# NATURAL HISTORY



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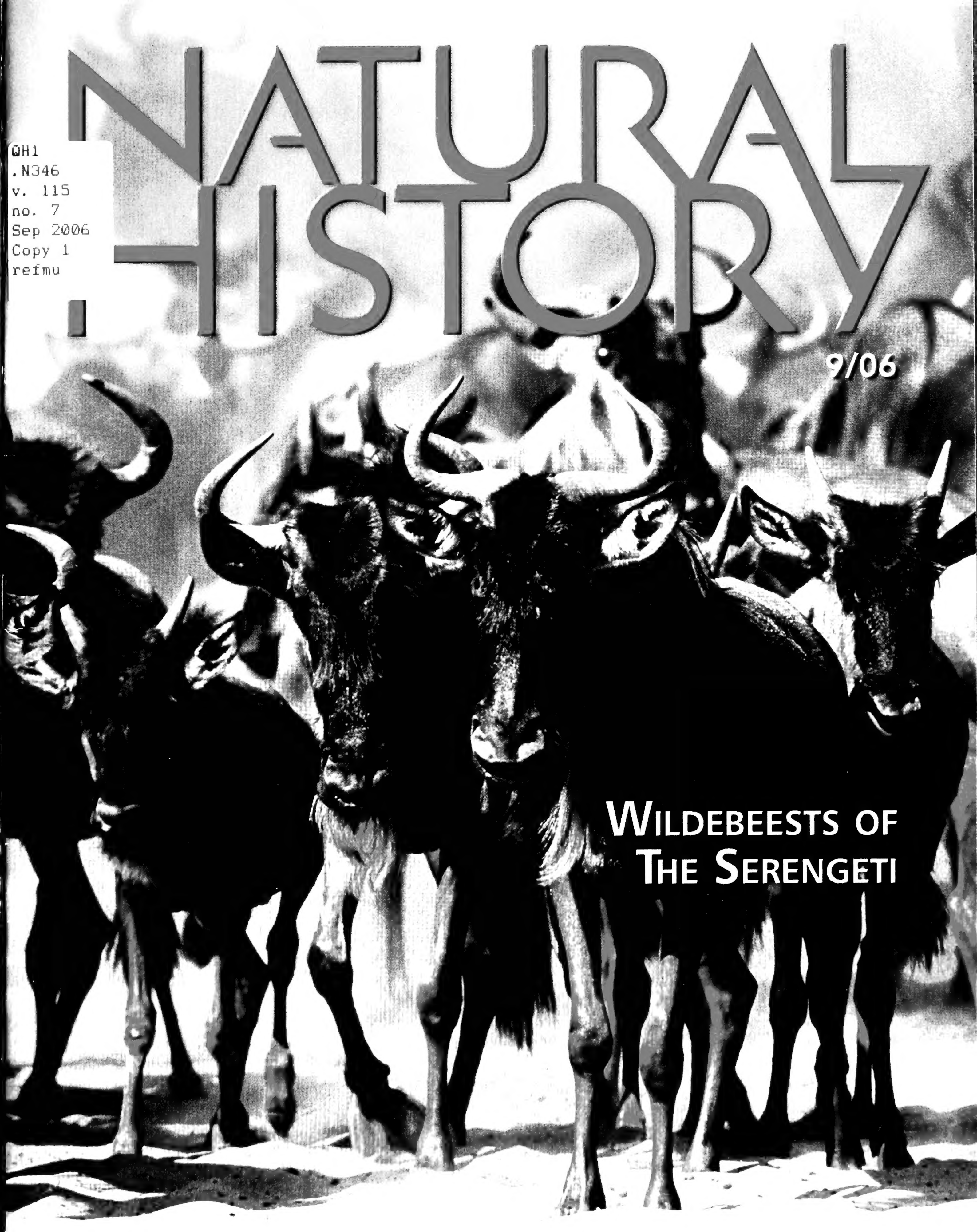

## WILDEBEESTS OF THE SERENGETI

# NATURAL HISTORY

SEPTEMBER 2006 VOLUME 115 NUMBER 7


## FEATURES



ON THE COVER:
Wildebeests migrate across Tanzania's Serengeti National Park. Photograph by Anup Shah

# NATURAL HISTORY

## DEPARTMENTS



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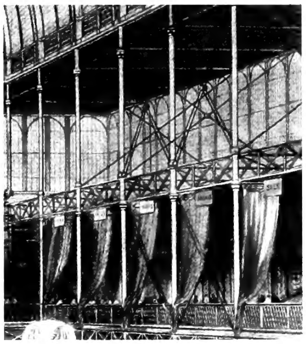

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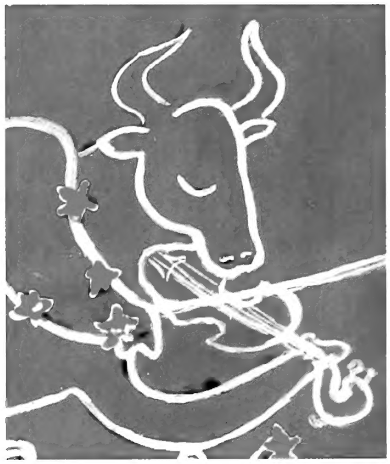

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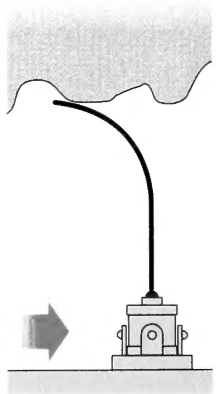

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**PICTURE CREDITS: Page 63**

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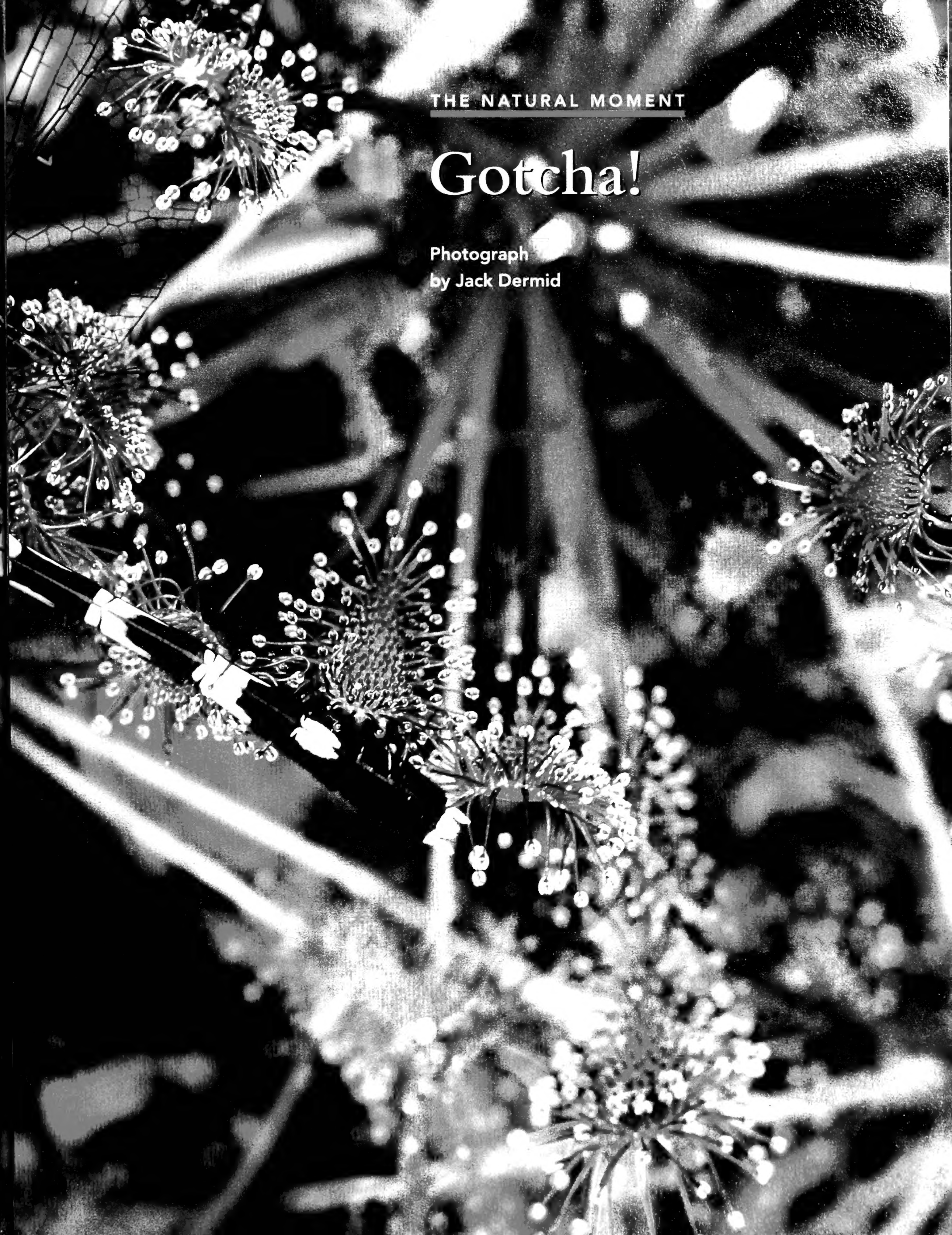
THE NATURAL MOMENT

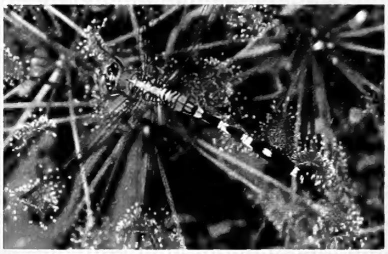
# Gotcha!

Photograph
by Jack Dermid



## THE NATURAL MOMENT

◄ *See preceding two pages*



Precisely because they are full of pitfalls, swamps offer splendid refuge to those adept at sidestepping sinkholes. For dragonflies and other insects, a watery pit makes a good breeding site, and a thin skin of marshy soil makes for an easy landing pad. Still, not every surface is safe. The Eastern pondhawk dragonfly *(Erythemis simplicicollis)*, pictured here, fell prey to another peril of swamp life: the trap set by an insectivorous sundew plant.

The Green Swamp Preserve, near Bolivia, North Carolina, sprawls across some 16,000 acres of shrubby bog land surrounded by pine savannas. That unusual ecosystem boasts at least fourteen species of plants that feast on live insects. It may be the most diverse carnivorous plant reserve in the world—one reason Jack Dermid, a photographer and self-proclaimed outdoor wanderer, regularly hikes there.

Dermid was on the fringe of the swamp one late-summer afternoon when he noticed a resting dragonfly. On closer inspection he realized a spatulate-leaf sundew *(Drosera intermedia)* had the hapless insect ensnared in its sticky tentacles—tied down as securely as Gulliver was by the Lilliputians. The sundew was already draining the juicy carcass of its nitrogen supply.

Was the pondhawk new to the hazards of Green Swamp? Perhaps. Recent research shows that dragonflies migrate great distances—as far as ninety-three miles in a day. Whether visitor or denizen, though, this one didn't make it out of the labyrinth alive. —*Erin Espelie*

## UP FRONT

# Life Support

Quick—name an important mammal of the African savanna. If you're like me, you probably thought of the lion, the cheetah, the hyena, or any of several other toothy carnivores. But supporting many of those impressive creatures is the herbivore known as the gnu—or, more formally, the wildebeest. So when Richard D. Estes approached us about contributing an article to *Natural History* ("Wildebeests of the Serengeti," page 28), we became as excited as crocodiles hiding in a wildebeest watering hole. Estes is perhaps the world's leading expert on the wildebeest, one of Africa's signature large mammals, and no one is better suited to bringing all of us up to date on the gnus from the Serengeti.

So important is the wildebeest to the ecological health of the African savanna that biologists label it a "keystone" species. And for their part, wildebeests have adapted marvelously well to their role as Africa's hot meal on the hoof. Vast herds of them remain constantly on the go. Some 80 percent of the females manage to give birth within just a few weeks, ensuring that though some of the calves will become hyena fodder, plenty of others will survive to reproduce another day. The calving strategy also keeps the food glut brief enough to prevent a permanent expansion of predators. Precocious "gnuborns" fit right into the herd's strategy of moving on: they struggle to their feet, on average, within seven minutes after birth, ready for the dusty trail.

• • •

From our perspective as creatures living at the bottom of the atmosphere, the high mountains seem one of the most inhospitable places on earth. The air is thin, the sunlight burns, the wind howls, and the weather is unpredictable. Most of us are amazed when we discover, say, a wildflower growing in a crevice on a steep boulder field above 12,000 feet. It's a natural response, but by now it ought to be recognized as a parochial one. "Extremophiles"—the very name reflects our provincialism—live everywhere: in the superheated water and hydrogen sulfide issuing from deep-sea vents, in caves isolated from sunlight for millions of years, between layers of sea ice floating in the Arctic Ocean.

Yet until recently, even professional biologists had fallen into the anthropocentric trap of assuming the alpine zone is a sparse and barren land. Writer Kevin Krajick and photographer Carsten Peter ("Living the High Life," page 44) endured pounding headaches and worse at 17,000 feet in order to accompany a biological expedition whose goal was to prove the reverse. And sure enough, the slopes of the high Andes turned out to be home to a surprising diversity of life. Expedition members made so many new discoveries that their simple, factual descriptions sounded, unintentionally, like comic repetition: "the world's highest frog," "the world's highest worm," "the world's highest clam," "the world's highest leech." In fact, the superlatives reflected a lack of prior scientific attention as much as the expedition's own good luck. Making new discoveries in the mountains is easy, explained the expedition's chief scientist, Stephan R.P. Halloy, "because we are *looking* here."

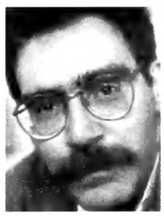
—Peter Brown

## CONTRIBUTORS

Photographs by **JACK DERMID** have appeared in the pages of *Natural History* for more than fifty years—including the cover images for the April 1954 and April 1957 issues. He is retired from the University of North Carolina, Wilmington, where he taught environmental science and marine biology. Dermid has hiked countless miles all over the United States, always with camera in hand, but he made his photograph of a dragonfly trapped by a sundew plant ("The Natural Moment," page 4) less than thirty miles from his home in Wilmington. His photographs have been exhibited at the North Carolina Museum of Natural Sciences in Raleigh and featured in *Amphibians and Reptiles of the Carolinas and Virginia,* published in 1980 by the University of North Carolina Press. He also co-authored *The World of the Wood Duck.*

More than forty years ago **RICHARD D. ESTES** ("Wildebeests of the Serengeti" page 28) chose the western white-bearded wildebeest as the subject for his doctoral dissertation; he has continued his field studies of that African antelope ever since. He is chairman emeritus of the Antelope Specialist Group of the IUCN (World Conservation Union). Among his original contributions is the hypothesis that where natural selection favors mixed-sex herds, differences in appearance between males and females are minimized ("The Significance of Horns and Other Male Secondary Sexual Characters in Female Bovids," *Applied Animal Behaviour Science* **29:**403–51, 1991). He is awaiting test results of another original hypothesis, that estrus in female western white-bearded wildebeests is synchronized by the calls of rutting bulls. Estes lives in New Hampshire, where he is working on a book about his favorite animal.

After spending ten years as a roadie in the music business, **STUART BEARHOP** ("Change in the Air," page 36) decided to pursue his other longstanding passion—natural history, particularly birds. After earning his undergraduate and doctoral degrees at the University of Glasgow, he became a lecturer at Queen's University Belfast, in Northern Ireland, where he is currently based. Bearhop's main research interests are foraging ecology and avian migration. In addition to examining migration patterns in European blackcaps, he is studying the impact ferrets have had on ground-nesting birds after the ferrets were introduced to an island off the northern coast of Ireland to control rabbits. He is also using isotope ratios and GPS technology to pinpoint the foraging patterns and mating locations of albatrosses.



Last year, after investigating how climate change is affecting high-alpine areas, **KEVIN KRAJICK** ("Living the High Life," page 44) was invited to join a group of biologists on a "peak-hopping" expedition in the Andes. A New York City–based journalist who specializes in science and the environment, Krajick is used to natural extremes, having traversed sea ice, climbed to the tops of the world's tallest trees, and descended to the bottom of the deepest mines. His previous articles for *Natural History* include "The Crystal Fuel" (May 1997), about the presence of methyl hydrates in the ocean floor, which won the American Geophysical Union's Walter Sullivan Award for Excellence in Science Journalism. Widely published in magazines and newspapers, Krajick is also the author of *Barren Land: An Epic Search for Diamonds in the North American Arctic* (W.H. Freeman, 2001). The book tells the real-life adventure of two small-time prospectors who discovered a great diamond mine in Canada's far north.


NATURAL HISTORY





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*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.



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## Infinite Multiverse

Alex Vilenkin's article, "Beyond the Big Bang" [7–8/06], is stimulating and fantastic at the same time. The mind boggles at the thought that there are replica worlds in an infinite number of universes created by "eternal inflation."

How would the author's theory change if universe creation (each big bang) were a stochastic rather than a deterministic event? That is, what if the laws of physics in even some small way were random in those first trillionths of a second of creation?

*Walter Ulrich*
*Pearland, Texas*

Alex Vilenkin's assertion that the number of universes is infinite relies on an analysis that shows the rate of increase of false-vacuum regions to be larger than their decay rate. Can that conclusion be tested experimentally?

*Fred Haag*
*Burnt Hills, New York*

Alex Vilenkin's article looks like another example of a theory that cannot be tested. Mr. Vilenkin is careful to establish that the size of an "island universe" would be so large that communicating with another universe or testing the existence of another would be impossible. To me, as a mere mathematician, that circumstance seems to imply there is no way for us to determine whether Mr. Vilenkin's theory is true or false.

Another problem I have is Mr. Vilenkin's assertion that since there is only a finite number of possible kinds of "island universes," and since there is an infinite number of them scattered about the universe, there must be an infinite number of island universes just like ours. But Mr. Vilenkin's conclusion does not follow; all that follows is that there must be at least one island universe that occurs an infinite number of times.

*Nolan Wallach*
*University of California, San Diego*

There is indeed an infinite number of universes in which Alex Vilenkin reaches his conclusion: "With humankind reduced to absolute cosmic insignificance, our descent from the center of the world . . . is now complete." There is also an infinite number of universes in which Mr. Vilenkin concludes the exact opposite. I quote: "With humankind restored to absolute cosmic significance, our ascent to the center of the world . . . is now complete."

How does he (or rather they) reach this conclusion? Check out a copy of the alternative *Natural History*! And which conclusion is superior? One suspects this matter must be settled among themselves by the alternative Alexes.

*Robert P. Largess*
*Boston, Massachusetts*

ALEX VILENKIN REPLIES: Walter Ulrich asks what would happen if different island universes are characterized by different values of the constants of nature (and thus by different laws of physics). That possibility is being actively discussed by cosmologists. The "choice" of the constants is stochastic, and the theory of eternal inflation is used to predict the most probable values that we (typical observers in the multiverse) are most likely to observe. One such prediction (for the so-called cosmological constant) has already been confirmed—perhaps the first evidence that there is indeed a huge multiverse out there.

Fred Haag wonders whether a certain property of the false vacuum can be verified experimentally. But a false vacuum will not be generated in the laboratory any time soon, because of the enormous energy required to do so. Still, there is a good theoretical reason to think that the rate of false-vacuum expansion is greater than the rate of its decay. If it were not, the universe would not expand by much before the false vacuum decayed, and inflation would not be able to account for the huge expanding universe that we observe.

The points raised by Nolan Wallach are discussed in detail in my book *Many Worlds in One*. Briefly, other island universes are not directly observable, but their existence follows from the theory of inflation. The theory is supported by data in the observable part of the universe, and that gives us reason to believe its conclusions about the parts we cannot observe.

It is true that infinite space does not, by itself, guarantee that all possibilities are realized. Random quantum fluctuations, however, supply an additional ingredient. All possible island universes that do not violate the laws of physics have nonzero quantum mechanical probabilities, and so they must occur somewhere in the multiverse.

*"I said I wanted a wild beast in bed, not a wildebeest."*

## Collateral Damage

David Barraclough's article, "Bushels of Bots" [6/06], noted that every large animal species (including the rhinoceros) hosts several endemic species of parasites and commensals, such as flukes, protists, roundworms, and tapeworms. When a host species goes extinct, it carries several other species "down" with it.

It is hard for most people

to appreciate parasites and endocommensals as a valuable part of biodiversity, but by most estimates they make up between 60 and 70 percent of all species on Earth. I can't help but wonder what magnificent flukes, nematodes, and tapeworms once inhabited the great dinosaurs, the massive ground sloths, or the great diversity of early lobe-finned fishes.
*David Zeigler*
*University of North Carolina*
*Pembroke, North Carolina*

### Sharp Medicine

In his article on porcupine quills ["Smart Weapons," 3/06], Uldis Roze measured the large force needed to pull a quill out of an animal's skin. I, too, have had the discomfort of watching a young veterinarian pull quills out of the long nose of my dog. He did indeed have to pull quite hard!

But I was told by an elder vet that the struggle had not been necessary. If the young vet had clipped the quills, enabling the air in them to escape, they would have collapsed and been much easier to pull out.
*Tana Hemingway*
*Mesquite, New Mexico*

ULDIS ROZE REPLIES: In spite of the old vet's suggestion, porcupine quills are not hollow—they are filled with a spongy matrix that keeps them from collapsing when clipped. In fact, clipping the quills increases their danger to the victim. A clipped quill may splinter in such a way that it can't be held by pliers. Then the broken tip may break free and travel in the body. Tana Hemingway should "stick" with the young vet.

### Runaway Inflation?

In Robert H. Mohlenbrock's article, "Along the Pothole Trails" [6/06], an extra zero has crept into the text. In describing Interstate State Park, he states that Lake Superior is 1,000 miles away.

According to my trusty road atlas, and my odometer, the distance between St. Croix Falls, Wisconsin, and the western end of Lake Superior is only 100 miles.
*Robert D. Esko*
*South St. Paul, Minnesota*

### Correction

The locator map that accompanies Robert H. Mohlenbrock's article, "Along the Pothole Trails" [6/06], incorrectly places the area of detail. The area is north of St. Paul, Minnesota, not south.

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.*

SAMPLINGS

# Cooked Fish and Fowl

It's no secret that Earth's warming climate is imperiling many denizens of the maritime north. Two new studies show its effect on the breeding behavior of the Atlantic cod and a common seabird known as the Arctic tern. Cod populations have suffered precipitous declines in recent years, largely because of overfishing. In the North Sea, the species is now virtually absent from its southern range. To understand why, Anna Rindorf and Peter Lewy, fisheries scientists at the Danish Institute for Fisheries Research in Charlottenlund, analyzed hydrographic records and cod survey data spanning the years 1983 until 2003. The investigators discovered that the recent series of warm, windy winters swept cod eggs and larvae northward and may have reduced their survival in the southern parts of their range. The cod's tendency to spawn where it was born leads subsequent generations to begin their travels at ever higher latitudes. Without a string of cold, calm winters and restrictions on fishing in southern areas, the cod of the North Sea is unlikely to regain its former range, never mind its former numbers. (*Journal of Applied Ecology* **43**:445–53, 2006)

*Cod fishing in Norway, above; Arctic tern, far left*

In a second study, Anders P. Møller, an evolutionary biologist at Pierre and Marie Curie University in Paris, and two colleagues discovered that by 1998 Arctic terns were laying eggs eighteen days earlier than they were in 1929. Generations of biologists have been fitting birds with identifiable leg rings for more than a hundred years. Because young birds are ringed before they leave the nest, Møller could estimate when, on average, terns laid their eggs. He then related the historical egg-laying dates to data on local and regional climate. Steadily warming temperatures, Møller says, explain the advancing dates. (*Journal of Animal Ecology* **75**:657–65, 2006)

*—Nick W. Atkinson*

# What's in a Mane?

African lions have been classified into as many as twenty-three subspecies, many of them on the basis of variations in the appearance of the males' manes. Some populations have an extensive coverage of long, dark hair, whereas others have almost no shag at all. Even within populations, manes vary a great deal according to a given lion's age, health, nutrition, social status, and testosterone levels, among other factors. A recent study, however, shows that yet another factor affects mane growth, and that manes may not be such a good way to distinguish subspecies after all: the king of beasts' mane, it seems, varies with climate.

Bruce D. Patterson, a zoologist at the Field Museum in Chicago, and three colleagues studied lions living in seventeen zoos in various climatic regions of the United States—many of the factors that affect mane growth in wild lions are held constant in zoos. Sure enough, climate explained much of the variation among the zoo lions' manes. Patterson's team concludes that the manes of many of the subspecies may actually reflect environmental—not genetic—differences.

