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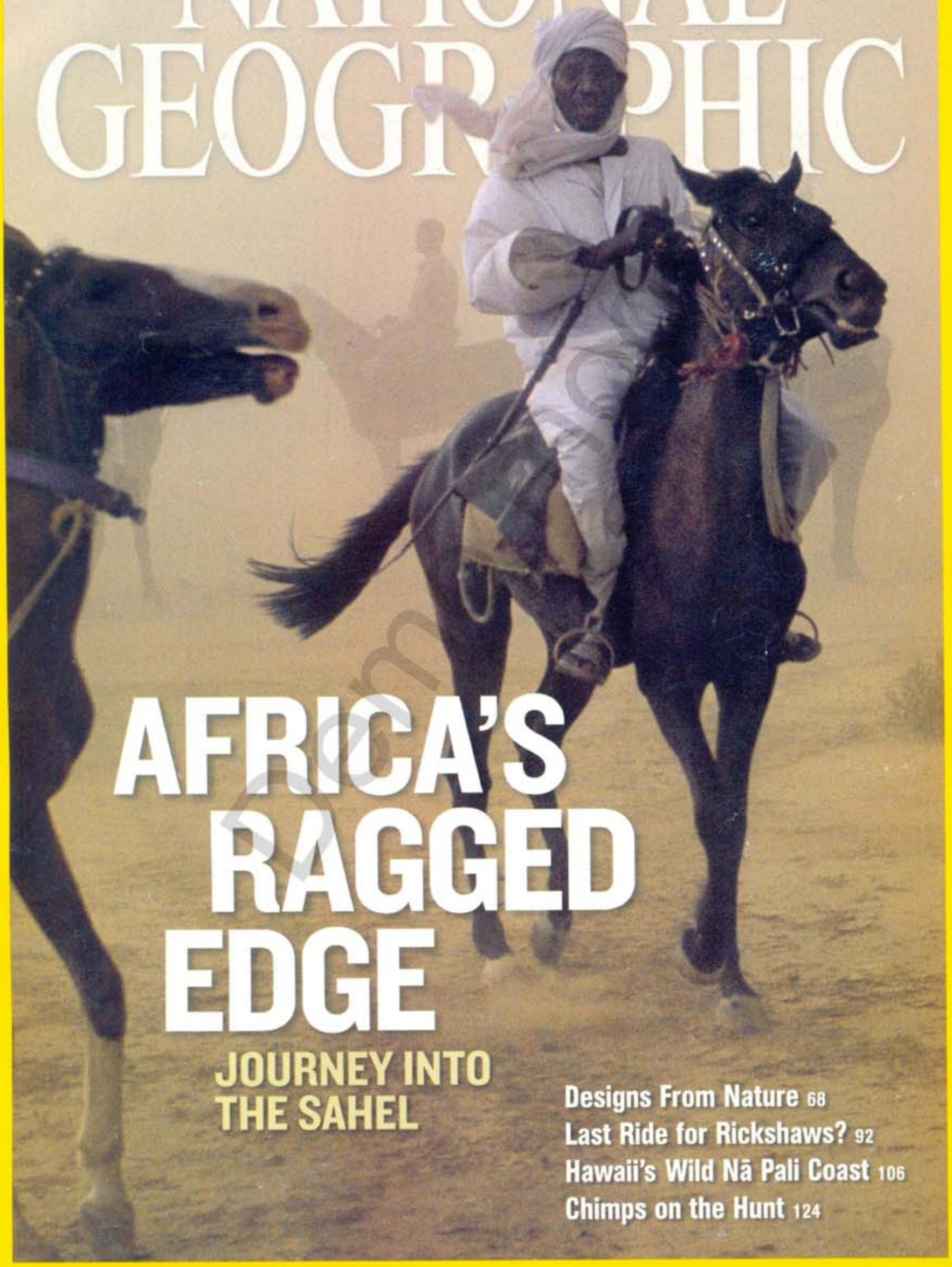
NATIONAL GEOGRAPHIC



AFRICA'S RAGGED EDGE

JOURNEY INTO THE SAHEL

NATIONAL GEOGRAPHIC

APRIL 2008 · VOL. 213 · NO. 4

A Fongoli male chimp dashes along the ground, chasing another male and pant-hooting—one of many vocalizations common among these primates. Story on page 124.

PHOTO: FRANS LANTING

Features

COVER Turbaned riders converge on Abéché, one of Chad's largest cities, for a popular horse race in July. **PHOTO BY PASCAL MAITRE**

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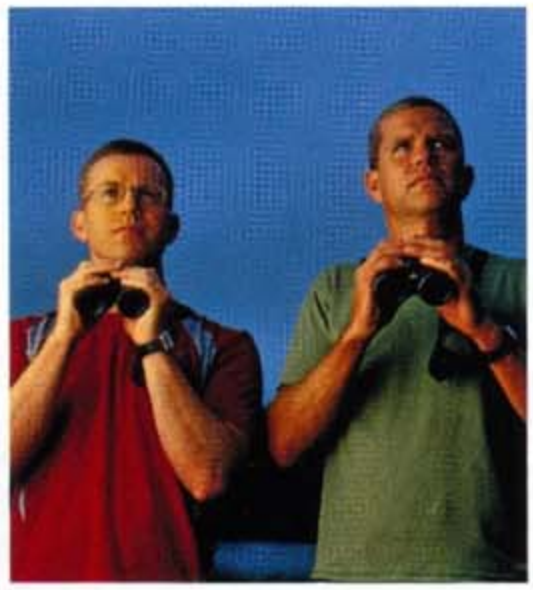
Your Shot

Designer Mice



Bird Blitz

On the Web

ngm.com

So You Want to See Our Pictures
A novice Tibetan monk, a dreamy Finnish waterfall, a bug that looks like…Elvis? Each day, *National Geographic* photo editors select an entrancing photo for Our Shot.

Read Our Minds
At Blog Central you'll find out how photo editors pick images for the magazine, what Pop Omnivore thinks of the entertainment media, and much more.

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PHOTOS (LEFT TO RIGHT): LISA GONNELLI; VINCENT J. MUSI; MICHAEL O'BRIEN

EDITOR'S NOTE

I'm in Khartoum, Sudan, in a shabby hotel room with Idriss Anu and Daoud Hari. Their eyes are wide with fear. They want to be anywhere but here. Idriss is a driver and Daoud, an interpreter-guide. The two have just spent five weeks imprisoned in Darfur with Paul Salopek—the writer who hired them while on assignment for *National Geographic*—because they illegally crossed the border from Chad to Sudan. After intense negotiations, all were released from jail; now Paul is on his way back to the United States. But what about Idriss and Daoud? I've promised Paul I'll get them home safely,

Daoud Hari (left) and Paul Salopek (center) were imprisoned in Sudan.

but it won't be easy. The Sudanese rebels who arrested them confiscated their identity papers. A U.S. Embassy official explains that a diplomat from Chad will arrive to help with the papers. We'll need more than that, I think. We'll need a miracle. That miracle appears in the form of dedicated diplomats from Chad and the U.S. Embassy. Two days later Idriss and Daoud fly home.

Paul took a risk when he crossed Sudan's border. He paid dearly. He didn't want to break the law, but felt there was no other way to tell this story, because the Sudanese authorities keep Darfur and its war off-limits to journalists. Those who help and guide us in dangerous, unfamiliar places are the often unsung heroes behind the work of any writer or photographer. Idriss and Daoud also took a risk and paid the price. They, too, wanted the story told.

PEOPLE BEHIND THE STORIES

■ **Mary Roach** Among the savanna-woodland chimpanzees of eastern Senegal, where she was reporting "Almost Human," Roach got

an unlikely lesson in angling. "We kept watching the chimps termite fish," she says, describing how the animals would casually dip vines into low mounds, then gently pull them up laden with supper. "They made it look really easy. When we actually tried it though, it was impossible. I felt completely incompetent." Trying to catch dinner was only half the fun. On a dare, Roach tasted the termites. "They had huge pincers. Ugh!"

■ **Joel K. Bourne, Jr.** Hundreds of feet above the sea on Hawaii's Kalalau Trail, *Geographic* contributing writer Bourne ran into a man clad

only in running shorts. Bourne was working on this issue's "Fortress Coast," the man on an eroded section of the trail with a pickax. The man was a former marine who'd been living there for months, repairing the trail and helping injured hikers. The two chatted on the cliff edge as tour helicopters buzzed past and tour boats motored by below, making it the most remote place with the least solitude on the entire island. As they parted, Bourne thanked the man for his trail work. The man shrugged, said, "Somebody's got to do it," and went back to his labors.

PHOTOS (CLOCKWISE FROM LEFT): CANDACE FEIT; PHYLLIS CHRISTOPHER; KELLY STRYKER

NATIONAL GEOGRAPHIC

Inspiring people to care about the planet

The National Geographic Society is chartered in Washington, D.C., as a nonprofit scientific and educational organization "for the increase and diffusion of geographic knowledge." Since 1888 the Society has supported more than 8,000 explorations and research projects, adding to knowledge of earth, sea, and sky.

LETTERS

December 2007 *"Bethlehem 2007 A.D." touched a nerve with readers. "It amazes me that in this day and age there is still violence related to religious beliefs," wrote Steve Michalski of Silver Spring, Maryland. "Walls, barbed wire, bombs, and guns have nothing to do with truth. A piece of land has nothing to do with what is truly holy."*

Comment on April stories at **ngm.com.**

Bethlehem 2007 A.D.

We have just returned from traveling in the West Bank and Israel, spending the night with families in Bethlehem and Jenin and visiting Jerusalem, Ramallah, Hebron, Tel Aviv, and Sederot. Our group, including Christians and Jews, felt safe at all times. Everyone welcomed us warmly, thanked us for coming, and asked us to tell people at home about their lives. Perhaps the most important thing we outside the Holy Land can do to further a just peace is to go and see the situation firsthand and simply be present with those working so hard for peace. There are many such courageous people on both sides.

JUDY AND MICHAEL WHITE
Ashland, Ohio

Until Palestinians come to terms with the reality of an Israel that is here to stay and start looking to a future they can build instead of trying to destroy what others have created from nothing, there will be no peace. It is time for the Palestinians to produce some honest, forward-thinking leaders to pull them out of their swamp of irrational hatred and into the 21st century. The ball is clearly in their court.

PAULA KLEIN
Indian Wells, California

What a shameful legacy for Israel to collectively punish civilians by locking them behind a three-story-high wall, separating them from jobs and family lands. Or is it the Israelis who are locked in? Time will tell.

JUDY BUETTNER
Haiku, Hawaii

Two important points must be made about your article on Bethlehem. First, it is unfortunate that Bethlehem residents must be closed in due to Israel's security wall. However, until they choose to deal with the terrorists in their midst, their difficulties are preferable to the possibility of my child being blown up on a bus. Second, it is astonishing that the author never asked the obvious question: If life is so difficult in the overwhelmingly Muslim city of Bethlehem, why are only the Christians leaving? What we're hearing is that militant Islamists are making life increasingly unbearable for the Christian "infidels" there. In other words, just as they are pledged to make the land of Israel *Judenrein*, so too are they striving to make Bethlehem *Christianrein*.

GILA MANOLSON
Jerusalem, Israel

The only way to achieve a tolerant community is by all sides striving to integrate with each other, not necessarily religiously or culturally, but in schools, workplaces, and in every aspect of daily life. I wish more than anything that a leader from each group will emerge and be able to achieve peace between the truly great people of all sides in this land.

PAUL JANEWAY
Woodland Hills, California

While you make a point of the separation fence in Israel, it is hardly the only one. There are many in the world, and I would like to point out that the United States has a fence just like the one in Israel, on the border with Mexico.

GABRIEL R. STUART-SIKOWITZ
Gaithersburg, Maryland

This article confirms my belief that religion—not money—is the root of all evil. That Jews and Muslims kill each other with the excuse that "My God is better than your God" also reminds me of the German proverb "Against man's stupidity even the gods fight in vain." Thank God I am an atheist!

CARLOS MUÑOZ
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Extreme Dinosaurs

Dracorex surely qualifies as an extreme dinosaur, but we contend it is also a youthful dinosaur, a juvenile *Pachycephalosaurus*. We hypothesize that the horns and spikes on the "flat-headed" *Dracorex* erode as the dome develops with age. Some paleontologists might consider this extreme, but we observe a similar pattern in the closely related late Cretaceous *Triceratops*. Delta-shaped bones first appear in juveniles along the edge of the skull. As *Triceratops* grows, these bony triangles erode and merge with the frill in subadults, and disappear entirely in adult skulls. The pair of dominant horns over its eyes point backward in juveniles before eroding to grow forward in subadult and adult *Triceratops*. We hypothesize that this extreme morphology enhances visual communication and signals sexual maturity in these dinosaurs.

MARK B. GOODWIN
Museum of Paleontology
University of California
Berkeley, California

JOHN R. HORNER
Museum of the Rockies
Montana State University
Bozeman, Montana

Corrections, Clarifications

December 2007
The *Styracosaurus* skull shown on page 56 should have been credited to the collection of the Canadian Museum of Nature, Ottawa.

April 2007
The Marilyn Monroe art glass bead shown on the Culture page "Unstrung History" was made by Emiko Sawamoto.

Goodwin's and Horner's hypothesis that Dracorex *represents a juvenile* Pachycephalosaurus *was presented at the Society of Vertebrate Paleontology meeting in late October 2007, after our December feature on extreme dinosaurs had gone to press. Regardless of its age at time of death, the creature merits a place in our gallery of Mesozoic oddities.*

I was fascinated with the resemblance of the head-on view of the albatross to the Concorde airplane. There is something symbolic in this: The albatross flew first and is still doing so, while the Concorde is extinct.

When I saw the image of the *Masiakasaurus* speeding through shallow water, my first thought was the mouth of a gharial, the croclike reptile from the river Ganges. It feeds on fish and has the same protruding teeth as the creature shown in your magazine.

FRANK LENICH
Bayreuth, Germany

It surprises me that paleontologists don't ask military people about dinosaur survival tactics. The short arms of the *Carnotaurus* suggest a scavenger more than they do a perfect killing machine. If one bit me, I'd just whip my big tail around and knock him off. Modern carnivores like the African big cats use claws on long arms and big teeth for killing. In the case of the duck-billed *Parasaurolophus walkeri*, wouldn't an acoustics check of that tube be a way to check it out for hornlike noises? Musical instrument makers would probably bend over backward to help prove or disprove these claims.

JIM CHORN
Portland, Oregon

Are you sure you have your facts straight? That *Masiakasaurus* sure looks like one of my former bosses.

EARLE KOLBE
Alcoa, Tennessee

On the Wings of the Albatross

I, too, admire many qualities of the albatross. But it is hardly "fueled by clean, self-renewing, zero-emissions energy," as described in your article. The albatross emits gases just as an SUV does, and the excrement issuing from its "tailpipe" is hardly a clean by-product of its metabolism. Birds are among the biggest polluters of land, water, and buildings. And the so-called self-renewing part of the equation is accomplished at the expense of other species eaten by the albatross.

JOSEPH LEASER
Oceanside, California

When I got to pages 86-7, I was fascinated with the resemblance of the head-on view of the albatross to the Concorde airplane. There is something symbolic in this: The albatross flew first and is still doing so, while the Concorde is extinct.

BILL LATHLEAN
Pleasanton, California

See How You're Doing Was the photo you submitted to Your Shot selected as one of our Daily Dozen best? If so, you can check in every day to watch its progress on our Voting Machine, as the Your Shot online audience rates its favorites on a scale of one to ten. We now publish each month's top-scoring photograph—including Lisa Gonnelli's (bottom)—in *National Geographic*. For more information go to *ngm.com/yourshot*.

Glenn Losack New York, New York

A blind Haitian man minds his sleeping grandchild in San Pedro de Macorís, Dominican Republic. Photographer Glenn Losack, 53, is a practicing psychiatrist but says, "I make photography my priority."

Lisa Gonnelli Pilesgrove, New Jersey

The sky's a favorite subject for Lisa Gonnelli. When she saw this circum-horizontal arc—a colored cirrus-cloud display—she "started taking pictures. This is one of 85." Gonnelli, 44, works as a bookkeeper. Online voters named her photo their October 2007 Top Shot.

On Time We all have our ways of marking time. As a *National Geographic* photographer, my life is measured from one story to the next. I bought my first house in Nebraska while I was on assignment shooting America's Gulf Coast. My oldest son was born in the middle of a long story about the Endangered Species Act. My daughter came along with a pack of gray wolves.

Twenty stories later, though, it's the story on Alaska's North Slope that I'll remember most. It was about the loss of wilderness and innocence—and the story during which my wife got cancer. That's the one that made time stand still.

Kathy and I met at a blues bar in college. She had long blond hair and thought I was funny. Beautiful, graceful, and patient, she has remained my muse for 24 years, despite the thousands of times I've forced her to be photographed. She may have gotten tired of it now and then. I stopped taking pictures on the day she found that tumor in her right breast. It was the size of a hen's egg. Weirdly, it was Thanksgiving. By Christmas, the chemo had her weak and bedridden. Some days she was so sick she couldn't watch TV. One day she couldn't even talk.

The Sartore family—Cole and Kathy (above), Ellen, Spencer, and Joel—lives every minute to the fullest in Lincoln, Nebraska.

Early detection saves lives. But ours was not early. By the time you can feel it yourself, it's often bigger than the doctors want it to be.

Cancer is a thief. It steals time. Our days are already short with worry. Then comes this relentless disease, unfair as a hailstorm at harvesttime. But cancer also has the power to transform us, for good. We learn to simplify, appreciating what we have instead of lamenting what we don't. Cancer even made me a better father. My work had made me a stranger to my three kids. But now I pay attention to what really matters. This is not a race. This is a new way of life and new way of seeing, all from one malicious lump.

In the end each of us has so little time. We have less of it than we can possibly imagine. And even though it turns out that Kathy's cancer has not spread, and her prognosis is good, we try to make it all count now, appreciating every part of every day.

I've picked up my camera again. I watch the sky, searching for beautiful light. When winter storms come, Kathy and I gather our children and take the time to catch snowflakes on our tongues. After all, this is the good stuff. This is what we're living for.

VISIONS OF EARTH

Antarctica Not far from its Franklin Island colony, a lone Adélie punctuates the looping scrawl of penguin tracks across plates of Ross Sea pack ice. Some 2.7 million of the birds populate the Ross Sea region.

PHOTO: JOHN B. WELLER

Germany The see-through skin of an inch-long glass frog reveals her eggs. Native to Venezuela, the frogs lay eggs in bushes and trees overhanging streams. Tadpoles hatch, then tumble into the current to be swept away.

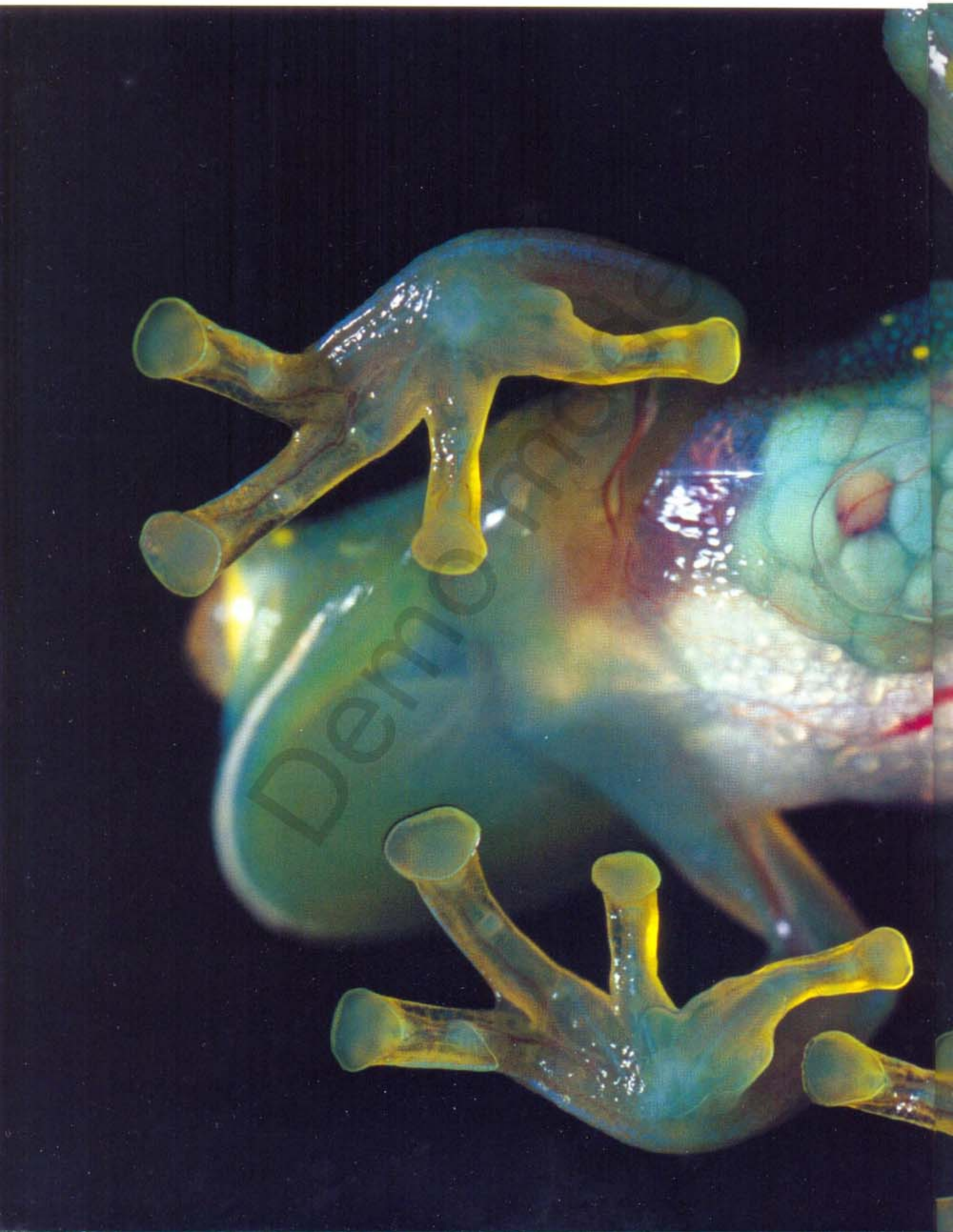


PHOTO: HEIDI AND HANS-JÜRGEN KOCH

United States A red-clay spray showers spectators at the mud-pit belly flop, highlight of the annual Summer Redneck Games in East Dublin, Georgia. Other events include a hubcap-discus throw and bobbing for pigs' feet.

