. The task seemed straightforward: conserve the forests to continue the harvest of timber, and manage game to ensure enough deer to hunt, birds to shoot, and trout to catch. People talked of conservation and wildlife as if the sins of the past could be remedied simply by better budgeting. And in 1909, no one embraced that cluster of ideas about conservation more enthusiastically than young Leopold.

If those views seem naively simplistic a century later, credit Leopold himself, who wrote and spoke about the critical problems of conservation for close to four decades. He authored a variety of professional articles and practical handbooks and, after 1933, spoke from a bully pulpit as a professor at the University of Wisconsin–Madison. Leopold's initial boosterism was soon tempered by the realization that one man's land management might be another's environmental destruction. A farmer who cleared weeds and brush for a profitable wheat crop might, at the same time, be removing plants that anchored soil against erosion and provided nesting places for game birds. How could the farmer be persuaded to adopt a balanced approach to his land? And what did "balance" mean in the first place?

Leopold's musings culminated in a book of essays, *A Sand County Almanac*, published shortly after his untimely death in 1948, at the age of sixty-one. *Sand County* treats the

Aldo Leopold, August 3, 1942

critical questions of land stewardship with such lyricism and clarity that it has become a classic of the modern environmental movement. It is a mature work; Leopold did not come by his ideas in one blinding flash of enlightenment. He lived through the Great Depression, the years of the Dust Bowl, and two world wars. Most important, he played a crucial role in developing the new science of ecology, and his conservation philosophy stressed the connections between the animate and the inanimate. He was even alert to the social and political aspects of the environment.

In our times, when "ecology" is a household word, it's easy to lose sight of what the word implies: not just crunchy-granola sentiments and good intentions, but attention to the intricate network of cause and effect that ties together every element of the natural world. Julianne Lutz Newton's lucid and perceptive intellectual biography of the great conservationist recounts the long process by which Leopold came to this realization. Her book shows how to read *Sand County* as more than just a paean to all that is wild and wonderful.

The First Copernican: Georg Joachim Rheticus and the Rise of the Copernican Revolution
by Dennis Danielson
Walker & Company; $25.95

Without the prodding of others, two of the greatest works of Western science—Newton's *Principia* and Copernicus's *De revolutionibus*—might never have seen the light of day. Newton, an otherworldly genius, began to develop his laws of motion as early as 1664, but squirreled away his notes as if they were no more than old tax forms. So what made him publish? Some twenty years later, his friend Edmond Halley, of comet fame, was curious about whether Sir Isaac had any ideas on what kept the planets in orbit. Sir Isaac did.

In similar fashion, Copernicus was too busy as a cleric and physician to pen more than a brief commentary about the sun-centered universe. His culture-changing book came about only under the urging of a young disciple, George Joachim Rheticus. Today Halley is almost as well-known as Newton, but Rheticus has gotten little more than passing mention.

Until now. Dennis Danielson, a professor of English at the University of British Columbia, has written a biography, both readable and scholarly, that restores Rheticus to his rightful position as a central intellect of the sixteenth century. Rheticus was only twenty-five when, in 1539, he first traveled to Frauenburg (in what is now Poland) to study with Copernicus. Yet he was already a scholar of exceptional promise. A professorship of mathematics had been created expressly for him three years earlier at the University of Wittenberg.

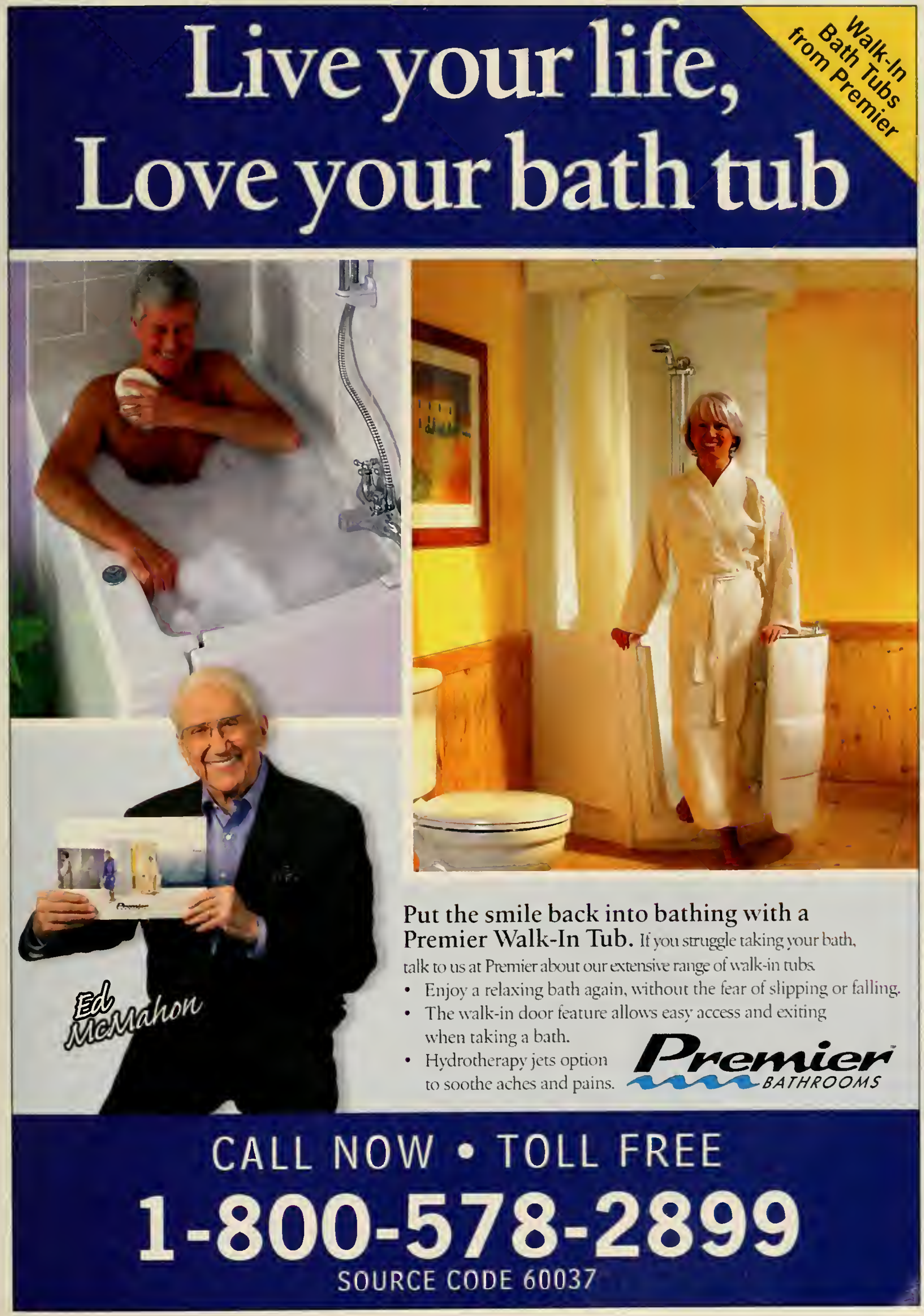
Diagram of Nicolas Copernicus's Sun-centered solar system, as it appeared in the original manuscript of De revolutionibus orbium cœlestium (1543)