An abundant mane signals a male's prowess, but the social advantages it confers conflict with the distinct physiological disadvantage—for a desert-dweller—of trapping heat. Indeed, wild lions from equatorial deserts tend to be virtually maneless compared with lions from cooler habitats. Investigators have assumed that reduced manes are an adaptation to heat. Patterson's group, however, found that winter—not summer—temperatures determined mane growth. Yet manes can't be an adaptation to cold because female lions don't have them. Clearly, it's going to take more work to figure out the mane game. (*Journal of Mammalogy* **87**:193–200) *—N.W.A.*

*Male lion in Kenya, with the wind in his mane*

# Written in Stone

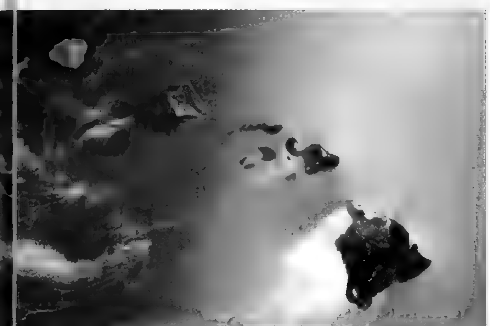
A dogma of the Earth sciences may be on shaky ground. Geologic hotspots—long thought to be relatively fixed points beneath Earth's shifting tectonic surface—are themselves moving around.

Hotspots are areas of long-term volcanic activity that have served as handy reference points for tracing the movements of tectonic plates. The Hawaiian Islands, for instance, are thought to have formed from the lava spewed by a hotspot up onto the Pacific plate as the plate moved northwestward over the hotspot. The islands, known as a hotspot "trace," thus record the track of the plate over the hotspot (which is now centered under the Big Island of Hawai'i). From the ages of the islands, the direction and speed of the plate's movement can be inferred.

To model the movements of the planet's plates, earth scientists have assumed for more than three decades that the hotspots remain fixed relative to one another, and that the plates themselves have not undergone any recent reorganization in the ways they butt up against one another. Now a statistical analysis by Shimin Wang and Mian Liu, geophysicists at the University of Mis-

# Many Like It Hot

Warmth and water do more than just make plants grow quickly. In the tropics, it seems, evolution itself proceeds at a faster pace than it does in temperate zones. Shane Wright, a biogeographer at the University of Auckland in New Zealand, and two colleagues studied forty-five pairs of closely related plant species. One member of each pair is from the tropics; the other hails from a temperate clime. To determine the rate of evolutionary change, the team



*Hawaiian Islands record the track of the Pacific plate over a geologic "hotspot."*

souri in Columbia, have confirmed mounting evidence that at least one of those assumptions must be wrong. The hotspot traces, they discovered, aren't where they should be if both assumptions are correct.

The geologists' analysis indicates that though there has been no major reorganization of the plates in the past 40 million years, the hotspots have been moving. The good news is that they seem to be moving in the direction opposite to that of the plates that overlie them. Thus geologists need not abandon hotspot traces to make inferences about the movements of the Earth's crust. (*Geology* **34**:465–8, 2006) —*N.W.A.*

compared a section of genetic code in the members of each pair with the corresponding section in a third species, the pair's closest relative. The tropical plants, Wright and his colleagues discovered, have evolved twice as fast, on average, as their temperate cousins.

Compared to cool, dry ecosystems, warm, wet ecosystems grow enormous numbers of organisms, which tend to have high metabolic rates. Wright thinks the higher productivity and faster metabolisms raise the likelihood of genetic mutations. More frequent mutations should lead to more rapid evolutionary change. Faster evolution, in turn, may cause species to proliferate. If so, Wright's discovery may explain the tremendous diversity of the tropical forests. (*PNAS* **103**:7718–22, 2006)

—*Krystin N. Mementowski*

# Who Needs Sex?

Sex is an evolutionary conundrum. If the point of sex, as most biologists believe, is to propagate your genes, parthenogenesis, in which females' eggs develop into young without fertilization by males, would seem to beat sexual reproduction hands down. Why split your genetic legacy with a second parent?

Yet the cost of sex doesn't stop 99.9 percent of known animal species from reproducing sexually. To understand why, biologists study the evolutionary history of the other 0.1 percent. Four evolutionary biologists, led by Michael Kearney of the University of Melbourne in Australia, studied two parthenogens in the deserts of Australia: a grasshopper *(Warramaba virgo)* and a gecko *(Heteronotia binoei)*. In both, parthenogenesis evolved as a result of hybridization between sexual ancestors. And in both, parthenogenesis probably arose not once but twice.

Kearney's team sequenced DNA from the parthenogenetic grasshoppers and geckos, then compared it to that of their sexual ancestors, which are still alive today. The team discovered that the first parthenogenetic populations of both grasshoppers and geckos had historically expanded their ranges at the same time and in a similar pattern. So had the second. During the same period—late in the Pleistocene epoch, which lasted from 1.8 million until 10,000 years ago—the Australian desert underwent a series of expansions and contractions. Kearney thinks the shifting desert habitat probably brought isolated populations of the animals' sexual ancestors into contact long enough for their asexual hybrid offspring to become established. Parthenogenetic reproduction might be advantageous in harsh climates where mates are hard to find. In more comfortable environments, however, the genetic diversity that sex bestows may outweigh the costs of sharing your genes. (*Molecular Ecology* **15**:1743–8, 2006) —*N.W.A.*

Warramaba virgo, *a grasshopper that reproduces without sex*

# Walkabout

About 5,000 years ago, after nearly thirty millennia in Australia, Aborigines began traveling a great deal throughout the continent and sharpening their tool-making skills. Was it a baby boom that prompted their cultural transformation, as some investigators contend, or something else? A new study indicates that a turn in the weather may have been part of the story.

Chris S.M. Turney and Douglas Hobbs, both archaeologists at the University of Wollongong in Australia, tracked the Aborigines' activity of the past 12,000 years from the dates of 710 archaeological samples—charcoal from fires and discarded shells—that were discovered throughout the northeastern state of Queensland. They then compared the pattern of activity to published geological records of the El Niño phenomenon, in which warming of the central and eastern equatorial Pacific Ocean alters weather patterns around the globe.

Five thousand years ago El Niño began to act as it does today: its frequency and severity increased and it brought periods of intense drought to northeastern Australia. Turney and Hobbs discovered that the start of the new El Niño pattern coincided with a boost in Aboriginal activity across Queensland's inland countryside. Subsequent spikes in activity were also in sync with periods of intense weather caused by El Niño.

The archaeologists think drought may have forced Aborigines to develop better tools, roam farther to hunt, and explore new areas in search of scarce necessities for survival. (*Journal of Archaeological Science*, in press)

—*Edyta Zielinska*

*Babbling baby: a young greater sac-winged bat*

# Side Benefits

Like right- or left-handed people, most animals seem to favor one side of their bodies for certain tasks. Lateralized behavior is a sign that the animals' brains are lateralized as well. But is there any benefit to having a lateralized brain? A recent study by Marco Dadda, a psychologist, and Angelo Bisazza, an evolutionary biologist, both at the University of Padua in Italy, suggests that lateralization may make animals better at the critical skill of multitasking—attending to two or more activities at the same time.

Goldbelly topminnows are small Central American fish that belong to the guppy family. Female goldbelly topminnows must put up with repeated attempts by males to mate with them. The suitors can be distracting, even exasperating, to females, particularly when they are trying to eat. Dadda and Bisazza compared the feeding efficiency of female goldbelly topminnows bred to be lateralized with that of females bred to have no side preference. When there were no distracting males, the two kinds of females caught food equally well. When randy males were present, however, only the lateralized females kept eating efficiently, while still avoiding unwanted advances. Parallel processing seems to benefit from a brain with asymmetrical function. (*Behavioral Ecology* **17**:358–63, 2006) —*Stéphan Reebs*

# Baby Bat Chat

"Goo-goo ga-ga" is an important step for a baby learning the intricacies of human language. Babies babble away with complete disregard for social context, happily practicing the sounds they will need to speak as adults. Only a handful of other animals, all with advanced vocal skills—a few primates, certain birds, and maybe some whales and dolphins—babble when they are young. Now a new creature has joined that elite group: the greater sac-winged bat of Central and South America, *Saccopteryx bilineata.*

The greater sac-winged bat is a chatty creature. Not only does it make sounds to catch prey by echolocation; it also barks, chatters, screeches, and whistles to attract or threaten other members of its species. Males even serenade females with courtship songs and repel competitors with territorial songs, just as birds do.

At several roosts in Costa Rica, Mirjam Knörnschild, a behavioral ecologist, Otto von Helversen, a zoologist, and a colleague, all from the University of Erlangen-Nuremberg in Germany, recorded sounds made by young sac-winged bats that had not yet been weaned from their mothers. Like baby babbles, the pups' vocalizations were similar to adults' calls, and the pups made them without regard for social context, typically while alone. Intriguingly, pups of both sexes practiced parts of the courtship and territorial songs sung in adulthood only by males. Babbling, the authors contend, may be essential for any animal to master a large vocal repertoire. (*Naturwissenschaften,* DOI 10.1007/s00114-006-0127-9, 2006)

—*S.R.*

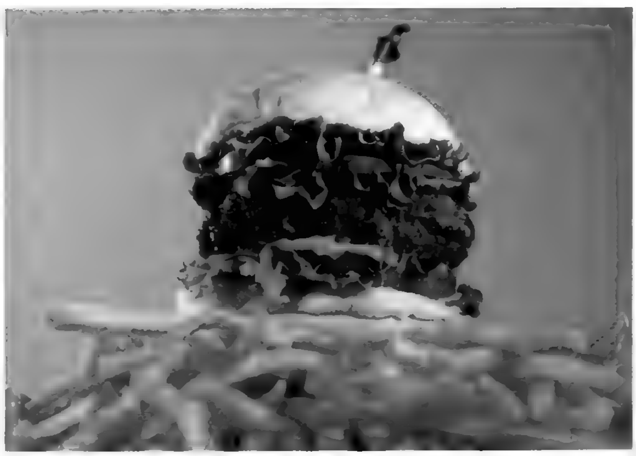
# Burgers and Flies

Grab that flyswatter! Public-health entomologists have discovered antibiotic-resistant bacteria lurking in the guts of houseflies buzzing around fast-food joints. Ludek Zurek and Lilia Macovei of Kansas State University in Manhattan, Kansas, captured more than 200 houseflies at five restaurants in a northeastern Kansas town. The entomologists isolated and cultured bacteria from the flies' guts, then exposed the bacteria to antibiotics. Two-thirds of the bacteria survived treatment with a single common antibiotic, and, of those, half survived treatment with two or more antibiotics. Zurek and Macovei also identified genes that confer immunity in most of the resistant bacteria's DNA.

The houseflies may have come from farms, the entomologists say. In the U. S., livestock are regularly dosed with antibiotics to encourage growth, and so their gut bacteria often evolve resistance to the drugs. Houseflies that develop in and feed on the animals' waste swallow bacteria when they eat. Then, being long-distance aviators, they can fly to town—hence their nickname in Zurek's lab: "flying manure."

Houseflies enjoy many of the same foods people do, including cooked meat and sweets. And they go to the same restaurants. They eat messily, spitting and regurgitating on their meal before digging in. In the process, a house-fly's lunch—which may be *your* lunch, too—is doused with the contents of the fly's gut, including any bacteria, antibiotic-resistant or not, that the fly is carrying.

As unappetizing as that may sound, most gut bacteria from flies are relatively harmless, so their immunity to antibiotics might not seem alarming. But bacteria readily exchange genes, so the gut bacteria could pass resistance genes on to nastier species, which houseflies also carry. And those little monsters can prove immune to current medical treatments—a mounting concern for physicians. (*Applied and Environmental Microbiology* **72**: 4028–35, 2006) —*Ciara Curtin*



# Shocking Truths

*If you break the sound barrier, you can make quite a stir.*

By Neil deGrasse Tyson

No matter what the threshold of your sensibilities, modern life can be shocking. A passenger cursing loudly in a crowded subway car may shock your sense of propriety. War profiteering may shock your sense of ethics. Torture may shock your sense of humanity. A scorched forest, a flooded city, a corpse lying unattended on a street can all be shocking sights.

But none of those scenes is likely to disrupt your personal set of molecules. A wholesale disturbance requires not figurative shocks but literal ones—and the cosmos has plenty of them. Huge flares rear up out of the Sun and launch billions of tons of plasma into the solar system at a million miles an hour; gigantic rings of million-degree gas race outward from exploding stars; colossal gas clouds, millions of times larger still, plunge into one another as galaxies collide, creating bursts of freshly formed stars. Find yourself near any of those phenomena, and you'll have more than your emotions to worry about.

Twentieth-century technology bequeathed its own versions of extreme shock waves. Some were unleashed by the detonation of the atomic bombs "Little Boy" and "Fat Man" over Hiroshima and Nagasaki in August 1945. Others were loosed by the hydrogen bombs "Mike" and "Bravo"—hundreds of times more powerful than their atomic predecessors—on the Pacific atolls of Eniwetok in 1952 and Bikini in 1954. One hesitates to contemplate the shock waves that might be wrought by twenty-first-century technology.

Shock waves begin from a simple fact of nature: molecules in a gas are always on the move. Not only do they stretch and shrink and twist and turn and vibrate, they also move, body and soul, from one place to another. In a split second, a meandering molecule bounces off neighboring molecules, transferring its energy from one to the next, and so on across the gas.

Intruders, too, can shake up a batch of molecules that are otherwise jiggling away in blissful isolation. When

a plane flies through the air, the solidly attached molecules of its nose part the gaseous molecules ahead of it, creating a huge ripple of pressure. The ripple passes from the layer of molecules closest to the plane, to the layer just ahead, and then to the layer just ahead of that, all at the speed of sound. Same thing happens ahead of the airplane's tail. As each layer feels the ripple, it bumps into the next layer, announcing the news of the oncoming plane. Meanwhile, the plane cruises through the air without incident.

But what happens if the plane flies faster than the time it takes for each layer to bump into the layer in front of it—faster, in other words, than the speed of sound itself? (At the frigid air temperatures at cruising altitude, the speed of sound is about 670 miles an hour.) If the plane is suitably designed and powered, it just busts through the medium's hapless molecules. All the pressure waves—including the ones created by the noise of the plane's engines—now pile atop one another, greatly amplifying the resulting sound.

Meet the sonic boom.

A sonic boom is the audio track of a shock wave. Anyone who happens to be nearby will hear it loud and clear. Amplify a plane's shock wave by a factor of ten, a hundred, a thousand, and you're on your way to simulating the conditions of some common happenings in outer space.

Every syllable you utter sends its own sound wave—its own wave of pressure—rippling through the air. When you stand in one spot and talk nonstop, each wave you generate forms a sphere that is centered on your mouth and expands at the speed of sound.

But let's say you're both chatty and speedy. If, for instance, you start at the base of the Washington Monument and talk while you walk north toward the White House, each new sound you make comes from a new expanding sphere that rides closer than normal to the leading edge of the preceding sphere and farther than normal from its trailing edge. Of course, the faster you walk, the closer together are the leading edges of successive sound waves.

Now suppose you walk so fast that the sound of your current syllable catches up with the sound of your previous syllable. If you keep walking and talking at that speed—the speed of sound—all your syllables will pile up together as you lay one track after another on the same leading edge. That would be your own personal shock wave. At that speed, about 770 miles an hour on a fall day in D.C. (and leaving aside the fact that the ferocious air resistance would dismember your body), you would arrive at the back door of the White House about three seconds after leaving the foot of the Washington Monument.

When physicists refer to the speed of an object in a medium, they almost always invoke "Mach" numbers. This unit is named for the nineteenth-century Austrian physicist and philosopher Ernst Mach. By definition, an object that moves at Mach 1 moves at the speed of sound. But don't ask, "How fast is that?" unless you're prepared to answer three questions: "What is the temperature of the medium? What kinds of molecules comprise it? How compressible is it?" Those questions arise because, unlike the speed of light in a vacuum, which is the same anywhere in the cosmos, the speed that corresponds to Mach 1 is strictly local.

Nowadays, encounters with Mach 1 are not rare. The snap of a damp towel against your friend's butt is a mini sonic boom. So is the rapid inflation of your car's airbag. Want bigger booms? Try Mach 2 (the recently retired Concorde commercial jet liner) or Mach 3 (the SR-71 Blackbird, a U.S. Air Force spy plane). How about Mach 25 (the space shuttle re-entering Earth's atmosphere)? And by the way, no matter the medium or the speed of sound within it, reaching similar Mach numbers creates similar physical phenomena.

Ever experience a dish-rattling sonic boom? Most likely it came from a small, high-flying military aircraft. But if the plane is very large or flies supersonically at a low altitude, the boom won't be so innocent. Flown low enough, even an ordinary fighter jet can lay down a carpet of sonic booms that not only rupture eardrums but also break windows and cause nosebleeds. As it re-enters Earth's atmosphere, the returning space-shuttle orbiter makes two ferocious booms, one from the nose and one from the tail. Fortunately, though, the orbiter slows to subsonic speeds before descending low enough for its booms to shatter your skull.

The solar system is no stranger to shock waves, though earthlings generally remain oblivious to them. Take a garden-variety, pebble-size meteor hurtling through Earth's upper atmosphere. It can easily be doing Mach 50. This intrusion precipitously compresses and heats the surrounding gases as well as the meteor itself, making both of them glow. As it plunges through the air, the little vagabond—commonly called a shooting star—forms shock waves. Slightly bigger meteors can explode violently, creating a fireball visible for hundreds of miles. Almost always, though, the meteor vaporizes at much too high an altitude for its sonic boom to be heard at Earth's surface, which is why meteor showers remain peaceable family outings rather than calamities that require military intervention.

Another solar-system specialty is the coronal mass ejection, which can be far less tranquil than a meteor shower. Every moment of every day, charged particles stream from the Sun at more than a million miles an hour. That's just the ordinary solar wind. But the Sun also undergoes an eleven-year cycle of activity that runs from the merely violent to the positively frenetic and then back again to violent. Several times a day during the peak of the cycle's frenetic stage, besides venting a steady solar wind, the Sun ejects several billion tons of plasma—tempestuous, deadly, multimillion-degree blobs of gaseous matter seething with charged particles, electric currents, and magnetic fields. Each of those blobs races outward even faster than the solar wind.

Occasionally a coronal mass ejection heads straight for Earth. Colliding supersonically with our planet's magnetic zone in space and with our atmosphere, it gives rise to a "bow shock," shaped like a huge sickle. The charged particles trigger lovely auroras near the magnetic poles. But once in a while the particle assault also disrupts power plants as well as navigation and communications satellites. On March 9, 1989, a large area of the Sun's surface suddenly broke out in sunspots, the telltale sign of a coronal mass ejection. Four days later the blob hit northeastern North America. Almost half the power of the 21,000-megawatt Hydro Québec grid vanished; the rest of the system collapsed in less than a minute. A nine-hour blackout ensued, suspending power to 6 million people in Canada and the United States.

Oddly, the Sun's surface temperature is "only" about 11,000 degrees F. Yet the corona, the Sun's outer atmosphere, which you might expect to be cooler, is more than 2 million degrees. That's because the Sun is like a gurgling, gaseous organism. Waves of magnetic energy move outward from deep within it and shoot supersonically across its surface and into the corona, destroying molecular bonds and forcing atoms to give up their electrons. So overwhelming is the heat that it can denude an iron atom of half its twenty-six electrons. In the late nineteenth century, astrophysicists observed this exotic state of iron in the Sun's corona. When they didn't recognize it from any known laboratory data, they thought they'd discovered a new, extraterrestrial element—which, no surprise, they dubbed coronium.

Out there beyond the solar system and between the stars, atoms and molecules are typically few and far between. But you don't have to look hard to find gas clouds actively engaged in the birth, life, and death of stars. The most extreme action, along with the most spectacular shock waves, comes from stellar death.

Take a star with at least eight times the Sun's mass. Any star that massive is born fast, shines bright, dies young, and leaves a beautiful corpse. It spends its entire life in the fast lane. Eventually, though, its fuel runs low and the fusion furnace at its core, which has kept the star from collapsing under its own weight, starts to shut down. At death, with no fuel left to fuse, the star swiftly implodes. The heat created by the precipitous collapse is so great that the entire wreck detonates in a titanic, multimillion-degree explosion that sends the star's outer layers bulldozing at hypersonic speeds into every gas cloud in the neighborhood. The star's guts spew forth at 12,000 miles a second, creating shock waves whose Mach numbers are in the thousands. And, as with iron in the solar corona, the maelstrom creates strange new versions of commonplace elements.

Astrophysicists call that short-lived spectacle a supernova. During its first several weeks it can outshine billions of suns. Nowadays, investigators identify hundreds of new supernovas each year. Those discoveries come about not because of the explosion but because of the shock waves that pass through the star's own outer layers and render the event visible across billions of light-years.

If you think a supernova shock front is big and bad, picture what happens when an entire galaxy crashes into its neighbors. Take the cluster of large galaxies called Stephan's Quintet, a collision of four galaxies plus one interloper that just happens to show up in the foreground. The colliding members of the group have torn gas clouds from their host galaxies and strewn them hither and yon, making a real mess of the environs. One protagonist, plummeting toward its three neighbors at speeds exceeding Mach 100, has created a bow shock so immense that its leading edge is larger than the entire expanse of our own Milky Way galaxy.

Speaking of the Milky Way, it's falling toward the Andromeda galaxy. Shock waves are forecast for a few billion years from now.

Back on Earth, if you want to blow something up, you need a bomb, a medium, and the shock wave generated by exploding the bomb within the medium. A conventional bomb doesn't just puff a gust of air, like the wolf in "The Three Little Pigs." The intense heat generated at the instant of detonation creates a ferocious pocket of expanding air that moves faster than the local speed of sound—a shock wave. Not only does the shock wave make a loud boom, but it also causes a catastrophic imbalance of pressure between the sides of nearby structures (and people) facing the explosion and the sides facing away. Such are the forces that blow things apart into unrecognizable fragments. The reason conventional bombs are generally useless in space, and are thus a poor defense against incoming asteroids, is that most of space is an airless vacuum. If you really want to destroy an asteroid, you'll have to plant the bomb deep inside, turning the asteroid itself into the medium.

Unlike a conventional bomb, an atomic bomb doesn't need a medium to make it lethal: the high-energy light of the explosion itself passes straight through the transparent air. If you're a slab of concrete with a high melting point, you can easily survive this phase. But if you're an organic life-form and happen to be positioned close to ground zero, you vaporize. Any surviving structures in the vicinity are then leveled by the stupendous shock wave that *is* carried by the medium.

When it comes to shock waves, however, neither atomic bombs nor hydrogen bombs can compete with gamma-ray bursts, the greatest blasts in the universe. Although not yet fully understood, they may be the death throes of supermassive stars under particular circumstances of rotation, environment, and orientation to our line of sight.

Bright enough to be seen from Earth no matter where in the universe it takes place, a cosmic gamma-ray burst is akin to a supernova on steroids. Between the burst and Earth lies the airless vacuum of space, and so there's a gap in the medium that might otherwise carry the burst's annihilating sound and fury down here to us. The resulting silence confirms that in space, not only will no one hear you scream, as Hollywood occasionally reminds us, but no one will hear you explode either.

*Astrophysicist* NEIL DEGRASSE TYSON *is the director of the Hayden Planetarium at the American Museum of Natural History. In October, catch him as he hosts the season premier of the PBS television series* NOVA scienceNOW. *Tyson's latest book,* Death by Black Hole: And Other Cosmic Quandaries*—an anthology of his favorite* Natural History *essays—will be published this fall by W. W. Norton.*

# By a Whisker

*Hairs (and steel wires) enable rats (and robots) to glean information about their surroundings in remarkable detail.*

By Adam Summers

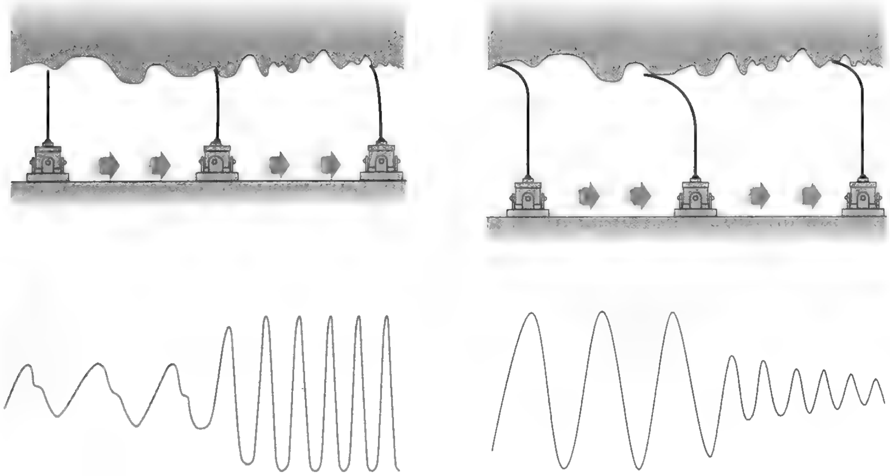
When we were children, my siblings and I spent summers in the woods of northern Canada. Sleeping in a rustic cabin, and listening to mice scamper across the rafters just above us, my fondest dream was that one of the rodents would stumble and plop right into my little sister's mouth. But for reasons I didn't appreciate at the time, she never had to contend with such an assault, even on the darkest nights. It seems that mice and rats have an unusual sensory system that works in total darkness: their whiskers. One research team is trying to unravel the workings of this hairy, touch-based system, partly in a push for better robotic sensors, and partly out of an interest in basic neurobiology.