See more Visions of Earth images at **visionsofearth.ngm.com.**

PHOTO: SOL NEELMAN

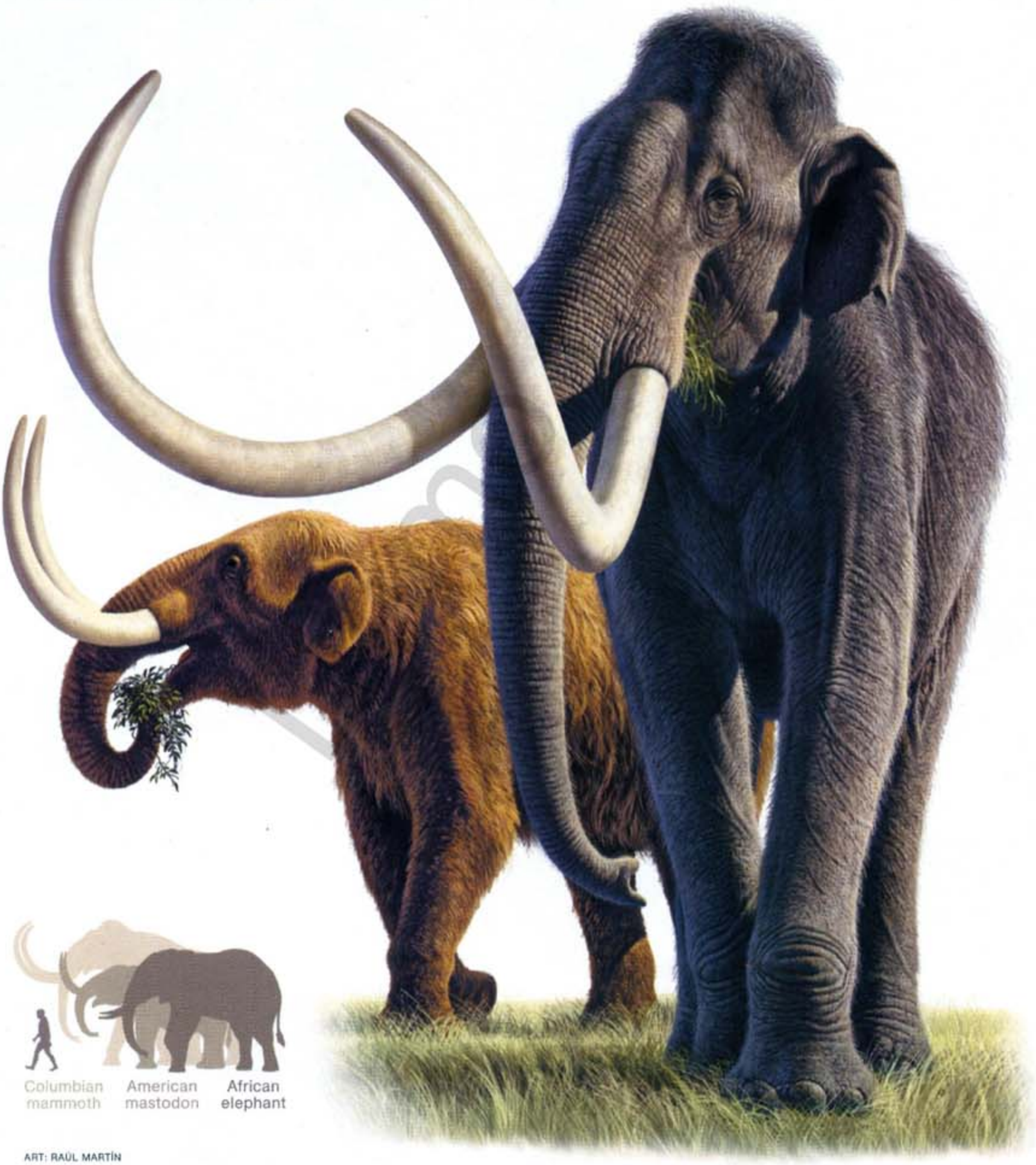
Kin by a Nose Mastodons and mammoths, extinct cousins of the elephant, were members of the order Proboscidea—animals with trunks. Recent discoveries (in Russia, Greece, and the U.S.) have put both beasts back in the spotlight. But how did they differ?

MASTODONS *(below, left)*: About the size of today's elephants, though more stoutly built, these ancient browsers had straight backs and a taste for twigs and leaves.

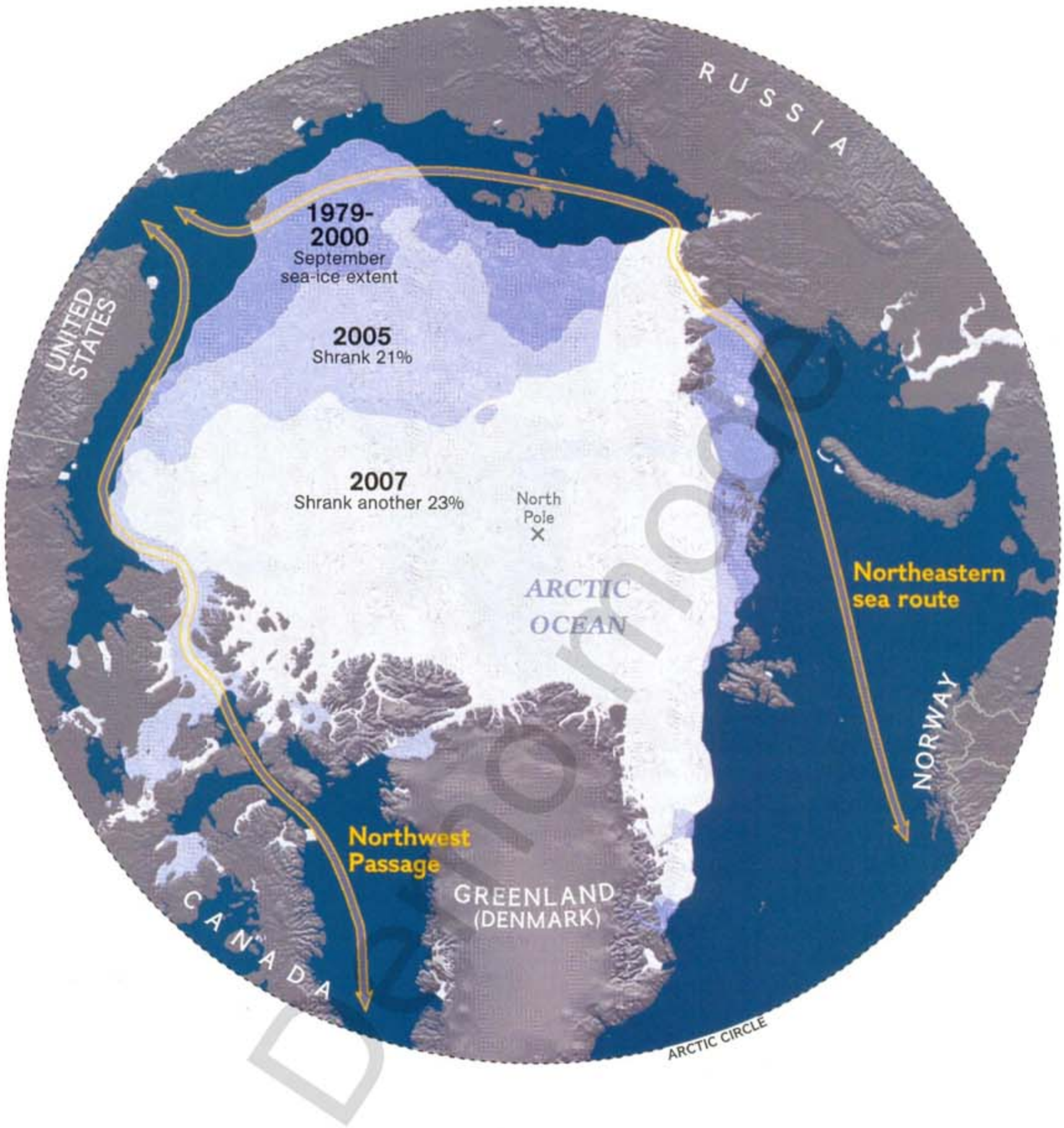
MAMMOTHS *(right)*: As tall as 13 feet at the shoulder, with short tails, sloping backs, and spiraling tusks, these behemoths were grazers that fancied grasses. *—A. R. Williams*

Teeth: Cone-shaped cusps (left) were used to crush. Flat, ridged ones (right) were good for grinding.

Mastodon Mammoth



ART: RAÚL MARTÍN



A once frozen passage opens.

Polar Bare Arctic sea ice always shrinks as summer warms the top of the world. But last year's melt was a stunner: By September the ice cover had declined from its previous low, in 2005, by an area larger than Texas and California combined, opening sea routes usually limited to icebreakers. In 1979, September ice extended 2.78 million square miles; last year it was 1.65 million. Scientists predicted global warming would mean the end of a year-round polar ice cap but didn't expect that until the late 21st century. Research published in 2007, however, says the meltdown is ahead of schedule and that the polar region could be open water by summer 2030. Or sooner. One oceanographer, using a different model, says 2013 could be the end of the Arctic as we know it. *—Chris Carroll*

NGM MAPS. SOURCE: NATIONAL SNOW AND ICE DATA CENTER. PHOTO: DAISY GILARDINI, RAINBOW IMAGES

Bird Blitz At one second after midnight on the second Saturday in May hundreds of birders around New Jersey will begin a competition that ends 24 frantic, caffeine-fueled hours later, when the World Series of Birding names its champions.

Teams vie in various categories, including grade-schoolers and over-55s. Winners identify the highest number of species within the state, from the conifer forests of Kittatinny Mountain to the salt marshes by the Delaware Bay. The top team total was 231 in 2003. Participants solicit pledges based on species count and have raised more than eight million dollars for environmental causes over the 24 years of the New Jersey Audubon Society event.

Bad weather? Flat tires? Jersey traffic? It's all part of the game. *—Mel White*

Play On! Read an account of the event at **ngm.com.**

The World Series Playing Field

Teams may begin and end their route anywhere within the state. All vehicles may be used—except aircraft.

Here are six prize finds at the World Series of Birding.

Least Bittern
Ixobrychus exilis
13 inches (length)
The *ku-ku-ku* call in the marshes of New Jersey's Great Swamp National Wildlife Refuge is from this secretive species.

Northern Saw-whet Owl
Aegolius acadicus
8 inches
It takes luck (or precontest scouting) to find this tiny owl, named for its raspy call of alarm—like a saw being sharpened.

Surf Scoter
Melanitta perspicillata
20 inches
Teams scan the Atlantic Ocean for the three species of sea ducks called scoters: surf, black, and white-winged.

Common Raven
Corvus corax
24 inches
A familiar bird in western mountains, the common raven only rarely nests in New Jersey. Its croaking call is deeper than the American crow's familiar *caw*.

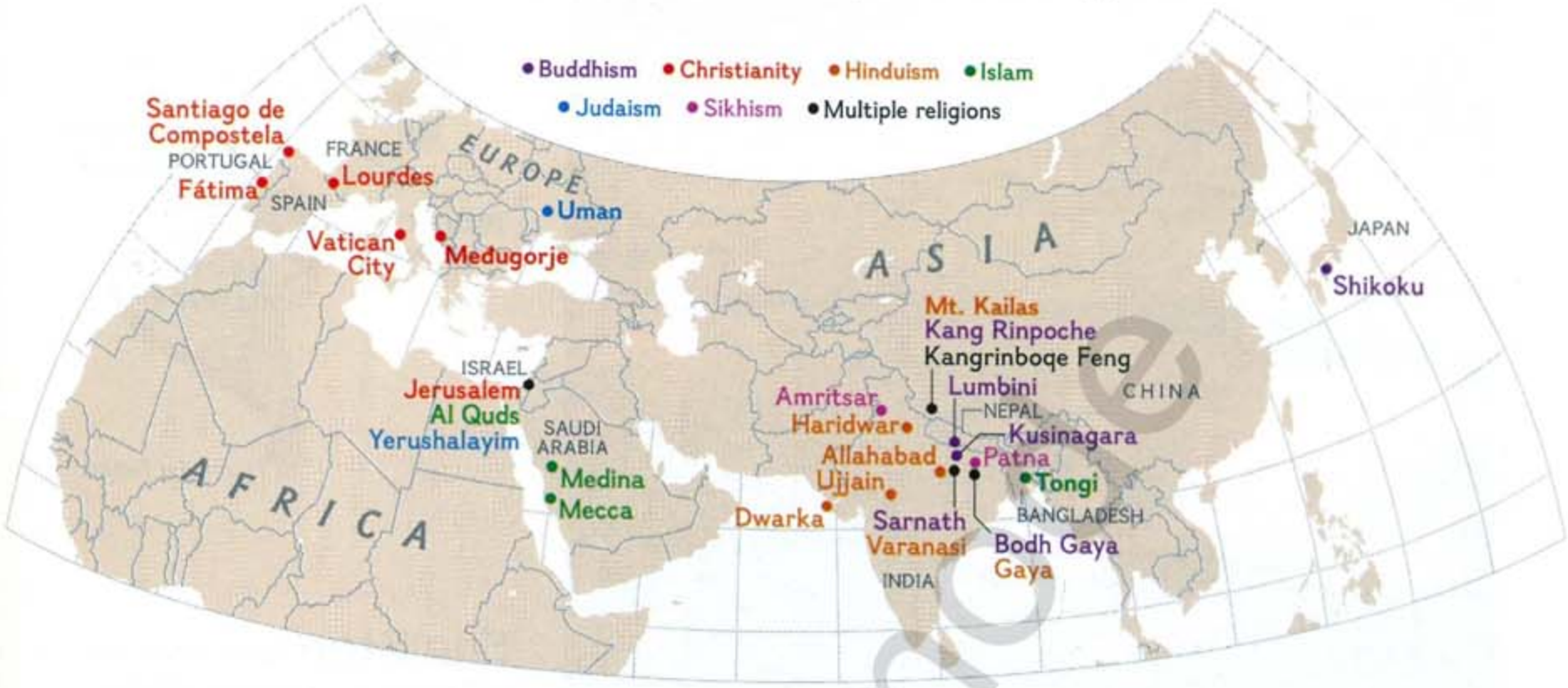
Summer Tanager
Piranga rubra
7.75 inches
Birders listen for the summer tanager's robin-like song in southern New Jersey's pine-oak woods. Its relative, the scarlet tanager, is more widespread in the state.

Yellow-crowned Night Heron
Nyctanassa violacea
24 inches
Southeastern wetlands are home to a small number of this mostly nocturnal heron, which feeds on crabs, crayfish, and frogs.

PHOTOS: MICHAEL O'BRIEN (LEFT); RON AUSTING, FLPA (OWL); GREG DOWNING (SCOTER); ARTHUR MORRIS, BIRDS AS ART (HERON, RAVEN); MARTIN KOPECKY (TANAGER); GREG LAVATY (LEAST BITTERN). NGM MAPS

Pilgrims' Progress

More and more, the faithful are flocking to pilgrimage sites on and off the beaten path. Detailed below: four places with a rising profile.



Medugorje, Bosnia and Herzegovina
In 1981 village youth said they saw the Virgin Mary on a cloud. Pilgrim count since then: millions.

Uman, Ukraine
The grave of Rabbi Nachman of Bratslav inspired the pilgrimage movie *Yippee: A Journey to Jewish Joy*.

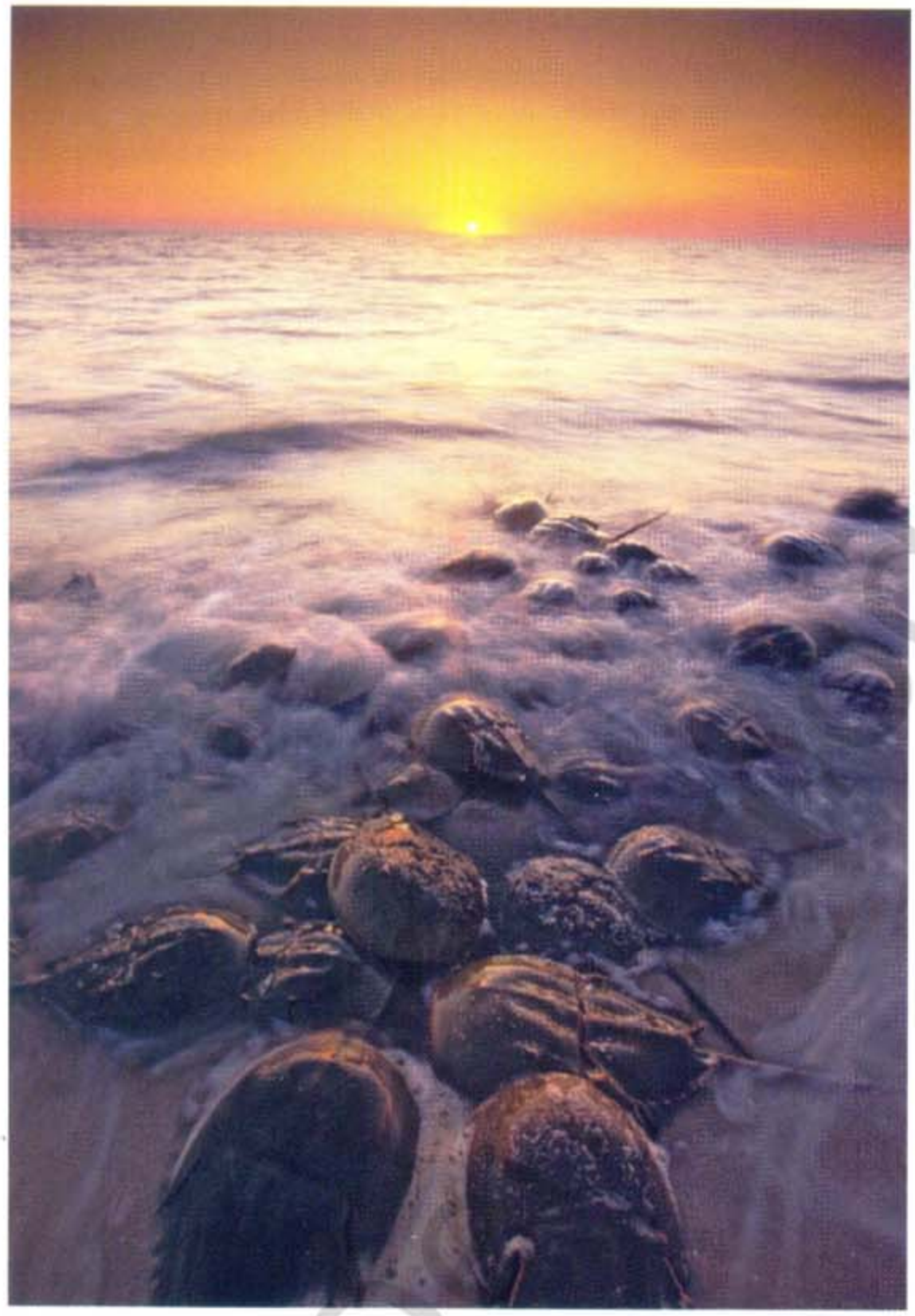
Mt. Kailas, China
Buddhists, Hindus, and others circle the peak to shed sins. Visits are increasing as travel to the area grows easier.

Tongi, Bangladesh
Last year a record 3 million Muslims, from 80 lands, sought blessings at the 3-day Bishwa Ijtema gathering.

Tens of millions of Hindu devotees come to Allahabad, India, each year for a "holy dip" in the Ganges River.

Faith tourism is a fast-growing industry that serves some 300 million travelers and produces an estimated 18 billion dollars in revenue a year. In India and Saudi Arabia, hotel chains are building for an influx; North American tour companies now cater to what was once perceived as a niche market. Rising disposable income, lower travel costs, and a desire to find journeys with a purpose are fueling what Kevin J. Wright, president of the World Religious Travel Association, describes as an increase in interest across faiths, both in traditional sites and in lesser known spots. Sometimes the shrine is new—Pope John Paul II's Vatican tomb. Others are in regions that until recently had been politically off-limits—Tibet, for instance. Whatever the destination, contemporary pilgrims seek what pilgrims always have, says religious-travel scholar David Gitlitz, "contact points between the human and the divine" at sites where they feel their prayers may be imbued with greater meaning and resonance. *—Diane Cole*

NGM MAPS. PHOTO: NIKOLAI IGNATIEV, ALAMY



Horseshoe crabs mate (top) and lay eggs (right) that feed red knots every May at the Delaware Bay, a crucial stop on their long northbound migration.

Egg Stop Each year, the red knots of Tierra del Fuego take a mighty flight. In February the shorebirds embark on a 9,300-mile trip to the Arctic—one of the world's longest migration routes. And they wouldn't make it without a Delaware Bay layover.