Rheticus was enthusiastic about Copernicus's novel idea of how the universe was constructed, and within two years of his visit he had published a short précis on the Copernican theory, the *Narratio prima* ("First Account"), the first public exposition of Copernicanism for general readers. He also took over the task of getting Copernicus, by then frail and infirm, to set down the mathematical details of his theory on paper. It was a difficult task, but the typeset pages arrived in 1543, as Copernicus lay on his deathbed.

For the rest of his life, Rheticus published seminal works on geometry, championed Copernicanism, and eventually pursued a second career as a medical doctor. But Rheticus never stayed long in one place. His sojourn with Copernicus was only one of several "research trips" he took to visit interesting thinkers. After Wittenberg he accepted a chair in Leipzig, only to leave soon afterward for Italy, to discuss mathematics with Girolamo Cardano. A natural restlessness, a taste for wine, the habit of living beyond his means, and a fondness for young men kept him on the move as the years went on. Yet he managed to remain remarkably productive until his death in 1574.

It's ironic that Rheticus's own astronomical work, unlike that of Copernicus, lay unfinished at Rheticus's death, and only twenty-two years later saw the light of day. Maybe it's doubly ironic that this work—calculating tables of trigonometric functions to at least ten decimal places by hand—could be done today with a disposable electronic calculator. But in the late 1500s, the tables were an impressive advance, and as useful to the scientific enterprise, perhaps, as the invention of the slide rule. They remained essential to astronomers for centuries thereafter. For his role in the birth of mathematical astronomy, Rheticus justly deserves to be remembered, along with Halley, as one of the fathers—and midwives—of modern science.

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.*


Live your life,
Love your bath tub
Walk-In Bath Tubs from Premier
Ed McMahon
Put the smile back into bathing with a Premier Walk-In Tub. If you struggle taking your bath, talk to us at Premier about our extensive range of walk-in tubs.
• Enjoy a relaxing bath again, without the fear of slipping or falling.
• The walk-in door feature allows easy access and exiting when taking a bath.
• Hydrotherapy jets option to soothe aches and pains.
Premier BATHROOMS
CALL NOW • TOLL FREE
1-800-578-2899
SOURCE CODE 60037

OUT THERE

Spin Control

How does swirling interstellar gas slow down enough to drain into a cosmic sink?

By Charles Liu

If our Sun turned into a black hole tomorrow, would Earth and the other planets suddenly fall into it?

Nope, no way. Black holes, weird as they are, don't "suck" matter. They're gravitational sinkholes, like any other object with mass, so from a distance they're no more destructive than any other lump of matter with an equivalent mass. As long as Earth maintains its angular momentum around the Sun (the product of its mass, orbital velocity, and distance from the Sun), our planet will stay serenely where it is.

Angular momentum is the key to all things spinning—from toy tops whirling on tables to giant planets revolving around distant suns to entire galaxies wheeling around a central black hole. You've doubtless seen figure skaters doing a scratch spin: starting with arms outstretched, they end up whirling dervishly as their arms are crossed close to their chests. One of the fundamental properties of physical systems is that (not counting friction) their angular momentum must stay the same. Thus, as their arms draw in (less distant mass), the skaters' spin velocities must increase.

The same relation holds for rotating liquids and gases. Take spiral galaxies, which look like cosmic pinwheels. The galaxy arms aren't solid. Rather, they're ephemeral patterns of gas flowing in the galaxy's disk; as the gas bunches up, it forms bright blue stars that outshine the regions between the arms. Any unprocessed gas stays in orbit, too, rather than funneling into the center—as long as it retains its angular momentum around the galaxy's center.

On Earth, friction is ubiquitous, and with time it bleeds angular momentum away from just about every spinning thing, making the spin slow down and eventually stop. Scientists who rely on spinning lab equipment—a gyroscope, a centrifuge—have to think hard about how to reduce friction to keep things spinning. We astronomers have the opposite problem. In outer space, friction is rare, so angular momentum rarely goes away; objects and systems spinning in space tend to keep spinning forever. So when things actually do stop spinning and fall into their center of gravity, we have to think hard to understand why.

But what makes stopping such a big deal? For a star to form, most of a vast, spinning disk of interstellar gas many billions of miles across must condense into a spherical blob less than a thousandth its original diameter. But if there's no way for the disk to shed much of its initial angular momentum, no star can form. In particular, if some of the angular momentum of the protostellar gas that formed our infant solar system more than 4 billion years ago hadn't dissipated, the gas would have kept spinning and never have collected in a ball. The Sun would never have been born, and we wouldn't be here today.

So what causes the matter swirling around a protostar to lose its angular momentum, fall in on itself, and form a star? According to one long-held idea, gas moving at various speeds caused turbulence in the swirling matter, which dissipated the angular momentum. Alas, that idea has just been dashed by a swirling canister of fluid slightly taller than a kitchen blender—and along with it, decades of astrophysical models have gone down the drain.

Of course, the aforementioned canister—designed and operated by a team of astronomers and plasma physicists led by Hantao Ji at Princeton University—is hardly your ordinary margarita-mixing machine. But forget that for a brief margarita moment, and think about what happens in an ordinary bar-top blender. The blender mixes the cocktail's ingredients because its rotating blades move its contents faster near the center and slower at the edge. That speed difference creates shear, which in turn creates turbulence—mini-whirlpools and eddies that interfere with the otherwise smooth-swirling flow. The turbulence sucks away the angular momentum of the protobeverage, which is mainly why the mixture stops spinning once the blades are stopped.