Rats and mice "whisk" as they walk. Dozens of long hairs flank their noses, and the animals rapidly sweep them forward and backward, exploring their environment the way a blind person might probe with a flexible cane. [*See illustration on this page.*] Rats are known to gather a remarkable amount of information about objects they whisk—remarkable because the hairs themselves are dead keratin without any sensors, just like the hairs on your head. Rats usually whisk objects in the dark at a frequency of about five to twelve hertz; that is, they sweep their whiskers back and forth between five and twelve times a second. Sensitive tissue at the base of each whisker receives the sensory information gathered in these swipes and transmits it to the brain. There, a kind of environmental map is assembled.

A group of investigators led by Mitra J. Hartmann, a biomedical engineer at Northwestern University in Chicago, has been trying to build a robot that "sees" its environment by touch, much the same way a rat's whiskers do. Hartmann's model follows the basic plan of a rat's muzzle, but for simplicity she started with only two rows of four whiskers, represented by miniature steel wires secured to a frame. Attached to each wire was a sensor that measured how much it curved at the base.

When the tip of a rat's whisker slightly grazes a tasty hunk of cheese, it bends into an arc with a distinct curvature. If the cheese is closer, the whisker bends even more, with a different curvature. Happily for Hartmann's analysis, the same mechanical principles apply whether the whisker happens to be a straight cylinder, as in her model, or one that tapers to a fine tip, as in the real rat whisker. By gathering the information about curvature from Hartmann's small array of eight whiskers, a computer was able to reconstruct

*Rat can explore the shape and texture of an object—here, a crumpled soda can—in total darkness, by sweeping its whiskers back and forth. Each whisker bends at some angle as it brushes against the object and then breaks free. Tissue at the base of each whisker senses the changing angles, which the rat's brain combines into a map of the rat's environment.*



*Wires mounted on small motors that move from left to right mimic a rat's whiskers sweeping across a bumpy surface. If a length of wire is plucked and allowed to vibrate freely, it vibrates at its own "natural frequency," which depends primarily on its length: the longer the wire, the lower its natural frequency, or pitch. In contrast, a wire that is swept across a bumpy surface is forced to vibrate at the frequency at which the tip encounters the bumps. When that frequency approximately matches the natural frequency of the wire, the wire resonates: the amplitude, or "loudness," of the vibration becomes large. Otherwise, the vibrational amplitude remains relatively small. Thus the short wire in the schematic diagram (left) responds weakly, at low amplitude, when it sweeps across the coarse-textured part of the surface, but responds strongly, at high amplitude, when swept across the fine-textured part of the surface. A longer wire (right) produces the opposite response.*

the shapes of the objects encountered by the artificial whiskers with remarkable fidelity.

Hartmann designed her model without knowing just how the rat processes the information gathered by its rapidly roving whiskers. But the success of her robotics experiments so intrigued her that she wondered whether the rat has innate sensors that can detect the curvature of each hair, much as her robotic sensors were doing. Does the rat's brain process the information from the whiskers much the way her computer was analyzing and integrating information from its artificial bristles?

By recording signals from a nerve ganglion in the face of a rat, Hartmann helped show that rats do indeed have neurons that encode a signal for curvature. She then realized how incredibly sensitive the neurons are. Other signals, at a higher input rate, were stimulating the neurons as well—signals that she hadn't initially equipped her robot to recognize. It seems that the neurons of a rat whisker fire in response to stimuli that reach the neurons at a hundred times the "whisking" frequency. Hartmann was reminded of two papers—one of her own and the other by Christopher I. Moore, now at M.I.T.—that examined the vibrations of rat whiskers. Might the higher-frequency responses have something to do with vibrations, she wondered, rather than the angle at which the whiskers curve?

Imagine a whisker as a single-pronged tuning fork whose pitch is determined by its shape. A short whisker would resonate at a high hum, whereas a longer hair would resound at a lower pitch. Because the rat's whisker array is a collection of similarly shaped hairs that vary in length and width, perhaps the rat could make some sensory use of the pitch of each whisker's vibration.

Hartmann and Moore established that vibrating whiskers do indeed have natural frequencies ranging from twenty-seven to 260 hertz, much higher than the normal whisking frequencies.

The ability to sense vibrations at various frequencies could be a powerful tool for exploring textures. A fine texture might set up a stronger vibration in a high-frequency whisker than it does in a low-frequency one. Thus a whisker array might be an ingenious technique for sensitively probing the ground over which a robotic rover is rolling [*see diagram at left*].

Vibrational cues could also be highly practical for determining the edges of objects. A whisker in contact with a piece of cheese has both ends relatively fixed: one is stuck in the rat's face, while the other is flattened against the cheesy surface. But when the whisker breaks free of the cheese, it must vibrate in a characteristic, and perhaps recognizable, way. It seems that rats can sense size, position, and texture just by sticking their noses into things.

I particularly enjoy research that goes from a model to an inspiring organism and back again, to see whether the lessons learned from the model apply in nature. That approach creates excellent opportunities for the study of an animal to further inform a design that is more practical, more workable, more flexible. To this day, Hartmann's laboratory is making great leaps in understanding how rats multitask to determine the shape of the objects in their world.

Of course I'm sorry I never knew about all this in my youth. I could have been live-trapping mice, de-whiskering them, and releasing those sensory-deprived creatures in the hopes of generating a rodent fall. Wouldn't my sister be thrilled?

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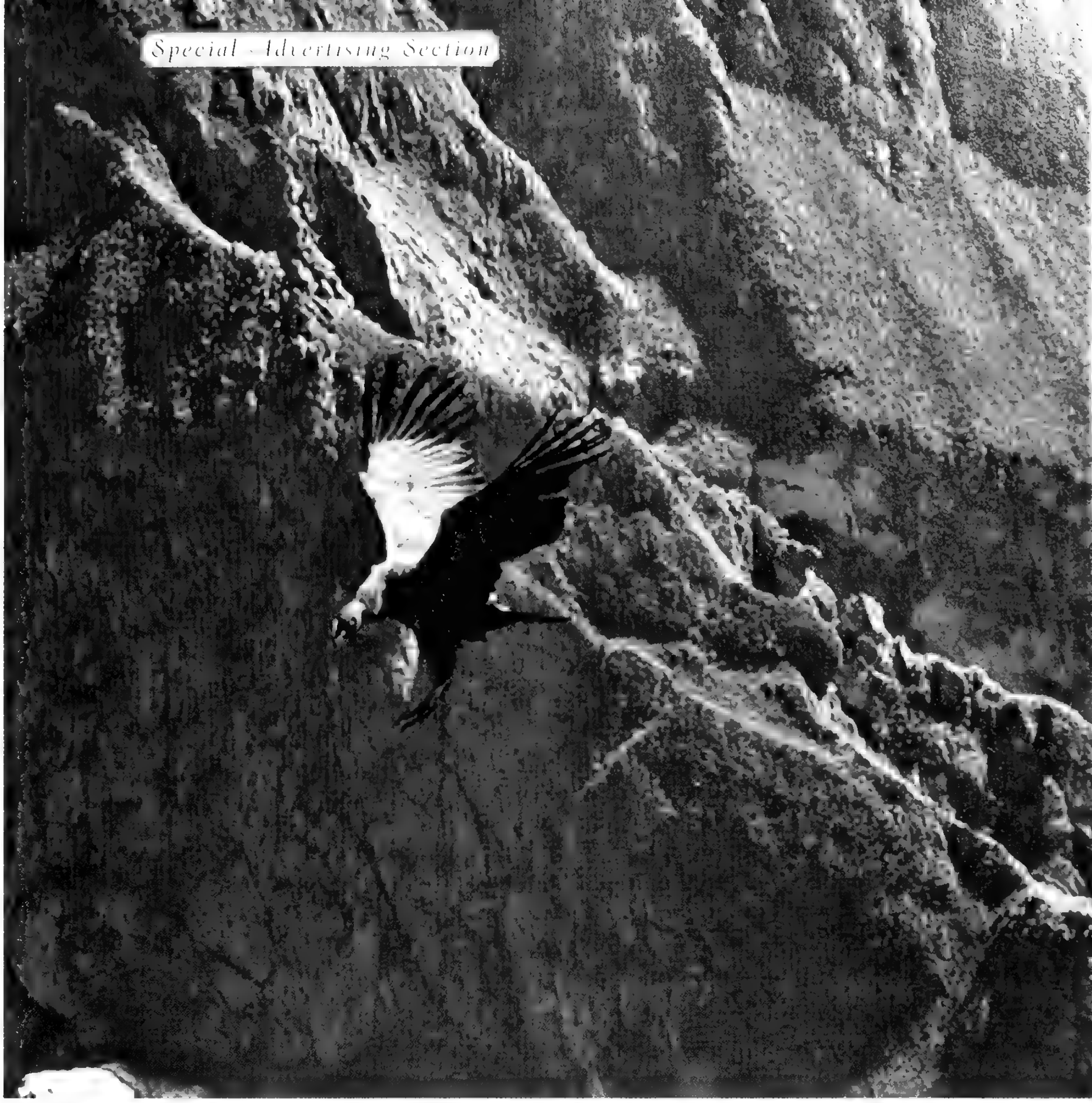
# PERU

PERU IS HOME TO ANCIENT CULTURES and a rich colonial tradition, and nature lovers know it is one of Earth's most biodiverse places. It has nearly 20 percent of the world's birds and 10 percent of the world's reptiles, and it has set aside 13 percent of its territory into protected natural areas.

Start your trip in the colonial cities of Lima or Cusco, which have numerous historical sites, all the sophistication and luxuries of modern urban centers, and can serve as the base for further adventures. You might explore the Nazca lines, take a boat ride on Lake Titicaca, or hike along ancient Incan paths in the Andes. From Cusco, you will want to see the spectacular ruins of Machu Picchu, about forty miles northwest of the city. Constructed between AD 1460 and 1470, and including about 200 buildings, Machu Picchu must have served as an Incan royal estate or religious retreat. Cusco is also a good starting point for a trip across the Andes to the Amazon, where you can spend a few days exploring Manu National Park. The park comprises the watershed of the Manu River, which flows along an extraordinary range of altitudes, from the high Andean plain down to the Amazon Basin. Manu is home to 20,000 plant varieties, 1,200 butterfly species, 1,000 bird species, 200 species of mammals, and countless reptiles, amphibians, and insects.



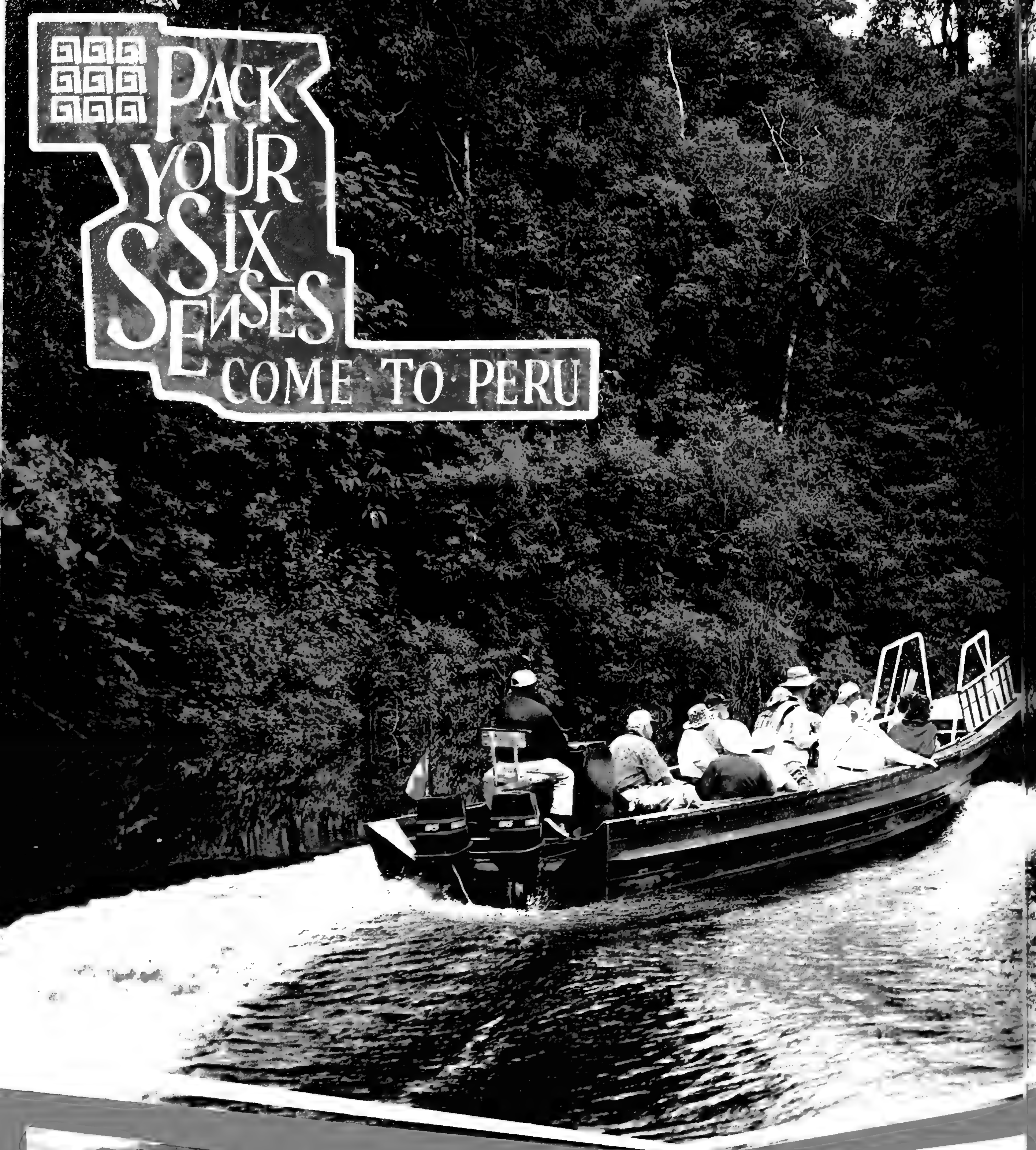
In the Manu rain forest, look for rare species such as the giant otter and the giant armadillo, and jaguars, which are often sighted here.

A more out of the way but spectacularly beautiful national park is Mount Huascaran. Set in the Andes Mountains' Cordillera Blanca, the world's highest tropical mountain range, the park includes the mountain of the same name, which towers at over 22,000 feet, as well as 26 other snow-capped peaks over 19,000 feet tall. Its 120 glacial lakes, glaciers, rivers, deep ravines, thermal springs, and varied vegetation—from humid montane forest to alpine tundra to puna plateaus—are home to the spectacled bear, the puma, vicuna, and North Andean huemul, a rare type of deer; notable birds include the Andean condor, giant hummingbird, and cordillera hawk. Allow yourself a few days here to acclimate to the high altitude.

Also off the beaten track but worthwhile is the Cerros de Amotape National Park in northwestern Peru. The park protects the vast equatorial dry forests of the Amotape Cordillera and its surrounding valleys, once intensely harvested for their valuable hardwoods, and tropical Pacific forests. The park shelters two endangered species on the brink of extinction: the American crocodile and the northeastern otter. It's also home to Tumbes howler monkeys, ocelots, and more than 100 bird species, many of which are endemic, such as the white-winged guan and the northern magpie.

No matter how far-flung your destinations, Peru is easy to visit and travel in, thanks to its highly developed transportation network and hotel infrastructure. It has 36 airports, and 9 of these are international. For more information, visit www.peru.info.

Left Machu Picchu Top Condor about to land on the Andes, Incan wall in Cusco, stack of colorful traditional Peruvian fabrics at a market in Pisac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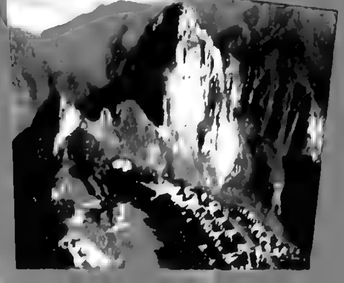


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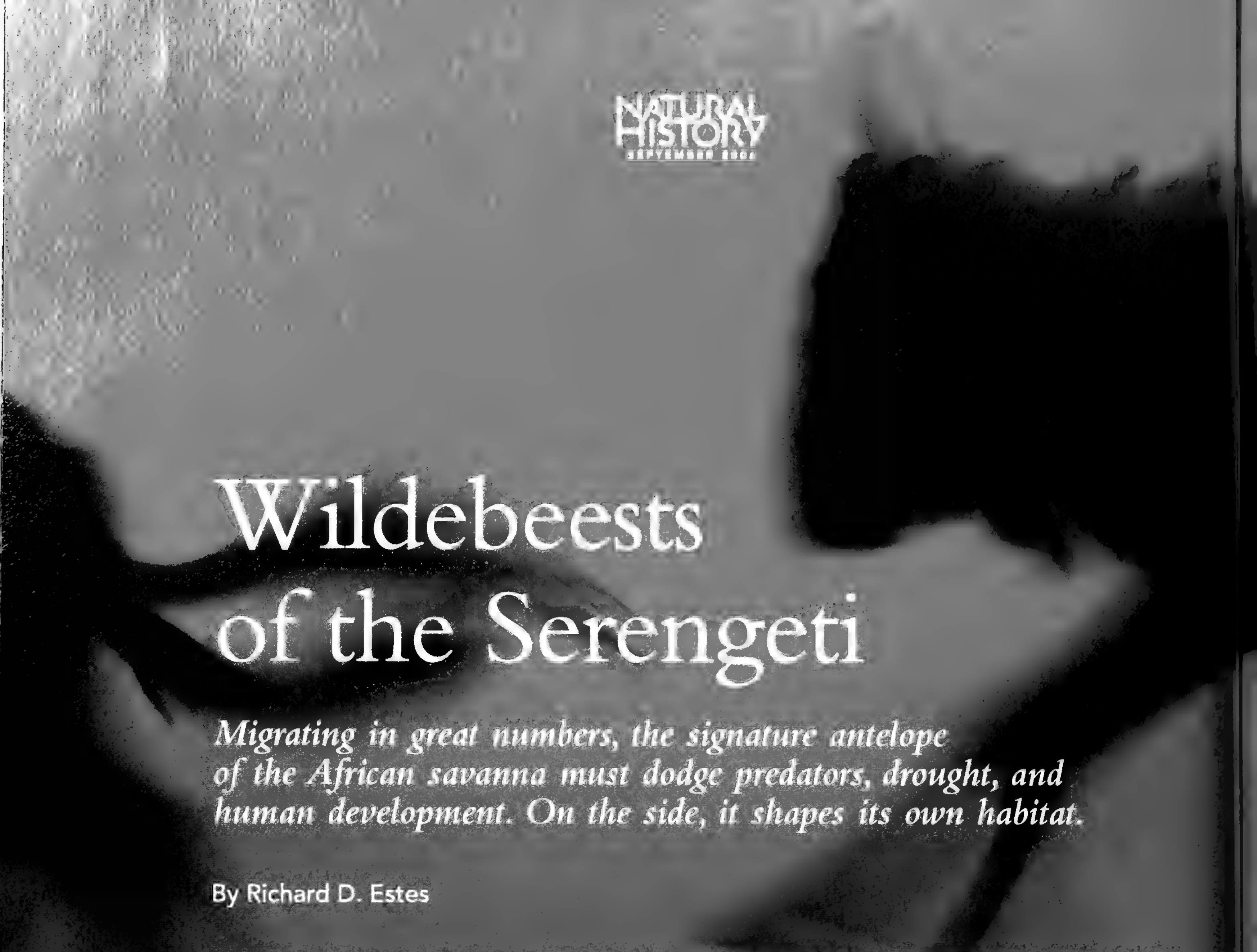


# Wildebeests of the Serengeti

*Migrating in great numbers, the signature antelope of the African savanna must dodge predators, drought, and human development. On the side, it shapes its own habitat.*

By Richard D. Estes

I often write, as I do here, on behalf of the wildebeest, or gnu: an antelope often portrayed as a homely, clownish creature put together out of spare parts. In fact, from a biological and ecological standpoint, the animal is a "keystone" species, one that has shaped and dominated its ecosystem, the semiarid savannas of eastern and southern Africa, for probably more than a million years.

But from the human perspective, the wildebeest may still need a champion; the lion, after all, is "king," and even among the herbivores, the elephant and the giraffe cut more dramatic figures. And so, because the wildebeest has been the main focus of my field studies for four decades, I feel the duty and enjoy the privilege of representing the species to my own kind. For the past twenty-five years I have published the *Gnusletter* of the Antelope Specialist Group of the World Conservation Union. Had I been among the early people who hunted and gathered on the African savannas, I'm sure the wildebeest would have been my totem, and I would have drawn pictures of it on cave walls.

The term "wildebeest" actually refers to two species, *Connochaetes taurinus* and *C. gnou*, thought to have split from a common ancestor at least a million years ago. Biologists also recognize five distinct subspecies of *C. taurinus* [*see map on page 31*]. Of all the wildebeests, only the western white-bearded wildebeest, *C. t. mearnsi*, still thrives in the immense migratory herds that are the hallmark of wildebeest adaptation. An estimated 1.25 million animals range across Tanzania's Serengeti National Park and adjacent regions, most migrating some 300 miles a year.

Unfortunately, all the other major wildebeest populations have crashed. The chief reason is that the ever-expanding human population, with its demand for land for agriculture and domestic livestock, has been interfering with the wildebeests' seasonal movements. In 1983, for instance, between 50,000 and 80,000 wildebeests perished when a fence blocked their escape from

Botswana's drought-stricken Central Kalahari Game Reserve [*see "Good Fences, Good Neighbors?" by Graciela Flores, June 2006*].

Even the Serengeti herds have suffered calamities. In the late 1880s, the rinderpest virus was introduced into the continent by Indian cattle brought in for the Italian army, which was establishing a colonial presence in the Horn of Africa. Within a few years, the virus killed as many as 90 percent of the continent's buffalo and cattle, as well as untold numbers of wildebeests and many other antelopes.

Yet the survivors of the pandemic, whose exposure earned them at least partial immunity, began rebuilding their populations within a decade or two. By 1963, rinderpest had disappeared from the Serengeti wildebeests. That population then multiplied fivefold, stabilizing at its present level of 1.25 million (give or take 10 percent) by the mid-1970s.

In the Serengeti, at least, it is still possible to observe the wildebeest's exquisite adaptations, both physical and behavioral, to a complex landscape. For one thing, the wildebeest must contend with a habitat where access to food and water depends on timing and location that can vary drastically from year to year. For another, the wildebeest must share the landscape with other animals—both with other herbivores, including other migrants, as well as with predators. Because the population has bounced back so robustly, the animal's future might seem assured. Yet no one really knows how resilient the species is. In 1993, for instance, a severe drought reduced the Serengeti population to below 1 million. Another disease epidemic could readily tip the balance even more drastically. And human development of the animal's former habitat in surrounding lands continues and accelerates, threatening to reduce

*Wildebeests kick up a lot of dust as they travel (photograph in the background of these two pages). They also leave a scented trail for others to follow, by depositing secretions from their front hooves.*

its range and its access to water resources. So as I study the animal's long-standing natural adaptations, I also am on the lookout for changes that may threaten the survival of the Serengeti herds.

Wildebeests are particularly well-suited to harvest the abundant short grasses that cover certain semiarid plains during the rainy seasons. The best-known such habitat is provided by the plains of the eastern Serengeti, where an impermeable hardpan underlies a fertile layer of volcanic soil. The grasses there are highly nutritious because they take up calcium and phosphorus trapped by the hardpan. They produce abundant forage during the short rainy season of November through December and, more predictably, in the long rains of April and May. Meanwhile, the nutrients in the manure wildebeests spread across the grasslands are recycled by millions of dung beetles.

In good years the pastures remain green across the seasonal gap between the rains, from January through March. But from June through October there is little or no rain, and the green of the short-grass plains turns to tan. The animals then have little choice but to leave their pastures in search of grazing and water in adjoining regions—where there is more rainfall, and the grasses are taller (though less nutritious) and stay greener longer.

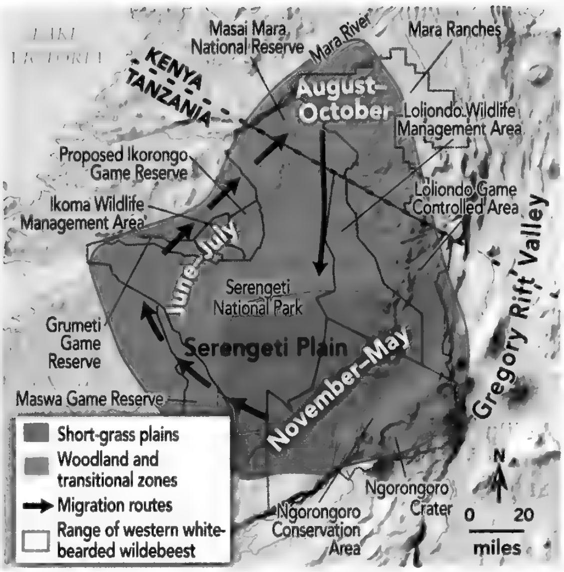
The wildebeest's feeding apparatus—a wide muzzle, a broad row of incisors, and flexible lips—is well adapted for taking big bites of short grass. And in overall build the wildebeest has evolved to survive the rigors of migration and evade predators. The body mass is concentrated in the upper torso and thick neck, and is supported by long, relatively spindly legs, which enable the animal to run in bursts as fast as forty miles an hour. In addition, the wildebeest has high shoulders and a back that slopes down to lower hindquarters, a configuration that locomotion specialists believe is energetically efficient for traveling long distances at an easy canter. The spotted hyena, the ranking predator of wildebeests, has a similar conformation.