In spring the hungry birds arrive. On the menu: horseshoe crab eggs. The crabs lay eggs in the sand, and red knots dig in. At the bay each bird must nearly double in weight, to about 6.4 ounces. Skinny birds can succumb to bad weather in their northern nesting grounds, if they make it at all. But horseshoe crabs are now harder to find. Since the early 1990s growing conch and eel fisheries have been using them as bait. Fewer crabs mean fewer eggs; fewer eggs mean fewer red knots. In Tierra del Fuego their numbers have fallen from 68,000 in 1985 to 17,000 in 2007. If the horseshoe harvests continue, red knots could be flying on empty. *—Helen Fields*

PHOTOS: DOUG WECHSLER, ANIMALS ANIMALS (RIGHT); JOEL SARTORE (BOTTOM LEFT); FRANS LANTING, NGM MAPS

A Mouse for All Seasons

Call the Jackson Laboratory in Bar Harbor, Maine, and you may hear: "All of our representatives are assisting other customers." Not unusual—till you consider that the flood of calls to the nonprofit is from people ordering mice. And not just any mice. These are bred with specific genetic makeups, each a model for a human disease or disorder—everything from bone loss to blindness, Alzheimer's to arthritis. Over 75 years the lab's catalog has grown to include more than 3,300 strains. Mouse farming gained new impetus from the recent sequencing of the human and mouse genomes, which confirmed how genetically similar the two species are (the differences have to do with when and where genes are activated). Last year Jackson shipped 2.4 million mice to 16,000 researchers worldwide. The most popular strain—the Black 6 (above), developed in 1921—has been used to study everything from diabetes to obesity, and has even traveled aboard the space shuttle. That's a mouse worth holding the line for. *—Peter Gwin*

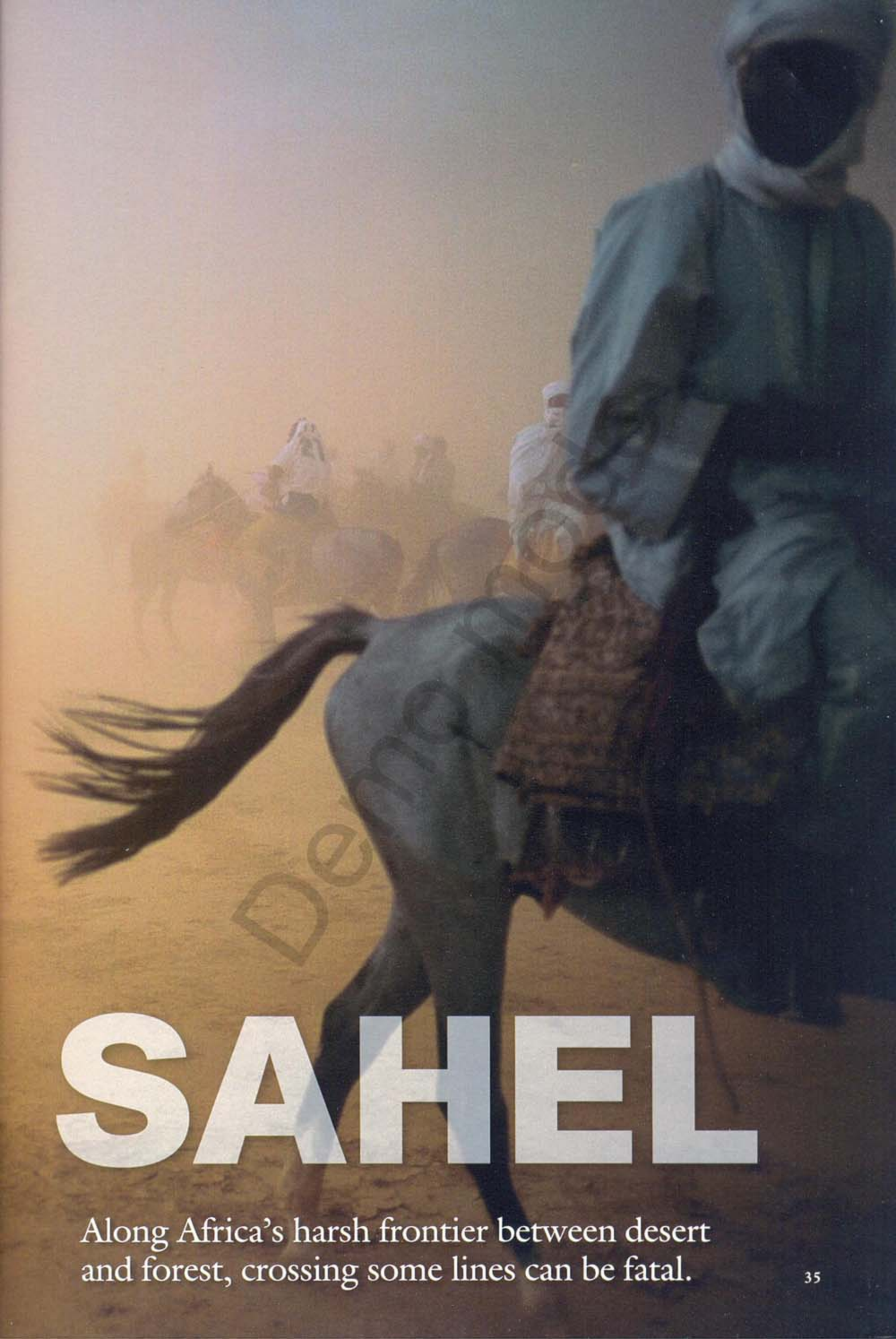
PHOTO: VINCENT J. MUSI

BY PAUL SALOPEK

PHOTOGRAPHS BY PASCAL MAITRE

In a blur of dust turbaned riders gather to watch a race in Abéché in eastern Chad. A thousand years ago men on horseback carried Islam and Arab culture across the vast, dry lands bordering the Sahara.

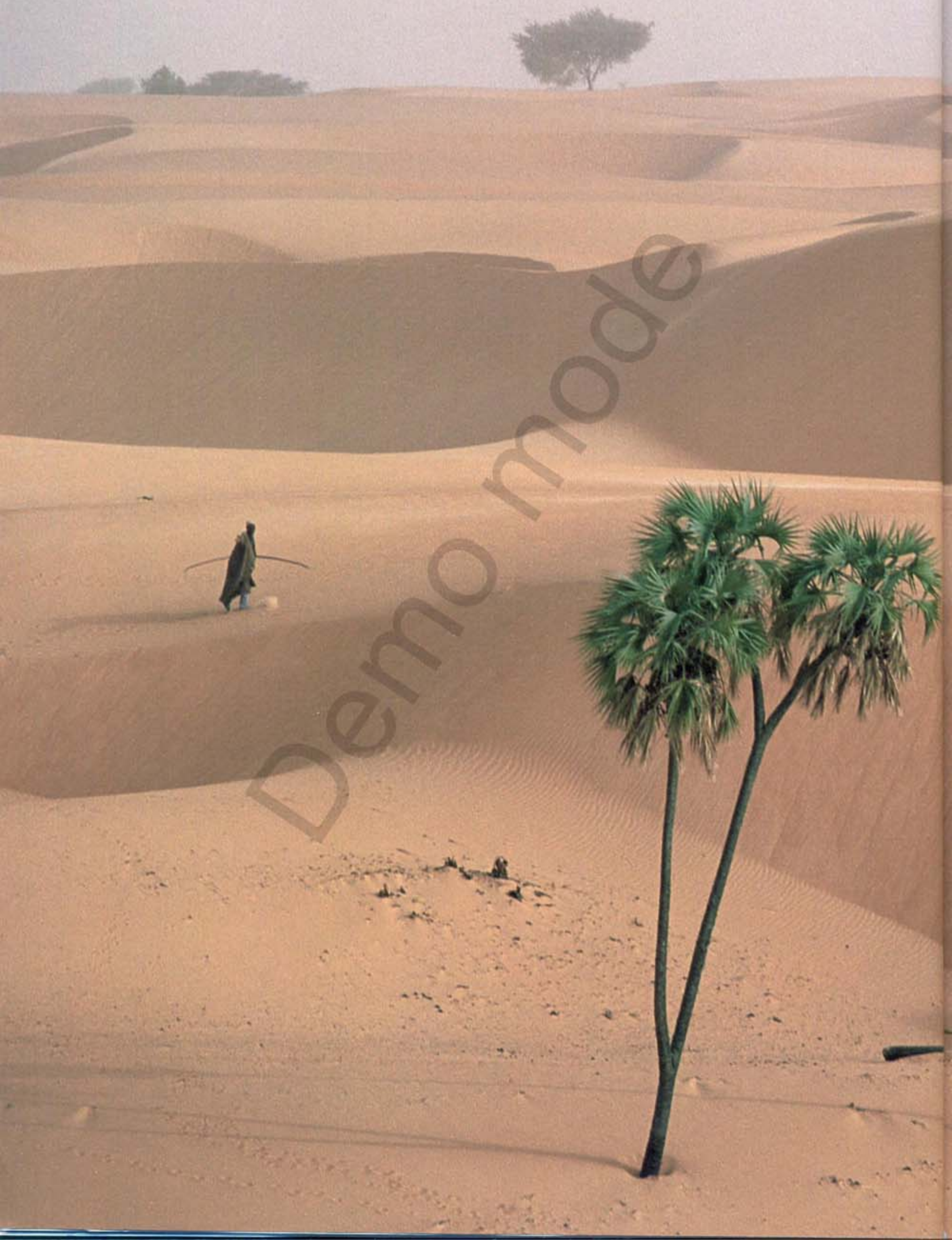
LOST IN THE



SAHEL

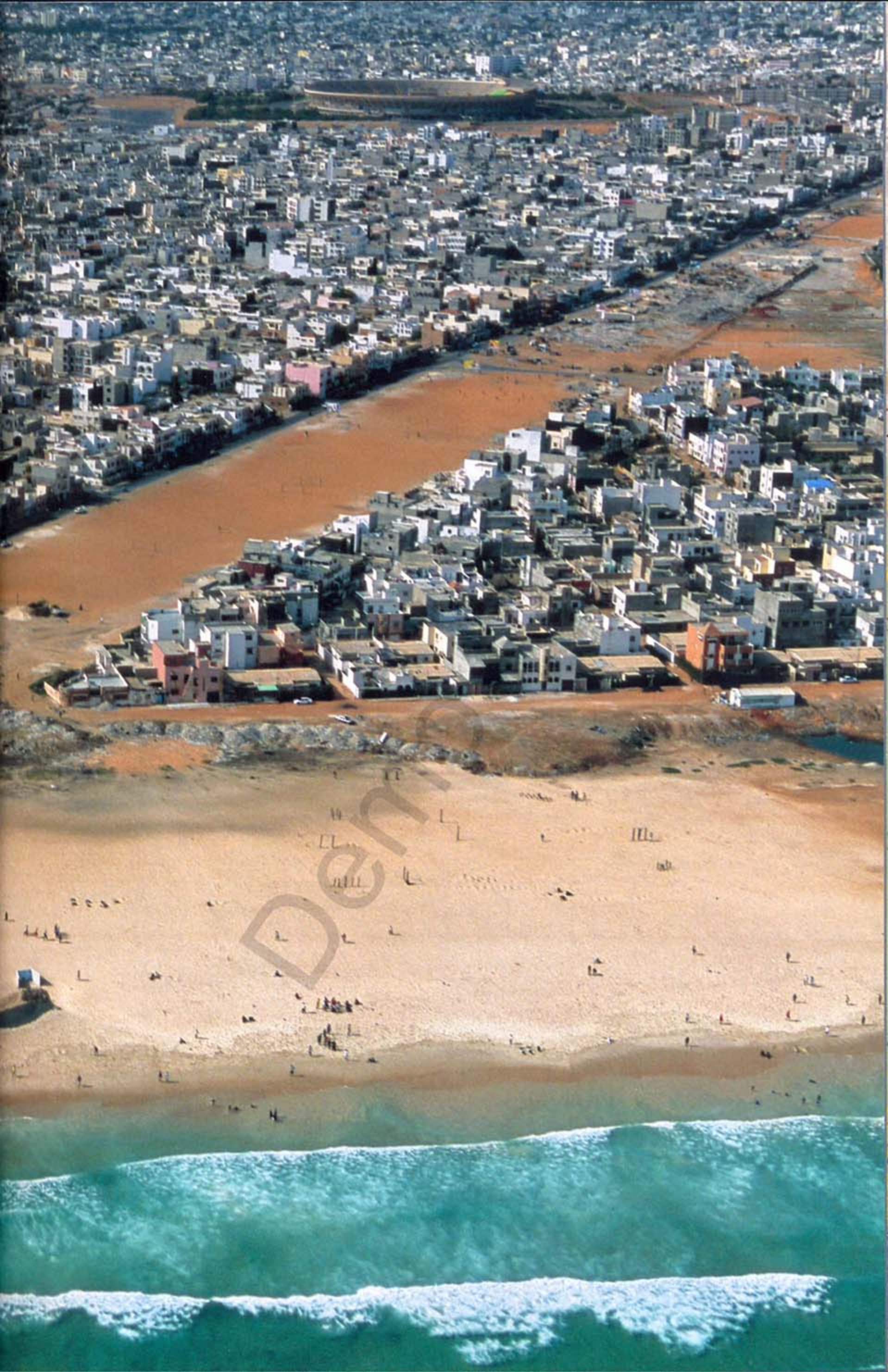
Along Africa's harsh frontier between desert and forest, crossing some lines can be fatal.

NIGER | Swallowing all but the tallest trees, dunes have buried cropland near the city of Goudoumaria, where a herder follows goats in search of forage. Reduced rainfall has withered vegetation and dried up wells in parts of southern Niger, forcing villagers to move. The Sahel experienced droughts in the 1970s and '80s, and although rainfall has increased since the 1990s, a decades-long dry spell continues.

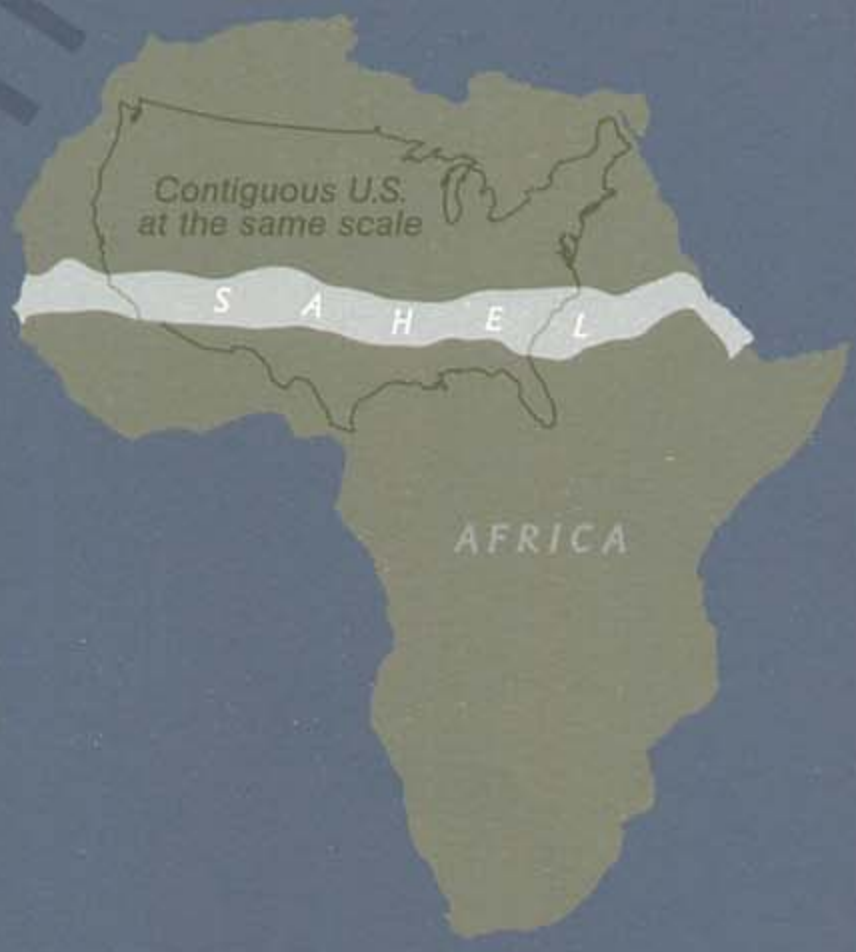


NIGER | Riding a mountain of belongings, migrants who had left Niger for Libya return home in the face of antiforeign sentiment. The Sahel was once the center of a camel-borne trade that took slaves, ivory, and gold to Europe and the Middle East, but it now lies on the margins of the world's economy. Many of the region's young men have gone to wealthier countries such as Libya and Algeria to find work.

SENEGAL | The Sahel ends at the Atlantic in Dakar, where open land may become a highway to relieve congestion in the densely populated capital. On the beach, fishing boats deliver catches by day and leave by night loaded with migrants risking a crossing to the Canary Islands—way station to Europe. Hundreds die every year, and though Spain and Senegal have increased air and sea patrols, the exodus goes on.



NIGER | Shoveling out a road near the village of Tali seems a hopeless task, but young volunteers earn tips from the few drivers who use the route—one way to get cash in this poor, mostly rural country where jobs are scarce. Despite such smothering sands, land-locked Niger is working to improve its roads, with help from Western donors and OPEC.



DEFINING THE SAHEL Lines linking areas of equal average rainfall bound a region whose northern and southern limits have fluctuated regularly over the millennia.

WESTERN SAHARA (MOROCCO)

MAURITANIA

MALI

ALGE

Taoudenni

Nouakchott

150 mm (5.9 in) isohyet 1931-1960

150 mm (5.9 in) isohyet 1968-1997

Niger

Tombouctou (Timbuktu)

Gao

Saint-Louis

Louga

Lompoul

Dakar

Île de Gorée

SENEGAL

600 mm (23.6 in) isohyet 1931-1960

600 mm (23.6 in) isohyet 1968-1997

Mopti

Niamey

Banjul

GAMBIA

Bamako

Niger

Ouagadougou

GUINEA-BISSAU

Bissau

GUINEA

BURKINA FASO

BENIN

Conakry

GHANA

CÔTE D'IVOIRE (IVORY COAST)

SIERRA LEONE

Freetown

TOGO

ATLANTIC OCEAN

LIBERIA

Yamoussoukro

Cotonou

Porto-N

Monrovia

Lomé

Accra

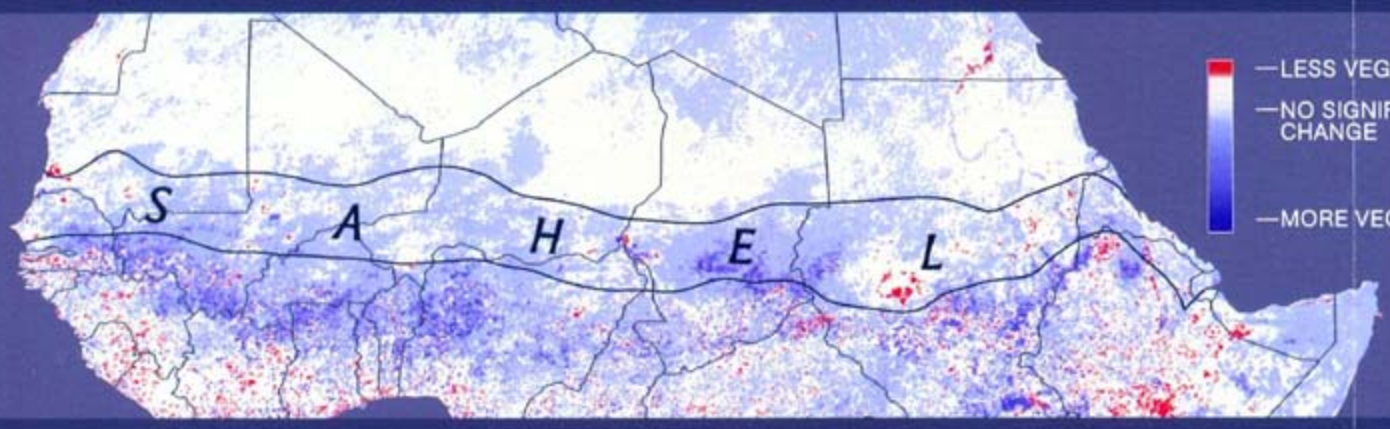
Abidjan

20°N

15°

10°

5°



UNEXPECTED GROWTH Ground surv
the quality of land in the Sahel has de
50 years—fewer trees and shrubs and
soils. But satellite data since 1982 sho
tion—natural and cultivated—has incre
from increases in rainfall. This may be
levels of carbon dioxide in the air have
which enhances the soil's ability to ho
to more growth. The data also sugges
areas vegetation has decreased more
causes: tree cutting, overgrazing, over

10°W

0°

ALGERIA

LIBYA

H A R

N I G E R

CHAD

Author was captured in this area Aug. 2006

Agadez

Aderbissinat

Tânout

Tali

H E L

Soubdou

Goudoumaria

Zinder

Niamey

Maradi

Kirou

Bugaje

Lake Chad

Bahay

Furawiya

Tiné

Kutum

Abéché

Gaga Refugee Camp

D A R F U R

Goz Beïda

N'Djamena

Kano

NIGERIA

BENIN

Niger

Abuja

otopou

Lagos

Porto-Novo

mé

CAMEROON

Malabo

Yaoundé

EQ. GUINEA

Libreville

EQUATOR

GABON

DEMOCRATIC REPUBLIC OF TH

CONGO

10°E

20°

SHIFTING RAINS

THE SAHEL | In this transitional zone at the edge of the Sahara, largest desert, rainfall varies from 6 inches a year in the dry nort the wetter south. Through much of the late 20th century, rising o temperatures altered rainfall patterns, and the precipitation didn't far north (black dotted lines) as it did from the 1930s to 1960 (re After the late 1960s the Sahel moved south and became drier. G turned barren, nomads lost their herds, and in the northern Sahe dunes, no longer anchored by vegetation, invaded some villages. rainfall has increased, and in many places, vegetation too. Scient that global warming will cause precipitation to become spottier reliable, with heavy and light rains at different times and in differ

WTH Ground surveys over time reveal that the Sahel has deteriorated during the past s and shrubs and thinner, less productive a since 1982 show areas where vegeta- ivated—has increased more than expected nfall. This may be partly because rising ide in the air have promoted plant growth, soil's ability to hold water, leading in turn data also suggest that in some scattered decreased more than expected. Likely overgrazing, overcultivation, and erosion.

SHIFTING RAINS

THE SAHEL | In this transitional zone at the edge of the Sahara, Earth's largest desert, rainfall varies from 6 inches a year in the dry north to 24 in the wetter south. Through much of the late 20th century, rising ocean temperatures altered rainfall patterns, and the precipitation didn't reach as far north (black dotted lines) as it did from the 1930s to 1960 (red lines). After the late 1960s the Sahel moved south and became drier. Green lands turned barren, nomads lost their herds, and in the northern Sahel, desert dunes, no longer anchored by vegetation, invaded some villages. Recently, rainfall has increased, and in many places, vegetation too. Scientists project that global warming will cause precipitation to become spottier and less reliable, with heavy and light rains at different times and in different places.

SUDAN | After a skirmish with government forces, Darfur rebels of the Sudanese Liberation Army (SLA) regroup at a vehicle carrying weapons and a bundle of amulets for magical protection. The SLA has fractured into factions that attack civilians and each other as often as they fight the Sudanese Army.

EDITOR'S NOTE | When journalist Paul Salopek entered Sudan to report on Darfur, he was captured by guerrillas, turned over to the government, and jailed as a spy. After five weeks he was released, following negotiations by *National Geographic* and the *Chicago Tribune* and intervention by Governor Bill Richardson of New Mexico. Salopek later returned to the Sahel to finish the story.

DARFUR—THE ROAD TO FURAWIYA

The road was not really a road.