On Earth, the onset of turbulence depends on a quantity first defined by the English mathematician-engineer Osborne Reynolds. In 1883, while studying the flow of liquids in pipes, Reynolds determined that as flow speeds up and pipe diameters increase, so does the likelihood of turbulence; furthermore, the higher the density of the fluid—molasses, say, rather than water—the lower the likelihood of turbu-

lence. He condensed all those factors into a single critical ratio, now known as the Reynolds number.

When fluid—liquid or gas—flows in a circular pipe at a Reynolds number greater than about 2,300, the flow is usually turbulent. In a see-through pipe, for instance, eddies and irregular flows would be clearly visible. So engineers design waterworks and gas pipeline systems with Reynolds numbers no higher than about 2,000.

Beyond Earth, fluid flows can dwarf terrestrial ones, and their Reynolds numbers do, too. The flow speeds of gas in a protostellar disk can be many thousands of miles an hour; the density of the gas is much less than a billionth that of water, and the channels of fluid flow can be millions of miles wide. Those factors push the Reynolds number up into the millions, billions, and even trillions. At first glance, then, you'd expect such a gas disk to have tremendous fluid turbulence, enough to drain the angular momentum rapidly out of the disk, causing the gas to pour into a single core.

But astroscale gas flows differ from terrestrial ones in another hugely important way. Earthbound flows are physically bounded on all sides, by a container, by the ground, or even by air pressure. The astronomical flows have no such boundaries, since they're held together only by gravity. So there's good reason to think that such a system does not act the same way as gas in a pipe or a margarita in a blender.

But how to prove it? No terrestrial laboratory can achieve the key astrophysical conditions—gargantuan Reynolds numbers in fluids spinning without physical boundaries. Ji and his colleagues, however, have come close. The experimenters placed water or water-glycerol mixtures in the space between two independently rotating cylinders (the larger one hollowed out to accommodate both the smaller one and the space for the liquid). Two pairs of rings, which formed the top and bottom of the inner space, could also move independently. The cylinders were spun rapidly, but at different speeds, to make the inside liquid swirl.

The apparatus enabled Ji and his colleagues to cause the Reynolds number of the fluid to reach 2 million—almost a thousand times higher than the point at which turbulence sets in on Earth, and approaching the numbers characteristic of astrophysical systems. Moreover, because of the freedom of movement of the rings at each end, Ji's team could simulate the unbounded conditions, the lack of physical "pushback," at the top and bottom surfaces of a protostellar gas disk more realistically than ever before. And guess what they observed? No turbulence. No loss of angular momentum. No fall-in. No model newborn star.

Well, obviously, stars do exist. So if fluid turbulence can't explain star formation, what can? It turns out that another, even more violent kind of rotating system may provide an answer.

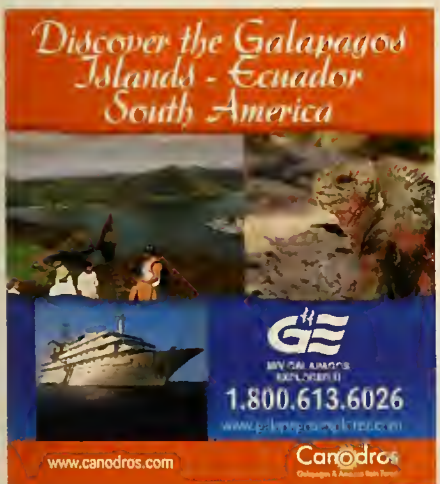
When gas accumulates in a disk around a dense, compact object such as a black hole, the gas becomes ionized, hence electrically charged. The charged, swirling gas generates magnetic fields that interact with the gas particles, creating an instability that can produce the turbulence needed to drain away the angular momentum. The result is a vigorous flow of matter into the center of the system and a corresponding outward flow of energy in the form of X rays and high-speed jets of particles.

So if protostellar disks have substantial magnetic fields, stars can probably still be born. Such fields are sure to be present in the final stages of star formation. But observations of known protostellar disks have shown that they are made up mostly of dense, cold dust and gas—the exact opposite of the conditions needed to create magnetic fields. So unless someone can figure out how nature gets around that problem, we astronomers are still left with our disks (and our heads) spinning, not knowing how to get them to stop.

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

EXPLORER GUIDE

EXPLORER GUIDE



FYi READER SERVICE

ADVENTURE TRAVEL/ TOURS

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

5. AMERICAN MUSEUM OF NATURAL HISTORY EXPEDITIONS
Join an AMNH Expedition and experience first hand the world's greatest wildlife areas, archeological sites and cultural treasures in the company of AMNH scientists and researchers.

6. AUSTRALIAN NATURAL ADVENTURES
Custom nature and soft adventure travel to Tasmania and Australia. Personal and small group touring based on your own interests and timetable. Accredited Tasmanian specialists.

7. CANODROS
Canodros offers up-scale services in Ecuador with the Galapagos Explorer II and Kapawi. We are committed to providing a memorable and enriching experience of the culture, and natural history.

8. CHEESEMANS ECOLOGY SAFARIS
Wildlife, birding and photography nature tours to the world's most pristine habitats. With 30 years experience, let us take you to the world's richest ecosystems. Non-smokers only.

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

10. 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.

11. LATIN TRAILS
Enjoy the natural wonders of South America on unique custom trips & expedition cruise voyages in the Galapagos Islands. Amazon River tributaries and Patagonia ice fields.

12. SERIOUS TRAVELER
Cultural Tours, Small Groups, Exotic destinations. Craft Tours, Libya, Iran, India, Faroes, Apulia, Tibet, Myanmar, Silk Road, Kenya, and much more! Travel Concepts International.

13. 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.

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

15. 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.

16. 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.

CANADA

17. NEW BRUNSWICK, CANADA
From the world's highest tides in the Bay of Fundy to rivers that reverse their flow. . . there are no small wonders in New Brunswick, CA!

18. NEWFOUNDLAND & LABRADOR, CANADA
It's a short trip to the very end of the Earth, where the dawn breaks first at the most easterly edge of the continent. Free Traveler's Guide at 1-800-563-6353 or NewfoundlandandLabrador.com.

19. QUEBEC CITY, CANADA
Discover the magic of North America's most European City! Only 40 minutes from the Old City, go birdwatching, hiking and enjoy yourself. Our waterfalls and our colorful region will charm you!

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

INTERNATIONAL TRAVEL

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

22. GUATEMALA
From our archeological skyscrapers to our quaint colonial cities; our Mayan culture to our vast natural resources. Come "Discover" our Mayan Spirit.

23. 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.

24. 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.