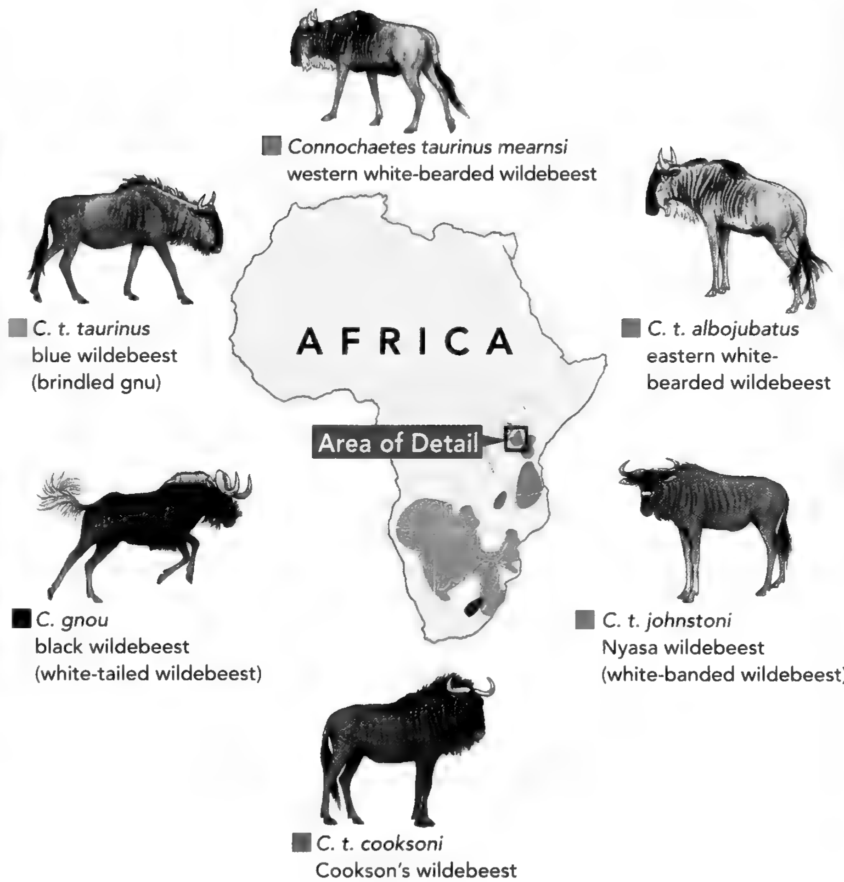
The openings of the wildebeest's nostrils are equipped with flaps that help filter the dust stirred up by thousands of migrating animals. Pungent secretions from glands in the front hooves help wildebeests follow each other by scent, even on the darkest nights. The wildebeest's dark color and reverse countershading (darker below and lighter above—the opposite of most antelopes) make it conspicuous and unlikely to be confused with any other herbivore. This uniform helps bind wildebeests together, but it also makes them conspicuous to predators. Their antipredator strategy must therefore rely on vigilance and flight.

*Newborn wildebeest gains its feet just a few minutes after birth. Even at the height of the calving season, the large aggregation of animals must keep moving from pasture to pasture. Hence, unlike the offspring of most antelopes, the young cannot adopt the strategy of remaining concealed from predators. Instead, they must be able to move almost immediately with the herd.*

The protagonist of the Serengeti, the western white-bearded wildebeest, *C. taurinus mearnsi*, has the darkest coloration of the five recognized subspecies of *C. taurinus.* It also features the shortest horns and the most vociferous bulls. By weight, wildebeests are the sixth largest of Africa's seventy-one antelope species, but *C. t. mearnsi* is the smallest subspecies: females average about 360 pounds, males about 460. Small size can be an advantage in hard times; in any event, it enables more individuals to concentrate on a pasture. Mitochondrial DNA studies by geneticist Nicholas J. Georgiadis, director of the Mpala Research Centre in Kenya, indicate that the subspecies has been separated for millennia from its closest relative, the eastern white-bearded wildebeest, by the western wall of the Gregory Rift Valley.

The wildebeest and two other major migratory species—the zebra and Thomson's gazelle—return to




*Current ranges of the recognized species and subspecies of wildebeests are shown at right; only the western white-bearded subspecies survives in substantial numbers, largely because it can migrate with the seasons to find suitable pasture (above). Elsewhere, wildebeest populations have crashed because people have encroached on their ranges, often fencing off vital migration routes.*

the short-grass plains as soon as the rains begin anew, usually in November. Births among all three species peak there from December through March. Even at the height of the calving season, however, wildebeests keep on the move from pasture to pasture. That need has led wildebeests to abandon a strategy practically universal among other antelope species, as well as deer. The calves of most antelopes remain too feeble to outrun predators for days or even weeks after they are born. So the prevailing survival strategy among those species is for newborns to hide until they grow strong enough to flee.

But for wildebeests the hiding strategy is really not an option. With the constant movement of the herd, a mother that stayed behind with a calf still in the hiding stage would expose both herself and her calf to far too much danger. Moreover, the calves retain the ancestral, tan coloration of most antelope newborns. That color is well adapted for concealment in tall grasslands, but in a mobile population that aggregates on short green pastures, the calves' color simply makes them more identifiable to predators.

In large part, wildebeests solved those problems by developing what are probably the most precocious calves of any ungulate. Newborns can gain their feet in as little as three minutes, and the average is only seven minutes [*see photograph on opposite page*]. Furthermore, instead of seeking seclusion before and after calving, as do typical "hider" antelopes, pregnant wildebeests in migratory populations gather together on calving grounds and drop calves by the dozens between dawn and midday. Once the newborns have gained their feet and have suckled for the first time, they are led into the nearest nursery herd, an association of mothers and their nursing young. The presence of calves that are a few days older—and by then hard to catch—helps conceal the most vulnerable day-old calves.

Wildebeests also took another important evolutionary step for protecting their calves: about four-fifths of the yearly crop is born within just a few weeks. The concentrated calving season is comparable to that of caribou in the Arctic. The difference is that the abbreviated caribou calving period is an adaptation to the short Arctic summer, when newborn calves are most likely to survive. Among wildebeests, the principal environmental pressure that drives the calving pattern comes from predators: spotted hyenas, first and foremost, but also cheetahs, lions, and wild dogs. The most obvious advantage of the wildebeest's short calving season is glutting the predators, which enables many calves to survive and at the same time keeps the predator population from increasing. Predator numbers would balloon if the births of the calves were spread out over the year.

Migration is another key factor in minimizing predation. After ranging the short-grass plains for six or seven months, the Serengeti wildebeests abandon them soon after the long rains end in May. The herds then spend the drier months mowing the tall grasses of the so-called woodland zone—which actually encompasses typical savannas (tree-studded grasslands) as well as open plains interspersed with woodlands of varying density. Here, too, armies numbering many thousands of wildebeests keep on the move. In contrast, hyenas and lions, the main predators, are tied to specific territories. They cannot simply follow the wildebeests wherever they go without trespassing on property defended by rival clans and prides.

How, I've long wondered, do the wildebeests of the Serengeti synchronize their reproduction? After all, the dramatic changes in the length of the day and night, which can serve as clues to the seasons in the temperate latitudes of southern Africa, are hardly noticeable in the tropics. More than forty years ago I hypothesized that the calling of the bulls triggered and synchronized estrus. The noise and confusion of the Serengeti rut, which coincides with the migration away from the short-grass plains and into the woodland zone, is a spectacle unequalled among land mammals. The sound and fury come from bulls staking claims to territories and competing to round up and mate with cows. Indeed, the bulls inseminate some 600,000 females in less than a month. How they manage to do it, though, is mystifying. All the action an observer is likely to catch goes into getting and holding females coveted by every neighboring bull.

**_The wildebeest's short calving season gluts the predators, enabling many calves to survive._**

My hypothesis about the source of synchronized estrus is being tested as part of a study of the reproductive physiology of Serengeti wildebeests. In 2003, a month before the rut, two groups of captured cows (one group penned with a bull) were continuously exposed to the recorded calls of rutting bulls, while a third, control group was kept isolated. The analysis of the thousands of samples of the captive cows' dung, collected throughout the study, is still underway. If my hypothesis is correct, the levels of reproductive hormones in the dung will show that estrus was more closely synchronized in the cows exposed to rutting calls than it was in the control group.

But assuming I was right, what sets off the bulls? Maybe the fecal-hormone assays will show some changes in the females' hormones that could arouse them. Or perhaps the males are simply reaching top condition at the end of the rains, attaining maximum testes size and testosterone production. Several months of increasing territorial activity precede the rut, and mating continues for as long as three months after the rut peaks. Indeed, some territorial activity is seen year round, which is good evidence that active bulls are ready and willing to breed. But one way or another, male aggression and sexuality reach fever pitch during the few weeks of the rutting peak.

Whatever stimulates the bulls, the dynamics of how they manage females and establish territories, both on the move and in more permanent locations, are complex. The prevailing system, in which large aggregations of wildebeests migrate over long distances, has presumably grown out of a nonmigratory system, in which a population's food and water requirements are satisfied more locally. I observed both patterns during my 1960s doctoral research in Tanzania's Ngorongoro Crater. Out of some 14,000 wildebeests, as many as 3,000 behaved as permanent residents. They could be found in specific areas that were not regularly invaded by the main population. There, discrete small herds of females, calves, and yearlings, numbering, on average, about ten animals each, circulated within a network of fixed territories defended by breeding bulls. Some of the resident bulls I kept track of maintained the same territory for more than two years.

The rest of the Ngorongoro wildebeest population migrated between pastures affording the best grazing on the hundred-square-mile crater floor, in aggregations of several thousand animals. The aggregations included competing, mature bulls, as well as noncompeting bachelor males (ranging from yearlings to oldsters), females, and young. When such an aggregation settled on a pasture, the accompanying mature bulls began staking claims to territories, pushing noncompeting males out to peripheral—and often substandard—grazing grounds and rounding up groups of females and young. Temporarily, then, the aggregation would be fragmented much like a resident herd, until the time came to migrate in search of new pasture.

In a resident population, one bull controls, on average, a territory of perhaps one hectare (a bit bigger than two football fields). That is actually a remarkably small area for such a big animal (a hartebeest bull, in contrast, may control a territory a hundred times as large). When an aggregation of

*Crocodile exacts a toll from a herd of wildebeests at a river crossing. Spotted hyenas and lions are among the other predator gauntlets that wildebeests run.*

wildebeests happens to move into a resident neighborhood, however, the spacing may be effectively halved, as outsider bulls infiltrate and temporarily set up shop amid the resident bulls.

At the height of the annual Serengeti rut the density is even higher: the average increases to three competing bulls per hectare. And it is not unusual to find two or even three bulls under the same tree, moving through a crowd of a hundred cows that are seeking shade from the midday sun. At first glance it might seem they are tolerating each other's close presence, willingly sharing the wealth of females. In fact, the packed bodies are just keeping them from catching sight of one another. The same screening effect enables noncompeting males to mingle in dense concentrations and thereby gain access to the best grazing, as long as they can escape the notice of territorial bulls.

The fact that males and females look so much alike promotes their association in mixed herds. The territorial males do stand out in the crowd, but that is primarily because of their behavior. Nevertheless, the physical similarities present a puzzle. According to Darwin's theory of sexual selection, reproductive competition between males, in systems

that enable the fittest males to monopolize matings, should lead to the development of conspicuous male secondary sex characteristics. For example, males endowed with larger size and weapons are most likely to prevail, and any such traits that are heritable will be passed along to their male descendants, leading to pronounced differences between males and females (so-called sexual dimorphism).

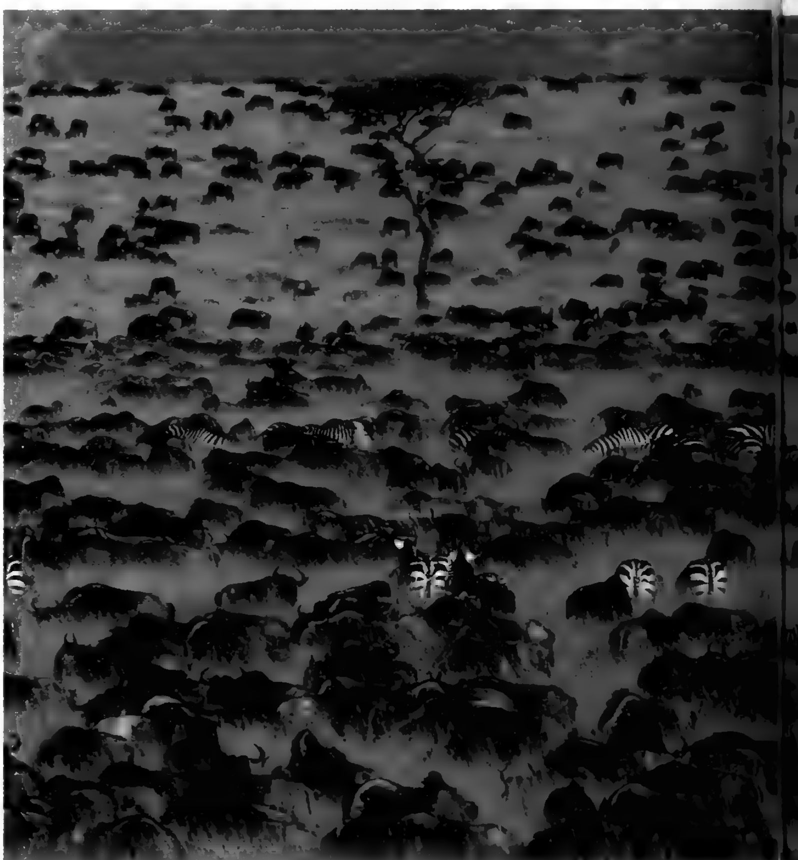
But that's not what happens among wildebeests. After years of pondering the puzzle, I developed my own hypothesis, that natural selection suppresses development of conspicuous male secondary sex characteristics in species that regularly associate in mixed herds. To be sure, competition among males of the same age and stage of development (peer competition) promotes the evolution of such characteristics. But as soon as young males look different from females, breeding males begin to treat them as potential rivals. Sooner or later, young males subjected to such despotic competition are driven out of the female herd and the familiar home range, and hence exposed to greater danger. So the longer adolescent males look and act like females, the better their chances of postponing eviction and surviving to reproduce.

There is a hitch, however, to how male sexual development plays out in bovids, the large family of ungulates that comprises the antelopes and other hollow-horned ruminants, such as cattle, goats, and sheep. Horns are the essential weapons with which bovid males compete for dominance; horns are also the most basic male secondary sex characteristics. Unlike the bony antlers of deer, they are permanent structures. Peer competition promotes their growth as early as possible, presenting a dilemma for the young male. A factor that comes into play here is the females' interest in protecting their male offspring from the aggression of breeding males. How can they help? One way is by growing horns themselves—and, among many bovids, including wildebeests, that is just what they do. Presto! Horns of similar shape and size carried by both sexes cease to be male sex symbols. As a consequence, horn development can (and does) begin much earlier than in species with hornless females.

In most species in which both sexes have horns, the females' horns do not grow as large or robust as the males' do. The reason, I presume, is that the females' mimicry of male horn development proceeds only to the stage at which young males are ready to leave the female herds and assert themselves in competition with other males. But in species where natural selection favors the continued association of adults of both sexes within herds, the females mimic horns and other male secondary sex characteristics all the way to maturity. Among western white-bearded wildebeests, females have even developed faux penile tufts that make it harder to tell the sexes apart.

*The sound and fury of the Serengeti rut comes from bulls competing to mate. Some 600,000 cows are inseminated in less than a month.*

In spite of years of observation, biologists still have much to learn about wildebeest ecology. For example, one way adult bulls express their aggressiveness is to use their horns to thrash small trees of a



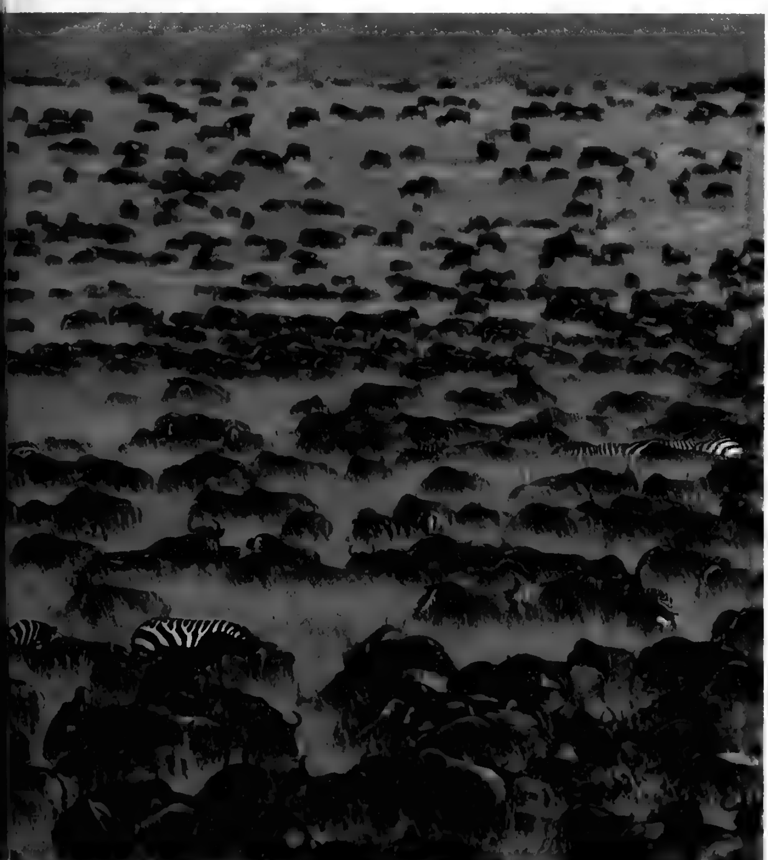
*Wildebeests share the tall grasses of Kenya's Masai Mara Reserve with zebras.*

certain size and "whippiness." The activity, which I call "horning," reminds me of a boxer working out on a punching bag. The behavior is easily overlooked, though, which may explain why Serengeti ecologists have not taken its impact into account. Yet the effects are plain to see: repeated horning debarks stems, breaks branches, and eventually kills the aboveground part of a tree. Such damage is commonly mistaken for elephant browsing, though on close inspection the differences are obvious.

In 1986 I had the chance to look for horning damage in several parks of South Africa and Namibia, where wildebeest populations had crashed after fencing prevented their migrations. The signs of horning there were scarce, and I noted that bushes and trees were invading formerly open grassland. In contrast, there was a marked opening up of the Serengeti woodlands in the 1970s and 1980s, as the wildebeest population, finally freed of rinderpest, increased apace. Together with my systematic observations of horning, the demographic data convince me that wildebeests, along with elephants and fire, have had profound environmental effects. That may seem astonishing, but when you consider that in the Serengeti a quarter-million competing bulls have been at it year after year, it seems less incredible. By adding tree-horning to the better-known effects of feeding, trampling, and depositing manure, it becomes clear that this antelope actively creates and helps maintain the kind of habitat that it needs.

At the same time, the areas available for grazing and access to water determine the size of the Serengeti wildebeest population. The equilibrium varies from year to year, depending on rainfall and on how much grass is produced. When there is not enough food, the weakest members of the population starve. In the absence of the occasional severe drought, most of the culling occurs late in the dry season, when the calves, whose nutritional needs for growth put them at particular risk, are most likely to lose condition and eventually succumb to parasites and disease. Those factors imply that despite its success, the western white-bearded wildebeest remains vulnerable.

Then there are the pressures of human development. The Serengeti wildebeests' access to Lake Victoria, only a mile or so from the western boundary of Serengeti National Park, was cut off years ago by lakeside settlement. How long can Tanzanian politicians resist the demands of the burgeoning human population for further expansion? Other threats are building in Kenya, even in the Masai Mara National Reserve, where most of the Serengeti wildebeest population ends up during the dry season.



Fortunately, the Kenyan government has put an indefinite hold on a hydroelectric scheme to divert a major tributary of the Mara River. Still, the energy project is not dead. Even more serious is the threat posed by the destruction of the Mau Forest, the catchment for the Mara River and other rivers. Illegal invasion of the forest by settlers is continuing apace. Tree-cutting, clearing, and farming have already diminished the flow of the Mara. Soil erosion is muddying the water and interfering with subsistence fishing. According to a study by the World Wildlife Fund, phosphates and nitrates in the river have already reached environmentally harmful concentrations. All those unfortunate developments are taking place against a background of global climate change that is creating an increasingly arid climate in East Africa.

If wildebeests could speak for themselves, I have no doubt that they would decry these developments. Since the animals are unable to, only we can speak out for their interests—and convince our fellow human beings that their interests are ultimately our own. □

# Change in the Air

*Songbirds with divergent migratory patterns may be a rare example of a hotly debated way of forming new species.*

*By Stuart Bearhop*

On a winter day in 1961, a cat prowling the Irish city of Dublin stalked a European blackcap, a small, gray warbler with a flute-like song. The cat got lucky—and so did I. Shortly after the cat captured the bird, a passerby chanced on the bird's remains. On closer inspection, the finder noticed a metal band around the victim's leg, inscribed with numbers and an address in Austria. So began what turned into an extraordinary piece of good fortune for ornithologists and evolutionary biologists, including me.

Ornithologists often fit birds with uniquely identifiable bands, but the chances of recovering them aren't much greater than finding a message in a bottle cast into the ocean. Out of more than 450,000 pied flycatchers banded in Europe during the past fifty to sixty years, for instance, fewer than five were recaptured in their wintering areas. But in this case, a Good Samaritan—perhaps an amateur birder—mailed the band to an Austrian ornithology society, about a thousand miles away. There it became the first break in solving a baffling migratory mystery.

In the 1950s and 1960s, substantial numbers of blackcaps began wintering in Britain and Ireland. No one could figure out where the birds were coming from. Ever since then, populations of blackcaps overwintering in Britain and Ireland have continued to grow. A recent survey by the British Trust for Ornithology reported blackcaps in more than 2,000 gardens throughout Britain and Ireland.

The Dublin cat's successful hunt provided the key clue for determining where the birds had started their journeys. Even more significant, the cat and serendipity had combined to give important new insight into what Darwin called "that mystery of mysteries," the origin of species.

*Pair of European blackcaps* (Sylvia atricapilla) *pause together on a branch, the female facing left, the male facing right. Distinct subpopulations of blackcaps may be undergoing sympatric speciation—diverging into two species despite living (at least part of the time) in the same place. The members of each subpopulation tend to choose mates only within their own group, in accord with their divergent migration patterns.*

When it comes to blackcaps, the mystery of the origin of species is wrapped in the enigma of migration. Aristotle was among the first to attempt an explanation for the seasonal appearance and disappearance of bird species. European robins that appear in winter, he noted, seem to be replaced by European redstarts in the summer. One species, he suggested, is "transmuted" into the other. Aristotle also proposed that birds hibernate, an idea that retained much popular support until the end of the nineteenth century.

Such notions may seem fanciful today, but the reality is even more astonishing. In some cases a bird weighing less than a third of an ounce flies 8,000 miles across large tracts of inhospitable habitat. Around the world, billions of birds take off in the fall for winter homes, unerringly navigating through night skies, hailstorms, and heavy fog. With equal skill and punctuality, they return to their birthplaces in the spring, to nest and breed through the end of summer. Yet despite long-standing fascination with this behavior, knowledge of many aspects of avian migration is still surprisingly limited.

Thus when European blackcaps began wintering in Britain and Ireland, ornithologists could reach no quick consensus about their origins. Some argued that the birds most likely came from Scandinavia, to the north; blackcaps breeding there, they noted, passed through Britain and Ireland in late autumn. Other ornithologists suggested that the visitors might have originated from any number of directions: blackcaps are among the most widespread songbirds in Europe.

The puzzle was harder than it might seem at first. One major obstacle was—and still is—that many bird species cannot be tracked throughout their annual cycles. Recent technological advances, such as transmitters that send signals via satellite, remain too large to attach to the smaller bird species. And the chances of recovering a band remain slim.

Making matters trickier still, migration is a highly plastic trait; that is, the genetic determinants of migratory path and direction vary a great deal from bird to bird. Hence migration patterns can respond quickly to natural selection.

Today's migration patterns in the Northern Hemisphere, for instance, must have evolved in the past 10,000 years or less, because much of the area from

*Four blackcap chicks beg for food from their mother. Because migration routes are genetically programmed, these chicks, once grown, will winter where their parents did.*

which or to which birds now migrate was under an ice sheet until then. On the evolutionary time scale, 10,000 years is a mere instant. All in all, it is extremely difficult to gauge whether present-day changes in migratory behavior, such as the blackcap's sudden winter preference for the British Isles, are a result of natural or human-generated pressures, no matter where the birds started from.

Faced with such subtleties, the eminent ornithologist Peter Berthold and his colleagues from the Max Planck Institute for Ornithology in Radolfzell, Germany, had ample reason to be grateful to the Dublin cat. In the early 1990s, they were still exploring the hypothesis that the blackcaps wintering in Britain and Ireland had migrated from Germany and Austria (where the cat's prey had come from), even though German and Austrian blackcaps traditionally go south for the winter, to Iberia and North Africa.