Its two ruts led into Darfur, to the war in western Sudan, from the unmarked border of Chad. So much of the Sahel was like this—unmapped, invisible, yet a boundary nonetheless. The land stretched away in a monotony of gravel pans and dried grasses so translucent—so brittle—they seemed made of blown glass. The iron horizons never budged. Yet we were crossing boundaries with every passing hour, mostly without seeing them.

After I was arrested and imprisoned in Darfur, an American soldier told me, shaking his head in disgust, "You fly over this place and all you see is miles and miles of nothing." But that was an outsider's delusion. Every outcrop and plain was parsed by unseen tangents, lines, ghostly demarcations. They portioned off the claims of tribes, individuals, clans. They bulged and recoiled according to war and season. No-go zones encircled water holes. Certain unseen lines, *masars,* dictated the migration routes of nomads. There was nothing haphazard about any of this. To cross one line or to venture too far from another might invite retribution, even death. And that was the ultimate line of them all in the Sahel: the one between knowing and ignorance.

The Sahel itself is a line.

The word means "shore" in Arabic, which implies a continental margin, a grand beginning and a final end. Stretching across northern Africa roughly along the 13th parallel, the Sahel divides—or unites, depending on your

WOMEN HAVE BEEN SINGLED OUT FOR MAXIMUM VIOLENCE IN DARFUR. MASS RAPES BY THE JANJAWEED HAVE BEEN DOCUMENTED. WOMEN HAVE BEEN BURNED ALIVE.

CHAD | Chased from her village by fighting, a woman digs for firewood in a displaced persons' camp near Goz Beïda. The area never had many trees, but now, with an influx of tens of thousands of Sudanese refugees and Chadians fleeing attacks by ethnic militias, roots are all that's left to burn.

philosophical bent—the sands of the Sahara and Africa's tropical forests. It is a belt of semi-arid grassland that separates (or joins) Arabs and blacks, Muslims and Christians, nomads and farmers, a landscape of greens and a world of tans. Some 50 million of the world's poorest, most disempowered, most forgotten people hang fiercely on to life there. And for 34 days in Darfur we joined their ranks.

There were three of us.

Idriss Anu drove the Toyota truck that would be stolen by militants. Daoud Hari was the translator, and for this he would eventually pay with severe beatings. We were en route to the village of Furawiya when the pro-government guerrillas rose silently from the grass.

"Stay in the car," Daoud said.

But it was already too late. Even as the gunmen sauntered up, their hair matted in dreadlocks and their chests slung with small blackened things that looked like dried ears but which were Koranic amulets, we still hadn't grasped that we had crossed a threshold where it no longer mattered what passport you carried, that you were young and loved, that your skin was supposedly not of a torturable color, or that you were a noncombatant. Words had lost all currency as words, and by the time the grinning teenager with the Kalashnikov reached for my door handle, we were condemned to live and die according to choices made by others. We had become truly Sahelian.

The Sahel is a line.

But it is also a crack in the heart—a tightrope, a brink, a ledge. See how its people walk: straight-backed on paths of red dust, placing one foot carefully before the other, as if balanced upon a knife edge. The Sahel is a bullet's trajectory. It is the track of rains that fall but never touch the sand. It is a call to prayer and a call for your blood, and for me a desert road without end.

GAGA REFUGEE CAMP, CHAD

My journey began among refugees in eastern Chad. This is where I met George Bush's father.

Bush tyrannized his family's small plot of

sand. He threw his mother's battered dishes to the ground, pulled on visitors' noses, and scampered away giggling. He got away with this because he was an only son. His elder sister, age four, despised him. Bush was fat-cheeked and two. "Boosh!" the refugees cooed. "Boosh-ka!" He was clearly a great camp favorite. This was in the Gaga settlement, where more than 7,000 Darfuris lived and died under UN canvas.

"Only George Bush can stop the Arabs in our land," said Bush's papa, Ahmed Juma Abakar. He corralled the boy in his lap. "When he grows up, he will help kill them."

Multiple lines of identity were braided through Abakar. He was a coffee-colored African with a puff of white hair on his chin. He was a Masalit, a member of one of the African farming tribes driven out of Darfur at gunpoint by the janjaweed, the Arab nomads armed by the Arab-dominated government of Sudan. He detested Arabs. Yet he himself spoke Arabic. He also served sugary tea in shot glasses like an Arab, wore a white Arabic robe, and prayed five times a day toward Mecca. I, too, find this puzzling.

The war in Darfur has killed at least 200,000 people and displaced more than two million. It may be the first genocide of the new century. But it also happens to be one of several similar, if smaller, conflicts boiling across the Sahel. Chad, Niger, Mali, Nigeria, and Senegal—low-intensity battles smoldered in each nation I visited. Niger was expelling its Mahamid nomads. Tuaregs were ambushing African soldiers in Mali. These clashes were parochial, obscure, yet part of an overarching quarrel: the eternal struggle over grass, water, and soil between pastoralists and settled peoples. Viewed this way, the Sahel represents the oldest killing field in human history. In the Sahel, Cain is still trading blows with Abel.

In Darfur the violence is infamous because Sudan's government had cynically armed one side—the Beni Husseins, Ereigats, and other Arab herders—against rebellious African farmers such as the Masalits and Furs. These two rivals, both Muslim, had earlier evolved a complex entente. When a farmer speared a nomad's camel, elders docked part of his harvest. The plaintiff usually claimed the grain in a hungry year. It was an antique food bank system. Murder between tribes was settled with a sliding scale of blood money—a hundred camels for a man, fifty for a woman.

A ten-pound machine with eleven moving parts has erased this legacy.

The flood of cheap Kalashnikov rifles into Darfur has devalued individual responsibility in warfare. It has undercut the tribal authorities. Young men who once sang songs to their favorite cows now serenaded their guns: "The Kalash brings cash / Without a Kalash you're trash."

"We used to get along," Abakar said. "The Arabs would graze their camels on our fallow fields. They were my father's friends."

I asked when Arabs and Africans would be brothers again. Abakar looked at me with genuine incredulity. He then tuned his transistor radio to the BBC. The Israelis were bombing Lebanon. *"Allah-u akbar!"* the old Muslim tribesman said, cheering on the Israel Defense Forces. He raised George Bush's chubby little arms in triumph.

DARFUR—TOWÉ VILLAGE

On our first night in Darfur the gunmen forced Idriss and Daoud into a pickup truck and drove them off into the moonlight. They tortured them out there, tied to a thorn tree for three days. Me they pummeled without enthusiasm inside an abandoned hut in the burned-out village of Towé. Between sessions, I lay trussed on my belly, breathing hard against a dirt floor that smelled of rancid butter. I squinted out a brilliant doorway at two women.

They were planting sorghum in a dry wadi.

The women's work appeared rudderless. They planted their seeds in lines that wriggled across the field, nudged here and there

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Paul Salopek is a Pulitzer Prize-winning foreign correspondent with the Chicago Tribune. *Pascal Maitre photographed oil in Africa in September 2005.*

NIGER | Huddled in the morning chill, students at a Koranic school in Goudoumaria prepare to learn the Sahel's mystical brand of Sunni Islam, mixing Sufi and African traditions. Lacking books or paper, they write verses from the Koran on wooden tablets in washable ink. When classes end, children who have come from distant villages to study with the school's marabout, or holy man, beg for alms for food.

NIGERIA | A sharia court efficiently settles a land dispute in Kano, a city on the Sahel's southern border whose Muslim majority lives under strict Islamic law. After years of corrupt and bureaucratic secular rule, most residents welcomed Kano state's imposition of sharia in 2000. But minority Muslim sects, human rights advocates, and Christians, especially those who could no longer sell alcohol for a living, protested.

by whims of conversation. The older woman swerved whenever she told jokes, and her seed rows lurched like cardiograms. She giggled into her hands often, and I decided she must be mad. The younger one was more solemn. She toiled briskly, with a sense of purpose, as if engaged in a race, and her planting was much straighter. A tiny child crawled at her side, trying to eat the seed grain. The women labored like this all day. Then, late in the afternoon, they quarreled, and their plantings veered apart in rancor.

It occurred to me that the women were doing more than growing food. They were sowing their autobiographies.

Sex jokes, village gossip, little wisps of song, rebukes to children—all of it lay scribbled in the eccentric lines of their crops.

Women have been singled out for maximum violence in Darfur. Mass rapes by the janjaweed are systematic and well documented. As part of a Sudanese campaign of ethnic cleansing, women have been burned alive, shot, bayoneted, and dumped down wells. These stories, too, would be recorded in their fields. Lying in the hut, I imagined flying low over the savannas of Darfur and reading the women's lives inscribed in plots of millet, peanuts, and sorghum. (See that row of melons ending abruptly at midfield? A Fur grandmother dropped her seed bucket and ran at the sound of approaching hoofbeats.)

In Towé the women were Zaghawa seminomads. The laughing one was named Fatim Yousif Zaite. She wasn't crazy. She was 40, with the burning, clairvoyant gaze of the starving, and a smile that transmitted the innocence of her heart. She brought me gourds of *asida,* a yellow lentil paste she could hardly afford to share. Once, while untied to eat, I grabbed both her dusty hands in mine. She sprang back in fear.

But I only wanted to thank you, Fatim. You will always be with me. The janjaweed may toss your kids into vats of boiling water as they had done to children in another village, and the Sudanese Air Force may bomb your wretched fields as they had before, killing five of your family members. But for three days in Darfur you were my mother.

KIROU BUGAJE, NIGER

A few months later I was in Niger. I took a bus east. The plains turned lush.

Oxcarts jerked along red roads, hauling mountains of peanuts. Children's laughter dribbled from the high grasses. The *thok-thok-thok* of women pounding millet telegraphed the news of full granaries.

This was a surprise. The Sahel of the imagination is a geographic hunger pang. Cataclysmic droughts scorched northern Africa in the 1970s and 1980s. The most recent famine lashed Niger as recently as 2005. In places, the Sahel continues to starve, to lose ground to the Sahara. On the banks of the Niger River houses lie buried in coffins of sand.

Yet in Niger, a country twice the size of France, researchers have been fascinated to discover that 19,000 square miles of savanna are more vegetated today than 20 or 30 years ago. Similar regeneration of trees, grasses, and bushes appears to be under way in parts of Mali and Burkina Faso. The most precious line in the Sahel has always been green. And lately it has been growing thicker, brighter, more lustrous.

Why?

Ecologists disagree. Some credit global warming, which may be boosting rainfall in sections of northern Africa. Others say years of warfare and chaos in the Sahel have depopulated the African countryside, allowing millions of acres to lie fallow and recover.

At the Hausa village of Kirou Bugaje, the plump chief, Abdurahaman Ademu, had his own explanation: the miraculous leaf of a tree.

"The *gao* improves our yields of millet and sorghum," Ademu said, padding in a white robe and sandals across his tree-shaded fields. "That's why we don't cut the trees down anymore. We plant around them."

The gao, an indigenous acacia known to biologists as *Faidherbia albida,* is a nitrogen-fixer like the alfalfa plant. Its leaf litter is rich in nutrients. Twenty-five years ago Ademu and

his people had wiped out virtually every tree within a day's walk to feed themselves in a famine. When their crops failed, they ate the leaves. When the leaves were gone, they razed entire groves to sell for firewood and buy food. But eventually, somewhere, someone remembered that the yields of grain were richer when sown in the fertile shade of surviving gaos. Husbanding wild trees is an ancient practice in the Sahel. Its importance was rediscovered. And from there, the dusty boughs of the gao spread in widening circles of green. Today, without fanfare or mercy concerts, some of the world's poorest farmers are busy stitching huge tracts of the Sahel back together again.

Ademu had three wives. Their names were Zeinahu, Hajara, and Hadjia. He had 20 children whom he called Hey You and This One. He was amused that I found his village beautiful.

At dusk the sky turned orange, and we ate spaghetti drowned in palm oil. The village chirped and squealed like a playground. A white moon rose, and out on the savanna the Fulani nomads were driving their lyre-horned cattle south into Nigeria. They were armed with bows, and some carried broadswords strapped to their backs. There hadn't been a war for years. Drifting to sleep on a prayer rug outside Ademu's family mosque, it was possible to imagine that there was nothing in the world that could not be reclaimed.

THE PLUMP CHIEF ADEMU HAD THREE WIVES. HE HAD 20 CHILDREN WHOM HE CALLED HEY YOU AND THIS ONE. HE WAS AMUSED THAT I FOUND HIS VILLAGE BEAUTIFUL.

DARFUR—GHOST HOUSE PRISON

On the third day of our captivity in Darfur, the gunmen traded Idriss, Daoud, and me to the Sudanese Army for a box of uniforms.

A military helicopter ferried us to El Fasher, the capital of North Darfur, but over Kutum, a loud banging made my muscles grab. We were taking rebel ground fire. Holes blinked open in the fuselage, and a bespectacled officer sitting across from me toppled out of his seat. He rolled around on the deck clawing at his back. It was just a spent round, so he survived. His comrades congratulated him as if he'd won the lottery. But the pilot knew better. After a hard landing at the airport, he jumped out of the machine and strode away without looking back.

We were taken to a "ghost house"—one of Sudan's many secret prisons. It was night. A gang of armed toughs screamed into our faces and shoved us against a mud wall. They called us spies and waved their cell phones in front of my eyes. The tiny screens displayed burning towers and lilliputian images of Osama bin Laden. I thought: This is the end. But of course it was only the beginning.

What can be said about those days?

An agent of the *istikhbarat* pawed through my cell's pit toilet each morning, looking for what I can't say. His work was unrewarded because I was on a hunger strike. I was protesting my being held separately, in solitary confinement. I resumed eating on the eighth day when the guards informed me they would force-feed me through a rubber tube. "Like Guantanamo," they said.

My dreams reached malarial intensity. I dreamed of my wife and of running through the wheat north of Mosul where the falling Iraqi shells made the sound of bedsheets ripping and of Don Benito soaking his oak plow in the ranch well in the Sierra Madre. I dreamed of men I had worked with at sea, and where did you go, Edie Brickell, and of *la vida loca.*

During one of the midnight interrogations I spotted a small, spiky animal sniffing its way across the interrogation room floor. It looked

IT IS A BELT OF SEMI-ARID GRASSLAND THAT SEPARATES (OR JOINS) ARABS AND BLACKS, MUSLIMS AND CHRISTIANS, NOMADS AND FARMERS. IT IS ALSO A CRACK IN THE HEART.

NIGERIA | Catholics celebrate Mass in Kano, where Muslims outnumber Christians ten to one. The Sahel marks the southern reach of early Muslim traders, sages, and armies, and the northernmost influence of later European missionaries. Most Christians came to Kano as merchants.

like a hedgehog. I was light-headed with hunger. I had long since run out of things to say. I reached down from my chair.

"Don't touch the hedgehog," the colonel said.

"OK."

I reached down again.

"Don't—touch—the—hedgehog!" It was his pet.

I remember this distinctly: My face felt odd. It was my first smile in ten days.

KANO, NIGERIA

I bumped south in a bush taxi shared with five Fulani nomads and 140 pounds of goat cheese bound for the markets of Nigeria. There were flies.

But for a fly, all of Africa might be Muslim.

Islam galloped across northern Africa by horse and camel while Christian Europe dozed under rulers like Henry the Quarrelsome or Ethelred the Unready. By A.D. 1000 Muslim emissaries—warriors, gold merchants, slavers, scholars, holy men—had planted the green flag of Muhammad and Allah on West African shorelines that wouldn't see the bleached sails of a Portuguese caravel for four centuries. But the bite of the tsetse fly, *Glossina,* barred the way south. A vector for the blood parasite that causes sleeping sickness, the insect killed off numberless waves of invaders and their horses in its lethal domain, the open woodlands below the Sahara.

Today the tsetses still reign, and the religious border still holds. North of the fly zone, Africa remains austerely Muslim; to the south lies a steamy patchwork of Christianity. I encountered this frontier in Kano.

Nigeria's second largest city lay smeared inside its smog. It received few tourists. It had a reputation for pious mayhem.

Hundreds had died in riots between hotheads among Kano's majority Muslims and thousands of minority Christian migrants from Nigeria's south. Conservative imams encouraged the governor to impose Islamic law, or sharia, on the state—a provocation in secular Nigeria—further inflaming tensions. Street

signs in the city were written in Arabic, and the shops were stocked by Lebanese, Yemeni, and Egyptian traveling salesmen. Motorcycle taxis didn't pick up women: Contact with male drivers was deemed unseemly. A few years ago local officials boycotted a UN antipolio campaign, claiming the vaccines were sterilizing Muslim girls. Polio, which had been almost wiped out in Africa, has since rebounded in Nigeria and is reinfecting surrounding countries.

There is now a black Taliban movement in Kano. One local mullah dubs himself "Kandahar," after the capital of Afghanistan's fanatics.

"I would pay with my blood if I preached inside the Old City," said Foster Ekeleme, the Methodist bishop in Kano's Christian outskirts.

Ekeleme was an Igbo from the southeast who moved with the stiff gait of a retired boxer. He had survived good and bad times between Kano's two great faiths. When I visited, he complained bitterly that his flock was targeted every time the U.S. bombed another Muslim country, but he ended with a plea. "I am hopeful! We Christians and Muslims must learn to coexist. Look—even my night watchman is Muslim!"

It was true. A bored Hausa youth in a white skullcap leaned against Ekeleme's church. The church itself was a fortress of raw concrete circled by a high iron fence. The fence was spiked. All that was missing was a moat. Suspecting that the Christians were speaking from a position of weakness, I consulted a Muslim thinker.

Salisu Shehu was a mellow scholar with droopy eyelids. He taught Islamic studies at Bayero University, where hand-painted billboards exhorted students to Dress Fashionable and Decently.

This is what the professor said: While it was lamentable that people had been burned, hacked, and shot to death for their choice of gods in Kano, the real enemy was poverty. Christian Igbos and Muslim Hausas required jobs. The youths were unemployed, restless. As for Islam in the Sahel, it was neither extremist nor intolerant—it was a very old type of Sufism expounded by the moderate Imam Malik; a nomad's faith rooted in the traders' live-and-let-live ethic.

"The Sahel isn't a wall between Africans," Shehu said. "It's a crossroads—a bridge."

Today that bridge is groaning. Both the Muslim and Christian populations of Africa have boomed over the past ten years. In the Sahel, where birthrates are among the highest in the world, mosques financed by conservative Middle Eastern states have sprouted in cities and villages. For their part, many of Africa's Christians aren't of the turn-the-cheek Presbyterian sort. Church loudspeakers boom out sermons, preachers bless militias, and several of the riots in Kano were ignited by Christian massacres of Muslims elsewhere in Nigeria. But I never got to meet the extremists.

At five in the morning my hotel phone rang. It was a secret policeman.

"Whatisyourpurposehere?" he demanded.

"Beg your pardon?"

"Youmustcometothelobbynow!"

The tone was clear if the English wasn't. My paperwork was in order. But I panicked. I raced through the list of sources who might have betrayed my presence in Kano, settling on a dour pharmacist who must have Googled my name and pounced on the recent headlines: Sudan Charges U.S. Journalist With Espionage.

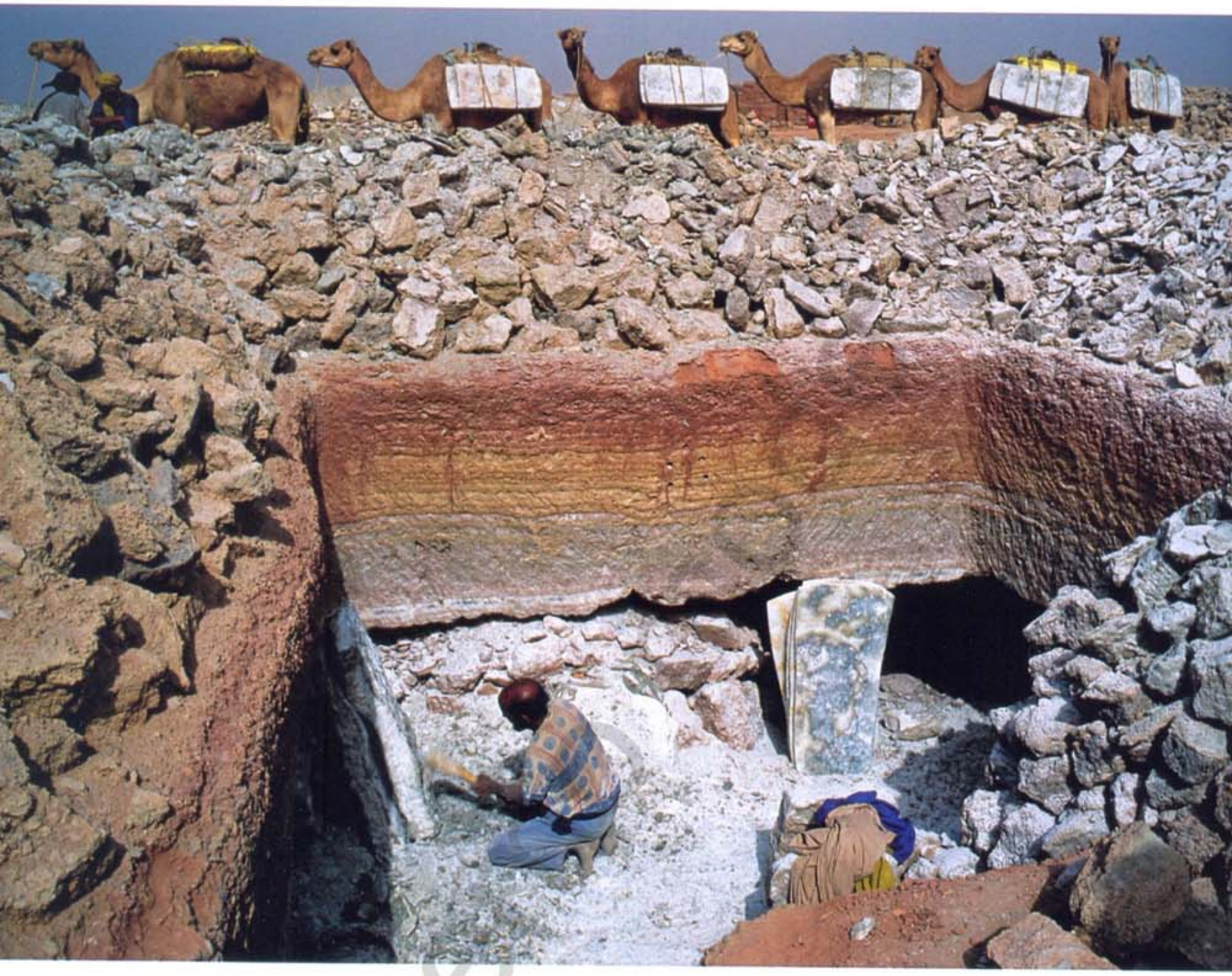
With the echoes of cell doors clanging inside my head, I made excuses to the agent in the lobby. I frantically began hiding my notes but only managed to throw out my back lifting the room's refrigerator. I tossed my bag out the second-floor window, eased myself down the exterior sill, and dropped the last nine or ten feet to the ground. My back exploded. So I quit. I gave up. Hobbling into the lobby jackknifed at the waist, with my T-shirt on backward and my surviving notes tucked into in my socks, I found the place empty. The policeman had got tired of waiting. This was Nigeria.