25. YUCATAN
You will be mystified, captivated and delighted by Yucatan. From prehistoric temples to indigenous theater, from colonial cities to mangroves, from convents to superb cuisine. . .come and visit Yucatan.

New Tubes

By Robert Anderson

For anyone interested in geology, what could be more exciting than hiking inside a volcano, along tunnels that, until fairly recently, flowed with torrents of molten rock glowing yellow at about 2,000 degrees Fahrenheit? Around the world, there are dozens of volcanic regions where you can do just that. Mind you, the tunnels you hike in, called lava tubes, are not the main vents that conduct magma up from the bowels of the earth. Rather, they are channels that form beneath or on the slopes of some volcanoes when huge volumes of lava drain from the crater's reservoir.

The Big Island of Hawai'i is lava-tube central, an ideal place to explore old, emptied-out ones and to see new ones in action, making the Big Island bigger. On the Internet, start at Dave Bunnell's "Virtual Lava Tube" site (www.goodearthgraphics.com/virtual_tube/virtube.html). Scroll down to the diagram by Carlene Allred and click on any one of thirty-six features of this alien world.

Sometimes unusual life-forms populate the area around the tubes. Kent Bridges, a botanist at the University of Hawai'i at Manoa, has prepared a virtual tour of the rainforest plants that grow along the walkway into the Thurston Lava Tube, one of the most accessible caves on the Big Island (www.botany.hawaii.edu/faculty/bridges/bigisland/thurston/thurston.htm). At Showcaves.com (www.showcaves.com/english/usa/caves/Kazumura.html) you can read about another of Hawai'i's popular attractions, Kazumura Cave, the longest tube system in the world, with a surveyed length of 36.8 miles.

The Web site of the U.S. Geological Survey's Hawaiian Volcano Observatory (hvo.wr.usgs.gov) has lots of good information on tubes still funneling lava to the sea. Click on "Kilauea" in the menu at the left, scroll down, and click on the link to a sketch that shows how the tubes relate to the main plumbing of "perhaps the world's most active volcano." On the main menu, click on "Ocean Entry" (under "Volcanic Hazards") and scroll down to select "Collapse of new land into the sea." The section shows how lava builds new but remarkably unstable land.

For a look at how the tubes operate, as seen from above, check out the time-lapse volcano movies under "Kilauea," on the main menu. All the movies are informative, but don't miss the one near the bottom of the list, titled "East Lae'apuki Lava Delta Collapse": it records how, in just five hours, some thirty-four acres of newly created land vanished into the ocean.

In the continental United States, lava tubes occur throughout the volcanic regions of the west. At "Volcano World" learn about Ape Cave National Volcanic Monument, on the slope of Oregon's Mount St. Helens (volcano.und.edu/vwdocs/msh/ov/ovb/ovbac.html). At almost 2.5 miles in length, the cave is purportedly the longest intact stretch of lava tube in the continental U.S.

Outside the U.S., the Undara lava tubes in Queensland, Australia, are among the longest and they provide a perfect habitat for hordes of bats (www.undara.com.au/geo). The Web site of a travel company called EWP has photographs of lava tubes in the Azores (www.ewpnet.com/azores/caves.htm).

Lava tubes are not even limited to earthly destinations. The Oregon L^5 society has links to information and images of lunar and Martian examples (www.oregonl5.org/lavatube). Such caves may offer human colonies the best protection from the harsh conditions on those distant worlds. Writing in *Astrobiology Magazine* (www.astrobio.net/news/modules.php?op=modload&name=News&file=article&sid=1260), Penelope J. Boston, an astrobiologist at New Mexico Tech in Socorro, considers "Life in a Lava Tube." Suddenly, that tube in Hawai'i is looking like a really great place to live.

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

By Joe Rao

Mercury becomes a morning object in March. It rises about an hour before the Sun and shines near the east-southeast horizon, well below and to the left of dimmer Mars. The Winged Messenger appears highest during the week of the 9th through the 15th, but is still no more than about eleven degrees above the horizon at sunrise. On the 13th Mercury glows modestly at magnitude +0.5, then brightens for the rest of the month. Unfortunately for observers in the northern United States, after the 15th it loses altitude, making it increasingly hard to see.

Venus is finally getting high enough in the west to command attention every clear evening after sunset. It is gaining prominence because as it traces its inside track around the Sun, it is gradually catching up with the Earth. Still well beyond the Sun as seen from our earthly vantage point, Venus appears too small and roundish to be a very interesting sight through a telescope.

Mars is shifting eastward throughout the month across the dim stars of the constellation Capricornus, the sea goat; viewed from near latitude forty degrees north, it rises just a few minutes before dawn. The Red Planet remains barely above the east-southeastern horizon during morning twilight. Shining at close to magnitude +1.2, it's the brightest object low in the southeast until Mercury appears.

Jupiter, in the southern part of the constellation Ophiuchus, the serpent holder, rises in the east-southeast around 1:45 A.M. local standard time on the 1st, and just before 1 A.M. local daylight time by the 31st. All month Jupiter lies about ten degrees from the bright star Antares, which rises above and to the right of the planet. The prime time to observe this majestic duo in the southern sky is just before dawn.

Saturn is in the constellation Leo, the lion, to the west, or right, of the "sickle," the backward-question-mark pattern. Saturn looks like a bright, yellowish-white, zero-magnitude "star" that is already high in the eastern sky at dusk. Saturn makes two interesting encounters with the Moon this month. Early on the evening of the 1st, the nearly full Moon approaches to within less than one degree, to Saturn's left. Then on the evening of the 28th, Saturn lies directly under a waxing gibbous Moon as darkness falls. As the night progresses, note how the Moon creeps toward Saturn, making its closest approach later that night.

The Moon is full on the 3rd at 6:17 P.M. eastern standard time (EST). Our satellite wanes to last quarter on the 11th at 11:54 P.M. and to new on the 18th at 10:43 P.M. The Moon waxes to first quarter on the 25th at 2:16 P.M.

A total eclipse of the Moon takes place on the 3rd and lasts six hours and nine minutes. Across the Americas, when the Moon rises, the eclipse is already in progress. In fact, for much of the eastern third of the U.S. and east central Canada, the Moon comes up completely immersed in the Earth's shadow. For the central U.S. and west-central Canada, the rising Moon is already exiting the dark umbral shadow of the Earth. From the western third of the U. S. and western Canada, little or no eclipse is visible. Totality begins at 5:44 P.M. EST and lasts seventy-four minutes.