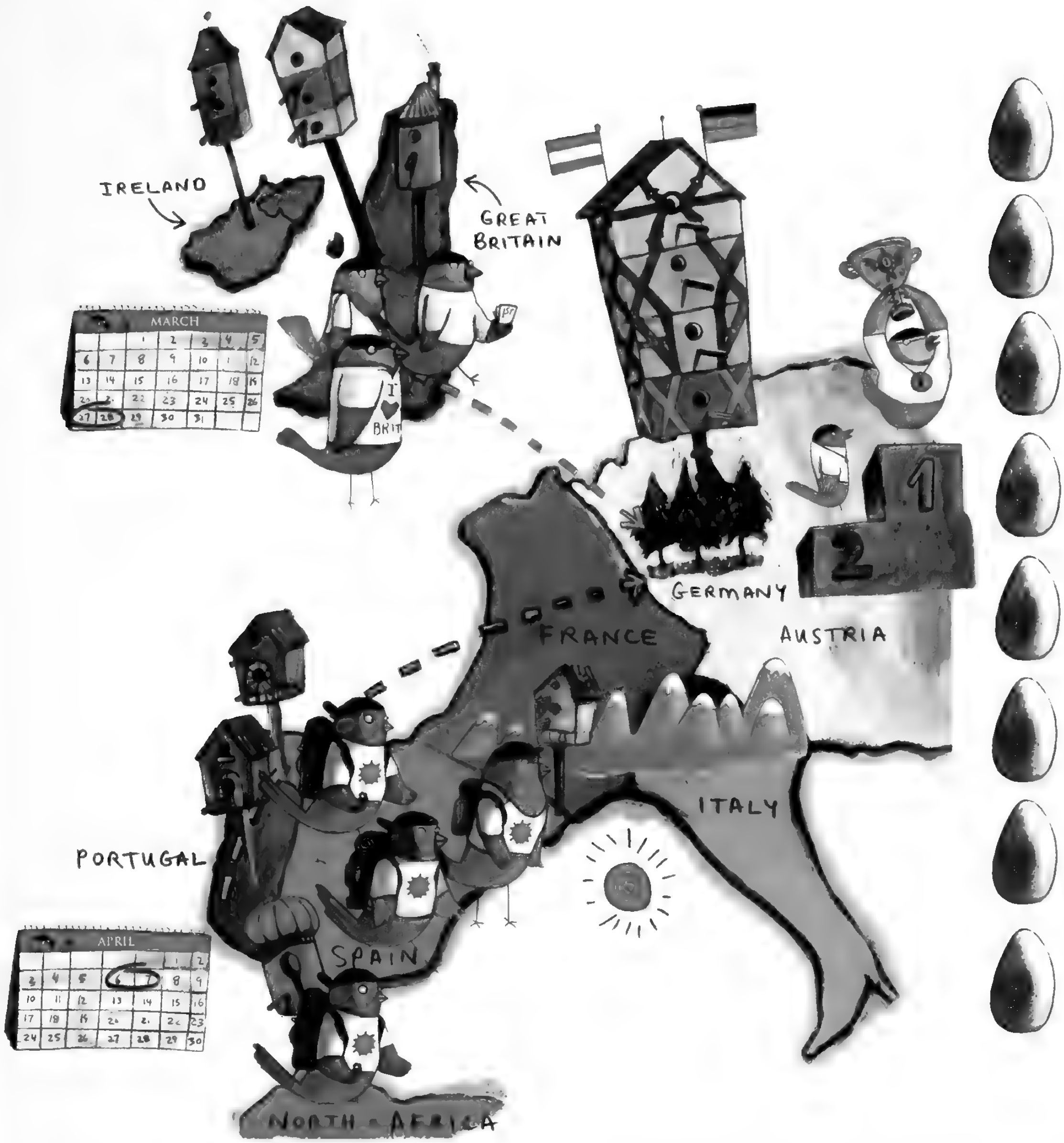
To test his suspicion, Berthold captured blackcaps that were wintering in England and transferred them to Germany. He kept the birds there until the following autumn, when they would feel the innate urge to migrate. He confined the birds to a large enclosure with a transparent roof and an ink pad at its base—a common research technique of the time. The birds' feet, coated with the ink, left a ready record of the direction they hopped. And he found that, rather than hopping toward the southwest, as German blackcaps do when heading for Iberia, the captured blackcaps hopped slightly north of west, in the direction of the British Isles.

Even more important, Berthold and his colleagues showed that the new migration pattern was heritable. The team bred blackcaps that wintered in England or Ireland with blackcaps that wintered in Spain or Portugal. The hybrid young of those pairs hopped in an intermediate direction, toward a perhaps fatally inappropriate destination somewhere off the Atlantic coast of France. The results strongly suggested that the new flight path from central Europe to the British Isles evolved because of a genetic shift.

Berthold's team argued that such a genetic shift could have provoked the explosive growth in the blackcap population wintering in the British Isles only if there were substantial survival advantages to the shift. But what were the advantages? One idea was that since the Second World War, birds had been attracted to Britain and Ireland by increased provisioning of bird feeders, additional planting of berry bushes, and a series of mild winters. Berthold also pointed out that migration routes between Germany and the British Isles are much shorter than the ones between Germany and Iberia or North Africa. That could leave the northwestward migrators with more energy to devote to reproduction.

A more subtle, but possibly more important, advantage was the effect of the winter home on the timing of seasonal events. In the spring, blackcaps begin their migration and reproductive development only when the length of daylight reaches a certain threshold. Berthold realized that the daylight in the British Isles reaches that threshold about ten days earlier in the season than the daylight in Iberia or North Africa, because of the Earth's tilt. The timing difference seemed crucial in two ways.

First, the northern blackcap populations would probably arrive at the German breeding grounds first. After all, not only do they have a shorter distance to travel, but their departure would also be triggered ten days earlier than the departure of the southward-migrating populations. The early birds



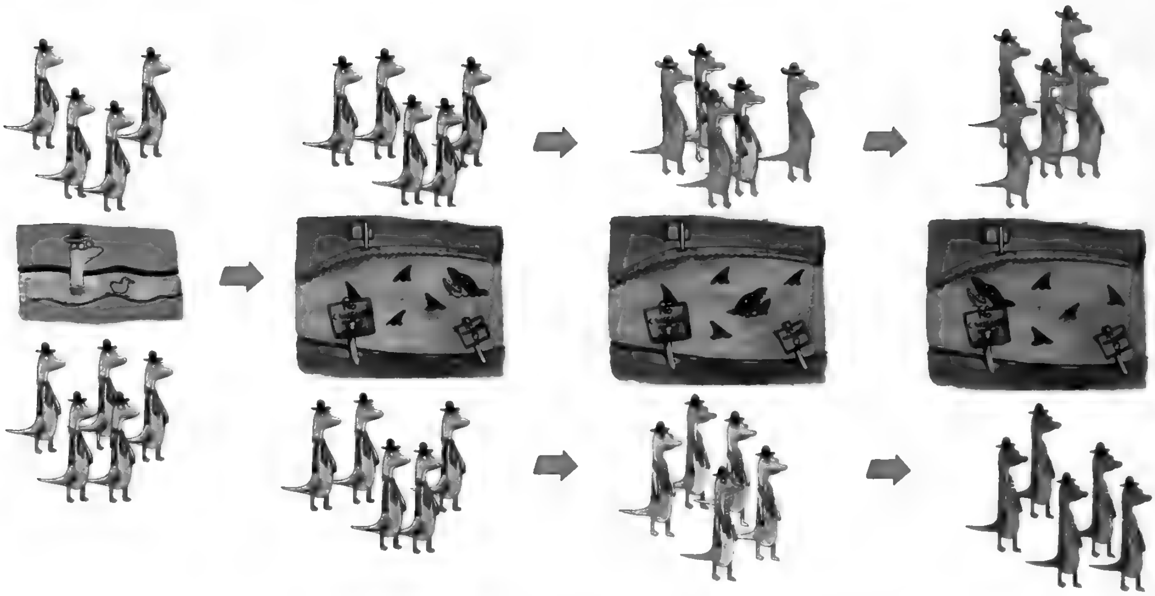

*Two winter vacation spots attract blackcaps from their summer homes in Germany and Austria: the British Isles (Britain and Ireland) and the region encompassing Spain, Portugal, and northern Africa. When spring comes, the birds return to central Europe to breed. The ones that winter in the British Isles (the "northern" blackcaps) return first because they set off about ten days earlier than their "southern" counterparts, and their migration paths are shorter. The shorter paths save them energy for breeding and protecting their nests, and their early arrival enables them to seize the best territories with the best foraging opportunities. All those factors may help explain why the northern blackcaps lay more eggs than their southern brethren.*

could claim the best territory for mating and caring for their young, with good cover for nest protection and an abundance of insects for feeding chicks. In many bird species, territorial quality is known to be an important factor in breeding success.

Second, the northern birds would be ready to breed earlier, too. Because of the timing and travel differences, then, it seemed reasonable that the two blackcap populations would be apt to mate "assortatively" with respect to their wintering trait. The northern-wintering males would pair with northern-wintering females, and the southern-wintering males would pair with southern-wintering females.

Assortative mating may seem like a minor and esoteric academic concept. Yet if blackcaps pair off assortatively, their behavior has major implications for biologists' understanding of how breeding populations can become reproductively isolated. Such isolation is the first stage in speciation, or the formation of a new species.

Evolutionary biologists usually think of speciation in its "classic"—or, more formally, allopatric—form, and they have amassed plenty of evidence in favor of the process. In allopatric (literally, "other land of origin") speciation, a once-unified population becomes divided by a geographic barrier such as a



*Allopatric speciation, the classic way new species originate, is shown in the schematic drawings. In spite of a small stream in the midst of a population of lizards, individual lizards on both sides of the stream readily interbreed with each other. Then, over time, the stream swells to become a river the lizards cannot cross, separating them into two subpopulations that can no longer reach each other to mate. As random genetic mutations develop within each group, the two groups diverge until two distinct species form, no longer capable of interbreeding. The geographic barrier that leads to allopatric speciation need not be a river: deserts and mountains, for instance, can play the same role.*

newly formed river. Genetically, the two isolated subpopulations then diverge, until they form two distinct species no longer capable of interbreeding.

In blackcaps, however, the subpopulations would be divided by time instead of space. That is, the birds all breed in Central Europe but get started at different times. Blackcaps would thus be evidence of how subpopulations can become isolated in the same place, the first stage in a hypothetical process known as sympatric (literally, "same place of origin") speciation. The idea that speciation could take place sympatrically has been hotly debated for years.

So the stakes were high as Berthold set about trying to prove that blackcaps were diverging sympatrically. To succeed, he needed a way to identify the two kinds of avian migrants reaching the German breeding grounds. During several winters in the early 1990s, he visited the British Isles to mark blackcaps with bands. But back at the breeding grounds, he encountered the same problem I described earlier. Finding small numbers of marked birds lost in a multitude of unmarked birds breeding across vast tracts of southern Europe calls to mind the words "needle" and "haystack." The scientific developments that enabled his hypotheses to be tested were still several years away.

Almost a decade passed before I came into the picture. I had been exploring a technique known as stable-isotope analysis. Isotopes are forms of the atoms of a given chemical element that differ slightly in mass. An example is deuterium, or "heavy hydrogen," a stable, nonradioactive isotope that occurs in nature. Deuterium makes "heavy water" when it combines with oxygen to form $H_2O$. Throughout much of the Northern Hemisphere, the proportion of deuterium in rainwater tends to be correlated with latitude. Plants and insects drink the rainfall and birds eat berries and insects, so a "signature" of the ratio of deuterium to ordinary hydrogen is transferred to the birds' tissues.

During my discussions with a colleague, the ornithologist Robert W. Furness of the University of Glasgow, we realized that the deuterium-hydrogen signatures might be just the right information to test Berthold's ideas. Our hope was that all we would need were a few clippings from the tips of the claws of migrants recently arrived on the German breeding grounds. Blackcaps' claws grow slowly throughout the year. If we could analyze the deuterium in them, we might learn where the birds had wintered.

The first step was to test whether the deuterium signatures in the claws of birds in the two wintering areas were sufficiently distinct. So for two consecutive winters, starting in 2001, I traveled around Britain, Ireland, Portugal, and Spain, collecting claw clippings from as many blackcaps as I could lay my hands on.

To narrow my search, I posted a call on a British bird-watching Web site. Happily, a slew of bird-watchers with gardens responded. In each garden, I

Firefinch

# Song Lines

*by Robert B. Payne and Michael D. Sorenson*

Indigobird

Assailed by the piercing, seemingly nonstop demands of a wailing newborn, what mother has not wished, at least for a moment, that she could outsource her childrearing to some kind neighbor? Wouldn't it be nice to fly off for a week, a month—forever—to reclaim freedom, silence, and perhaps even romance? Indigobirds are living this fantasy.

They are also providing biologists with another good example of what Stuart Bearhop is describing among European blackcaps in his article, "Change in the Air": the process of sympatric speciation, in which one population of animals splits into two species in the same geographic location.

Ten closely related indigobird species, all native to Africa, consistently lay their eggs in the nests of other birds, mostly firefinches. Then they take off—saving themselves the hassle of foraging for food for their young and freeing themselves to breed again. The firefinches, meanwhile, raise the indigobird young along with their own chicks in the same nest.

Why doesn't the firefinch parent kick the intruders out of her nest? Even among people, it would be the rare neighbor who would put up with your kids forever without making a squawk. For one thing, when indigobird chicks open their mouths to beg for food, the firefinch mother sees an intricate pattern of black, blue, yellow, and white stripes and dots that, through natural selection, have evolved to look indistinguishable from those of her own chicks. The indigobird chicks also mimic the movements, and, in some species, the begging calls of the host's own chicks.

Yet surprisingly, our observations show that firefinches are not always duped by such evolutionary disguises. When food is in short supply, firefinches may remove the interloper's egg, which differs in size from her own. But when food is plentiful, firefinches raise the indigobird chick. The apparent selflessness of the firefinch may actually mask self-interest: evicting an indigobird egg may pose too much risk that the firefinch will damage her own eggs in the process.

Remarkably, it turns out that the unusual parenting behaviors of firefinches and indigobirds were responsible for the evolution of the current array of indigobird species, each associated with different hosts. Songs were the key. Each new indigobird species got its start when one or more females laid their eggs, accidentally or opportunistically, in the nests of a novel host. Their offspring, even in that first generation, comprised a new, reproductively isolated "song population" or "host race." When the offspring reached sexual maturity and began courtship, the males of the new song population sang the firefinch songs they had learned from their foster father. Female indigobirds chose the males that sang the songs the females had heard as chicks, songs imprinted in their memories. (As with most other songbirds, the male indigobirds sing, but the females do not.)

The result was that birds living in one area sorted themselves into mating groups according to the songs they sang and the kinds of finches that raised them. Once the mating groups formed, the stage was set for sympatric speciation. Genetic data show that the ten distinct indigobird species that now occur across Africa evolved not over millions of years, as is typical for other bird species, but over just tens of thousands of years. Such rapid emergence of distinct species is a remarkable example of both sympatric speciation and adaptive evolution.

Could we re-create and experimentally confirm the critical behavioral conditions that led to new indigobird species? To do so, we populated an aviary with a pair of village indigobirds *(Vidua chalybeata)*, along with twelve pairs of Bengalese finches *(Lonchura striata)* and twelve pairs of red-billed firefinches *(Lagonosticta senegala)*. The birds chose mates from among the available members of their own species, and began to breed.

As expected, the female indigobird in our aviary laid each of her eggs in the nest of a firefinch, her typical host, and then mated again. Typically she would lay one egg a day in a firefinch nest, then move on to another firefinch nest after one or two days of laying. We gingerly relocated some of the indigobird eggs we found in firefinch nests to the nests of Bengalese finches, a "novel" host.

Soon enough, the male indigobird chicks were imitating the songs of their new Bengalese finch parents. The crucial test came when the young indigobirds were ready to mate: we played a tape of indigobirds singing firefinch songs through one loudspeaker, and indigobirds singing Bengalese songs through a second loudspeaker. The female indigobirds raised by Bengalese parents clearly preferred the Bengalese songs, sexually approaching the speaker.

The same young indigobird mothers also laid their eggs in nests of the novel host, the Bengalese finch. The indigobirds made that choice even though nests of the host species their *own* mothers had intended to use—namely, the nests of the firefinch—were available in the same aviary. In a similar way, indigobirds in West Africa recently colonized two new host species, setting off the early stages of what could be more indigobird speciation.

As for the indigobird's traditional host, the firefinch, we have observed a surprising example of its "open-mindedness" toward alternative parenting arrangements. An adventurous indigobird climbed into a nest already occupied by male and female firefinches. No matter: the intruder snuggled in, laid her own egg, and abandoned it to the good graces of the firefinches, which then took on foster duty—an instance of tolerance that seems altogether out of sync with the commoner image of the natural world as "red in tooth and claw."

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put up fine polyester "mist nets," so as to catch the blackcaps flying past. One trick was to attract them with a recording of their flutelike songs. My fieldwork often amounted to sitting in the kitchen of a keen garden bird-watcher, drinking tea, and listening to the recording until a blackcap arrived—not at all unpleasant work. (I owe a great debt of gratitude to all of the householders who supported the project.) Eventually, a bird would get tangled in one of the nets, and then fall, unharmed, into a pocket at the bottom of the net. Then I would hold the bird in my hand while I gently clipped less than a millimeter off a toenail.

*Male blackcap begins singing to attract a mate as soon as he arrives at the blackcap breeding grounds in the spring. Female blackcaps, like most other female birds, do not sing.*

Meanwhile, in Ireland, a team led by Brendan Kavanagh of the Royal College of Surgeons in Ireland collected samples from birds in and near Dublin. When I got to Iberia, things were a bit more arduous—I got up before dawn every day and spent two New Year's on my own (almost too hard for a Scotsman to bear).

But when the results of the isotope analysis came back from Jason Newton at the Scottish Universities Environmental Research Centre, all the work seemed worthwhile. We found a large and consistent difference between the deuterium values in the claws of the two wintering populations. The deuterium signatures would indeed mark the breeding birds according to their various winter habitats.

We now had to collect information from blackcaps in Germany. That part of the fieldwork was coordinated by Wolfgang Fiedler, one of Berthold's colleagues. Our first aim was to find evidence of assortative mating—that would confirm the existence of a hitherto undocumented path toward speciation. To do so, we needed to capture breeding pairs of birds. If blackcaps were mating assortatively, the deuterium signature in the claws of the male would correlate with that of the female he was paired with.

We were extremely excited when two years' worth of data told us exactly this story. We calculated that blackcaps were about two and a half times more likely to pair assortatively than mate at random. We had discovered the first concrete evidence that changes in the migratory behavior of birds could lead to some degree of reproductive isolation, proving what Berthold had surmised so long ago.

So what might be driving the assortative mating? We estimated the day of arrival on the breeding grounds for a number of males, simply by noting the day each bird started singing (males sing as soon as they reach their breeding grounds, whereas females do not sing at all.) The males' arrival dates correlated with the deuterium signatures in the birds' claws: the birds that wintered in the north were the earlier arrivals on the breeding grounds. Their head start is an important reason why assortative mating ensues.

To fit the final piece of the jigsaw, we had to see if any reproductive benefits grew out of the new migratory route. Those benefits would help explain why the northern population had increased so rapidly, the last of Berthold's longstanding ideas we were able to test. And, sure enough, females that paired with males from northerly winter homes laid more eggs than the female partners of southern males.

The extra fecundity could arise in several ways. Northern males, as early arrivals, would tend to settle on the best territories. For their part, the females might possess what could be described as "intrinsic female quality." Thus the "best" females would settle on the best territories, either by excluding other females or by becoming selected as the mates of the males first to arrive at the breeding site.

We also discovered that females wintering in northerly latitudes were more likely to produce successful clutches than females wintering farther south. We speculate that, indeed, the shortened migration route to the north saps less energy from the northern females, leaving them with greater resources to devote to reproduction.

Much more work will be needed before we can begin to answer even a few of the new questions our research has raised. Why, for instance, do blackcaps spend the winter in the British Isles today, when they never did before? Perhaps an increasingly more hospitable climate played a role. If so, behavioral shifts such as the one observed in blackcaps might be one way natural selection could buffer the effects of environmental change, at least among migratory birds.

Finally, since migration is such a plastic trait, is the new blackcap behavior just a short-term change, which will eventually disappear? Or is it the first step in the formation of a new species? If it is the latter, we bird lovers are privileged to have witnessed a novel kind of branching point in the history of life on this planet: a mode of speciation dramatic for its abruptness, compared to the glacial changes that usually characterize the time scale of evolution. □

# Living the High Life

*The mountaintop environment of the Andes harbors a Noah's ark of previously undocumented species.*

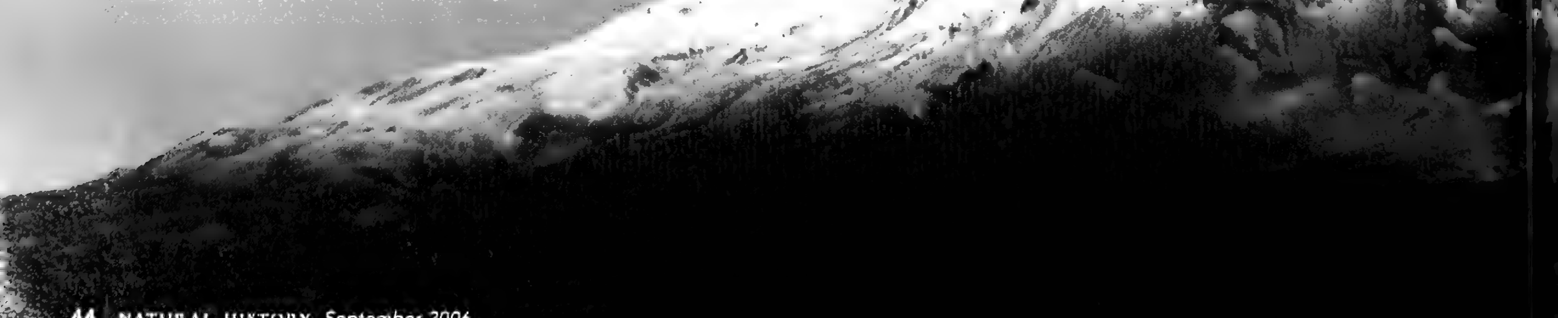
*By Kevin Krajick*
*Photographs by Carsten Peter*

Wind-driven hail lashes Preston Sowell and me as we top a 17,500-foot ridge in Peru's Cordillera Vilcanota. An avalanche thunders from a slope above—or was that real thunder? This close to the clouds, it can be hard to tell. I'm gasping in the thin air, and Sowell, a biogeochemist and mountaineer who works as a consultant in Boulder, Colorado, is on his twelfth ibuprofen for his throbbing, oxygen-starved brain. We're on what is perhaps an insane quest, but below we see what we are looking for—a grayish pool of water between ice cliffs and boulder fields. It might be the world's highest frog pond.

[illegible] living on the slopes of Bolivia's Mount Sajama.

We're part of a month-long expedition, pushing through the central Andes. The mountains are home to an astonishing variety of life-forms that survive amid thin soils, low oxygen, staggering winds, powerful ultraviolet rays, and surface temperatures that can plummet 90 Fahrenheit degrees when night falls. In this high zone there are hummingbirds with oversize wings to beat air that largely isn't there; spiders that wait for lowland insects to arrive on long-distance updrafts; microorganisms that eat rocks. The mountains around us are monstrous, but only the loftiest of them are cloaked in glaciers, thanks to the moderate precipitation and, just fourteen degrees south of the equator, the long days. (Not that ice stops life; biologists have found algae and invertebrates in and on Himalayan glaciers at least as high as 18,400 feet.)

"Mountains are hard to beat for biodiversity," Stephan R. P. Halloy, our chief scientist, has told me. One reason is that



Frog (Telmatobius marmoratus) was captured from a pond in Peru's Cordillera Vilcanota at 17,200 feet. The pond may have formed as little as a hundred years ago, as glacial ice retreated.