By sunrise I had bought all the open seats in an old Peugeot bush cab and left for Mali.

DARFUR—POLICE STATION JAIL

The Russians were very drunk. There were three of them—small, medium, and large—and the

NIGER | Women enlisted by the government of Niger plant shrub branches near Soubdou, securing them with grass to create grids of natural fencing that keep sand from blowing onto land used for crops and grazing (above). For each acre fenced, the group of women receives $80. Since the drought years in the 1980s, Sahelians have reclaimed damaged land by stabilizing dunes, cultivating trees, building rock walls to halt erosion, and sowing seeds in pits dug to catch rain.



MALI | As they've done for centuries, workers at the Taoudenni mine hack away at salt deposits to extract chunks of the mineral. Camel caravans transport the salt 400 miles south to Timbuktu, where a 132-pound slab of the highest quality sells for about $16. Caravans return with supplies and fresh laborers—mostly men and boys who owe city merchants money. Wrapped in rags, a miner's salt-scarred feet tell of the hard life awaiting those who come to this remote outpost—once a government prison—to work off debts.

ARMED TOUGHS CALLED US SPIES AND WAVED THEIR CELL PHONES IN FRONT OF MY EYES. THE SCREENS DISPLAYED BURNING TOWERS AND LILLIPUTIAN IMAGES OF OSAMA BIN LADEN.

NIGER | A U.S. Special Forces weapons sergeant in Maradi shows Nigerien soldiers how to maintain machine guns. Fearful that terrorism will take root in the lawless expanses of the Sahel, threatening global security and West African oil, the U.S. is training the region's militaries.

Sudanese police had shot out their truck windows. The guards pitched them into our cell at midnight. The Russians had broken curfew.

They were helicopter pilots contracted to AMIS, the beleaguered African Union peacekeeping force in Darfur. One began singing patriotic songs that would last all night, and the other two asked why I was there. I told them. I had crossed into Darfur illegally, through the side door of Chad, like scores of other Western journalists. But I had been caught. I faced a 20-year sentence. I had to repeat "spying" three times until they understood.

"Sudan"—spat the small one—"is fakit." He wore a mullet hairdo and yellow Beatle boots that curled at the tips like elf shoes. Eventually they would all be deported.

Another prisoner had meanwhile escaped in the night—a Darfuri gunrunner—leaving a cupful of his blood splashed on the jail yard wall. He'd maimed himself on the concertina wire. As a result, Idriss, Daoud, and I spent the next two days locked down with 16 other prisoners inside a 15-by-15-foot cell. We hunkered against each other in fetal positions like eggs incubating in a carton. Pickpockets, con men, goat rustlers, two street kids, and a lunatic took turns pissing out the barred door.

This was at the civilian police station, our second place of internment in El Fasher.

The cell's interior walls were polished black with human grease from the backs of sitting men. Above this wainscoting of grime rose thousands of scrawled names. And some of them were ours.

TIMBUKTU, MALI

In Mali I took a ferry up the Niger River to see the Sahel's most fabled backwater.

Timbuktu started as a nomads' watering hole, grew by the 16th century into the Oxford of the Islamic world (25,000 scholars once resided there), and has faded back into a geographic coma. Its sand alleys were like solar ovens. Goats jaywalked on the main street, and dehydrated tourists sent letters postmarked from a town synonymous with the uttermost

end of the Earth. I ducked into the shade of the Imam Ben Essayouti library for a glimpse of a golden age.

Banzoumana Traore was a Malian albino with hazel eyes and a loose cotton suit ablaze with blue and yellow polka dots. I looked again and saw that the dots were antimalaria capsules. Traore was the archivist at the library, which housed a remnant of Timbuktu's priceless trove of medieval manuscripts. With money from South Africa, the U.S., Arab countries, and Europe, small private libraries like this one were popping up all over Timbuktu. They held the Sahel's most astonishing intellectual legacy: tens of thousands of hand-lettered manuscripts, some stored in caves and household cupboards since the city's fall to the Moroccans in 1591. There was love poetry composed in Moorish Spain. There were tracts on Islamic jurisprudence and centuries-old essays on, among other subjects, astronomy, optics, medicine, ethics, and botany. Gazing on these fragile treasures, it was hard not to lament the dearth of book learning in the Arabic-speaking world. A recent UN study found that only 10,000 books have been translated into Arabic over the past 1,200 years—barely equivalent to the number of books Spain translates every year.

Traore's bright pink index finger slid across inks concocted from lampblack. He read aloud of a slave girl in ninth-century Baghdad who shamed the caliph's advisers in a contest of wits (a lesson on women's worth), of a discourse on the Islamic propriety of smoking tobacco (the 223-year-old conclusion was positive), and of an antique memory aid for learning algebra (by matching certain tones to numbers, students could sing out equations).

Timbuktu had been ruled by the kings of Mali and Songhai, by the Moroccans and the colonial French. "Local families guarded the manuscripts through it all," a proud Traore said.

When I arrived, yet another empire was eyeing desolate Timbuktu.

U.S. Special Forces bucked through town in dusty Humvees. Having learned a lesson from Afghanistan—ignorance isn't bliss, and ruinscapes of poverty, violence, and neglect incubate a murderous rage—Washington was taking a renewed interest in Muslim black Africa. The Pentagon was spending a hundred million dollars a year to train impoverished Sahelian armies in antiterror tactics. A brand-new Africa command center, AFRICOM, would come on line in October 2008, though few African countries wished to host it.

This murky front in the global war on terrorism was yet another invisible line in the Sahel.

It zigzagged across the dunes north of Timbuktu where Green Berets taught Malian soldiers how to ambush Algeria-based jihadists. The Malians were underfed, hyper-courteous, and lacked even the most basic equipment. Some were deaf. Others needed eyeglasses. "They shoot into the sand," drawled a U.S. master sergeant. The world's elite soldiers swooped down on outlying villages like well-toned aid workers, vaccinating babies, filling cavities, and deworming bony nomad cattle. But the most effective hearts-and-minds operation I saw was illicit.

His name was David. His shaved head was burned puce by the sun, his eyes glittered with resolve, and he was a 16-year U.S. Army veteran. He had been deployed to Africa before and wished to convert to Islam, which shows that there is no occupation without counter-occupation. He slipped out of the Special Forces compound at 9 p.m. and drove to the mud-brick palace of Timbuktu's imam. "My gun—I forgot about my gun," he said, realizing he couldn't very well take his pistol to a conversion ceremony. He stashed the weapon under the SUV seat.

The imam was round and jolly and sat cross-legged under a whirring ceiling fan. A television muttered the latest soccer score between Lyon and Real Madrid. The imam instructed David to repeat the *shahadah* three times and lectured him at length on the five pillars of faith, in both Songhai and French.

"I missed some of that," David said.

A half dozen Malian youths took pictures with their cell phones. They were trembling

with excitement. A modern centurion embracing Allah in exotic Timbuktu was a once-in-a-lifetime sight. It made almost anything seem possible. David would later be reprimanded for violating security procedures. But for a few electric minutes amid the tan dunes of Africa, the shadows of Abu Ghraib receded.

"Fin du cérémonie!" declared the imam, clapping his hands. He added for David's sake, "Mission accomplished!" I liked the imam immensely. He was dying to catch the end of the soccer match.

DARFUR—JUDICIARY PRISON

Thursdays were judgment day in El Fasher.

At our third jail, a concrete cellblock outside the local courthouse, Sudanese magistrates in pale blue leisure suits rendered their verdicts according to *hudud*, the Islamic punitive code, and police meted out sentences on the spot with an oxhide whip. I had never seen anyone flogged before. They forced us to watch.

The whip landed with a muffled pop on the backs, buttocks, and legs of prisoners. It was astonishing: How could human beings sweat so much—so fast? After ten blows the prisoners were wet as swimmers. At twenty, the courtyard wall behind the whipping post was spattered with their sweat. The men's muscles spasmed. Their torsos writhed like trees in a gale. But their grit beggared belief. One middle-aged convict, a Darfuri with the respectable, middle-class look of a schoolteacher, took a hundred lashes without crying out. When it was done, he walked with great purpose across the yard, as if on some errand, and toppled facedown in the dust. He was an adulterer.

The chief whip man was Corporal Salah.

He was built square as a butcher's block, and at age 30, his hair was leached of color. Near the end of our imprisonment, on the days when I was feeling bright, I accepted his challenges to play chess. He almost always won. He was a student of the aggressive moves of Bobby Fischer. When he spoke, it was usually in the immature certainties of jihad—"once the world converts to Islam"—but his frequent sighs told a story of repressed ambition. At night he pored over textbooks on microbiology. He dreamed of laying his big, blunt-fingered hands on the brows of patients in hospital wards. He saw himself clad in the snowy whites of a doctor, not the coarse fatigues of a cop.

Will you believe me when I tell you that there was gentleness in Corporal Salah's heart? That he spoke to his victims tenderly, urging them not to be afraid, even as he scourged the hide on their backs?

By this time our whereabouts had become known. An American Air Force lieutenant colonel and a Marine major brought us Cheez Whiz and every other thing, and an American diplomat brought me Faulkner. Eventually Bill Richardson, governor of my home state of New Mexico, intervened. Daoud and Idriss returned to Chad, to the high wire of the Sahel. I tumbled 20 hours across the Earth in the governor's borrowed jet.

I was doing laundry two months later when the telephone rang. It took me a moment to connect the wiry voice of the caller to certain muscular hands—the fingers clamped on men's shoulders, guiding them firmly to a wall flecked with sweat.

"Hello my friend," Corporal Salah bellowed.

He was shouting over a poor connection. He was in Khartoum, he said, where he'd been transferred, unhappily, to a bigger prison. He asked after my health. But what he really wanted to talk about was the U.S. visa lottery.

SAINT-LOUIS, SENEGAL

The last line in the Sahel was the Atlantic.

The Senegalese capital of Dakar had the fevered feel of an embarkation point—a maritime city of pushy touts, whores for every pocketbook, and scraps of cardboard flattened on sidewalks where visa hunters camped in lines outside European embassies. A reverse trickle of European youngsters, tattooed, puffing cigarettes, self-conscious in their skins, strolled the waterfront. They rode ferries to Île de Gorée, to see the famous "doorway of no return" for slaves bound for the Americas

and Europe. (In truth, few of the estimated 10 to 28 million Africans sold into bondage in the New World ever passed that way.) Senegalese papers told lurid tales of a new exodus: African migrants dying en masse while trying to reach the Canary Islands, an outpost of Europe, in motorized canoes.

For me the Sahel ended at the door of Didier, the captain of one of these boats. I met him in Saint-Louis.

He lived on the beach in a shack above the high-tide mark. He agreed reluctantly to talk. What he was doing was illegal. He had already steered two shiploads of Senegalese, Malians, Guineans, Nigerians, and Burkinabes to the Canaries. All had hocked their bicycles, their wives' treadle sewing machines, their parents' barren farms, their slum shacks—everything they owned to make the $900 passage to a Sahelian's version of El Dorado: washing dishes in Valencia or hustling leatherware in the piazzas of Rome. Twelve paying customers had died on him. They had gone out of their heads, Didier explained. They guzzled seawater on the five-day, 800-nautical-mile journey through the Atlantic's swells.

"We read the Koran over them and threw them over," he said. "Otherwise they start to stink."

Didier was leaving that evening with another canoe. He would earn a small fortune, a thousand dollars (a good year's wages) in a week. He was beautifully muscled. Yet despite his virile swagger in brand-new jeans and red T-shirt, his glances collapsed inward with fear. He was a man poised on a gangplank. Ambulances were wailing that entire afternoon in Saint-Louis. An emigrant canoe had foundered offshore. Bodies washed up with all the skin abraded from their arms where they had clung to the doomed boat's gunwales. More than a hundred people were missing.

Tens of thousands attempt this passage every year. Hundreds die. The Europeans were sending naval vessels to try to stop them.

What was going on here could just as well be called the mass evacuation of Africa as much as "illegal migration." It was a desperate flight from a way we'll never be. An underpaid schoolteacher in North America or Europe earns not ten times, not twenty times, but a hundred times more than millions of Sahelians. To think such ravening disparity will somehow never touch you is foolish. In the teeming fishermen's quarter of Saint-Louis, among the shanties where battered TVs disgorged idiotic French reality shows, and in the sand alleyways speckled with goat droppings, there was talk of bigger canoes, of more barrels of diesel fuel crammed into holds—reenacting the old slave crossing to the Caribbean, to America.

THE SAHEL IS A BULLET'S TRAJECTORY. IT IS THE TRACK OF RAINS THAT NEVER TOUCH THE SAND. IT IS A CALL TO PRAYER AND A CALL FOR BLOOD, AND FOR ME A DESERT ROAD WITHOUT END.

I watched Didier leave at sunset.

I last saw him standing stiffly at the tiller of his boat, wearing a red slicker, nosing out of the harbor amid a screen of other fishing smacks. He did not acknowledge my wave. A little girl did cartwheels on the beach among piles of human waste. Impossibly clean white birds pecked at things. Didier's canoe diminished into a darkening sea that seem sketched in charcoal. I was secretly with them. I saw myself huddled in that plank boat. But even if we all survived, I wasn't sure we would ever truly escape the Sahel.

Dividing Line Journey into the harsh and often volatile Sahel with photographer Pascal Maitre and writer Paul Salopek at **ngm.com.**

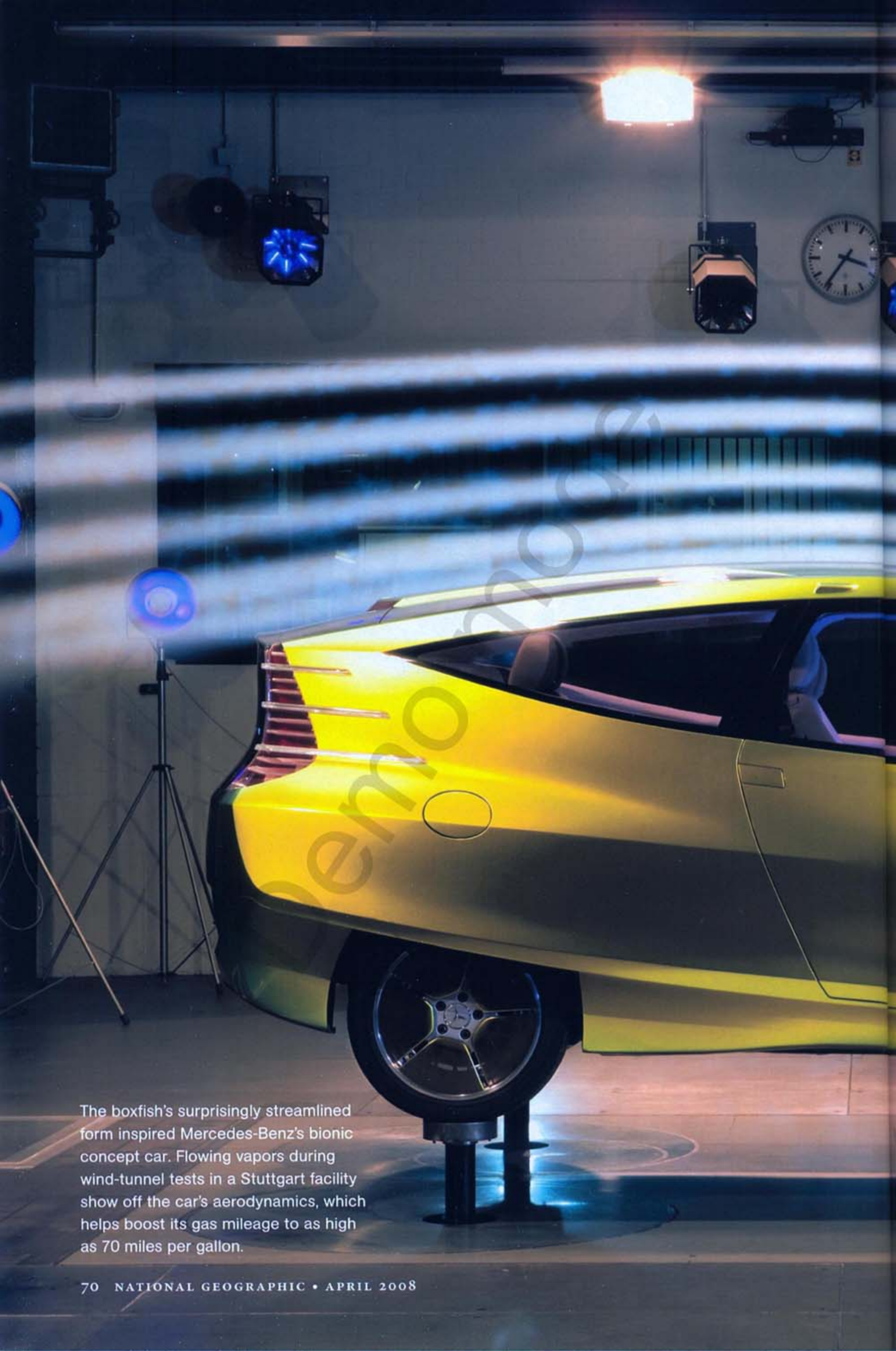
CHAD | A sudden downpour drenches women near Abéché during the rainy season. Changing climate has already brought the Sahel not only drier weather but also rains that fall too heavily, too early, or too late: In September 2007 floods inundated the normally parched region. As they have for centuries, the Sahel's people are finding ways to adapt in a land so uncompromising that failure means death. □

BIOMIMETICS

design by nature

What has fins like a whale, skin like a lizard, and eyes like a moth? The future of engineering.

Behind the squared-off contours of the boxfish lies a lesson in sleek design. Low drag helps the fish swim up to six body lengths per second, stabilized by the keel-like edges of its carapace.



The boxfish's surprisingly streamlined form inspired Mercedes-Benz's bionic concept car. Flowing vapors during wind-tunnel tests in a Stuttgart facility show off the car's aerodynamics, which helps boost its gas mileage to as high as 70 miles per gallon.

BY TOM MUELLER PHOTOGRAPHS BY ROBERT CLARK

One cloudless midsummer day in February, Andrew Parker, an evolutionary biologist, knelt in the baking red sand of the Australian outback just south of Alice Springs and eased the right hind leg of a thorny devil into a dish of water. The maneuver was not as risky as it sounds: Though covered with sharp spines, the lizard stood only about an inch high at the shoulder, and it looked up at Parker apprehensively, like a baby dinosaur that had lost its mother. It seemed too cute for its harsh surroundings, home to an alarmingly high percentage of the world's most venomous snakes, including the inland taipan, which can kill a hundred people with an ounce of its venom, and the desert death adder, whose name pretty well says it all. Fierce too is the landscape itself,

Sipping through a foot, the thorny devil lizard of the arid Australian desert demonstrates its ability to wick water to its mouth via channels between its scales. Scientists hope to mimic the mechanism to develop water-capture technologies for dry regions.

where the wind hissing through the mulga trees feels like a blow dryer on max, and the sun seems three times its size in temperate climes. Constant reminders that here, in the driest part of the world's driest inhabited continent, you'd better have a good plan for where your next drink is coming from.

This the thorny devil knows, with an elegance and certainty that fascinated Parker beyond all thought of snakebite or sunstroke. "Look, look!" he exclaimed. "Its back is completely drenched!" Sure enough, after 30 seconds, water from the dish had wicked up the lizard's leg and was glistening all over its prickly hide. In a few seconds more the water reached its mouth, and the lizard began to smack its jaws with evident satisfaction. It was, in essence, drinking through its foot. Given more time, the thorny devil can perform this same conjuring trick on a patch of damp sand—a vital competitive advantage in the desert. Parker had come here to discover precisely how it does this, not from purely biological interest, but with a concrete purpose in mind: to make a thorny-devil-inspired device that will help people collect lifesaving water in the desert.

A slender English academic with wavy, honey-blond hair beneath a wide-brimmed sun hat, Parker busied himself with eyedroppers, misters, and various colored powders, the better to understand the thorny devil's water-collecting alchemy. Now and then he made soft, bell-like, English-academic sounds of surprise and delight. "The water's spreading out incredibly fast!" he said, as drops from his eyedropper fell onto the lizard's back and vanished, like magic. "Its skin is far more hydrophobic than I thought. There may well be hidden capillaries, channeling the water into the mouth." After completing his last experiment, we gathered up his equipment and walked back to our Land Cruiser. The lizard watched us leave with a faint look of bereavement. "Seeing the devil in its natural environment was crucial to understanding the nature of its adaptations—the texture of the sand, the amount of shade, the quality of the light," Parker said as we drove back to camp. "We've done the macro work. Now I'm ready to look at the microstructure of its skin."

A research fellow at the Natural History Museum in London and at the University of Sydney, Parker is a leading proponent of biomimetics—applying designs from nature to solve problems in engineering, materials science, medicine, and other fields. He has investigated iridescence in butterflies and beetles and antireflective coatings in moth eyes—studies that have led to brighter screens for cellular phones and an anticounterfeiting technique so secret he can't say which company is behind it. He is working with Procter & Gamble and Yves Saint Laurent to make cosmetics that mimic the natural sheen of diatoms, and with the British Ministry of Defence to emulate their water-repellent properties. He even draws inspiration from nature's past: On the eye of a 45-million-year-old fly trapped in amber he saw in a museum in Warsaw, Poland, he noticed microscopic corrugations that reduced light reflection. They are now being built into solar panels.