A partial eclipse of the Sun takes place on the 19th, visible to varying degrees across much of central and eastern Asia, as well as throughout most of Alaska.

The vernal equinox takes place at 8:07 P.M. on the 20th. Spring begins in the Northern Hemisphere; autumn begins in the Southern Hemisphere.

Daylight saving time returns on the 11th for much of Canada and the U.S. Set clocks ahead one hour ("spring forward").

Unless otherwise noted, all times are eastern daylight time.

EXPLORING SCIENCE AND NATURE

Around the Country

ARIZONA
Phoenix
ARIZONA SCIENCE CENTER
Through May 28: **"Body Worlds 3: The Anatomical Exhibition of Real Human Bodies."** Visitors can learn about anatomy, physiology, and health by examining real human bodies that have been preserved through a process called plastination. The exhibition includes more than 200 authentic human specimens—entire bodies illustrating neurological, circulatory, and other systems, as well as individual organs and body slices.
600 East Washington Street
602-716-2000
www.azscience.org

CALIFORNIA
Los Angeles
NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY
Ongoing: **"Hall of Gems and Minerals."** Dig into this expansive suite of galleries and discover the science behind the beauty of Earth's treasures. Presenting mineralogy basics and mining practices, as well as specimens you can touch, the exhibition is a dazzling delight. Don't miss the Hixon Gem Vault and its stunning collection of diamonds, emeralds, rubies, sapphires, and other rare gemstones.
Exposition Park
900 Exposition Boulevard
213-763-DINO
www.nhm.org

San Diego
SAN DIEGO NATURAL HISTORY MUSEUM *Through April 29:* **"Playing with Time."** Nothing gets too old in this exhibition, because you

Benitoite is a rare gem mineral found only in California's San Benito County south of San Jose. This large specimen of stacked benitoite crystals is on display in the "Hall of Gems and Minerals" at the Natural History Museum of Los Angeles County.

get to control the passage of time, slowing down or speeding up as you explore change in living things, the Earth, and the universe. Watch time-lapse photography of plants that seem to dance while they grow; see how scientists study ice cores to discover evidence of climate change; use computer animations to visualize the expansion of the universe; and much more.
Balboa Park
1788 El Prado
619-232-3821
www.sdnhm.org

San Francisco
CALIFORNIA ACADEMY OF SCIENCES *Ongoing:* **"Xtreme Life: On Earth and Beyond?"** Discover how animals and microbes that live in hot springs, deep-sea vents, and polar ice might yield clues about extraterrestrial life. With highlights from the academy's specimens and from scientists' ongoing research, this exhibition explains how scientists study extreme environments on Earth to form theories about how life might exist elsewhere in the universe.
875 Howard Street
415-321-8000
www.calacademy.org

COLORADO
Denver
DENVER MUSEUM OF NATURE AND SCIENCE
Opening March 2: **"Benjamin Franklin: In Search of a Better World."** More than 250 artifacts from the scientist-statesman's life—including his original printing equipment and personal copy of the U.S. Constitution—help celebrate the 300th anniversary of his birth. Visitors can climb aboard a 25-foot ship model to recreate his method of charting the Gulf Stream and investigate several of the other scientific questions that intrigued him in a time when science as we know it today was called "natural philosophy."
2001 Colorado Boulevard
800-925-2250
www.dmns.org

CONNECTICUT
New Haven
PEABODY MUSEUM OF NATURAL HISTORY *Ongoing:* **"Hall of Minerals, Earth, and Space."** This new geology exhibition explores the birth of the universe and the forces that shaped Earth's early geology: earthquakes, volcanic eruptions, and meteor collisions. Visitors can also discover how the planet's rocky surface—on land and under the oceans—interacts with the atmosphere and waters to create Earth's livable climate.
Yale University
170 Whitney Avenue
203-432-5050
www.peabody.yale.edu

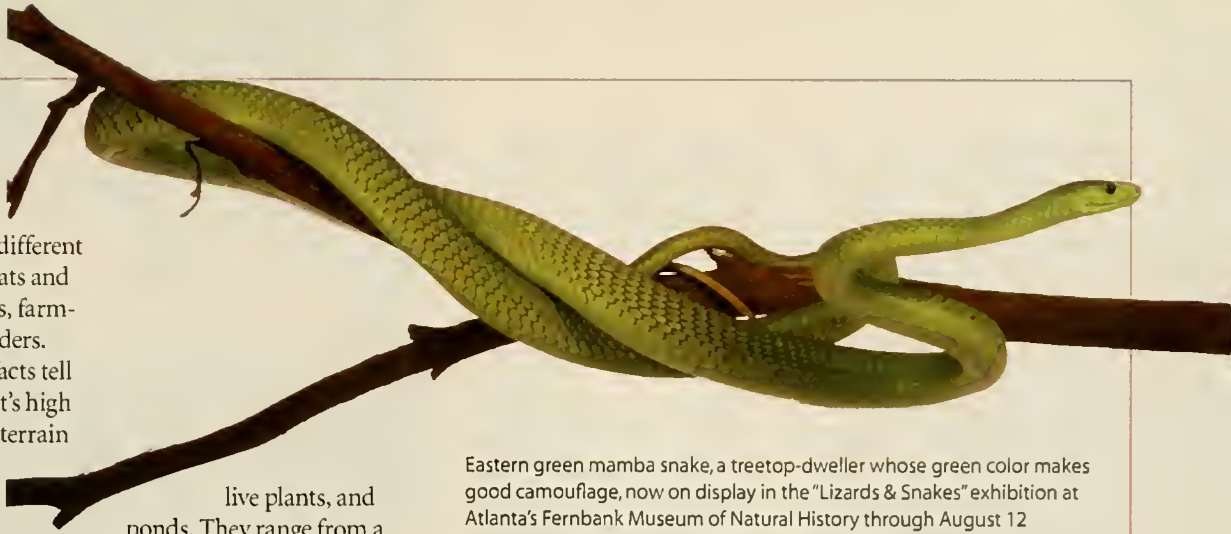
FLORIDA
Gainesville
FLORIDA MUSEUM OF NATURAL HISTORY *Through May 28:* **"Tibet: Mountains and Valleys, Castles and Tents."** Dozens of beauti-

Tube worms, crabs, and other animals form complex communities near hydrothermal vents in the ocean; specimens such as the ones pictured here are displayed in the "Xtreme Life" exhibition at the California Academy of Sciences in San Francisco.