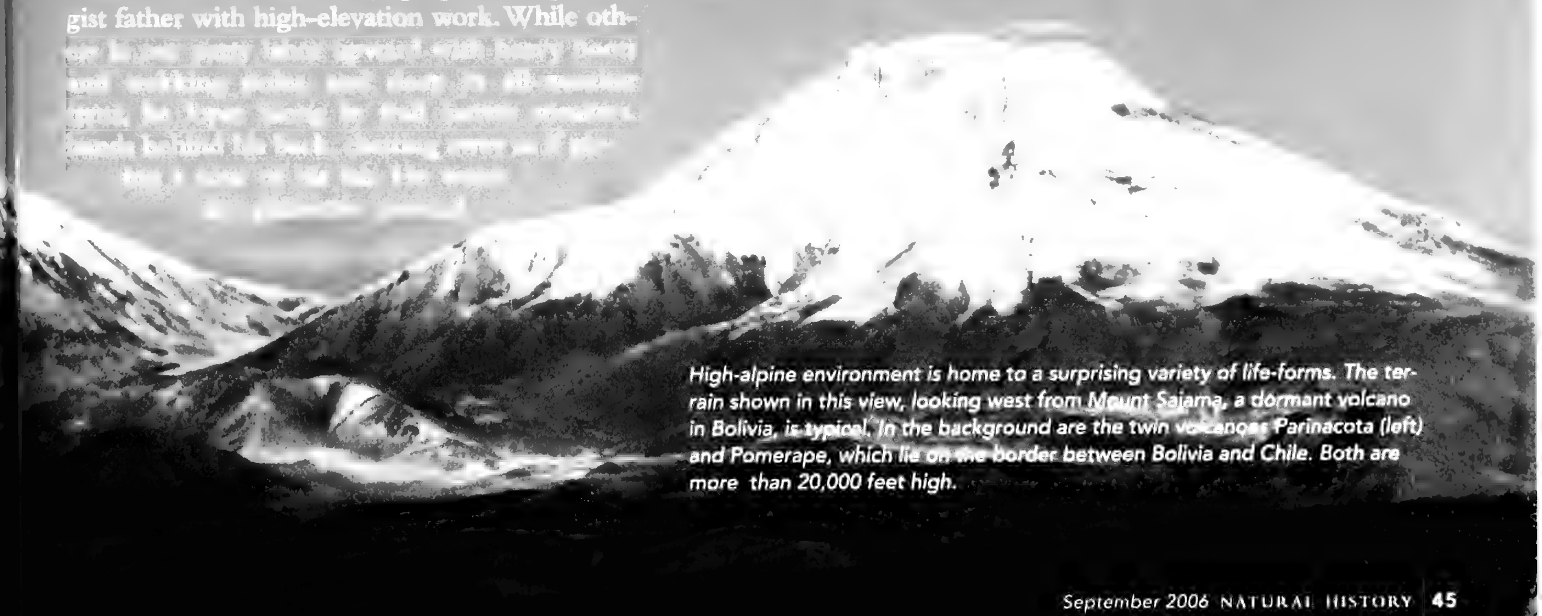
rise in elevation is the rough equivalent of a 150-mile journey away from the equator—so ecosystems in the mountains get stacked vertically. And the land area decreases as you climb, so new climate zones at successively higher elevations are confined to successively smaller plots. The highest zone, the alpine zone, covers only 3 percent of Earth's landmass, yet perhaps 10,000 plant species live there—many evolving on just one or two islandlike peaks, separated by oceans of lowlands.

Halloy, an alpine ecologist who consults for the World Wildlife Fund and teaches at San Andrés University in La Paz, Bolivia, seems specially evolved, too. A Belgian raised in Africa, the United States, and Argentina, he was just twelve when he started helping his herpetologist father with high-elevation work. While oth- [illegible]

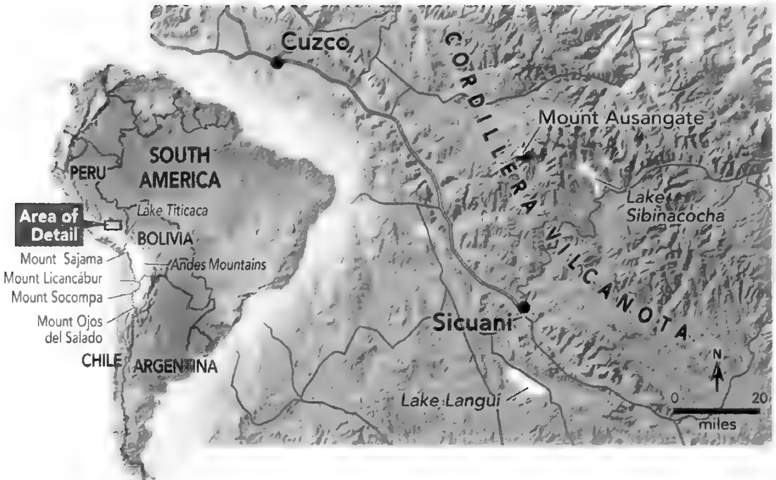
his neck like a religious medal, and sets his sleeping bag out under the stars most nights.

The co-leader of our expedition is Anton Seimon, a Columbia University geographer and climber who has organized scientific treks like this one through the Vilcanotas for the past five years. In 2004 he and his wife Tracie A. Seimon, a cell biologist also at Columbia, discovered tiny, unidentified tadpoles near our pond—apparently the world's highest known amphibians. Sowell and I hope to spot adults, to prove they are breeding here.

The higher you go, of course, the thinner the air. Animals and peoples of the high Andes (and in other high regions such as the Himalayas and the high Ethiopian plateau) have evolved bigger lungs or beefed-up blood chemistry for delivering more oxygen. Many low-



High-alpine environment is home to a surprising variety of life-forms. The terrain shown in this view, looking west from Mount Sajama, a dormant volcano in Bolivia, is typical. In the background are the twin volcanoes Parinacota (left) and Pomerape, which lie on the border between Bolivia and Chile. Both are more than 20,000 feet high.




land visitors can adjust to the altitude, but there are limits. The ancient Inca capital of Cuzco, gateway to the Vilcanotas, lies at more than 11,000 feet—high enough to inflict fatigue, panting, nausea, and heart palpitations on the unacclimated. Above Cuzco, entire sectors of nature drop out. Most reptiles cannot take the cold; neither can trees, whose sap, even in adapted species, cannot flow in temperatures much below freezing. In most places, plant life begins to wink out altogether above 16,500 feet. It is too cold, and nutrients—even soil—are too scarce.

But our party has also been witness to change. From Cuzco we reached the last-stop market town of Sicuani and headed up a precarious dirt road. Along the road we saw lowland competition invading the high realms. Everywhere, on terraces cut into impossible slopes, Quechua-speaking farmers had planted potatoes—the world's highest crop—as they have for millennia. But in the past three decades the average temperature in the central Andes has risen 1.8 degrees—far more than in most of the rest of the world. As a result, farmers have extended their fields up to 15,000 feet, from a 1970s record of 14,000 feet. Livestock is moving up, too: at 15,400 feet, we began a three-day trek across a great rolling plateau, where thin native plant cover is being crew-cut by increasing numbers of domesticated llamas and alpacas. Their cousin, the wild and woolly vicuña, is retreating to the most extreme elevations.

*Tarantula found at 14,700 feet in the Cordillera Vilcanota is thought to be both a species new to science and the highest tarantula species yet identified. The tarantula is already well known to local Quechua inhabitants, however, who call it* campo-campo.

Even the glaciers that mark the end of the grazing range are receding with accelerating speed, some as much as 650 feet a year. Once forced to the summits, like the animals, they may vanish into thin air—a fate already predicted for lower-lying glaciated ranges in Europe, New Zealand, and North America by the end of this century. For now, though, the lofty Vilcanota chain—whose highest peak, at 20,944 feet, is Ausangate—is still capped by the tropics' greatest ice masses. (In Spanish, a peak such as Ausangate is called a *nevado,* which means "snow-covered.") Here, the alpine biosphere is still just rising, not disappearing.

Near the end of our hike up a long, high valley, we saw plants thinning to bare stone and distant clouds of sunlit snow blowing off the peaks like flares. There we met our last local inhabitant. Mario Condoré Ya, a thirtyish herder, pointed ahead to our destination. "I don't go up there," he said. "There is nothing for the alpacas to eat." He gave a whistle, and his herd started trotting toward him from a half-mile away.

But there is life up there. Another member of our team, Steven K. Schmidt, a microbiologist at the University of Colorado at Boulder, and his graduate students have shown that many high slopes of bare-looking sand and scree teem with previously unsuspected microscopic life. Bacteria, fungi, and protozoa all thrive—in such volume that they may play major roles in the water chemistry of the surrounding lowlands and even in the cycling of global nutrients.

At about 16,000 feet, after crossing a mile-long jumble of newly melted-out glacial debris, we reached the fast-wasting ice front close to the head of the valley. I hopped onto a solid-looking sandbar—and promptly sank to my knees in quicksand. That hazard, I learned, is common in the fine debris eroding out of ice fronts. After I wrenched myself free, Schmidt told me that the microorganisms in the mud now mucking up my boots probably originate in or under the ice. The ice is also releasing pollen, trapped in the glacier as it

*Tussock grass has colonized an ice-free corridor of terrain that has opened up in the past quarter century because of the recession of an ice cliff. The corridor, now about 250 yards wide, lies at about 17,700 feet in the Cordillera Vilcanota.*

formed, having been swept up on persistent air currents—as it continues to be—from subtropical lowlands. The pollen grains, as many as 55,000 in a quart of meltwater, nourish fungi. I was immediately reminded of Lawrence W. Swan, an alpine biologist who studied the Himalayas in the mid-twentieth century: some insects and spiders there, he noted, subsist on a manna of lowland plant fragments and live prey. Swan named an entire new life zone for its dependence on that curious food source: the Aeolian biome, after Aeolus, Greek god of the wind.

Schmidt's research also suggests that various bacteria live off the underlying rocks, depositing acids that dissolve out nutrients. Those nutrients then pass into the ground to fuel successor communities. Just beyond the ice front we found the water gooey with photosynthetic cyanobacteria. On bare sand, their dark masses were building into crusts, to form the beginnings of soil. Not much farther on, a few plants were taking root.

In places less recently plowed by ice, plants bloomed everywhere. On the first day at our study area near one of our campsites at the valley's head, Halloy's colleague Alfredo Tupayachi, a biologist at the National University of San Antonio Abad in Cuzco, discovered what he declared to be the world's highest known orchid. The plant is a diminutive relative of lowland species, growing along a mossy seep at 16,240 feet. Like most alpine plants (including the potato, a high Andean native), it is small, low-lying, and covered with insulating hairs, and it keeps most of its mass below ground.

The next morning we ascended a knife-edge moraine to a windy 17,200-foot summit of bedrock riven with cracks. It was still dusted with snow, which falls almost every night, then melts off in the fierce, unfiltered morning sun. After just a few hours of work, Tupayachi and Halloy counted sixty-two species of vascular plants, mosses, and lichens, including a few probably new to science. The regular snowfall may actually help the plants, Halloy said; it insulates them from subfreezing nights, then feeds them meltwater when the sun appears.

In among the flowers buzzed darkly colored ground-nesting bees. Lowland species cannot move their wings in low temperatures, but these bees have powerful muscles that generate their own heat, enabling them to get going early in the morning. Most of the other invertebrates we spotted—a few grasshoppers, beetles, and the like—were flightless. Some biologists suggest that flightlessness is an adaptation to an environment where wind blasts, unhindered by topography, would blow most flying insects away, but other explanations are possible. For example, flight may be energetically too costly.

As for the frogs, our hunt began in a series of rocky ponds nearby. Within minutes, Tracie Seimon had several specimens of *Telmatobius* tadpoles—fat, squishy things the size of a quarter and darkly colored, like the bees. The tadpoles have

*Polylepis* trees on Mount Sajama grow at elevations as high as 17,400 feet, a world record for trees. In most places *Polylepis* trees are being exterminated by woodcutting and grazing, as roads penetrate farther upland.

plenty to eat here: the water is alive with aquatic invertebrates. Sowell probed one mucky bottom with a sieve and came up with some pea-size clams. A mollusk expert, Robert P. Guralnick, also of the University of Colorado at Boulder, would later judge them to be among the world's highest known clams. Descended from an ancient lineage, they had arrived here by unknown means.

Squirmier things appeared in the sieve, and Sowell shouted: "Look—the world's highest worm! Hey! The world's highest leech!" This "world's highest" business soon became a stock joke with us—but it was true. "We're finding them here because we are *looking* here," said Halloy. "In most places, no one has looked yet."

As we stand on our 17,500-foot ridge looking down on the pond we have discovered, Sowell and I are not doing as well as those tadpoles. By day, we have been alternately warding off cold in layers of fleece and down, and slathering on sunblock to keep from being broiled. At night, I have awakened countless times in the blackness, gasping; on the autopilot of sleep the body frequently forgets to breathe enough at high elevation. During our nasty two-hour scramble through rising ridges of loose boulders, every step has been torture. When we reach the pond, it looks lifeless except for a few spiky plants on the fringes. In search of frogs, we turn over rocks for an hour—a simple task at lower levels, but excruciating here.

Then I hear Sowell whoop. Cupped in one hand he holds a *Pleurodema marmorata* the size of a quarter—as of this moment, the world's highest known adult frog. Suddenly, we feel invigorated. "I guarantee you, Tracie's going to be up here tomorrow, trying to beat this," he says.

The next night, Tracie and Anton Seimon stumble into camp well after dark. Tracie's fingers are bleeding from overturning stones at a high pass above where we had been—17,700 feet. As recently as the 1990s perhaps as much as fifty feet of ice stood there. Here in this brand-new environment, the Seimons have come upon a sight that stuns them. In the shallows along the edges of at least eight pools, water is frothing with hundreds of black tadpoles—"Like when you draw a big fishing net in," says Anton.

From mountaintop to mountaintop, life-forms that have adapted to the high altitudes find it hard to mingle across the intervening valleys, and so evolution has taken them on different courses. We move on to Bolivia's highest peak, Mount Sajama, a dormant volcano whose 21,463-foot snowcap rears out of a vast, dry highland plain. The mountain is worshiped by the indigenous Aymara people as a god. Biologists, too, see it as magical, for it is ringed with trees rooted at heights no tree should reach, sprinkled with bizarre-looking plants, and roamed by predators so elusive few humans have ever seen them.

The trees, which range through much of the Andes, are *Polylepis,* called *queñua* by the locals. Few other tree species exist much past 9,800 feet; on Sajama the queñuas go to 17,400 feet, a world record. On our hike up the mountain's arid lower flanks, we pass under their wind-twisted limbs [*see photograph on this page*]. The biggest ones we see are only about fifteen feet tall, but their growth rings show some are hundreds of years old.

*Surveying the growth of lichen on the surface of a boulder is part of an initiative to monitor plant biodiversity in the high-alpine environment. Here Halloy (right) and Karina Yager, an anthropologist with the expedition, sample the lichen density and variety at 17,200 feet in the Cordillera Vilcanota with the help of a netted grid.*

Biologists have discovered unique communities of insects living in the bark and debris around their trunks; the insects, in turn, feed various bird species, including *Cinclodes aricomae,* whose world population is estimated at no more than a few hundred. New species continue to be discovered among the queñua, but some may not last long. In most places the trees are being fast exterminated by woodcutting and grazing, as roads penetrate more high places.

Interspersed among the trees are bright green lumps that I at first take for moss-covered boulders [*see photograph on page 44*]. They are *Azorella compacta,* nonwoody plants whose giant tap roots reach deep underground. Aboveground, they produce canopies of tightly packed rosettes that, like corals, grow slowly outward in layers. Very slowly. Halloy, who has studied them, points to a "baby" about the size of a dessert plate. "Two hundred years," he says. Later, we find another one about ten feet across. "Two, maybe three thousand," he says. They look cushiony, but their surface is as hard as wood because of their dense growth and fortification with superhard resins.

Another thing about them: they likely retain inner rings of old leaves—along with dust, debris, and pollen trapped over the ages. "The scientist who learns to read their insides will have the history of the Andes laid out before him," remarks Halloy, patting one behemoth. "Climate, volcanic eruptions, vegetation, everything. Before the Inca. Before Christ." He raps on the surface with his knuckles. "Hey! Who's in there?" he laughs.

As a group of us hike toward Sajama's snowcap, we glimpse vicuñas galloping in groups of fours or fives over distant rises, then disappearing without a sound, like ghosts. Covered in supremely fine wool and able to bound up sheer slopes, they seem perfectly adapted to their harsh surroundings. But something has been catching up with them even here: we have seen their carcasses in a dozen places. Sajama hosts predators such as Andean foxes and pumas, and there have been rumors of Andean mountain cats—a species so secretive no one photographed a live one until 1980. Halloy and a partner made the first photographs when they encountered one in northern Argentina and followed it for a couple of hours. Yet curiously, the dead vicuñas we have seen appear untouched by predators. A park ranger suggests they are being killed by lightning, but some of the scientists doubt lightning could strike that often.

The next afternoon we are spread across various sites when the sky darkens and thunder booms. Up this high, you are literally in the clouds—and thus literally in the middle of the frequent electrical storms generated by the ice particles circulating in the clouds. Often the storms only growl and back off, but this time we are caught. Sheets of stinging hail bury rocks and impale themselves on spiky plants. Lightning bolts tear horizontally in all directions, striking pinnacles and slopes. Twice they hit a hill the botanists and I have just abandoned for lower ground; nearby, a fire springs up. Anton and Tracie Seimon, dodging bolts on another ridge, feel their scalps and fingers tingle, and their metal trekking poles begin to buzz ominously. Suddenly, routine death by lightning around here seems very plausible indeed.

*Quechua woman harvests potatoes in a river valley in the Cordillera Vilcanota. Domesticated in the Andes, potatoes are well adapted for cultivation in high-altitude and cold regions throughout the world.*

The Himalayas, of course, also hold many records for life at high elevations. On Mount Everest, bacteria are found at 27,500 feet; the jumping spider *Euophrys omnisuperstes* lives among the rocks at 22,000 feet; and a single woolly flowering plant of the species *Saussurea gnaphalodes* was observed at 21,000 feet. A lichen, *Lecanora polytropa,* has been recovered on loose stone at 25,000 feet on nearby Mount Makalu. But the record holder for a complex ecosystem lies in the Andes.

In 1983 Halloy had heard reports of verdant plant communities at the 19,844-foot summit of Socompa, a dormant volcano on the border between Argentina and Chile. Climbing up to a height usually devoid of visible life, he discovered thirty-six species of mosses and bryophytes in mats as much as two inches thick. He also found mites, tiny crablike springtails, flies, a finch, and a leaf-eared mouse, all apparently making a living. The secret? The still-active basement of Socompa releases a gentle flow of heat, water vapor, and carbon dioxide to its roof. Around small fumaroles, soils are heated to more than a hundred degrees, and plants can take advantage of the moisture and carbon dioxide that are otherwise in short supply. Halloy's find was all the more astonishing because the plants on Socompa are not alpine species, but migrants from remote cloud forests. Socompa's lower slopes lie amid thousands of square miles of salt flats and badlands, and are mostly lifeless.

Halloy is not able to enjoy a triumphal return visit to Socompa's summit, at least on this trip. After traveling for days in the desert and making a brutal near-vertical climb through the loose scree, we establish a base camp halfway up the mountain. But the next morning we are driven down by bad weather and exhaustion. For once, it is too cold for even our chief scientist to sleep outside, and at one point the wind nearly blows me off a crag. Still, against Halloy's advice, three of us press on—Sowell, along with our photographer, Carsten Peter, and David Scott, an athlete helping the team—and manage to reach a small moss garden at 19,160 feet. They find warm gases emanating from several small, circular holes—one covered by a six-inch-wide flap of moss that gently flips open every few seconds once enough pressure has built up.

Other lightly sleeping volcanoes might host communities even higher up their slopes, but only some may provide the right range of temperature, humidity, and gases required for life. One candidate is Ojos del Salado, on the border between Argentina and Chile—at 22,600 feet, the world's highest active volcano. From the rim of the summit crater, Halloy has glimpsed fumaroles inside, along with what might be patches of green, though no biologist has yet reached that spot.

High volcanoes are worth exploring because they are "dead ringers for early Mars," according to Nathalie A. Cabrol, a NASA geologist who heads a new project to investigate such places as 19,400-foot Licancábur on the border between Bolivia and Chile. There, a small lake in the summit crater swarms with strange algae and microcrustaceans, possibly fueled by geothermal springs. She believes even higher lakes remain to be discovered.

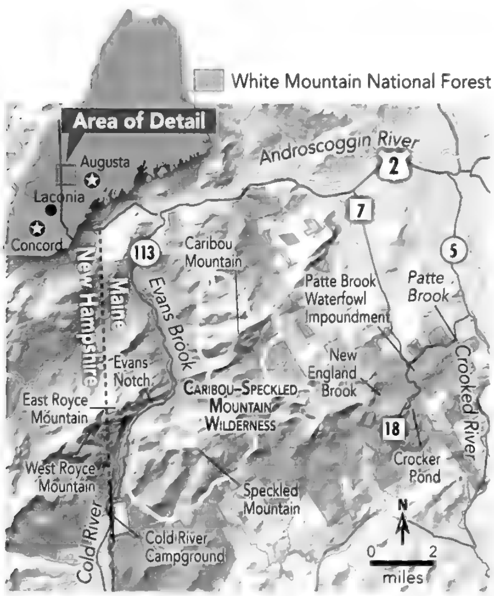
After we straggle back from Socompa, I ask Halloy if he feels disappointed at retreating. "Not at all," he says. "Humans don't necessarily belong at the top of the mountain. But the mountain will still be there if we decide to come back some day." □

# Over the Hills and Through the Woods

*The Maine way into the White Mountains*

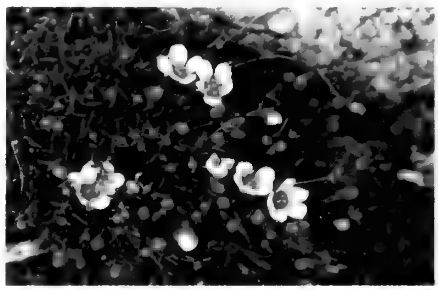
By Robert H. Mohlenbrock

Although most of White Mountain National Forest is in New Hampshire, its easternmost arm, comprising more than sixty-five square miles, lies in western Maine. More than a third of the Maine portion is designated the Caribou–Speckled Mountain Wilderness, named for its two highest peaks. Rising to 2,840 feet, Caribou Mountain bears the name of a species whose range extended into the state until the early twentieth century. Slightly taller, at 2,906 feet, Speckled Mountain is so called because in autumn the evergreen foliage of the conifer forest is dotted with the golden brown of American beech, the red and yellow of red maple, and the orange of sugar maple.




The wilderness can be reached from Maine State Route 113. From Fryeburg, a town about fifty miles northwest of Portland, the narrow, scenic highway runs north, paralleling the picturesque Cold River. Veering for a little part of the way into New Hampshire, it passes the forest's Cold River Campground before re-entering Maine. About three-tenths of a mile farther on it reaches the trailhead for Royce Trail, which heads northward to Mad River Falls (a pretty spot about a mile and a half away) and beyond. From the same trail crossing, Bickford Brook Trail heads eastward into the Caribou–Speckled Mountain Wilderness and connects with the Red Rock Trail, which climbs over Speckled Mountain. Before heading out on those and other trails, hikers should be sure to get suitable maps and equipment [*see visitor information on opposite page*].

Route 113 itself tops out at Evans Notch, where a small parking spot to the side of the road offers a panoramic view west across the upper reaches of the Cold River to East Royce and West Royce mountains. The road then descends to a junction with U.S. Highway 2. Several other trailheads



Common variety of mountain sandwort

## HABITATS

Coniferous forest In the cool, moist upper elevations, the dominant trees are balsam fir, eastern hemlock, white pine, and white spruce, which tower over a low shrub layer of American yew, common mountain holly, spiny swamp-currant, squashberry, and swamp red currant. Although often carpeted with mosses, the forest floor also supports a rich array of wildflowers. Spring bloomers include bead-lily, bunchberry, Canada mayflower, goldthread, painted trillium, pink lady's-slipper, and star-flower. Wildflowers that bloom from late July until frost include large-leaved goldenrod, lesser rattlesnake-plantain, mountain woodsorrel, pointed-leaved aster, twinflower, and white rattlesnake root. Among the native ferns are mountain wood fern and toothed wood fern.

Deciduous forest Where conditions are relatively dry, and usually at the lower elevations, deciduous trees predominate, although red pine and white pine do occur. Principal species are American beech, basswood, northern red oak, paper birch, red maple, sugar maple, white ash, wild black cherry, and yellow birch. Common shrubs include beaked hazelnut, bush honeysuckle, pagoda dogwood, and red-berried elder.

In the spring, foamflower, purple trillium, small-flowered crowfoot, and both purple- and yellow-flowered violets add color to the forest floor. Among the summer and au-

*Maine stream near the eastern boundary of the White Mountain National Forest*

into the wilderness can be found along the way, including Caribou Trail, which climbs to the flat granite top of Caribou Mountain.

The granite summit and high ledges of Caribou Mountain have little soil, as a result of a past fire. From a distance they appear bare of vegetation. In fact, despite the dry conditions created by exposure and wind, certain low-growing plants survive on the gravel-strewn and rocky surfaces. Among them is White Mountain silverling, an herb in the pink, or carnation, family, which grows in small tufts. I consider it a rare variety of *Paronychia argyrocoma*. The plant has many narrow, almost needlelike leaves, whose edges are curled under. Its tiny flowers lack petals, but they grow in clusters surrounded by silvery bracts—hence the name "silverling." Mountain sandwort, another member of the pink family, often grows along with the silverling, hugging the bare granite in dense, tangled mats. Each plant has scores of threadlike stems that bear soft, limp, extremely narrow leaves. I regard it as a distinguishable, rare variety of *Minuartia groenlandica*.