Parker's work is only a small part of an increasingly vigorous, global biomimetics movement. Engineers in Bath, England, and West Chester, Pennsylvania, are pondering the bumps on the leading edges of humpback whale flukes to learn how to make airplane wings for more agile flight. In Berlin, Germany, the finger-like primary feathers of raptors are inspiring engineers to develop wings that change shape aloft to reduce drag and increase fuel efficiency. Architects in Zimbabwe are studying how termites regulate temperature, humidity, and airflow in their mounds in order to build more comfortable buildings, while Japanese medical researchers are reducing the pain of an injection by using hypodermic needles edged with tiny serrations, like those on a mosquito's proboscis, minimizing nerve stimulation.

"Biomimetics brings in a whole different set of tools and ideas you wouldn't otherwise have," says materials scientist Michael Rubner of MIT, where biomimetics has entered the curriculum. "It's now built into our group culture."

Shortly after our trip to the Australian desert, I met up with Andrew Parker again, in London, to watch the next phase of his research into the thorny devil. Walking from the Natural History Museum's entrance to his laboratory on the sixth floor, we traversed warehouse-size halls

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Tom Mueller writes for the New Yorker, Atlantic, *and other publications. Robert Clark photographed the October 2007 cover story on biofuels.*

cocklebur

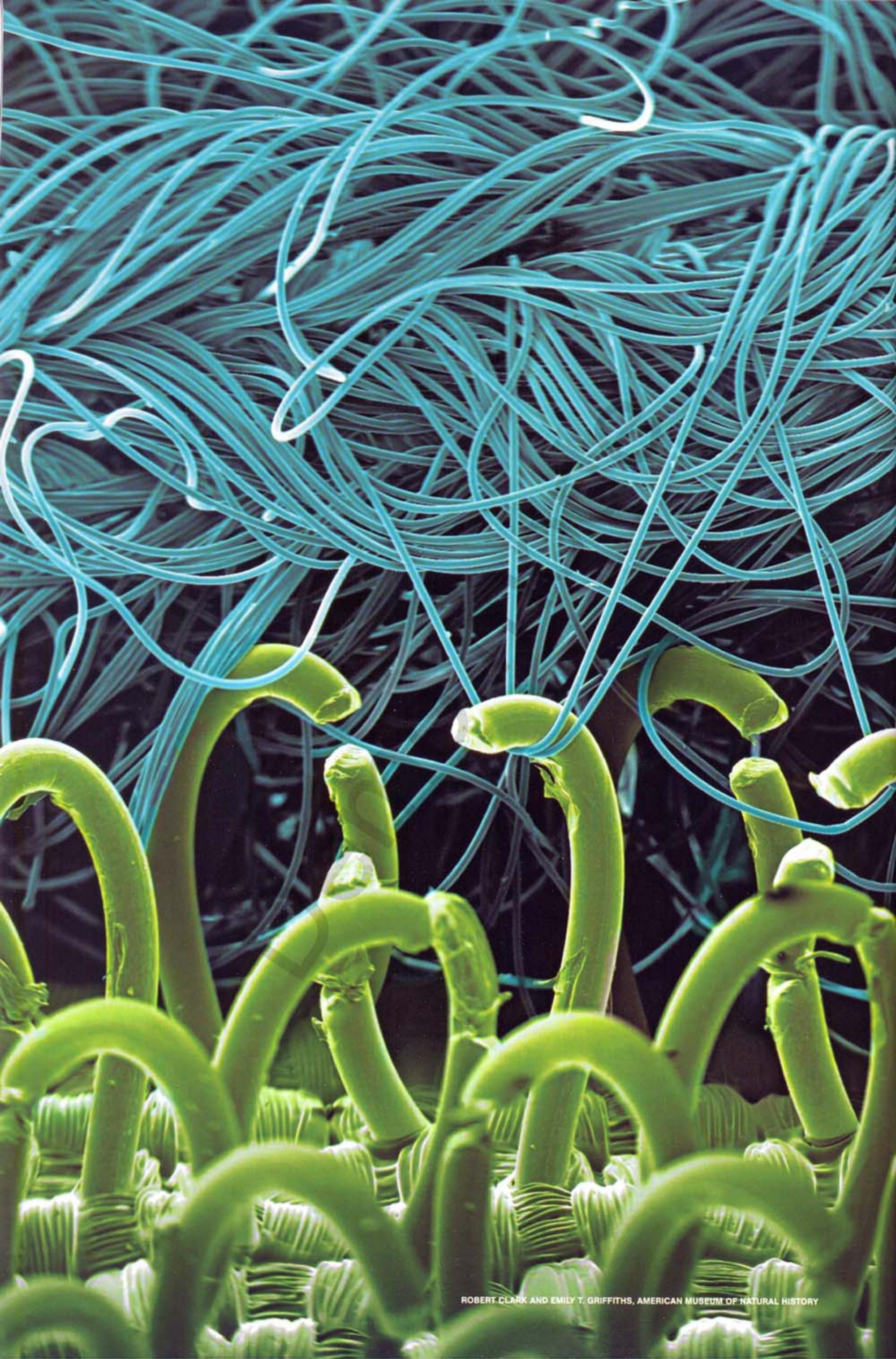
Examining burs plucked from his pants and dog's coat after a hike in 1948, Swiss engineer George de Mestral found their spines were tipped with tiny hooks—sparking his invention of Velcro. He was disappointed that fashion designers didn't rush to adopt his product—"likely because of that ripping sound," says his cousin Etienne Delessert. But Velcro found loftier applications, says Delessert, "in the first artificial heart surgery and on trips into space."

filled with preserved organisms of the most exuberant variety. In one room were waist-high alcohol jars of grimacing sea otters, pythons, spiny echidnas, and wallabies, and one 65-foot-long case containing a giant squid. Other rooms held displays of gaudy hummingbirds, over-the-top toucans and majestic bowerbirds, and shelf after shelf filled with beetles as bright as gemstones: emerald-green scarabs, sapphire-blue *Cyphogastras*, and opalescent weevils.

To Parker this was not a mere collection of specimens, but "a treasure-trove of brilliant design." Every species, even those that have gone extinct, is a success story, optimized by millions of years of natural selection. Why not learn from what evolution has wrought? As we walked, Parker explained how the metallic sheen and dazzling colors of tropical birds and beetles derive not from pigments, but from optical features: neatly spaced microstructures that reflect specific wavelengths of light. Such structural color, fade-proof and more brilliant than pigment, is of great interest to people who manufacture paint, cosmetics, and those little holograms on credit cards. Toucan bills are a model of lightweight strength (they can crack nuts, yet are light enough not to seriously impede the bird's flight), while hedgehog spines and porcupine quills are marvels of structural economy and resilience. Spider silk is five times stronger by weight and vastly more ductile than high-grade steel. Insects offer an embarrassment of design riches. Glowworms produce a cool light with almost zero energy loss (a normal incandescent bulb wastes 98 percent of its energy as heat), and bombardier beetles have a high-efficiency combustion chamber in their posterior that shoots boiling-hot chemicals at would-be predators. The *Melanophila* beetle, which lays its eggs in freshly burned wood, has evolved a structure that can detect the precise infrared radiation produced by a forest fire, allowing it to sense a blaze a hundred kilometers away. This talent is currently being explored by the United States Air Force.

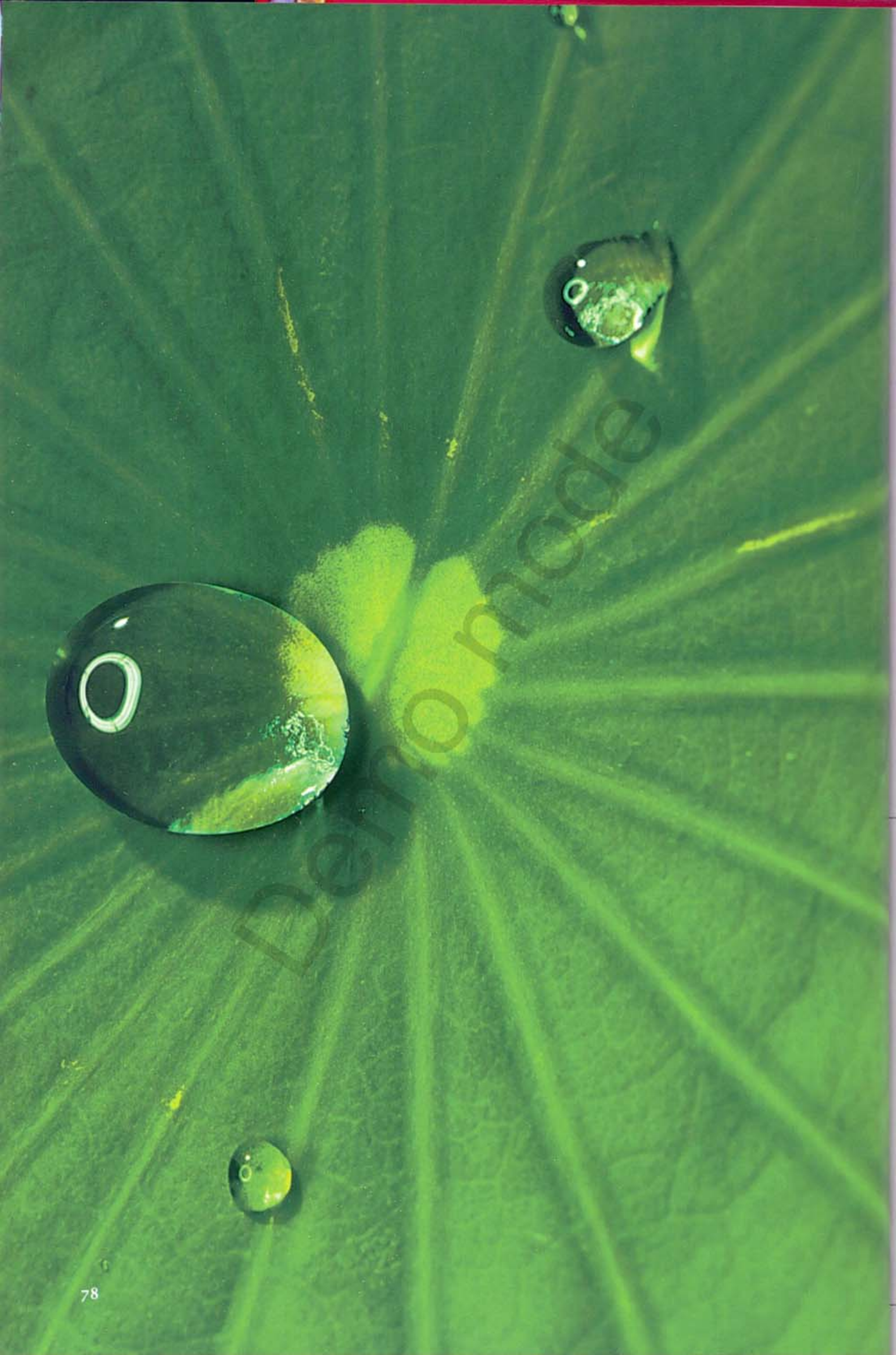
"I could look through here and find 50 biomimetics projects in half an hour," Parker said. "I try not to walk here in the evening, because I end up getting carried away and working until midnight."

In one such late-night creative burst eight years ago, Parker decided to investigate the water-gathering skills of a desert beetle by building an enormous sand dune in his laboratory. This



ROBERT CLARK AND EMILY T. GRIFFITHS, AMERICAN MUSEUM OF NATURAL HISTORY

With a hook-and-loop construction that grips instantly but lets go with a tug, Velcro (electron micrograph, left) is now as ubiquitous as the zipper. NASA was an early user, sending Velcro to the moon on space boots and suits—including Apollo astronaut John Young's glove in 1972 (above)—on tabs to latch down loose items in zero gravity, and inside helmets as nose scratchers.



tenebrionid beetle flourishes in the Namib Desert in southwestern Africa, one of the world's hottest, driest environments. The beetle drinks by harvesting morning fogs, facing into the wind and hoisting its behind, where hydrophilic bumps capture the fog and cause it to coalesce into larger droplets, which then roll down the waxy, hydrophobic troughs between the bumps, reaching the beetle's mouth. Parker imported several dozen beetles from Namibia, which promptly scampered all over the lab when he opened the box, but eventually settled contentedly on the dune. There, using a hair dryer and various misters and spray bottles, Parker simulated the conditions in the Namib Desert well enough to understand the beetle's mechanism. He then replicated it on a microscope slide, using tiny glass beads for the bumps and wax for the troughs.

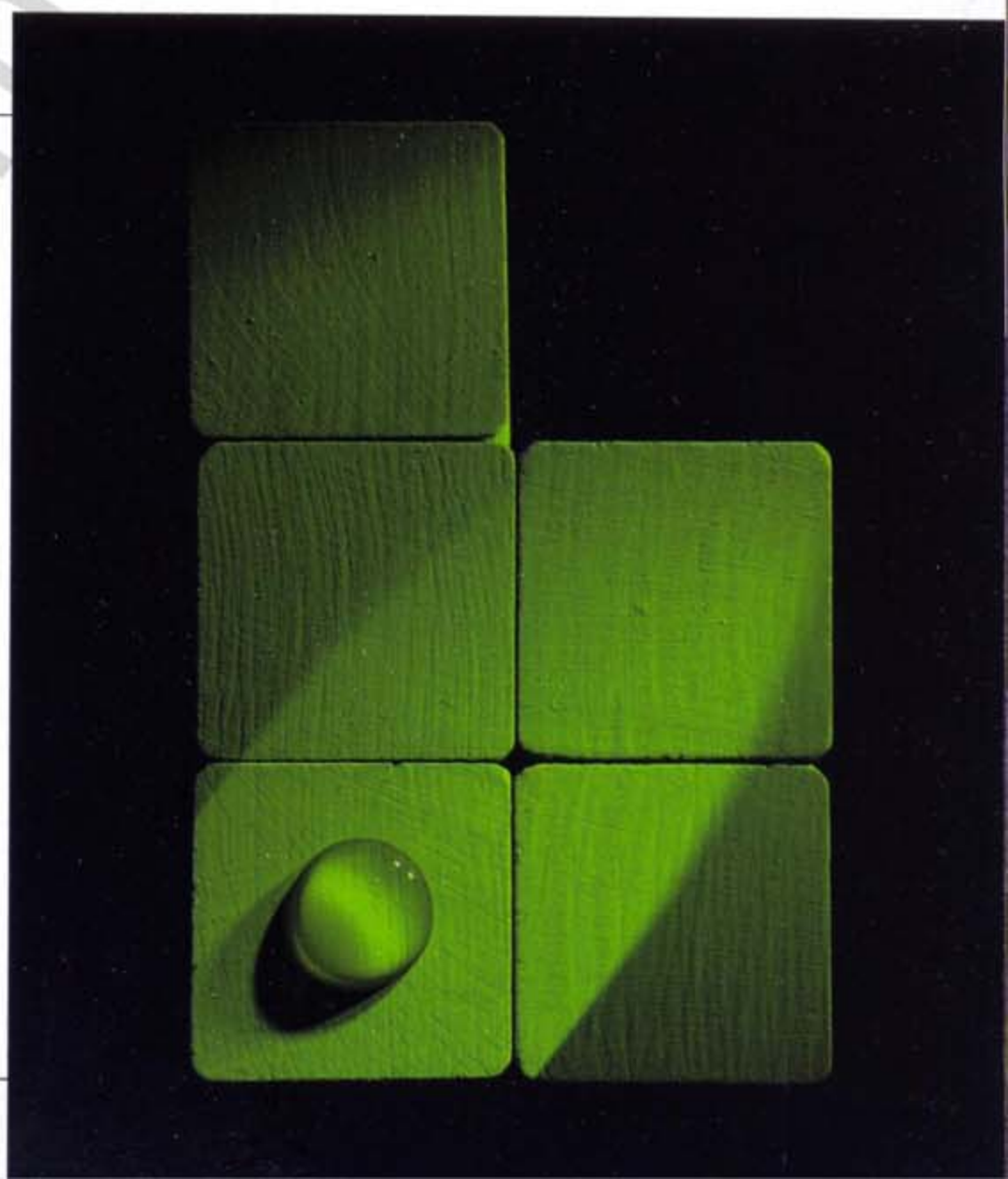
For all nature's sophistication, many of its clever devices are made from simple materials like keratin, calcium carbonate, and silica, which nature manipulates into structures of fantastic complexity, strength, and toughness. The abalone, for example, makes its shell out of calcium carbonate, the same stuff as soft chalk. Yet by coaxing this material into walls of staggered, nanoscale bricks through a subtle play of proteins, it creates an armor as tough as Kevlar—3,000 times harder than chalk. Understanding the microscale and nanoscale structures responsible for a living material's exceptional properties is critical to re-creating it synthetically. So today Andrew Parker had arranged to view the skin of a thorny devil museum specimen under a scanning electron microscope, hoping to find the hidden structures that allow it to absorb and channel water so effectively.

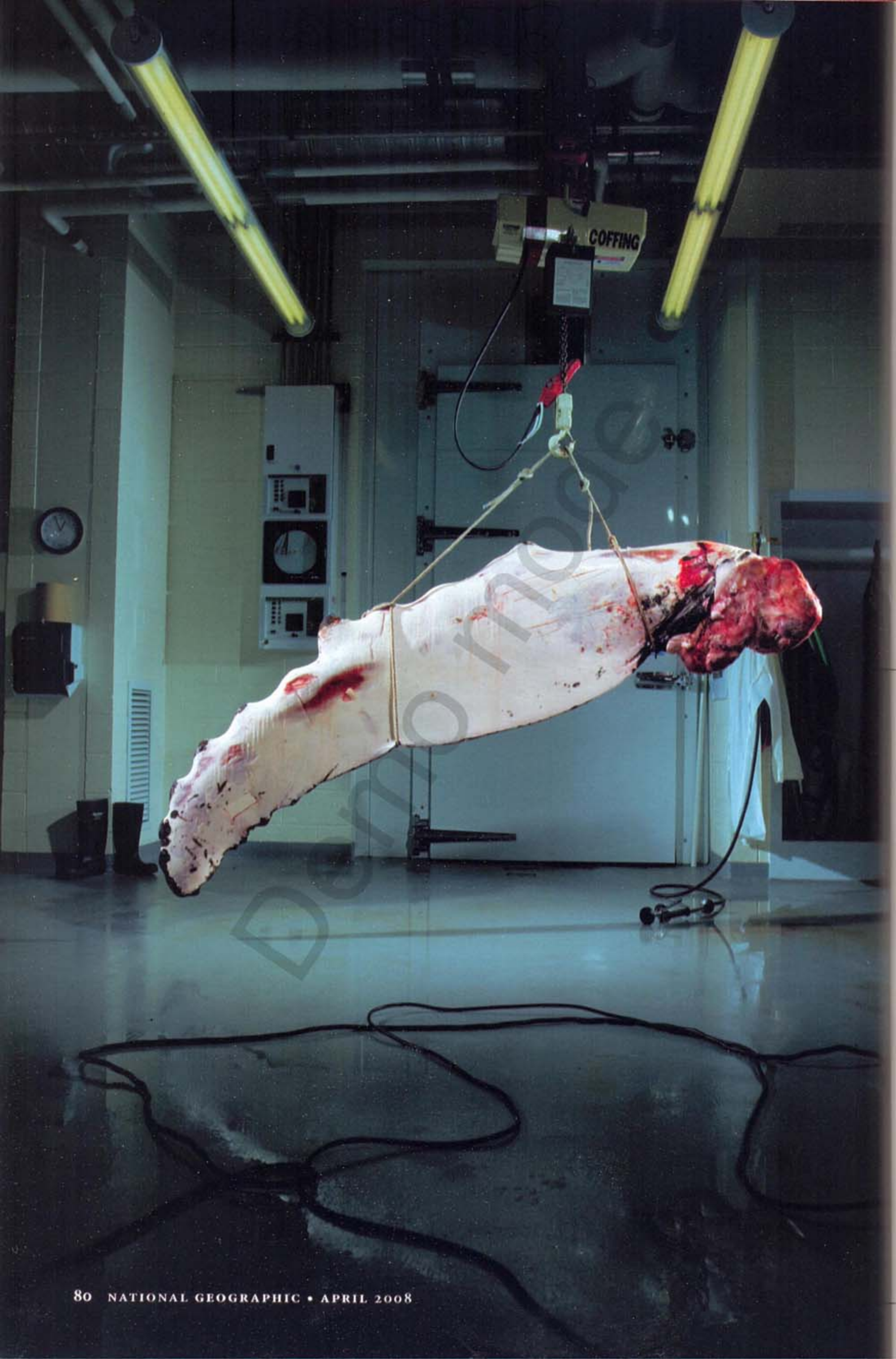
With a microscopist at the helm, we soared over the surface of the thorny devil's skin like a deep-space probe orbiting a distant planet, dipping down now and then at Parker's request to explore some curious feature of the terrain. There seemed to be little of interest in the Matterhorn-like macrostructure of an individual thorn, though Parker speculated that it might wick away heat from the lizard's body or perhaps help capture the morning dew. Halfway down the thorn, however, he noticed a series of nodules set in rows, which seemed to grade down to a larger water-collection structure. Finally we dove into a crevasse at the base of the thorn and encountered a honeycomb-like field of indentations, each 25 microns across.

"Ah-ha!" Parker exclaimed, like Sherlock Holmes alighting upon a clue. "This is clearly a superhydrophobic surface for channeling water

lotus leaf

In 1982 botanist Wilhelm Barthlott of the University of Bonn in Germany discovered in the lotus leaf a naturally self-cleaning, water-repellent surface. The secret lies in waxy microstructures and nanostructures that, by their contact angle with water, cause it to bead and roll away like mercury, gathering dirt as it goes. Barthlott patented his discovery, calling it the Lotus Effect. It has found commercial application in products like the biomimetic paint Lotusan (on blocks at right). Infused with microbumps, the paint is reputed to repel water and resist stains for decades.




COFFING

between the scales." A subsequent examination of the thorny devil's skin with an instrument called a micro-CT scanner confirmed his theory, revealing tiny capillaries between the scales evidently designed to guide water toward the lizard's mouth. "I think we've pretty well cracked the thorny devil structure," he said. "We're ready to make a prototype."