ful objects from pre-1950 Tibet help illustrate the lifestyles of two very different populations: aristocrats and commoners—traders, farmers, and nomadic herders. The exhibition's artifacts tell the story of how Tibet's high elevation and barren terrain influenced economics, religion, and the arts.
University of Florida
Cultural Plaza
SW 34th Street and Hull Road
352-846-2000
www.flmnh.ufl.edu

Tampa
MUSEUM OF SCIENCE AND INDUSTRY (MOSI) *Ongoing:* "Disasterville." Hold on tight in this new permanent installation that vividly re-creates floods, hurricanes, tornadoes, wildfires, and other natural disasters in the unfortunate town of Disasterville. The interactive exhibition explains the science behind each threat, as well as constructive steps you can take to prepare at your own home for nature's fury. The WeatherQuest area provides an innovative role-playing experience, in which teams form TV news crews that investigate and report on the crises as they unfold.
4801 East Fowler Avenue
813-987-6100
www.mosi.org

GEORGIA
Atlanta
FERNBANK MUSEUM OF NATURAL HISTORY
Through August 12: "Lizards & Snakes: Alive!" More than 60 living squamates (reptiles with scales) are on display in re-created habitats, complete with rock ledges, tree limbs, live plants, and ponds. They range from a four-inch tropical lizard to a 15-foot Burmese python. Interactive stations let visitors listen to recorded squamate sounds, explore the inner workings of a rattlesnake, and more. The exhibition also features a wide range of squamate fossils and casts, as well as information on current research and breakthroughs in scientific applications, such as advances in diabetes research made possible by studying Gila monster venom.
767 Clifton Road NE
404-929-6300
www.fernbank.edu/museum


Eastern green mamba snake, a treetop-dweller whose green color makes good camouflage, now on display in the "Lizards & Snakes" exhibition at Atlanta's Fernbank Museum of Natural History through August 12

HAWAI'I
Honolulu
BISHOP MUSEUM *Through April 15:* "Lost Maritime Civilizations of Ancient China." Archaeological artifacts discovered in southeast China during the past 50 years—many never before seen outside of the country—document several prehistoric seafaring societies that flourished between 7,000 and 3,000 years ago. The exhibition portrays populations that are now thought to have migrated to islands throughout the Pacific Ocean, eventually forming Polynesian, Melanesian, and other civilizations.
1525 Bernice Street
808-847-3511
www.bishopmuseum.org

ILLINOIS
Aurora
SCITECH HANDS ON MUSEUM *Ongoing:* "Virtual Reality." An innovative gallery lets you explore things that might otherwise be too small, too far away, or too dangerous to see. Put on some special goggles, sit in front of the large computer-graphics screen, and watch a beating heart, fly around Jupiter and its moons, look inside an ant, or circle around the Wright brothers' first airplane.
18 West Benton Street
630-859-3434
scitech.mus.il.us

Chicago
THE FIELD MUSEUM *Through April 1:* "Gregor Mendel: Planting the Seeds of Genetics." Featuring most of the surviving artifacts from Mendel's life, this exhibition tells the story of his investigation into the way pea plants inherit physical traits, and how his theories influenced the modern field of genetics. In addition, interactive exhibits let visitors recreate some of his experiments, use DNA to determine where flamingos belong on a "family tree" of birds, and more.
1400 South Lake Shore Drive
312-922-9410
www.fieldmuseum.org

INDIANA
Fort Wayne
SCIENCE CENTRAL *Ongoing:* "Observation Gallery." Practice observing like a scientist to gather information about the world around you. Examine starfish and hermit crabs at the Ocean Tidal Pool, discover the dynamics of sound at the Whisper Dishes, launch a wind missile from the Air Cannon, and much more.
1950 North Clinton Street
260-424-2400
www.sciencecentral.org

MEMBERSHIP HAS ITS REWARDS
Institutions marked with participate in the Passport program run by the Association of Science-Technology Centers (ASTC). If you're a member of a participating museum or science center, you may receive free admission at nearly 300 other institutions around the world.

See www.astc.org/passport for more information.

FROM LEFT: NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY/A.R. KAMPF; CALIFORNIA ACADEMY OF SCIENCES; AMERICAN MUSEUM OF NATURAL HISTORY/D. FINNIN

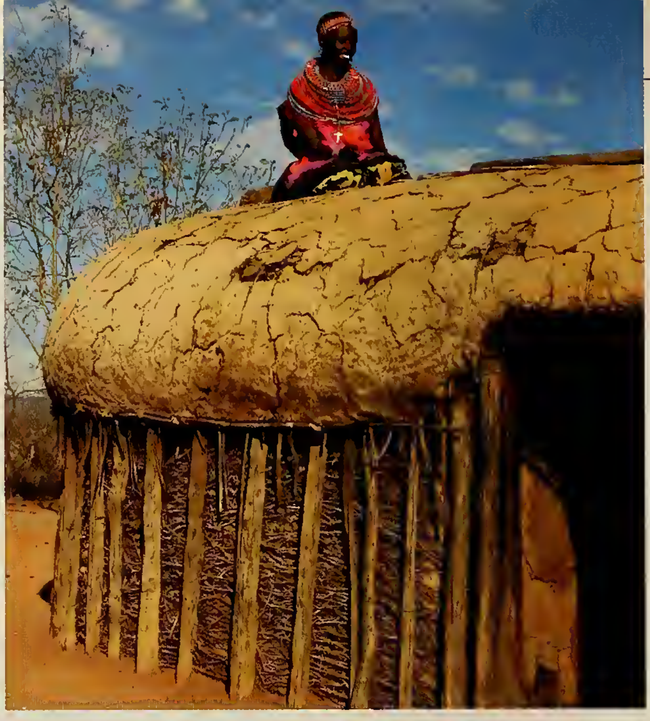
MISSISSIPPI
Jackson
MISSISSIPPI MUSEUM OF NATURAL SCIENCE
Through May 13: "Jewels of the Sea: Walter Anderson's Aquatica." Drawings, block prints, and watercolors portray crabs, fish, sea turtles, and other aquatic animals of the Mississippi Sound the way Anderson saw them—interacting with the natural world but often hidden from human view. Many of the artworks are recently restored after sustaining damage in Hurricane Katrina, and some are being shown to the public for the first time.
2148 Riverside Drive
601-354-7303
www.mdwfp.com/museum