Maine State Route 5 lies east of the wilderness area and away from the mountains, but it does give access to several scenic brooks and ponds in the national forest. You can turn onto Forest Road 7 to drive a four-mile-long, self-guided tour, the Patte Brook Auto Tour. After paralleling the brook for more than a mile, the road reaches a turnoff leading to a granite dam built nearly 200 years ago to regulate water-power for a downstream saw mill. The U.S. Forest Service has repaired the long-neglected dam to create forty-five acres of marshland and ponds. Known as the Patte Brook Waterfowl Impoundment, the acreage is managed as a wetland for wildlife by the U.S. Forest Service. Some areas along the brook have also been cleared of trees, mostly speckled alders. The clearings were intended to benefit ruffed grouse, which feed on insects in the sunlit grasses, but they also serve as spring courting grounds for woodcock, and they attract deer and black bears. Apple trees left over from the time the land was farmed grow here and there.

Beyond the turn-off for the dam, the tour route veers left off Forest Road 7 and onto Forest Road 18. On the west side of the road, just before it crosses New England Brook, is a small, glacial bog. The name "glacial" reflects its origins more than 10,000 years ago, when a block of glacial ice melted in a shallow depression. In the intervening millennia, the resulting pond filled in with deep beds of sphagnum. Because there is no natural outlet, the water has become acidic and thus attractive to acid-loving plants, particularly members of the heath family.

The road ends at Crocker Pond, a lovely pond stocked with brook trout.

*ROBERT H. MOHLENBROCK is a distinguished professor emeritus of plant biology at Southern Illinois University Carbondale.*

**VISITOR INFORMATION**
White Mountain National Forest
719 Main Street
Laconia, NH 03246
603-528-8721
(Patte Brook Auto Tour: 603-466-2713).
www.fs.fed.us/r9/forests/white_mountain/
and www.wilderness.net

tumn bloomers are blue heart-leaved aster, elliptic shinleaf, roadside agrimony, spotted coralroot (a plant devoid of chlorophyll that lives off organic matter in the soil), and wrinkle-leaved goldenrod. New York fern is abundant on the forest floor.

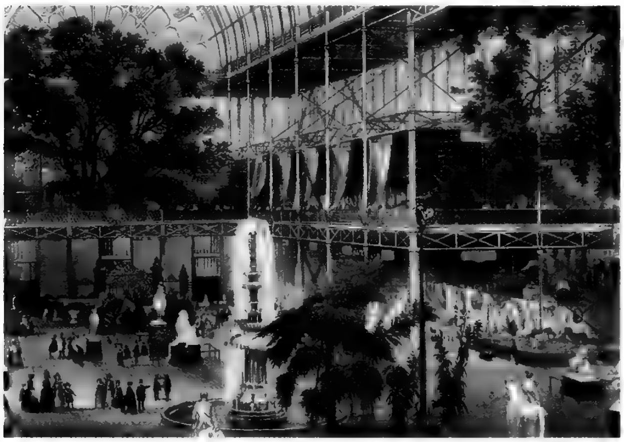
**Exposed granite summit and ledge** Dwarf birch and dwarf white birch are often present, along with wildflowers. In addition to the rare White Mountain silverling and mountain sandwort, the wildflowers include cowwheat, Drummond's rock cress, mountain white potentilla, pale corydalis, pinweed, and purple crowberry. Several members of the heath family also grow here and there, among them bog bilberry, mountain cranberry (also called lingonberry), and sheep laurel.

**Bog and swamp** Black ash, black spruce, and larch (tamarack) are the principal trees; lower-growing trees and shrubs include American alder-buckthorn, Labrador tea, leatherleaf, meadowsweet, mountain serviceberry, red osier-dogwood, rhodora, silky willow, small cranberry, sweet gale, winterberry, and withe rod. Among the numerous wildflowers are bristly crowfoot, narrow-leaved gentian, pink Saint-John's-wort, purple swamp aster, tall white bog orchid, three-leaved false Solomon's seal, water avens, white turtlehead, and three kinds of willow herbs.

By Laurence A. Marschall

*"The Busiest Man in England": A Life of Joseph Paxton, Gardener, Architect, and Victorian Visionary*
*by Kate Colquhoun*
*David R. Godine, Publisher, 2006; $30.00*

Among the great engineering marvels of the 1800s, surely the Crystal Palace ranked supreme. Erected to house London's Great Exhibition of the Works of Industry of All Nations in 1851, it was the largest building built to date, a third of a mile long, 450 feet wide, and enclosing an area of almost twenty-one acres. Like the Brooklyn Bridge and the Eiffel Tower, the other iconic structures of the age, the Crystal Palace celebrated new technology. Its skeleton was made of cast iron, not timber, and its outer walls and roof were sheathed in plate glass, more than 200,000 panes held in place by 205 miles of sash bars. During the six months of the exhibition 6 million people passed through its galleries, and, when it was later reconstructed on a permanent site in south London, the huge building continued to attract and delight weekend crowds until it was gutted by fire in 1936.


Arched transept of the Crystal Palace soars over an elm tree in Hyde Park, London, during the Great Exhibition of 1851, as shown in a contemporary engraving.

It was no coincidence that the Crystal Palace resembled a giant greenhouse. Its architect was Joseph Paxton, chief gardener and landscape designer for the Duke of Devonshire. In the preceding twenty-five years, Paxton had transformed Chatsworth, the Duke's estate, into the most advanced and most spectacular botanical park in Europe. At Chatsworth, a variety of innovative structures housed plants from all over the globe. In one great greenhouse, heated by solar power and subterranean boilers, the temperature was regulated so that one end was temperate and the other end subtropical. From a surrounding gallery, visitors could gaze down at a jungle of exotic trees—coconut palms and date palms, banana and cinnamon. Birds flitted above carpets of ferns, and fish swam in artificial lagoons. In an age obsessed with natural history, Paxton's gardens were a collector's dream, and his fame, even before the Crystal Palace, was nearly universal.

Paxton promoted his innovative ideas through a series of periodicals which he founded and edited—*Horticultural Register,* begun in 1831, and *Magazine of Botany,* begun in 1834—along with several popular gardening books. He succeeded not simply through the cleverness of his ideas, according to writer Kate Colquhoun, but also through the power of his personality. Paxton's industry, clarity of expression, and fundamental sense of decency made him an ideal manager. Everyone who met him admired him, and the many friendships he made during his lifetime were deep and enduring.

Yet that same industriousness and friendliness made Paxton the archetypal workaholic of the Victorian Age. He was the "busiest man in England," according to Charles Dickens, who worked for him briefly as editor of the *Daily News,* a liberal newspaper Paxton founded in 1846. As Paxton's fame grew, the demands on his time grew enormously, and it seemed he could never say no to an appealing idea. He accepted commissions to design municipal parks and private estates, developed railway lines, planned municipal waste sewage systems, and even served in Parliament, all the while carrying on the duties of gardener, editor, and family man. When he died at age sixty-one in 1865, prompting an effusion of public adulation, the editor of *Punch* simply wrote in his diary, "More fatal overwork."

Kate Colquhoun's masterful biography of Paxton more than does justice to this remarkable overachiever. She traces his rise from humble farm-laborer's son to pillar of society by providing a perceptive portrait of the culture that celebrated his talent. Like many self-made men, Paxton was also a product of his time, caught up by the unrestrained curiosity and entrepreneurialism of the Victorian Age. If his name, like that of the great Crystal Palace, is no longer a household word, this book will serve as a handsome memorial, and should stand the test of time.

*Tasmanian Devil: A Unique and Threatened Animal*
*by David Owen and David Pemberton*
*Allen & Unwin, 2006; $24.95*

Whoever coined the phrase "big things come in small packages" may have been thinking of the Tasmanian devil. Although the little marsupial weighs no more than about twenty-five pounds, its ferocity is the stuff of legend. They say its teeth are sharp enough to devour a horse, bones and all. They say it hunts in packs, relentlessly chasing down even the largest prey, and leaves nothing behind. They say it reeks of death, and that those who have encountered a devil in the wild—if they live to tell about it—never forget its awful smell.

But don't believe everything "they" tell you. According to David Owen, a Tasmanian novelist, and David Pem-

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In the final lecture, Professor Sapolsky explores the implications of our emerging understanding of the origins of individual differences, for these discoveries are changing the way we think about ourselves. Where do you draw the line between the essence of the person and the biological abnormalities? Who is biologically impaired, and who is just different? How much should we worry about the temptation to label people as "abnormal"? And what happens when we each have a few of these abnormalities?

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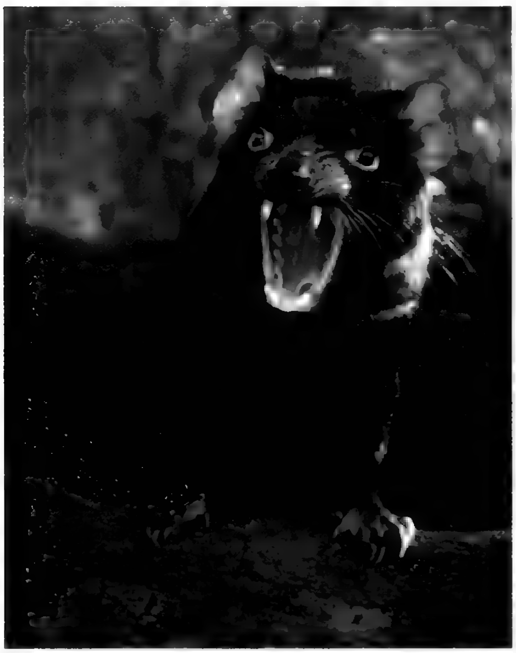
berton, a zoologist and curator at the Tasmanian Museum and Art Gallery in Hobart, only a little is known about devil behavior in the wild, but it's clear that most of the tales of terror are exaggerations. In truth, the Tasmanian devil is generally a timid creature. Although its jaws are strong and its bite can be deadly, it is an opportunistic omnivore, not a vicious predator. Roadkill, dead fish, and fat wombats are staples of its diet, with tadpoles and moths added as garnish.

Another myth is that devils hunt in packs. In fact, they prefer the solitary chase; their reputation for wolflike vigilantism may have arisen from their tendency to dine with friends. When a devil encounters a substantial carcass, a possum, say, or a young sheep, it signals its neighbors with loud shrieks, so that all can share the bounty. The sight of these small, active creatures tearing gobbets of flesh while screaming at each other may present a distressing tableau, but it's no more cause for alarm than a flock of crows or vultures pecking at a fresh corpse.

In spite of their bad reputation, Tasmanian devils have had their champions over the years. One of the most unlikely was a well-to-do Victorian animal fancier named Mary Grant Roberts, who began breeding and nurturing captive devils in a private zoo in Hobart in the late 1800s. She kept several families of devils, and wrote perceptively of their feeding, breeding, and social habits. "I, who love them, and have had considerable experience in keeping most of our marsupials," Roberts wrote in 1915, "will always regard them as first favourites, my little black playmates." Roberts's motherly enthusiasm for Tasmanian devils was matched by the scientific attraction they exerted on a Tasmanian biology professor named Theodore Thomson Flynn, the father of the actor Errol Flynn. The elder Flynn was the first to describe the anatomy and physiology of the devil in meticulous detail.


*Tasmanian devil reinforces its reputation for ferocity.*

Still, much remains to be learned about devils. They are hard to observe in the wild, and only a few professionals study them—among them Pemberton. Farmers continue to view them as a menace, and though the bounty on them, imposed in the 1800s, is no longer in place, devils have been adversely affected by human development on their remote island home. Yet at the same time, the devil has become a popular symbol of Tasmania, celebrated locally in tourist brochures and worldwide as the Warner Brothers cartoon character Taz. On balance, the will to protect the devil is there, but the way remains unclear.

In recent years an alarming new element has entered the picture: a grim affliction known as devil facial tumor disease, or DFTD. First recognized by a wildlife officer named Nick Mooney in 1996, the disease deforms, then kills. No one knows what causes DFTD—virus, environmental pollutant, invasive microorganism, or, as most recently suggested, allograph transmission, whereby an infectious cell line passes directly from one animal to another through a bite—but it may ultimately determine whether the Tasmanian devil makes it in the wild. Tracking its cause and finding a cure is the most urgent item on the agenda for the human advocates of this remarkable marsupial.

***A Land Gone Lonesome: An Inland Voyage Along the Yukon River***
*by Dan O'Neill*
*Counterpoint, 2006; $24.95*

Leaving Dawson by canoe, as Alaskan writer Dan O'Neill did one fine August day in 2001, you can travel downstream eighty-five miles on the Yukon River, to Poppy Creek, without meeting a single year-round resident. It wasn't always that way. Around 1900, with the Klondike in the grip of gold fever, several thousand people lived along the Yukon between what was then called Dawson City, in Canada, and Circle City, Alaska. Some had houses in settlements such as Charley River, Coal Creek, and Star City, where post offices and general stores served the population; others preferred the solitary life of hunting, trapping, and prospecting from cabins scattered along the great river and its tributaries. In the warm months, sternwheelers carried people and produce along the main channel of the Yukon; in winter, mail carriers plied the snowy trails along its banks, stopping at well-stocked roadhouses never separated by more than a day's dog-sled journey.

Nowadays, gold fever is just a memory; the old towns and roadhouses lie abandoned. Still, wilderness living has its attractions, and in the 1970s, when disaffected youth from the Lower 48 were moving back to the land, the Yukon saw a brief resurgence of homesteaders. John McPhee wrote memorably of these folks in a series of articles for *The New Yorker* and in his 1977 book *Coming into the Country.* McPhee depicted the new homesteaders as latter-day pioneers, self-reliant and sometimes eccentric, seeking to live a life more genuine than the one afforded by urban civilization. Although probably only a few of the new settlers

were aware of the fact, the rugged outback they were entering lacked even the minimal support systems the Klondike settlers had enjoyed fifty years earlier. Mail delivery had ceased; steamers no longer ran; and the bankside trails were overgrown.

In his weeks on the river, O'Neill passed through the same territory McPhee had written about, but most of the back-to-the-landers of the 1970s had gone. Indeed, except for a few people with seasonal cabins along the river, the land today is arguably emptier than it was before the gold rush. O'Neill's journal records all that is left of the Yukon subsistence lifestyle: a few burnt-out ruins, a few moldering homesites, and a few remaining hunters and trappers who tell fireside stories of colorful characters from the homesteading days.

They may recall Dick Cook, a prickly trapper who lived down by the mouth of the Tatonduk, and who perennially tangled with the government about supposed incursions on his independent lifestyle. Or Jan and Seymour Able, who lived for two years under a parachute in the woods near Glenn Creek. Or Richard Smith, who survived a bad mauling by a bear, and whose cabin near Eureka Creek was carried away one spring by ice floes, only to be redeposited, several days later, just a few feet from where it had originally stood.

Ogilvie Mountains, Yukon Territory, Canada

Although it is a journal of desolation and fading memory, O'Neill's book is not about the passing of an obsolete lifestyle. To hear him tell it, there are still hundreds of people who would like to eke out a living fishing, trapping, and running dogs along this wild waterway. But apparently, the federal government doesn't see that as a legitimate wilderness activity. In 1980, partly as a result of the same environmental sensitivity that motivated McPhee's homesteaders, much of the area was put under federal control as the Yukon–Charley Rivers National Preserve. Although the legislation recognized "subsistence lifestyle" as a "cultural value," and permitted limited homesteading in the new park, the Park Service has generally been unaccommodating to trappers and fishermen. As old residents drift away in frustration, new ones have been discouraged from moving in. Old, neglected cabins have fallen into disrepair.

"It didn't work out as McPhee had hoped," writes O'Neill. "The way the law was implemented, the way the regulations were drafted, subsistence is regarded less as a value than as a nuisance." Journeying with him through the remnants of a once-vital backwoods society, one comes to understand that a wilderness should be a home to people as well as to salmon, moose, and bear.

*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.*

# Noble Gas

*By Robert Anderson*

Ever wondered how many helium balloons it would take to lift yourself off the ground? If sanity has kept you from finding out, you'll enjoy Jeff Whitehead's video of a safely tethered helium flyer in the crucial experiment (humanbeingcurious.com/page17/page16/page16.html). The results would have been more dramatic, however, if the pilot had cut her tethers to drift free, as "Lawn-Chair Larry" did in 1982 (go to markbarry.com or to darwinawards.com/darwin to read that remarkable story). More recently, John Ninomiya, a licensed hot-air balloon pilot, has made about forty such free-flying helium-powered flights (go to clusterballoon.org to find out more).

Given the rarity of helium on earth, using the noble gas for filling a party balloon seems just, well, frivolous. Making up just 0.0005 percent of the atmosphere, helium is so diffuse it wasn't detected until 1868, and then only from a mysterious line in the solar spectrum. For that reason, Sir J. Norman Lockyer, a British astronomer, named it after Helios, the Greek sun god. Go to "Astronomy Picture of the Day" at antwrp.gsfc.nasa.gov/apod/ap960520.html to see our star glowing in the light emitted from hot, ionized helium.

Modern astronomy has revealed that helium is the second most common element in the universe, after hydrogen, making up nearly a quarter of the mass of visible matter. An entertaining Web site called "The Big Bang Time Machine" (schoolscience.co.uk/flash/bang.htm) takes you back to the earliest moments of the universe, when, among other things, hydrogen and helium condensed into being after the big bang's burst of incredible heat. (Use the time machine's green joystick to go back and forth.) A Web page at the University of Tennessee Astrophysics Group (csep10.phys.utk.edu/astr162/lect/cosmology/hotbb.html) details how the formation of helium supports the big bang model. For basic information about helium, go to theodoregray.com/PeriodicTable/#tabletop and click on the symbol "He" at the upper right. In addition to making the most beautiful periodic table on the Internet, Theodore Gray has collected fascinating specimens of the elements, which you can view by scrolling down the page for each one.

For eighty years almost all of the world's extracted helium has come from the natural-gas fields around the Oklahoma panhandle. Compared with the cosmic helium, the Oklahoma helium is relatively young, a by-product of radioactive decay deep within the earth. Until recently the U.S. government stockpiled excess helium in an underground reservoir near Amarillo, Texas. The National Academy of Science has an excellent overview of the helium supply—past, present, and future—in an online report at darwin.nap.edu/books/0309070384/html titled "The Impact of Selling the Federal Helium Reserve."

Chapter three describes the unique properties that make the gas indispensable to modern technology. Remaining liquid down to absolute zero (at least at ordinary pressures), helium is critical to many devices that require extreme cold—such as the powerful superconducting magnets in MRI imaging machines, which consume about a third of the gas now collected. And because helium does not react with other elements, it is used for making controlled atmospheres, for pressurizing, and for purging in many industrial processes, as well as for welding and for gas mixtures that deepwater divers can breathe safely.

Because pure helium gas can slip through holes that would stop any other gas (that's the reason helium balloons go flat so quickly), it is a common leak detector. An article from the Houston Geological Society (hgs.org/en/art/?162), titled "Helium Exploration—A 21st Century Challenge," gives more insight on meeting the growing demand for this noble gas.

In the more distant future, helium might help solve one of humanity's most pressing problems: how to supply abundant energy without increasing greenhouse gases or poisoning the environment with radiation. The key may be helium-3, a rare isotope on Earth, but which occurs in abundance in lunar soil (see the article in *Wired* magazine titled "A Helium Shortage?" at wired.com/wired/archive/8.08/helium.html). As a fuel for fusion reactors, helium-3 could, in principle, provide limitless energy, with little residual radiation. Harrison H. Schmitt, the only geologist to step on the Moon, is a proponent of returning there someday to mine it for helium. To listen to him lecture on the subject, go to Google's video search engine (video.google.com) and type in "Schmitt helium," or try mitworld.mit.edu/video/159 for a more lengthy presentation. If his dreams are ever realized, helium will be a noble element indeed.

*Robert Anderson is a freelance science writer living in Los Angeles.*

# Celestial MUSYC

*Cosmic ABCs keep astronomers spellbound.*

By Charles Liu

Acronyms are everywhere, alphabetically infecting daily life, IMHO (in my humble opinion). So perhaps we astronomers can be forgiven for sliding down the slippery slope of cryptic capital letters: MHD (magnetohydrodynamics), SETI (search for extraterrestrial intelligence), LGM (little green men).

Overall, though, we're pretty good at keeping things unacronymed, giving fairly simple names to cosmic phenomena. A reddish star that's really big, for instance, is called a red giant; a whitish star that's really small is a white dwarf. But it's back to the ABCs when we name our scientific projects, from the strictly functional (VLT for Very Large Telescope) to the embarrassingly cute (LALA for Large Area Lyman-Alpha survey).

Lest you think I'm blamelessly poking fun at my colleagues, I freely admit my own recent foray into acronymic vanity. A couple of years ago, I was invited to join a major international scientific collaboration that would examine four widely separated patches of sky, each a little larger than the size of the full moon. The survey would make images at many wavelengths of electromagnetic radiation (infrared, all the colors of visible light, ultraviolet, and X-ray) with the goal of examining how populations of galaxies changed with the passage of cosmic time.

As work progressed on this ambitious cosmic survey, we realized we needed a public name for our project. Members of the team ruminated on this question for days, weeks, even months. Who knows how much highly trained scientific brainpower was siphoned away from studying the mysteries of creation for the creation of acronyms? Finally, after dozens of candidates were proposed, everyone agreed that the acronym for our survey would acknowledge the two primary institutions in the collaboration: Yale University, and the University of Chile, in Santiago. One question remained. Would it be the Multiwavelength Survey by Chile-Yale (MUSCY), or the Multiwavelength Survey by Yale-Chile (MUSYC)? In the end, though a MUSCY survey might smell good enough, we agreed that MUSYC would sound much more harmonious.

Its whimsical name notwithstanding, MUSYC has moved forward rapidly. And perhaps not surprisingly, the objects we have studied so far are generally referred to by their acronyms: AGN, DRGs, and LAEs. AGN, active galactic nuclei, are supermassive black holes that act as gravitational dynamos at the hearts of galaxies, converting the potential energy of infalling matter into powerful outflowing jets and electromagnetic radiation. DRGs, distant red galaxies, are, well, galaxies that are distant (between 8 and 12 billion light-years from Earth) and red, emitting so much more red light than blue light that it sometimes looks as if their stars are older than the universe itself [*see "Seeing Red," by Charles Liu, March 2005*].

LAEs—Lyman-alpha emitting galaxies or Lyman-alpha emitters—are particularly intriguing as markers of cosmic evolution, because they have no obvious counterparts in the local universe (AGN and DRGs at cosmic distances—many billions of light-years away—have similar counterparts closer by). LAEs get their name from the American physicist Theodore Lyman, who in the early twentieth century discovered that hydrogen gas emits ultraviolet light. LAEs are small, young, and bursting with new stars. According to a study led by Eric Gawiser, a postdoctoral fellow at Yale and one of MUSYC's principal investigators, they appear to be the primitive progenitors of modern, mainstream galaxies such as our own Milky Way.

When an atom is struck by another atom or a sufficiently powerful photon, the sudden influx of energy can tear one or more of the atom's outermost electrons away from the rest of the atom. The remaining atom, now ionized, with a net positive charge, readily recombines with other, free-flying electrons nearby. The new electrons, however, can fall only to certain discrete "levels" opened up by loss of the earlier electrons: levels dictated by the atom's quantum mechanical structure. If it helps, think of the structure as a big pachinko machine—those vertical pegboardlike games in which little steel balls fall from top to bottom—and imagine each recombining electron as one of the steel balls dropping downward through the machine.

Every time the electron falls from one atomic energy level to a lower one, the atom releases energy in the form of electromagnetic radiation—that is, light—at a specific wavelength or color. So within every cloud of ionized gas, electrons combining with ions are like balls at the top of atomic pachinko machines, in which the electrons cascade downward until they reach their lowest energy state. And the more likely a particular bounce, the more light of that color emerges from the cloud.

For hydrogen atoms, the most likely intra-atomic step downward is the one that takes the electron from its second-lowest energy state to its lowest, or "ground," state. The light emitted by this bounce, whose wavelength was first measured by Lyman, is the brightest spectroscopic feature emitted by any cloud of ionized hydrogen gas. Because most of the atoms in the universe, by far, are hydrogen, you would think that "Lyman-alpha" radiation would be easy to detect. It would be worth detecting, too, because Lyman-alpha radiation is a good measure of how much ionized hydrogen there is in any particular place in the universe.

There are, however, two obstacles to detecting Lyman-alpha transitions. First, their emitted light shines in the ultraviolet part of the electromagnetic spectrum, at a wavelength of 121.6 nanometers, or just under 1/200,000 of an inch. On top of that, light at this wavelength is easily absorbed by intervening matter—it can't even get through Earth's atmosphere, for instance. Out in deep space, just a little bit of metallic or molecular dust mixed into a cloud of nearly pure hydrogen gas can quench 99 percent or more of the Lyman-alpha light produced in the cloud. And the universe is, on the whole, a very dusty place.

To observe the radiation from Earth, Gawiser and his colleagues took advantage of the effects of cosmic expansion. At cosmic distances, the farther an object is from Earth, the faster it is moving away. The motion lengthens the wavelengths of the object's light beam, just as the whistle of a train sounds at a lower pitch when it is receding than when it is approaching. The cosmic wavelength-stretching is called redshift. At large enough distances—about 10 billion light-years or more—the wavelength of the ultraviolet light from Lyman-alpha transitions is so stretched by the recessional speed of its source that it shifts into the visible part of the spectrum. The redshifted light from distant LAEs can thus be seen with earthbound telescopes.