Enter the engineers. As the next phase in his quest to create a water-collection device inspired by the lizard, Parker sent his observations and experimental results to Michael Rubner and his MIT colleague Robert Cohen, a chemical engineer with whom he has worked on several biomimetics projects in the past. Rubner and Cohen are neatly groomed gentlemen who speak in clipped phrases and look frequently at their watches. While Parker likes to explain his work via a stroll through a botanic garden or by pulling out drawerfuls of bright beetles in a museum, they are more likely to draw a tidy graph of force over time, or flip through a PowerPoint presentation on their laptop. But a pooling of biological insight and engineering pragmatism is vital to success in biomimetics, and in the case of Parker, Cohen, and Rubner, it has led to several promising applications inspired by the Namib beetle and other insects. Using a robotic arm that, in a predetermined sequence, dips slides into a series of nanoparticle suspensions and other exotic ingredients, they have assembled materials layer by layer that have the same special properties as the organisms. Soon they hope to apply the method to create a synthetic surface inspired by thorny devil skin.

Though impressed by biological structures, Cohen and Rubner consider nature merely a starting point for innovation. "You don't have to reproduce a lizard skin to make a water-collection device, or a moth eye to make an antireflective coating," Cohen says. "The natural structure provides a clue to what is useful in a mechanism. But maybe you can do it better." Lessons from the thorny devil may enhance the water-collection technology they have developed based on the microstructure of the

whale flipper

Translating whale power into wind power, biomechanist Frank Fish helped design turbine blades with tubercles (nodules) inspired by the flipper of a humpback whale (left, from a deceased animal). The flipper's scalloped edge helps it generate force in tightly banked turns. The whale-inspired blades are being tested at the Wind Energy Institute of Canada (below) to see if they can make more power at slower speeds than conventional blades, and with less noise.

Namib beetle, which they're working to make into water-harvesting materials, graffiti-proof paints, and self-decontaminating surfaces for kitchens and hospitals. Or the work may take them in entirely new directions. Ultimately they consider a biomimetics project a success only if it has the potential to make a useful tool for people. "Looking at pretty structures in nature is not sufficient," says Cohen. "What I want to know is, Can we actually transform these structures into an embodiment with true utility in the real world?"

Which, of course, is the tricky bit. Potentially one of the most useful embodiments of natural design is the bio-inspired robot, which could be deployed in places where people would be too conspicuous, bored to tears, or killed. But such robots are notoriously difficult to build. Ronald Fearing, a professor of electrical engineering at the University of California, Berkeley, has taken on one of the biggest challenges of all: to create a miniature robotic fly that is swift, small, and maneuverable enough for use in surveillance or search-and-rescue operations.

If a blowfly had buzzed into Fearing's office when we first sat down on a warm March afternoon, the windows flung wide to the garden-like Berkeley campus, I would have swatted it away without a second thought. By the time Fearing finished explaining why he had chosen it as the model for his miniature aircraft, I would have fallen on bended knee in admiration. With wings beating 150 times per second, it hovers, soars, and dives with uncanny agility. From straight-line flight it can turn 90 degrees in under 50 milliseconds—a maneuver that would rip the Stealth fighter to shreds.

The key to making his micromechanical flying insect (MFI) work, Fearing said, isn't to attempt to copy the fly, but to isolate the structures crucial to its feats of flying, while keeping a sharp eye out for simpler—and perhaps better—ways to perform its highly complex operations. "The fly's wing is driven by 20 muscles, some of which only fire every fifth wing beat, and all you can do is wonder, What on Earth just happened there?" says Fearing. "Some things are just too mysterious and complicated to be able to replicate."

After CalTech neurobiologist Michael Dickinson used foot-long plastic wings flapping in two tons of mineral oil to demonstrate how the fly's U-shaped beat kept it aloft, Fearing whittled the complexity of the wing joint down to something he could manufacture. What he came up with resembles a tiny automobile differential; though lacking the fly's mystical 20-muscle poetry, it can still bang out U-shaped beats at high speed. To drive the wing, he needed piezoelectric actuators, which at high frequencies can generate more power than fly muscle can. Yet when he asked machinists to manufacture a ten-milligram actuator, he got blank stares. "People told me, 'Holy cow! I can do a ten-gram actuator,' which was bigger than our whole fly."

So Fearing made his own, one of which he held up with tweezers for me to see, a gossamer wand some 11 millimeters long and not much thicker than a cat's whisker. Fearing has been forced to manufacture many of the other minute components of his fly in the same way, using a micromachining laser and a rapid prototyping system that allows him to design his minuscule parts in a computer, automatically cut and cure them overnight, and assemble them by hand the next day under a microscope.

With the microlaser he cuts the fly's wings out of a two-micron polyester sheet so delicate that it crumples if you breathe on it and must be reinforced with carbon-fiber spars. The wings on his current model flap at 275 times per second—faster than the insect's own wings—and make the blowfly's signature buzz. "Carbon fiber outperforms fly chitin," he said, with a trace of self-satisfaction. He pointed out a protective plastic box on the lab bench, which contained the fly-bot itself, a delicate, origami-like framework of black carbon-fiber struts and hairlike wires that, not surprisingly, looks nothing like a real fly. A month later it achieved liftoff in a controlled flight on a boom. Fearing expects the fly-bot to hover in two or three years, and eventually to bank and dive with flylike virtuosity.

To find a biomimetic bot already up and running—or at least ambling—one need only cross the bay to Palo Alto. Ever since the fifth century B.C., when Aristotle marveled at how a gecko "can run up and down a tree in any way, even with the head downward," people have wondered how the lizard manages its gravity-defying locomotion. Two years ago Stanford University roboticist Mark Cutkosky set out to solve

this age-old conundrum, with a gecko-inspired climber that he christened Stickybot.

In reality, gecko feet aren't sticky—they're dry and smooth to the touch—and owe their remarkable adhesion to some two billion spatula-tipped filaments per square centimeter on their toe pads, each filament only a hundred nanometers thick. These filaments are so small, in fact, that they interact at the molecular level with the surface on which the gecko walks, tapping into the low-level van der Waals forces generated by molecules' fleeting positive and negative charges, which pull any two adjacent objects together. To make the toe pads for Stickybot, Cutkosky and doctoral student Sangbae Kim, the robot's lead designer, produced a urethane fabric with tiny bristles that end in 30-micrometer points. Though not as flexible or adherent as the gecko itself, they hold the 500-gram robot on a vertical surface.

But adhesion, Cutkosky found, is only part of the gecko's game. In order to move swiftly—and geckos can scamper up a vertical surface at one meter per second—its feet must also unstick effortlessly and instantly. To understand how the lizard does this, Cutkosky sought the aid of biologists Bob Full, an expert in animal locomotion, and Kellar Autumn, probably the world's foremost authority on gecko adhesion. Through painstaking anatomical studies, force tests on individual gecko hairlets, and slow-motion analysis of lizards running on vertical treadmills, Full and Autumn discovered that gecko adhesion is highly directional: Its toes stick only when dragged downward, and they release when the direction of pull is reversed.

With this in mind, Cutkosky endowed his robot with seven-segmented toes that drag and release just like the lizard's, and a gecko-like stride that snugs it to the wall. He also crafted Stickybot's legs and feet with a process he calls shape deposition manufacturing (SDM), which combines a range of metals, polymers, and fabrics to create the same smooth gradation from stiff to flexible that is present in the lizard's limbs and absent in most man-made materials. SDM also allows him to embed actuators, sensors, and other specialized structures that

sharkskin

An electron micrograph reveals sharkskin's secret to speed: tooth-like scales called dermal denticles. Water "races through the microgrooves without tumbling," says shark researcher George Burgess, reducing friction. "It's like a fast-moving river current versus the gurgling turbulence of a shallow stream." The scales also discourage barnacles and algae from glomming on—an inspiration for synthetic coatings that may soon be applied to Navy ship hulls to reduce such biofouling.

"No shark will mistake me for one of its own," says ten-time Olympic medalist Gary Hall, Jr., training at Florida's Race Club. But sharkskin denticles spurred the design of his Speedo Fastskin, whose texture functions to reduce drag, bumping up speed.

make Stickybot climb better. Then he noticed in a paper on gecko anatomy that the lizard had branching tendons to distribute its weight evenly across the entire surface of its toes. Eureka. "When I saw that, I thought, Wow, that's great!" He subsequently embedded a branching polyester cloth "tendon" in his robot's limbs to distribute its load in the same way.

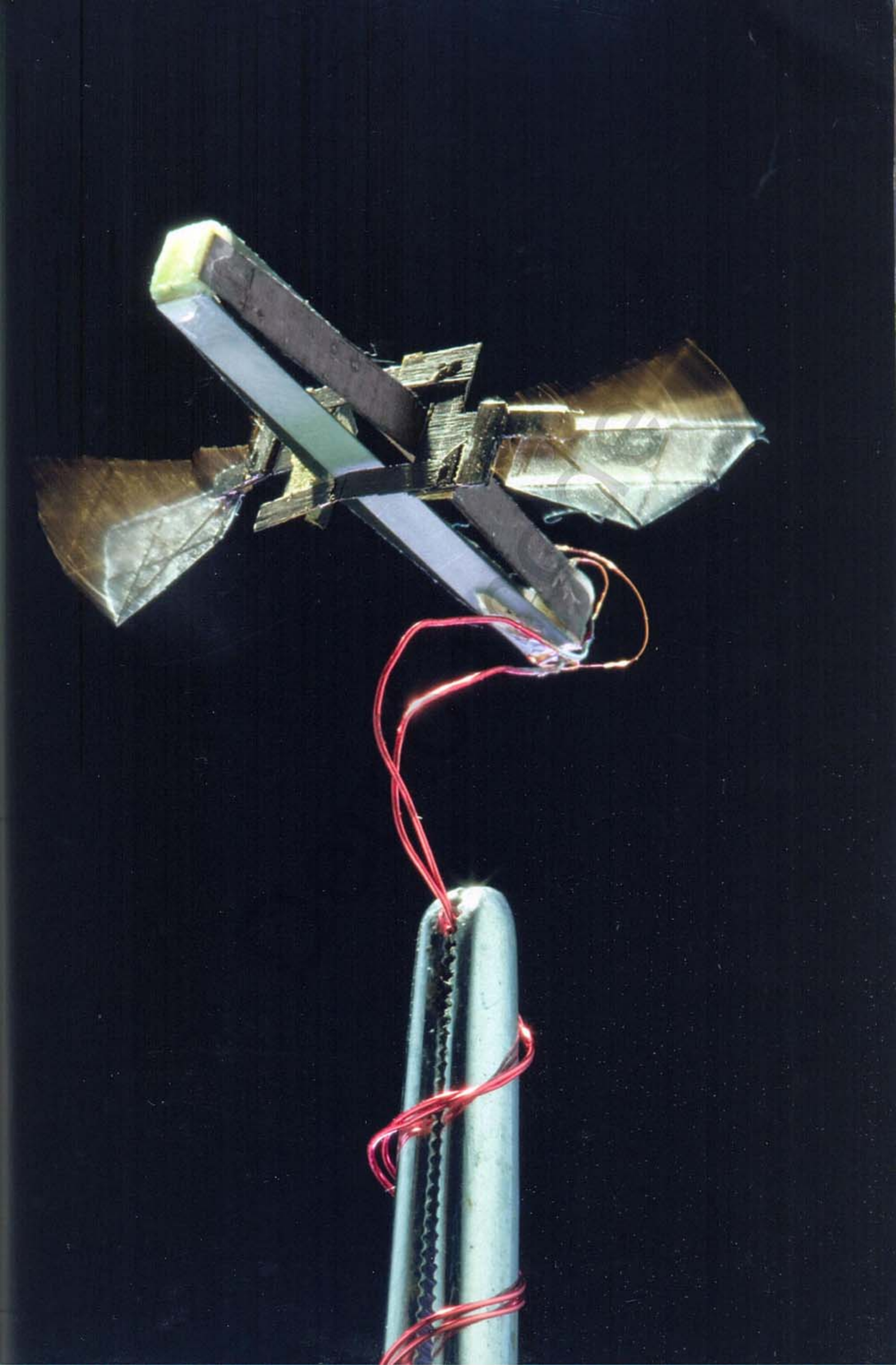
Stickybot now walks up vertical surfaces of glass, plastic, and glazed ceramic tile, though it will be some time before it can keep up with a gecko. For the moment it can walk only on smooth surfaces, at a mere four centimeters per second, a fraction of the speed of its biological role model. The dry adhesive on Stickybot's toes isn't self-cleaning like the lizard's either, so it rapidly clogs with dirt. "There are a lot of things about the gecko that we simply had to ignore," Cutkosky says. Still, a number of real-world applications are in the offing. The Department of Defense's Defense Advanced Research Projects Agency (DARPA), which funds the project, has it in mind for surveillance: an automaton that could slink up a building and perch there for hours or days, monitoring the terrain below. Cutkosky hypothesizes a range of civilian uses. "I'm trying to get robots to go places where they've never gone before," he told me. "I would like to see Stickybot have a real-world function, whether it's a toy or another application. Sure, it would be great if it eventually has a lifesaving or humanitarian role...."

His voice trailed off, in a wistful, almost apologetic tone I had heard undercutting the optimism of several other biomimeticists. For all their differences in background, temperament, and ultimate aims, most practitioners conclude their enthusiastic discourses on their bio-inspired invention with a few halfhearted theories on how it may someday make its way into the real world. Often it sounds like wishful thinking.

For all the power of the biomimetics paradigm, and the brilliant people who practice it, bio-inspiration has led to surprisingly few mass-produced products and arguably only one household word—Velcro, which was invented in 1948 by Swiss chemist George de Mestral, by copying the way cockleburs clung to his dog's coat. In addition to Cutkosky's lab, five other high-powered research teams are currently trying to mimic gecko adhesion, and so far none has come close to matching the lizard's strong, directional, self-cleaning grip. Likewise, scientists have yet to meaningfully re-create the abalone nanostructure that accounts for the strength of its shell, and several well-funded

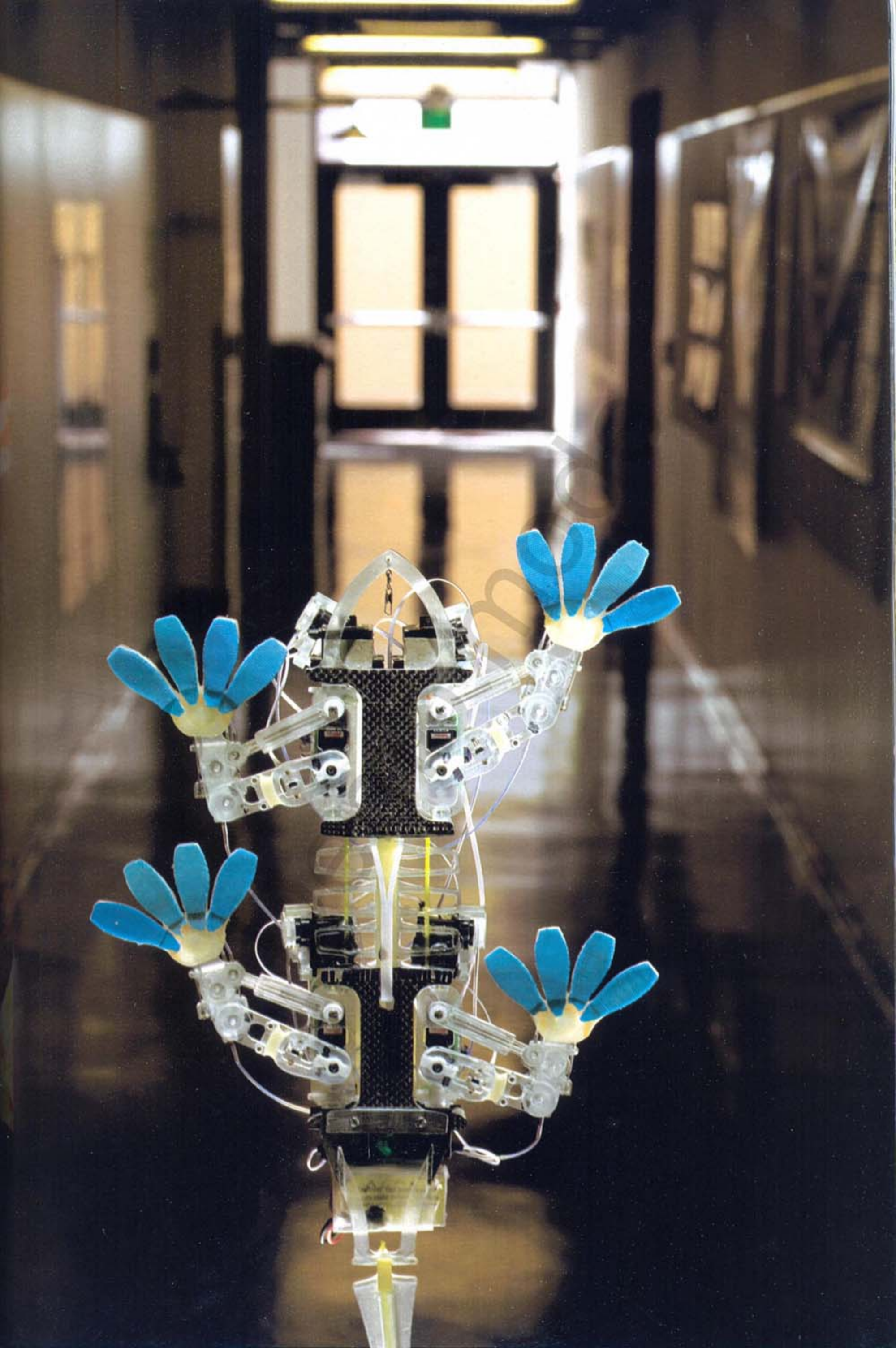
fly wing

The flutter of the micromechanical flying insect (right) doesn't yet match the complex U-shaped motion achieved by its living muse, the blowfly. But the robot could soon take flight untethered. Powered by tiny electric actuators along its sides, the bot's fragile wings beat up to 275 times per second, even faster than the bug's that inspired it. "A true fly's wings are remarkable, rotating in every stroke," says UC Berkeley's Ron Fearing. "Our challenge is to get a working mechanism in a device one-twentieth the weight of a paper clip."



gecko foot

A tokay gecko's toes sport spatula-tipped hairs (some 6.5 million of them per toe) that adhere to surfaces at the molecular level, giving the lizard nimble footing even on walls and ceilings. Stickybot (far right), at Stanford University, makes a foray onto similar terrain. Bristled toes grab and let go, and the bot's limbs mimic the gecko's own anatomy. But so far it moves at a relative snail's pace. Designers hope it may one day be used in search-and-rescue applications.



biotech companies have gone bankrupt trying to make artificial spider silk. Why?

Some biomimeticists blame industry, whose short-term expectations about how soon a project should be completed and become profitable clash with the time-consuming nature of biomimetics research. Others lament the difficulty in coordinating joint work among diverse academic and industrial disciplines, which is required to understand natural structures and mimic what they do. But the main reason biomimetics hasn't yet come of age is that from an engineering standpoint, nature is famously, fabulously, wantonly complex. Evolution doesn't "design" a fly's wing or a lizard's foot by working toward a final goal, as an engineer would—it blindly cobbles together myriad random experiments over thousands of generations, resulting in wonderfully inelegant organisms whose goal is to stay alive long enough to produce the next generation and launch the next round of random experiments. To make the abalone's shell so hard, 15 different proteins perform a carefully choreographed dance that several teams of top scientists have yet to comprehend. The power of spider silk lies not just in the cocktail of proteins that it is composed of, but in the mysteries of the creature's spinnerets, where 600 spinning nozzles weave seven different kinds of silk into highly resilient configurations.

The multilayered character of much natural engineering makes it particularly difficult to penetrate and pluck apart. The gecko's feet work so well not just because of their billions of tiny nanohairs, but also because those hairs grow on larger hairs, which in turn grow on toe ridges that are part of bigger toe pads, and so on up to the centimeter scale, creating a seven-part hierarchy that maximizes the lizard's cling to all climbing surfaces. For the present, people cannot hope to reproduce such intricate nanopuzzles. Nature, however, assembles them effortlessly, molecule by molecule, following the recipe for complexity encoded in DNA. As engineer Mark Cutkosky says, "The price that we pay for complexity at small scales is vastly higher than the price nature pays."

Nonetheless the gap with nature is gradually closing. Researchers are using electron- and atomic-force microscopes, microtomography, and high-speed computers to peer ever deeper into nature's microscale and nanoscale secrets, and a growing array of advanced materials to mimic them more accurately than ever before. And even before biomimetics matures into a commercial industry, it has itself developed into a powerful new tool for understanding life. Berkeley animal locomotion expert Bob Full uses what he learns to build running, climbing, and crawling robots—and they in turn have taught him certain fundamental rules of animal movement. He has discovered, for example, that every land animal, from centipedes to kangaroos to humans, has precisely the same springiness in its legs and generates the same relative energy when it runs. Kellar Autumn, the gecko-adhesion specialist and a former student of Full's, regularly borrows bits of Cutkosky's Stickybot to compare them with the animal's natural structures and to test central assumptions about gecko biology that cannot be learned from the geckos themselves.