MISSOURI
Saint Louis
SAINT LOUIS SCIENCE CENTER
Through March 25: "SportsWorks." Test your mind and your body in one of the largest sports and science exhibitions in the world, and discover what athletes know about biology, health, and training. Step into a regulation batting cage and toss a pitch to a virtual major leaguer, try your hand (and feet) at climbing a rock wall, experience gravitational force on a bicycle-powered vertical loop high above the ground, and much more.
5050 Oakland Avenue
800-456-SLSC
www.slsc.org

NEW MEXICO
Albuquerque
NEW MEXICO MUSEUM OF NATURAL HISTORY AND SCIENCE *Ongoing:* "STARTUP: Albuquerque and the Personal Computer Revolution." Historical artifacts, interactive exhibits, and videos in this new permanent exhibition explain how microcomputers developed—and how they transformed society. From early electronic computer toys such as Hasbro's Think-A-Tron, through an early personal computer (the Altair 8800), to today's advanced hardware and software, the show traces the PC industry's Albuquerque roots and subsequent growth. Additional galleries celebrate the innovative spirit of young 1970s programmers and invite visitors to speculate about the future of personal computers.
1801 Mountain Road NW
505-841-2800
www.nmnaturalhistory.org

NEW YORK
New York
AMERICAN MUSEUM OF NATURAL HISTORY *Through August 19:* "Gold." Some of the world's largest and most spectacular gold nuggets are on display in this exhibition, along with cultural artifacts such as gold records, Oscar and Emmy statuettes, and a Kentucky Derby trophy. The show also illustrates the processes of prospecting, mining, and refining, and brilliant gold objects document the various ways people have valued and used gold across continents and through time.
Central Park West
at 79th Street
212-769-5100
www.amnh.org

Tupper Lake
THE WILD CENTER, NATURAL HISTORY MUSEUM OF THE ADIRONDACKS *Ongoing:* "Living River Trail." At this spectacular new museum in the heart of New York's Adirondack Park region, the exhibition traces a river's course from the mountains down to the marshlands. Visitors can discover bog, forest, and stream ecosystems, as well as live animals that inhabit them, such as river otters and rare brook-trout species.
45 Museum Drive
518-359-7800
www.wildcenter.org



People have used dried animal dung for thousands of years, for fuel and shelter, as explained in the "Scoop on Poop" exhibition, now at The Academy of Natural Sciences in Philadelphia through May 13.

Unbroken perfume vials were among the many personal effects recovered from the wreck of the *Titanic* on the ocean floor. The *"Titanic"* exhibition, now at the Cincinnati Museum Center through May 6, includes ship fittings, dining ware, and other artifacts.

NORTH CAROLINA
Raleigh
NORTH CAROLINA MUSEUM OF NATURAL SCIENCES
Ongoing: "Terror of the South." Walk through a beautiful setting of Cretaceous plants, but be prepared to come face-to-face with the 110-million-year-old bones of *Acrocanthosaurus* as it lunges toward its hapless sauropod lunch. This is the world's only displayed specimen of *Acrocanthosaurus*, which roamed 45 million years earlier than the famous *T. rex*, and farther south in North America.
11 West Jones Street
877-4NATSCI
www.naturalsciences.org

OHIO
Cincinnati
CINCINNATI MUSEUM CENTER *Through May 6:* "*Titanic*: The Artifact Exhibition." A felt bowler hat, cut crystal decanters, and hundreds of other artifacts recovered from *Titanic*'s final resting place help tell

the story of the ship and its tragic end. The exhibition also highlights the science and technology used to recover and preserve the objects, which were in varying states of disintegration and encrusted with salt and bacteria.
Union Terminal
1301 Western Avenue
800-733-2077
www.cincymuseum.org

PENNSYLVANIA
Philadelphia
THE ACADEMY OF NATURAL SCIENCES *Through May 13:* **"The Scoop on Poop: The Science of What Animals Leave Behind."** Discover how animals use their solid waste to build homes, hide from enemies, send messages, cool off, and even attract mates in this playful exhibition designed to increase your "#2 IQ." The show also explores the many ways that scat can become an important clue to the health and behavior of animals—for farmers, Masai tribesmen, and veterinarians.
1900 Benjamin Franklin Parkway
215-299-1000
www.ansp.org

TEXAS
Fort Worth
FORT WORTH MUSEUM OF SCIENCE AND HISTORY *Ongoing:* "Lone Star Dinosaurs." This new permanent exhibition puts visitors in paleontologists' shoes by providing opportunities to experience fieldwork and then try out laboratory and imaging processes. Visitors can map a dig site, extract fossils from rock, and create a digital picture that summarizes their findings. The show also features five new dinosaur species found in Texas, including two that are not yet named, and describes what scientists are learning from the fossils.
1501 Montgomery Street
817-255-9300
www.fwmuseum.org

Houston
HOUSTON MUSEUM OF NATURAL SCIENCE *Through May 6:* "Frogs: A Chorus of Colors." Hop into a herpetological world in this exhibition devoted to the evolution and biology of frogs. More than 100 living frog specimens—representing species from around the world—showcase the diversity of these animals, from the golden mantella to the Chinese gliding to the not-so-plain American bullfrog. An interactive station enables visitors to hear recorded frog calls, and a virtual dissection exhibit enables you to examine the insides of a frog.
One Hermann Circle Drive
713-639-4629
www.hmns.org

UTAH
Salt Lake City
UTAH MUSEUM OF NATURAL HISTORY *Through May 20:* "From Above." You could imagine you're an eagle soaring above the southwestern desert when you visit this exhibition of 60 large-scale photographs. Photographer Adriel Heisey captured aerial views of Aztec Ruins National Monument, Casas Grandes, Chaco Canyon, and many other places from an ultralight airplane [*see "On the Trail of the Ancestors," by Craig Childs, page 58*]. The images reveal imprints left on the land by ancient and modern cultures.
University of Utah
1390 East President's Circle
801-581-6927
www.umnh.utah.edu

VIRGINIA
Martinsville
VIRGINIA MUSEUM OF NATURAL HISTORY *Ongoing:* "Chinasaurs: The Great Dinosaurs of China." Huge skeleton casts from China—many making their first trip to the U.S.—highlight similarities between dinosaurs from Asia and those from North America, but they also illustrate several unique characteristics. From *Monolophosaurus,* with its unusual curved headcrest, to *Lufengosaurus,* with its widely spaced teeth, the exhibition presents a fascinating overview of dinosaur life in China during the Triassic, Jurassic, and Cretaceous periods.
21 Starling Avenue
276-634-4141
www.vmnh.net