Dust was the second problem. How much dust was in the vicinity of the LAEs? Would the proportion of Lyman-alpha transitions detected be sufficient to give a clear picture of those galaxies? With the 6.5-meter Magellan-Baade Telescope at Las Campanas, Chile, Gawiser's team supplemented MUSYC images with spectroscopic data of the same distant LAEs. He discovered that, at a distance of around 11 billion light-years, the Lyman-alpha light escaped the LAEs just fine—so well, in fact, that when the light left those galaxies they probably harbored hardly any dust at all. Moreover, though they are only about a tenth the mass of the Milky Way, they form stars at rates as much as ten times faster than stars form in our galaxy.

What do those results imply? Interstellar dust is the by-product of stellar aging and stellar death. No dust means no old stars, so these LAEs are young and newly formed. Furthermore, their rapid rate of star birth means that a substantial number of new stars would appear in them in a very short time. Large galaxies like the Milky Way are hypothesized to have formed from the merging of many small, young galaxies, and Gawiser's findings lend strong support to that picture. If a dozen LAEs had fallen together between 10 and 11 billion years ago and merged into a single spinning system, they could readily have formed the bulk of a galaxy like ours.

As we MUSYC team members do our work—not just on LAEs, but also on the aforementioned AGN and DRGs and so many other fascinating kinds of objects—we're looking forward to sharing our scientific symphony with everyone within earshot. Like almost all the large surveys in modern astronomy, the data we obtain will be made available to the general public within a year or two of completion. That way, other investigators can bring their expertise and insights to bear on the data as well. Already MUSYC is rolling off the tongues of astronomers worldwide, along with other cute and clever alphabetic packets such as GOODS, GEMS, and FIRES, all as we explore the mysteries of the COSMOS. Ah, but those are acronyms—and stories—for another day.

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

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# EXPLORER GUIDE

By Joe Rao

Mercury is at superior conjunction (beyond the Sun as seen from Earth) on September 1, and enters the evening sky. Unfortunately for observers in the Northern Hemisphere, Mercury lies well south of the Sun, toward the west-southwest at sunset, and so it never gets much above the horizon all month long. Even at the end of September the planet is still mired deep in bright evening twilight and sets less than forty-five minutes after sunset. Observers in the southern United States (and farther south) might be able to spot it with binoculars, but it's a long shot at best.

Venus begins the month rising a bit more than an hour before sunrise. But throughout the month it's also rapidly sliding toward the Sun, so by month's end it rises only about a half hour before the Sun. In the end, even its great brilliance (magnitude −3.9) can't keep it from getting lost in the glare of the bright morning sky. On the morning of the 6th, Venus comes within just three-quarters of a degree of the bluish star Regulus, in the constellation Leo, the lion. You may need binoculars to detect Regulus so low in the dawn; it shines only 1/130 as bright as Venus.

Mars is too close to the Sun this month to be seen. It reaches conjunction with the Sun in late October and remains out of sight until it returns as a morning "star" in December.

Jupiter is visible in the southwestern evening sky at dusk, setting just after 10 P.M. local daylight time at the beginning of September. By the end of the month it is setting below the west-southwestern horizon just after the end of evening twilight—around 8:30 P.M. Between the 6th and the 17th, Jupiter lies within one degree of the star Zubenelgenubi, in the constellation Libra, the scales. The closest approach comes on the 11th, when the big planet passes a half degree to the upper right of the star, their third close encounter this year. On the 25th Jupiter lies to the upper left of the crescent Moon. On the following evening, it appears to the Moon's upper right.

Saturn, now in Leo, continues to climb progressively higher in the east-northeastern sky throughout the month. Now shining at magnitude +0.5, it rises around 4:45 A.M. local daylight time at the start of September, and at about 3 A.M. by the 30th. Any telescope magnifying more than thirty times can reveal the famous ring system; Saturn's rings are tipped 15.1 degrees toward Earth at the start of the month, but the angle closes to 13.7 degrees by month's end.

The Moon is full on the 7th at 2:42 P.M. It wanes to last quarter on the 14th at 7:15 A.M. and becomes new on the 22nd at 7:45 A.M. As September ends, the Moon waxes to first quarter on the 30th at 7:04 A.M.

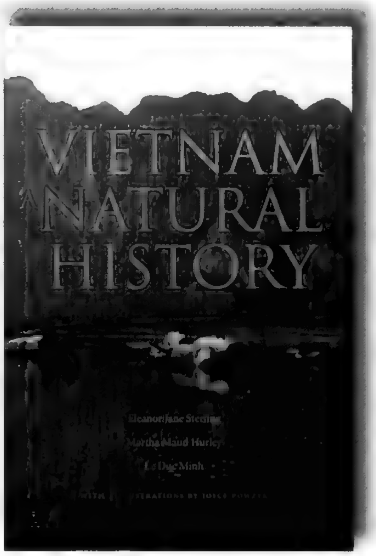
A small partial lunar eclipse is visible on the 7th from most of Europe, Africa, Asia and Australia. The Moon spends more than ninety-two minutes inside the darkest part of the Earth's shadow, which, at maximum coverage, darkens about 19 percent of the lunar diameter. There is also an annular (ring) eclipse of the Sun on the 22nd. The entire disk of the Moon will appear in silhouette against the Sun, producing a dazzling ring of sunlight on the sky that is visible along a path that crosses the South Atlantic Ocean. The only land areas that can see the annularity (just after sunup) lie in Guyana, Suriname, and French Guiana. A partial eclipse is visible from eastern South America and southern and western Africa.

The Equinox occurs at 12:03 A.M. on the 23rd. The Sun, which appears to make its annual circuit of the sky along the ecliptic, crosses the projection of the Earth's equator against the sky and plunges into the Southern Hemisphere. Autumn begins in the Northern Hemisphere, while spring begins in the Southern.

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

# Biodiversity Near and Far

From Central Park to Southeast Asia, the Museum's conservation efforts are truly global in scope. Consider *Vietnam: A Natural History* (Yale University Press), the fruit of a conservation biology research and training project begun by AMNH's Center for Biodiversity and Conservation (CBC) in Vietnam nearly a decade ago, and the first comprehensive work on the country's extraordinary flora and fauna and diverse natural areas. Scientists, armchair naturalists, and travelers will find this book an engaging guide to all that Vietnam has to share about its past and present beauty, history, and diversity—biologically, geologically, and culturally.




Coauthored by CBC Director Eleanor J. Sterling and CBC Biodiversity Scientists Martha M. Hurley and Le Duc Minh, the book is spectacularly illustrated with maps, photographs, and 35 original watercolors, and offers an accessible yet scientifically rigorous examination of Vietnam's plant and animal life along with in-depth discussion of the factors shaping their evolution, distribution, and conservation.

In part because of Vietnam's complex cultural and political history, we have only just begun to study its great biological diversity, rich in plants, animals, and natural habitats. *Vietnam: A Natural History* reports on rare and unique organisms—dozens of newly described species of amphibians, birds, and mammals—and explores the long history of human occupation in the country, including the effects of the Vietnam-American War on the region's fragile and widely threatened biodiversity.

The authors provide detailed descriptions of key natural areas to visit, where a traveler might explore limestone caves or glimpse some of the country's 27 known monkeys and apes and more than 850 bird species, many of which can be found only in Vietnam or adjacent regions.

A majority of the authors' royalties earned from sales of this book will be contributed to an educational fund supporting Southeast Asians working in biodiversity conservation.

Closer to home, CBC Associate Director Felicity Arengo and CBC Metropolitan Biodiversity Program Manager Liz Johnson were among those representing the Museum at the 2006 Central Park BioBlitz, a 24-hour event aimed at adding to species lists of living things in this landmark New York City park and at increasing public awareness about biodiversity in an urban environment. Among the finds by Museum scientists: nearly 20 possible land and freshwater mollusk species and 7 species of social wasps, proving that even in this much-studied setting, there are still discoveries to be made.

D. FINNIN/AMNH

## *LIZARDS & SNAKES: ALIVE!*

**Through January 7, 2007**

More than 60 live animals shed light on the often-overlooked world of lizards and snakes in the AMNH's latest captivating exhibition, *Lizards & Snakes: Alive!* Camouflaging themselves in their re-created habitats; scurrying, slithering, or shimmying; eating daintily or ravenously, these creatures are endlessly fascinating. Plus, interactive exhibits, puzzles, touchable models, and more show visitors the similarities and differences among this amazing assortment.

## PEOPLE AT THE AMNH

**Liz Johnson**
Manager, Metropolitan Biodiversity Program
Center for Biodiversity and Conservation


D FINNIN/AMNH

If anyone can coax city dwellers to appreciate worms and other woodland creatures in the world hidden underfoot, it's Liz Johnson, Manager of the Metropolitan Biodiversity Program for the Museum's Center for Biodiversity and Conservation. Her enthusiasm for the richness of life in the region is infectious.

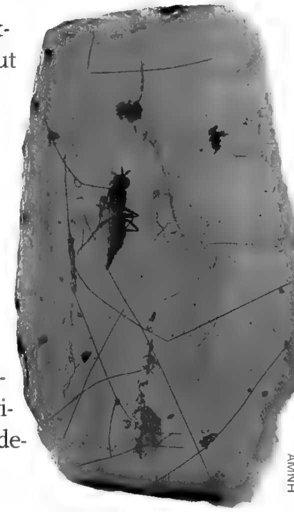
"There's nature in the City. It's all around us," she said in a recent interview. "What we have in New York is pretty amazing and just as important to conserve as something in the tropical rain forest."

And Liz would know. Since arriving at the Museum nine years ago—armed with degrees in ecology, geology, and wildlife biology—she's been involved in both gathering and disseminating information, from fieldwork that literally unearthed a new species of centipede in Central Park to coauthoring *Life in the Leaf Litter,* a popular guide to urban invertebrates. She's currently editing New York State's first biodiversity conservation book and a primer on sprawl in New Jersey aimed at local officials on the front lines of land use.

A New Jersey native, Liz lives doors from the Delaware River with her husband, an endangered species biologist for the state of New Jersey, whom she met when previous work led her to consult him about the plight of piping plovers and least terns at the Jersey Shore. Not surprisingly, their 4-year-old daughter Karla is already "becoming a good field biologist. She's curious about everything," Liz said proudly. "She'll even hold snakes, caterpillars, and worms."

# Ancient "Web Site" Holds Clues to Insect Evolution

Entomologists have long suspected that spiders' eating habits played a role in early insect evolution but proof was elusive, given the rarity of fossilized spiders or their silk. Until now. A pencil-thin rod of amber found in Spain has preserved within it a 110-million-year-old spider web—the oldest ever found—and, snagged in its silk, the telltale remains of the weaver's prey: a fly, a mite, a beetle, and a wasp.


AMNH

It's what's for dinner: A fly in the genus *Microphorites* (at left) is trapped in the amber section with the most complex web fragment.

"The advanced structure of this fossilized web, along with the type of prey that the web caught, indicates that spiders have been fishing insects from the air for a very long time," said David A. Grimaldi, Curator in the American Museum of Natural History's Division of Invertebrate Zoology and coauthor of a report describing the discovery in the journal *Science.*

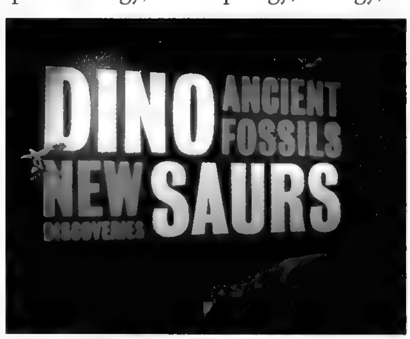
The fossilized web, which has at least 26 strands, was most likely spun by an orb-weaving spider. Tangled within it are ancestors of the same creatures that are the most common prey of today's orb-weaving spiders and are numbered among the most diverse groups of flying insects in existence. This latter fact is key as the web dates from the Early Cretaceous Period, a time of explosive diversification of both flowering plants and pollinating insects. Spider predation could have influenced evolutionary improvements in the insects' ability to navigate and forage among the flowers.

"Spiders today have a huge impact as predators on insect populations, along with birds and bats," explained Dr. Grimaldi. "This new finding suggests that spiders exerted a similar selection pressure on insects 110 million years ago."

# Taking the Show on the Road

Millions of visitors to Manhattan enjoy the American Museum of Natural History's special and permanent exhibitions each year. But there are also millions of people who never come to New York City who take advantage of the Museum's unique content—through the Museum's traveling exhibitions.

The Museum launches two to three major special exhibitions annually, relating to paleontology, anthropology, biology, astronomy, and more. Once the exhibition closes at the Museum, it travels to other natural history museums, science centers, and planetariums around the world. Currently traveling are *Darwin; Einstein; The Genomic Revolution;* and others; as well as three of the Museum's planetarium shows: *Passport to the Universe; The Search for Life: Are We Alone?;* and *SonicVision.*




*Dinosaurs: Ancient Fossils, New Discoveries,* a huge hit at the AMNH, is currently showing at the California Academy of Sciences in San Francisco.

These traveling exhibitions have a tremendous reach: they have appeared in over 20 cities in the United States, 5 cities in Canada, and in numerous other locations internationally. Visit www.amnh.org to find out what may be coming to your neighborhood.

# Museum Events

AMERICAN MUSEUM OF NATURAL HISTORY

www.amnh.org

## EXHIBITIONS

**Lizards & Snakes: Alive!**

*Through January 7, 2007*

Live lizards and snakes are the center of attention in this engaging exhibition that explores these creatures' remarkable adaptations. Fossil specimens, life-size models, and interactive stations complement the more than 60 live animals representing 26 species.

*Lizards & Snakes: Alive!* is organized by the American Museum of Natural History, New York (www.amnh.org), in collaboration with Fernbank Museum of Natural History, Atlanta, and the San Diego Natural History Museum, with appreciation to Clyde Peeling's Reptiland. *Lizards & Snakes: Alive!* is made possible, in part, by grants from The Dyson Foundation and the Amy and Larry Robbins Foundation.

**EXTENDED! Voices from South of the Clouds**

*Through January 2, 2007*

China's Yunnan Province is revealed through the eyes of the indigenous people, who use photography to chronicle their culture, environment, and daily life.

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

**Yellowstone to Yukon**

*Through January 15, 2007*

Spectacular photographs of landscapes and wildlife emphasize the diverse flora, fauna, and geology of the Yellowstone to Yukon corridor—an area connecting habitats so that wide-ranging animals can travel unimpeded by human structures and developments.

This exhibition was developed by the American Museum of Natural History's Center for Biodiversity and Conservation in concert with the Yellowstone to Yukon Conservation Initiative and the Wilburforce Foundation and is made possible by their support. Additional generous support provided by the Woodcock Foundation.

**Vital Variety**

*Ongoing*

Beautiful close-up photographs highlight the diversity of invertebrates.

## FIELD TRIPS AND WORKSHOPS

**Animal Drawing**

*8 Thursdays, 9/28–11/16*
*7:00–9:00 p.m.*

The celebrated dioramas, dinosaur skeletons, and other distinctive features of the Museum serve as the setting for an intensive after-hours drawing course with Stephen C. Quinn, Department of Exhibition. Learn about the gifted artists who created the world-class dioramas as you sketch subjects in their "natural" environments.

**Fall Birds Walks in Central Park**

*Eight-week sessions begin on 9/5, 9/6, and 9/7.* Visit www.amnh.org for details. Observe the fall migration of birds in Central Park with naturalists Stephen C. Quinn (Tuesdays, 7:00 a.m.), Joseph DiConstanzo (Wednesdays and Thursdays, 7:00 a.m.), and Harold Feinberg (Thursdays, 9:00 a.m.). Learn how to use field marks, habitat, behavior, and song as aids in identification.

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The cougar, also known as the panther, mountain lion, or puma—has rebounded from near-eradication in the early 20th century.

**The World of Wine: Yesterday, Today, and Tomorrow**

*3 Tuesdays, 9/26–10/10*
*7:00–8:30 p.m.*

Learn about culture and winemaking around the world and through the ages with this course led by Louisa Thomas Hargrave, Director, Stony Brook University Center for Wine, Food, and Culture; Sal Diliberto, artisanal winemaker and owner of Diliberto Winery; and Jean-Louis Carbonnier, president of Carbonnier Communications. Wine tastings will be conducted weekly.

## FAMILY AND CHILDREN'S PROGRAMS

**Visit the Space Station!**

*Saturday, 9/17, 11:00–12:30 p.m. (Ages 4–5, each child with one adult) or 1:30–3:00 p.m. (Ages 6–7, each child with one adult)*

Does your child dream of being an astronaut? Through hands-on activities, demonstrations, and stunning video, you and your child can see what a day might be like living, working, and playing aboard the International Space Station. Prepare to blast off!

**Dr. Nebula's Laboratory Dino Adventure**

*Saturday, 9/30*
*2:00 p.m.*

Dr. Nebula's assistant, Scooter, is digging up a storm! Uncover the mysteries of the dinosaurs and what might have happened to them in this prehistoric adventure.

## HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME

***Virtual Universe***
**Expedition to the Moon**
*Tuesday, 9/5, 6:30–7:30 p.m.*

***This Just In...***
**September's Hot Topics**
*Tuesday, 9/19, 6:30–7:30 p.m.*

***Celestial Highlights***
**Chill in the Air**
*Tuesday, 9/26, 6:30–7:30 p.m.*

STARRY NIGHTS

*Live Jazz*

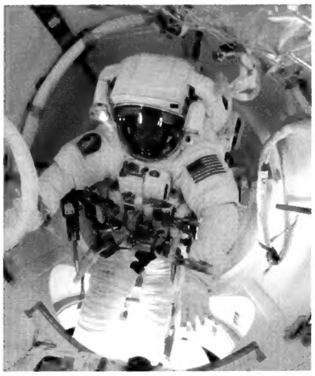
ROSE CENTER FOR EARTH AND SPACE

***Friday, September 1***
*6:00 and 7:30 p.m.*

© MICHAEL WONG

Javon Jackson

COURSE
**Introduction to Space Science: Motion and Matter**
*14 Thursdays, 8/31–12/7*
*6:30–8:30 p.m.*


NASA-MSFC

Astronaut James F. Reilly uses a new airlock to exit the International Space Station (ISS).

LECTURE
**The Trouble with Physics**
*Monday, 9/25, 7:30 p.m.*

**HAYDEN PLANETARIUM SHOWS**
***Cosmic Collisions***
Journey into deep space—well beyond the calm face of the night sky—to explore cosmic collisions, hypersonic impacts that drive the dynamic formation of our universe. Narrated by Robert Redford.

*Cosmic Collisions* was developed in collaboration with the Denver Museum of Nature & Science; GOTO, Inc., Tokyo, Japan; and the Shanghai Science and Technology Museum. Made possible through the generous support of CIT. *Cosmic Collisions* was created by the American Museum of Natural History with the major support and partnership of the National Aeronautics and Space Administration's Science Mission.

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

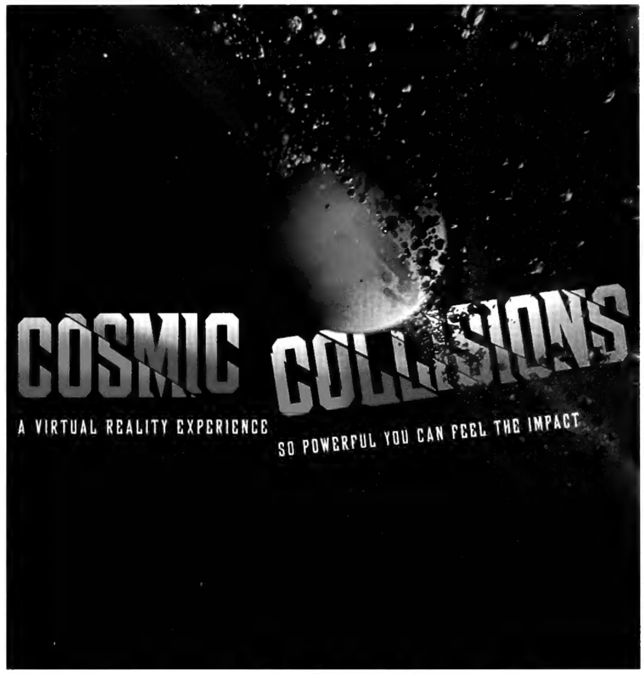
*SonicVision* is made possible by generous sponsorship and technology support from Sun Microsystems, Inc.

**LARGE-FORMAT FILMS**
LeFrak IMAX Theater
***Journey into Amazing Caves***
Visit www.amnh.org for showtimes.

IMAX films at the Museum are made possible by Con Edison.


BILL HATCHER

Dos Ojos, an underwater cave on the Yucatán peninsula of Mexico



AMNH

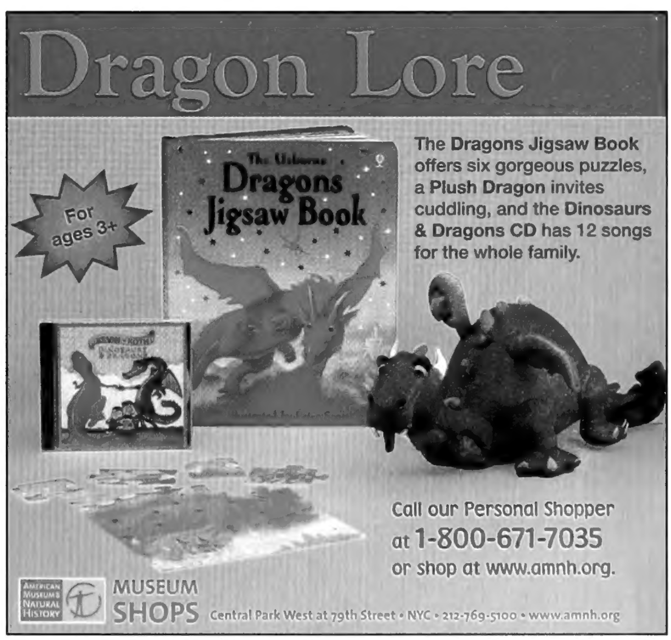
The Museum's spectacular new Space Show

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

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

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





ENDPAPER

# Where the River Stops Running

*Text and photographs by Tim Palmer*

Home was on a broad ridge where the river began. You couldn't see rippling pools, waterfalls, or rapids there. In fact, you couldn't even find our spring unless you looked for it.

My family's land was high in the watershed, stitched into the fabric of Appalachian foothills. As a kid I gradually pieced together the logic that the puddles and wet swale alongside our garden were somehow connected to the spring. When raindrops and snowflakes fell on our soil, they began a traceable journey downhill, bound for the Gulf of Mexico, 1,500 miles away.

As I grew older, I could count my years by how far downstream I had explored—every bend opened wonders to me. Beyond its outlet, our spring became a creek that ran down through a field, and out to a deepening woods. The woods were dominated by oak and hickory, and darkened here and there by an eastern hemlock. I spotted woodpeckers drumming on dead elms. At one of the widest places in my stream I flushed a duck. Being an upland boy, I had never seen waterfowl of any kind. Though only a mallard, I was thrilled at the iridescent green of its head and ran home to tell my mother.

During my high school years those Saturday-morning outings expanded to daylong expeditions. I packed lunch and hiked downstream as far as I could, my increasing endurance now a match for my unbounded curiosity. My stream grew in volume and its riffles gained some force. The water pooled up in places big enough for me to jump in. The stream and its valley were amazingly wild for being only forty miles from Pittsburgh.

Then one day I heard the incongruous rumble of truck noise ahead of me on my path. Approaching cautiously, afraid of what I would find, I saw that my wild stream tunneled into the darkness of a culvert beneath a four-lane highway. Then, with all its

distance covered, with its own life of intimacy past, my little stream entered the Ohio River.

At that time the Ohio was the largest, barge-floating cesspool in America. In a few short feet my family water mixed and then disappeared into the oily flow of that eastern behemoth. The river had once been one of the biologically richest waterways in America, but industrial barging had overrun it for generations.

In one culminating instant I understood what a stream should be, and what it shouldn't. I sensed something tragic in raindrops and headwater rivulets that had flowed into the wrong river. This awareness came solely from what I saw in that meeting point. I wanted to capture it in a picture, but couldn't: I didn't own a camera.

The Ohio stretched a quarter mile across. Aging steel mills rusted alongside it; traffic pounded its banks; and railroad tracks cordoned off the water. Furthermore, it stank. What had once been the ultimate life force had become a conduit for waste—a hazard to public health.

The combined effect assaulted my senses completely, yet something even more troublesome was amiss. Dirty water, after all, could be cleaned up. Then I realized: it had no flow. It didn't move. Later I would learn that the Ohio is dammed twenty-six times in 981 miles, with scarcely a hundred yards of free-flowing river to be found in its entire length.

The Ohio showed me what could happen to streams when they became rivers. At the time, I took my stream's dammed and polluted outcome simply as a lesson in the ways of the world. An accompanying sense of fatalism took me years to shed. What I saw of course doesn't happen to every stream, and even where it does, there's no reason it must stay that way forever. But these realizations would come later. At that moment, I had to walk back upstream—sensing the fate of my family's waters.

*TIM PALMER is an award-winning author, photographer, and conservationist, devoted to the preservation of rivers. This essay is adapted from his book,* Rivers of America, *which is being published this month by Abrams, New York.*