WASHINGTON
Seattle
PACIFIC SCIENCE CENTER *Through May 6:* "Grossology." The exhibition's subtitle is "The (Impolite) Science of the Human Body," and visitors quickly discover why. Through interactive stations, whimsical animatronic figures, and informative graphic panels, visitors can discover the scientific reasons why breath might smell bad or why mucous is sometimes green, among other things.
200 Second Avenue North
206-443-2001
www.pacsci.org

WISCONSIN
Milwaukee
MILWAUKEE PUBLIC MUSEUM *Through August 31:* "Nunnemacher Arms Collection." Trace the development of firearms around the world in this collection of historic weapons dating from the 17th century to the Second World War. U.S. objects include a Ferguson rifle from the Revolutionary War (one of the first rapid-firing rifles), Confederate firearms from the Civil War, and a series of Colt semi-automatic pistols from the early 1900s.
800 West Wells Street
414-278-2702
www.mpm.edu

Green tree frogs, typically living in tree canopies, often seek out pools of still water such as the ones found in a pitcher plant. The frog is one of many species on display in the "Frogs" exhibition, now at the Houston Museum of Natural Science through May 6.

CLOCKWISE, FROM UPPER LEFT: THE ACADEMY OF NATURAL SCIENCES/JOE MCDONALD, HOUSTON MUSEUM OF NATURAL SCIENCE/JOHN NETHERTON, HMS TITANIC, INC.

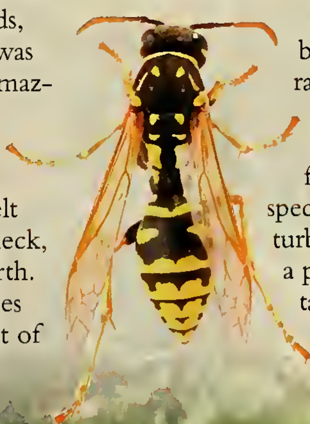
Notes from the Edge

By Robert R. Dunn

The first reports home from early European explorers in the tropics told of impenetrable jungles ("we hacked through a dense, green hell . . ."). But truth be told, the average tropical forest is fairly open. Large trees darken the forest floor, discouraging understory growth. What *is* impenetrable is the edge of the forest, where weedy species clamber for light, jostling into every empty space. The edge was the thorny tangle the explorers first confronted. Those who pushed on found a more inviting forest—albeit one that harbored malaria, the odd poisonous snake, and assorted other perils.

Those early encounters came to mind when I began teaching a summer field class in the Dominican Republic for college students from New York City. The course was held in a small patch of forest next to a seaside resort hotel (a location that posed multiple challenges, including how to keep students' attention when a topless bather walks by). One of my first goals was to get my charges used to the forest. They could appreciate nature, I reasoned, only if they learned to be comfortable in it.

So with practiced nonchalance, I began walking backward down a trail through the forest, twelve students in tow, waving my arms, pointing to snails, crabs, lizards, leaf forms, epiphytes. I was about to mention the amazing abilities of fungus-farming ants, when one of my waving arms hit something. I felt two sharp stabs in my neck, then a third, then a fourth. A most unscholarly series of expletives poured out of my mouth, and I ran a few steps farther down the trail, away from the angry wasps.



Unfortunately, with me out of the picture, the wasps changed targets. When I looked back, all I could see were flailing arms and legs as my students took off in the other direction. A few of them were screaming. Then I heard a louder scream as someone at the front of the pack discovered one more of nature's secrets: another wasp nest. Soon, all the students were running toward me again. It went on like this for a while, the fleeing mob bouncing back and forth between nests, until three students were stung, several were crying, and one was protesting loudly, "I want to go home."

The class did get better (though there was that brief incident with a manta ray . . .), but I feared that for most of the students the forest would remain forbidding. The wasps, a species most at home in disturbed parts of the forest, were a part of the forest's edge, the tangle beside the well-worn trail where weedy species thrive. The students would go home to tell their parents of a "dense, green hell." Worse, by virtue of its small size, our forest was more edge than middle, more barrier than invitation. Had we come to the Dominican Republic several hundred years earlier, the forest would have been both taller, with old growth, as well as deeper, less carved up into small plots, and with an open understory crisscrossed by animal paths.

Later in the summer I invited the students on another trip into the forest, this one optional, by night. I didn't expect many volunteers; even my wife opted out. I arrived early at the meeting place. No one was there. I turned off my light and waited in the dark, listening to the wild calls of forest insects, and the wilder calls of tourists jumping into the hotel pool.

As I was about to give up, one student arrived, then another. Soon, almost everyone was present, headlamp on, ready to go in. We walked slowly along the path, fanning our lights across the leaves, looking for the shine of eyes (I also kept an eye out for wasps).

That night we saw hundreds of animals that had been hiding during the day: crabs, sleeping lizards, sleeping birds, snakes, and even, as everyone crowded around me, a small mammal. It stumbled away through the leaves and branches before we could identify it. We followed it, down off the trail, past the wasps and weeds, beyond the tangled edge. No one said a word.

ROBERT R. DUNN is an assistant professor of zoology at North Carolina State University in Raleigh, and a frequent contributor to Natural History. *His most recent article ("Dig It!") appeared in the December 2006/January 2007 issue.*

Over the past 30 years, the Rolex Awards for Enterprise have helped scores of men and women make our world a better place. If, like them, you have a groundbreaking idea and the ability and determination to bring it to a successful conclusion, this is your chance to apply for a Rolex Award in 2008.

An international panel of distinguished specialists will judge entries on originality of thought, exceptional spirit of enterprise, and potential impact on society and human knowledge. The five most outstanding candidates will each receive $100,000 toward the completion of their projects and a personally inscribed gold Rolex chronometer. Up to five other applicants will each receive a substantial cash prize and a steel-and-gold Rolex chronometer. If you have a project in the fields of science, technology, medicine, exploration, environmental protection or cultural conservation, this could be your first step toward making it happen.

CALL FOR ENTRIES: THE 2008 ROLEX AWARDS. For further details or an application form, visit our website at www.rolexawards.com or write to: The Secretariat, The Rolex Awards for Enterprise, P.O.Box 1311, 1211 Geneva 26, Switzerland. DEADLINES: for Asia, the Pacific and North, Central and South America, May 31, 2007; for Europe, the Middle East and Africa, September 30, 2007.

The Rolex Awards for Enterprise

WWW.ROLEXAWARDS.COM