"It's no problem to apply a 0.2 Newton preload to a patch of gecko adhesive and drag it in a distal direction at one micron per second," Autumn says. "But try asking a gecko to do the same thing with its foot. It'll probably just bite you." □

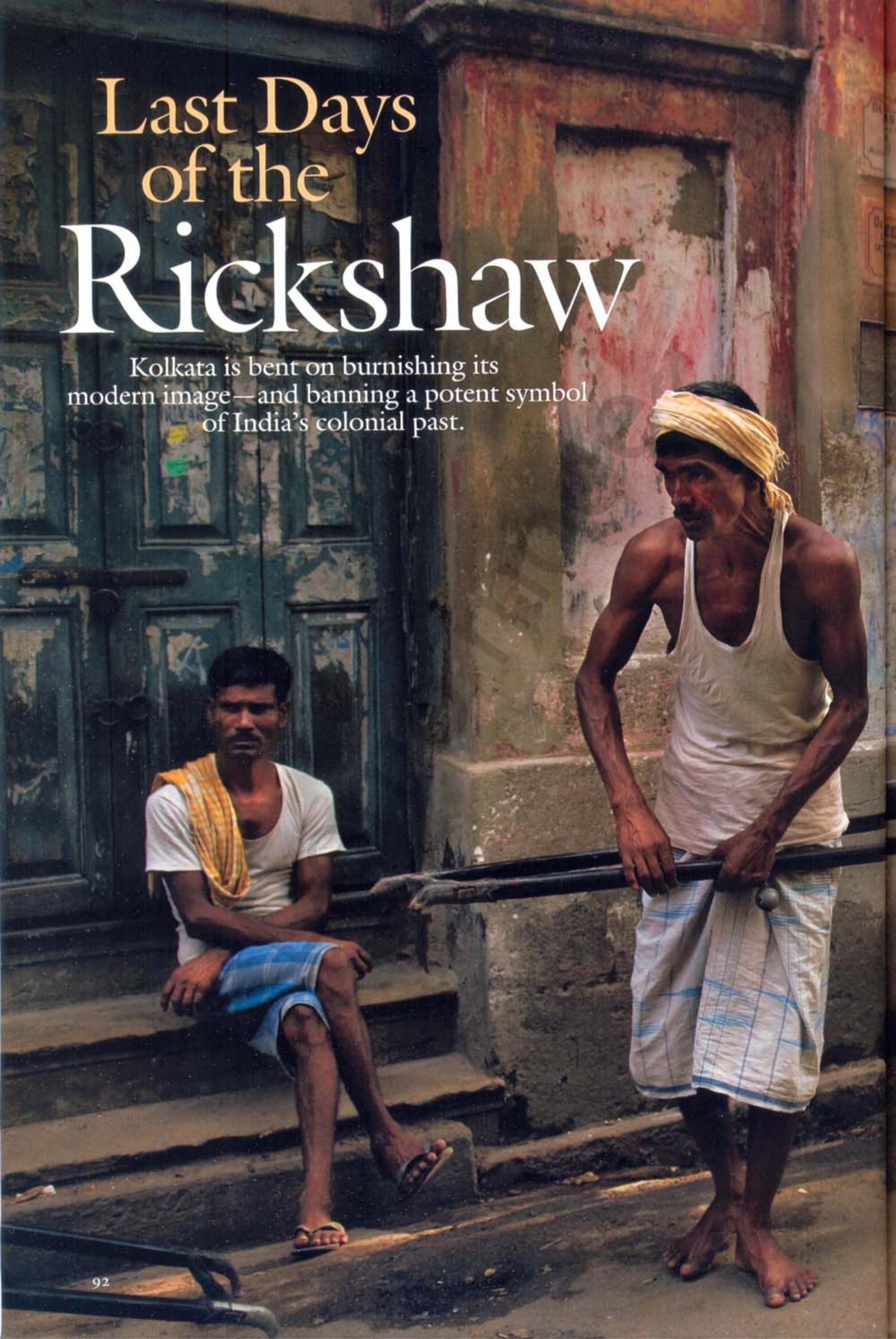
Designing Images How does Robert Clark come up with photographs that convey a concept? Learn how he shot this story in a video at **ngm.com.**

insect eye

In the 1960s scientists studying moth eyes at the nanoscale level discovered that their multifaceted surface (electron micrograph, right) is structured to reduce reflection. Engineers at Holotools in Freiburg, Germany, use lasers to sculpt similar facets on a photosensitive lacquer. Some 16 million "dots" of texture per square millimeter all but eliminate the glare on the right half of a computer monitor. It's an advanced biomimetic technology 40 years—plus eons of evolution—in the making.

Last Days of the Rickshaw

Kolkata is bent on burnishing its modern image—and banning a potent symbol of India's colonial past.



S. K. Bikari regularly pulls a pair of girls to school in the city's fading historic center, yet he rarely sees his own five children back home in the state of Bihar.

by Calvin Trillin
photographs by Ami Vitale

The strategy of drivers in Kolkata—drivers of private cars and taxis and buses and the enclosed three-wheel scooters used as jitneys and even pedicabs—is simple: Forge ahead while honking. There are no stop signs to speak of. To a visitor, the signs that say, in large block letters, OBEY TRAFFIC RULES come across as a bit of black humor. During a recent stay in Kolkata, the method I devised for crossing major thoroughfares was to wait until I could attach myself to more pedestrians than I figured a taxi was willing to knock down. In the narrow side streets known as the lanes, loud honking is the signal that a taxi or even a small truck is about to round the corner and come barreling down a space not meant for anything wider than a bicycle. But occasionally, during a brief lull in the honking, I'd hear the tinkling of a bell behind me. An American who has watched too many Hallmark Christmas specials might turn around half expecting to see a pair of draft horses pulling a sleigh through snowy woods. But what came into view was a rickshaw. Instead of being pulled by a horse, it was being pulled by a man—usually a skinny, bedraggled, barefoot man who didn't look quite up to the task. Hooked around his finger was a single bell that he shook continuously, producing what is surely the most benign sound to emanate from any vehicle in Kolkata.

Among the great cities of the world, Kolkata, the capital of West Bengal and the home of nearly 15 million people, is often mentioned as the only one that still has a large fleet of hand-pulled rickshaws. As it happens, that is not a distinction treasured by the governing authorities. Why? It's tempting, of course, to blame Mother Teresa. A politician in Kolkata told me that the city is known for the three *m*'s: Marxism, *mishti,* and Mother Teresa. (West Bengal has had a government dominated by the Communist Party for 30 years. Mishti is a sweetened yogurt that Kolkatans love, though they're also partial to a sweet called *rossogolla.*) There is no doubt that the international attention given to Mother Teresa's work among the wretched and the dying firmly linked Kolkata in the Western mind with squalor—no matter how often Kolkatans point out that Mumbai, for example, has more extensive slums, and that no other city in India can match the richness of Kolkata's intellectual and cultural life.

The most loyal booster of Kolkata would acknowledge that the city has had some genuinely trying times in the 60 years since India became independent, starting well before the emergence of Mother Teresa. The partition that accompanied independence meant that, without substantial help from

In the midst of a monsoon rain, Mohammad S. K. Rostam and his fellow rickshaw pullers provide the best transport through flooded streets.

Risking a fine, a puller takes a shortcut by traveling against traffic on a one-way street. With little education or professional training, the men who do this grueling work have few other job prospects. Many come from Bihar (map), one of India's poorest states.

the central government, Kolkata had to absorb several million refugees from what became East Pakistan. There were times in the 1970s and '80s when it seemed Kolkata would never recover from the trauma of those refugees, followed by another wave of refugees who came during the war that turned East Pakistan into Bangladesh. Those were years marked by power outages and labor unrest and the flight of industry and the breathtaking violence unleashed by the Naxalite movement, which began with peasants demanding land redistribution in rural West Bengal and was transformed by college students into urban guerrilla warfare. In 1985 India's own prime minister, then Rajiv Gandhi, called Kolkata "a dying city."

There are still a lot of people sleeping on the streets in Kolkata, but there have been great changes in recent years. After decades of concentrating on its base among the rural poor and disdaining outside investment, the Communist Party of West Bengal has fiercely embraced capitalism and modernity. Although the government's symbols remain what might be expected from a party that still has a politburo—street-name changes have resulted in an American consulate with the address 5/1 Ho Chi Minh Road—the city regularly courts Western delegations looking for investment opportunities. Kolkata now has modern shopping malls and modern overpasses. Walking around the city recently for a week or so, often as the only Westerner in sight, I was approached by precisely two beggars.

Still, the image of any city has a half-life of many years. (So does its name, officially changed in 2001 from Calcutta to Kolkata, which is closer to what the word sounds like in Bengali. Conversing in English, I never heard anyone call the city anything but Calcutta.) To Westerners, the conveyance most identified with Kolkata is not its modern subway—a facility whose spacious stations have art on the walls and cricket matches on television monitors—but the hand-pulled rickshaw. Stories and films celebrate a primitive-looking cart with high wooden wheels, pulled by someone who looks close to needing the succor of Mother Teresa. For years the government has been talking about eliminating hand-pulled rickshaws on what it calls humanitarian grounds—principally on the ground that, as the mayor of Kolkata has often said, it is offensive to see "one man sweating and straining to pull another man." But these days politicians also lament the impact of 6,000 hand-pulled rickshaws on a modern city's traffic and, particularly, on its image. "Westerners try to associate beggars and these rickshaws with the Calcutta landscape, but this is not what Calcutta stands for," the chief minister of West Bengal, Buddhadeb Bhattacharjee, said in a press conference in 2006. "Our city stands for prosperity and development." The chief minister—the equivalent of a state governor—went on to announce that hand-pulled rickshaws soon would be banned from the streets of Kolkata.

Rickshaws are not there to haul around tourists. (Actually, I saw almost no tourists in Kolkata, apart from the young backpackers on

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Calvin Trillin is the author of 25 books of journalism, fiction, verse, and autobiography, most recently About Alice. *Ami Vitale's photographs have appeared in* GEO, Newsweek, Time, Smithsonian, *and the* New York Times.

A rickshaw stand is also home to Dharmindra Singh (at left) and Bhanu Paswan, who brought their

families with them to live on the street rather than visiting them once a year in Darbhanga, Bihar.

Pullers pay $2.50 a month for lodging in a dera, which

Taking a break after lunch, rickshaw pullers crowd into their living quarters, called a dera. *Though religious tensions often run high in India, Hindus and Muslims share the tight lodging.*

Sudder Street, in what used to be a red-light district and is now said to be the single place in the city where the services a rickshaw *wallah* offers may include providing female company to a gentleman for the evening.) It's the people in the lanes who most regularly use rickshaws—not the poor but people who are just a notch above the poor. They are people who tend to travel short distances, through lanes that are sometimes inaccessible to even the most daring taxi driver. An older woman with marketing to do, for instance, can arrive in a rickshaw, have the rickshaw wallah wait until she comes back from various stalls to load her purchases, and then be taken home. People in the lanes use rickshaws as a 24-hour ambulance service. Proprietors of cafés or corner stores send rickshaws to collect their supplies. (One morning I saw a rickshaw wallah take on a load of live chickens—tied in pairs by the feet so they could be draped over the shafts and the folded back canopy and even the axle. By the time he trotted off, he was carrying about a hundred upside-down chickens.) The rickshaw pullers told me their steadiest customers are schoolchildren. Middle-class families contract with a puller to take a child to

sounds like a **good deal** until you've visited one.

On a visit from Bihar to celebrate a holiday, Rabson Khatoon and her grandchildren use her son's dera as a living room. It also serves as a garage, repair shop, kitchen, closet, bedroom, and bath.

school and pick him up; the puller essentially becomes a family retainer.

From June to September Kolkata can get torrential rains, and its drainage system doesn't need torrential rain to begin backing up. Residents who favor a touch of hyperbole say that in Kolkata "if a stray cat pees, there's a flood." During my stay it once rained for about 48 hours. Entire neighborhoods couldn't be reached by motorized vehicles, and the newspapers showed pictures of rickshaws being pulled through water that was up to the pullers' waists. When it's raining, the normal customer base for rickshaw wallahs expands greatly, as does the price of a journey. A writer in Kolkata told me, "When it rains, even the governor takes rickshaws."

While I was in Kolkata, a magazine called *India Today* published its annual ranking of Indian states, according to such measurements as prosperity and infrastructure. Among India's 20 largest states, Bihar finished dead last, as it has for four of the past five years. Bihar, a couple hundred miles north of Kolkata, is where the vast majority of rickshaw wallahs come from. Once in Kolkata, they sleep on the street or in their rickshaws or in a *dera*—a combination garage and repair shop and dormitory managed

Live chickens ride on Gopal Shaw's rig from the wholesale New Market to a retail shop. A puller's day

to a retail shop. A puller's day may begin with such early morning deliveries and end after midnight with passengers.

Some people will not ride because they are offended

by someone called a *sardar.* For sleeping privileges in a dera, pullers pay 100 rupees (about $2.50) a month, which sounds like a pretty good deal until you've visited a dera. They gross between 100 and 150 rupees a day, out of which they have to pay 20 rupees for the use of the rickshaw and an occasional 75 or more for a payoff if a policeman stops them for, say, crossing a street where rickshaws are prohibited. A 2003 study found that rickshaw wallahs are near the bottom of Kolkata occupations in income, doing better than only the ragpickers and the beggars. For someone without land or education, that still beats trying to make a living in Bihar.

There are people in Kolkata, particularly educated and politically aware people, who will not ride in a rickshaw, because they are offended by the idea of being pulled by another human being or because they consider it not the sort of thing people of their station do or because they regard the hand-pulled rickshaw as a relic of colonialism. Ironically, some of those people are not enthusiastic about banning rickshaws. The editor of the editorial pages of Kolkata's *Telegraph*—Rudrangshu Mukherjee, a former academic who still writes history books—told me, for instance, that he sees humanitarian considerations as coming down on the side of keeping hand-pulled rickshaws on the road. "I refuse to be carried by another human being myself," he said, "but I question whether we have the right to take away their livelihood." Rickshaw supporters point out that when it comes to demeaning occupations, rickshaw wallahs are hardly unique in Kolkata.

When I asked one rickshaw wallah if he thought the government's plan to rid the city of rickshaws was based on a genuine interest in his welfare, he smiled, with a quick shake of his head—a gesture I interpreted to mean, "If you are so naive as to ask such a question, I will answer it, but it is not worth wasting words on." Some rickshaw wallahs I met were resigned to the imminent end of their livelihood and pin their hopes on being offered something in its place. As migrant workers, they don't have the political clout enjoyed by, say, Kolkata's sidewalk hawkers, who, after supposedly being scaled back at the beginning of the modernization drive, still clog the sidewalks, selling absolutely everything—or, as I found during the 48 hours of rain, absolutely everything but umbrellas. "The government was the government of the poor people," one sardar told me. "Now they shake hands with the capitalists and try to get rid of poor people."

But others in Kolkata believe that rickshaws will simply be confined more strictly to certain neighborhoods, out of the view of World Bank traffic consultants and California investment delegations—or that they will be allowed to die out naturally as they're supplanted by more modern conveyances. Buddhadeb Bhattacharjee, after all, is not the first high West Bengal official to say that rickshaws would be off the streets of Kolkata in a matter of months. Similar statements have been made as far back as 1976. The ban decreed by Bhattacharjee has been delayed by a court case and by a widely held belief that some retraining or social security settlement ought to be offered to rickshaw drivers. It may also

Leaving Rickshaws Behind More of Ami Vitale's photos can be found at **ngm.com.**

by the idea of being pulled by another human being.

Pounding rough asphalt, often barefoot, earns a puller a meager but honest living. What will he do—and how will his clients get around—if rickshaws are finally forced off the roads?

have been delayed by a quiet reluctance to give up something that has been part of the fabric of the city for more than a century. Kolkata, a resident told me, "has difficulty letting go." One day a city official handed me a report from the municipal government laying out options for how rickshaw wallahs might be rehabilitated.

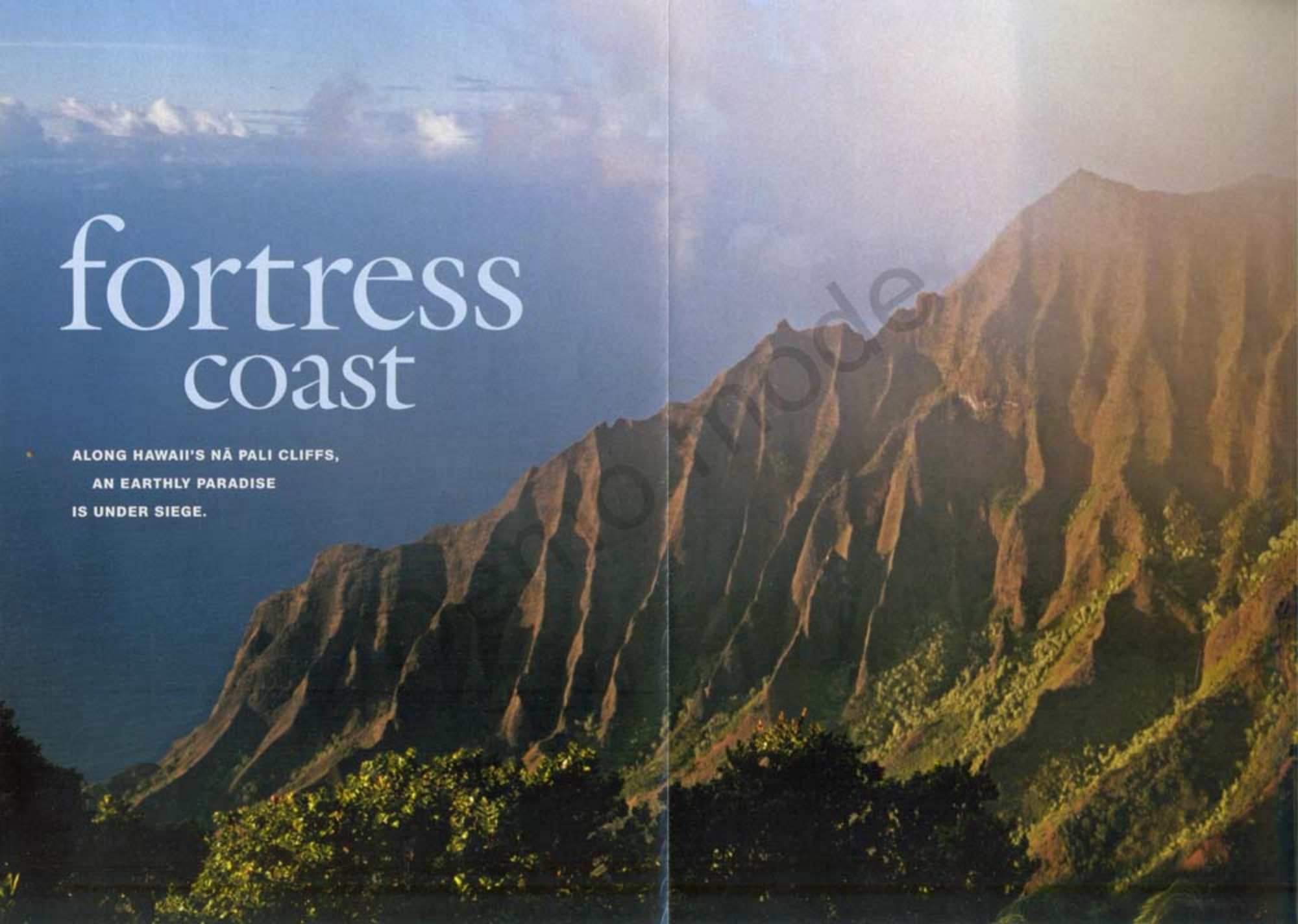
"Which option has been chosen?" I asked, noting that the report was dated almost exactly a year before my visit.

"That hasn't been decided," he said.

"When will it be decided?"

"That hasn't been decided," he said. □

Tumbling 4,000 feet from source to sea cave (left), Waiahuakua stream—"waters of the altar of the gods"—is one of many Nā Pali features venerated by early Hawaiians. Another hallowed spot is Polihale Beach and nearby cliffs (right), the jumping-off spot for spirits bound for the netherworld.



fortress coast

ALONG HAWAII'S NĀ PALI CLIFFS, AN EARTHLY PARADISE IS UNDER SIEGE.

Draped in iridescent hues, rugged Nā Pali Coast on Kaua'i provides a rampart against the Pacific—and a pot of tourist gold.

BY JOEL K. BOURNE, JR. NATIONAL GEOGRAPHIC CONTRIBUTING WRITER
PHOTOGRAPHS BY DIANE COOK AND LEN JENSHEL

The road to Shangri-la is supposed to be an ephemeral thing, a mystical path to a hidden valley where peace and beauty prevail. But on the Hawaiian island of Kaua'i it's simply Kuhio Highway, a twisty two-lane blacktop that ends in a muddy parking lot on the island's north shore. There, past the sands of Kē'ē Beach, the cliffs of Nā Pali rise straight from the green Pacific like giant palisades that keep the modern world at bay.

It's a lovely illusion, of course. Unlike the fabled Shangri-la, Nā Pali is emblazoned on every tourist map of Kaua'i—and this magazine is partly to blame. A single photo in a 1960 article on Hawaii unveiled a lush valley shielded by 3,000-foot cliffs to a generation hungry for just such a place. The caption read: "Napali's towering cliffs wall a Shangri-la valley accessible only by sea.... Junglelike glens tucked amid the ridges offer an unspoiled world for the adventurous."

That image, and many more that followed in print and film, inspired a pilgrimage that continues to this day. Some visitors kayak the 15-mile stretch of fluted cliffs, sea caves, and scalloped beaches during the calm seas of summer; others make the trip in "extreme" rafts, outboard-powered assault craft that can surmount almost any sea. Even more take the one-hour helicopter tour to get the *Jurassic Park* view—Nā Pali starred in that movie, as well as in *King Kong, South Pacific,* and many other Hollywood fantasies. The young in heart and leg hike a harrowing 11-mile goat trail to the largest of the valleys, called Kalalau, where they often overstay their five-day camping permits by weeks or even months.

All are latecomers to a geologic drama that has played out over millions of years. The Nā Pali Coast is the scarred shoulder of an ancient shield volcano that once rose more than five miles from seafloor to summit. Like all the Hawaiian islands, Kaua'i was born over a plume of magma called a hot spot. As tectonic forces moved the island off the hot spot, its volcanic fires cooled and water, Earth's elemental sculptor, took over. Rain—nearly a hundred inches a year in parts of Nā Pali—carved out the deep valleys from above and draped white-plumed waterfalls over the precipices. Giant winter waves exploded against the basalt cliffs as sea level rose and fell, gouging steep, unstable slopes. The result: a series of plunging valleys, fluted walls, and razor-sharp ridges soaring thousands of feet from the Pacific. On big screens and small, Nā Pali has come to represent paradise on Earth.

For the early Hawaiians, it was also home, a place to fish and plant their terraced taro fields. Their presence is palpable in Nu'alolo Kai, one of the westernmost valleys along the coast, now accessible only by boat. Signs of more than six centuries of continuous occupation dot the landscape: stone walls, ceremonial platforms, remnants of houses and canoe shelters, as well as numerous burial sites.

In Hawaiian culture everything in the world contains *mana,* a spiritual power imbued by the gods and the ancestors. The mana at Nu'alolo Kai is so strong even a visitor from halfway across the globe gets goose bumps. "The Hawaiians call the feeling 'chicken skin,'" says Alan Carpenter, an archaeologist with Hawaii's division of state parks, which administers the area. "I get it every time I come here."

For Randy Wichman and Sabra Kauka, this valley also inspires a powerful sense of peace and serenity. The two native Hawaiians are members of Nā Pali Coast 'Ohana, a local nonprofit group formed to protect the cultural

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Diane Cook and Len Jenshel's first joint project focused on volcanic landscapes. Their latest book explores the spectacle of public aquariums.

Invasive species, such as bamboo, rival native plants in Nā Pali's lush valleys.

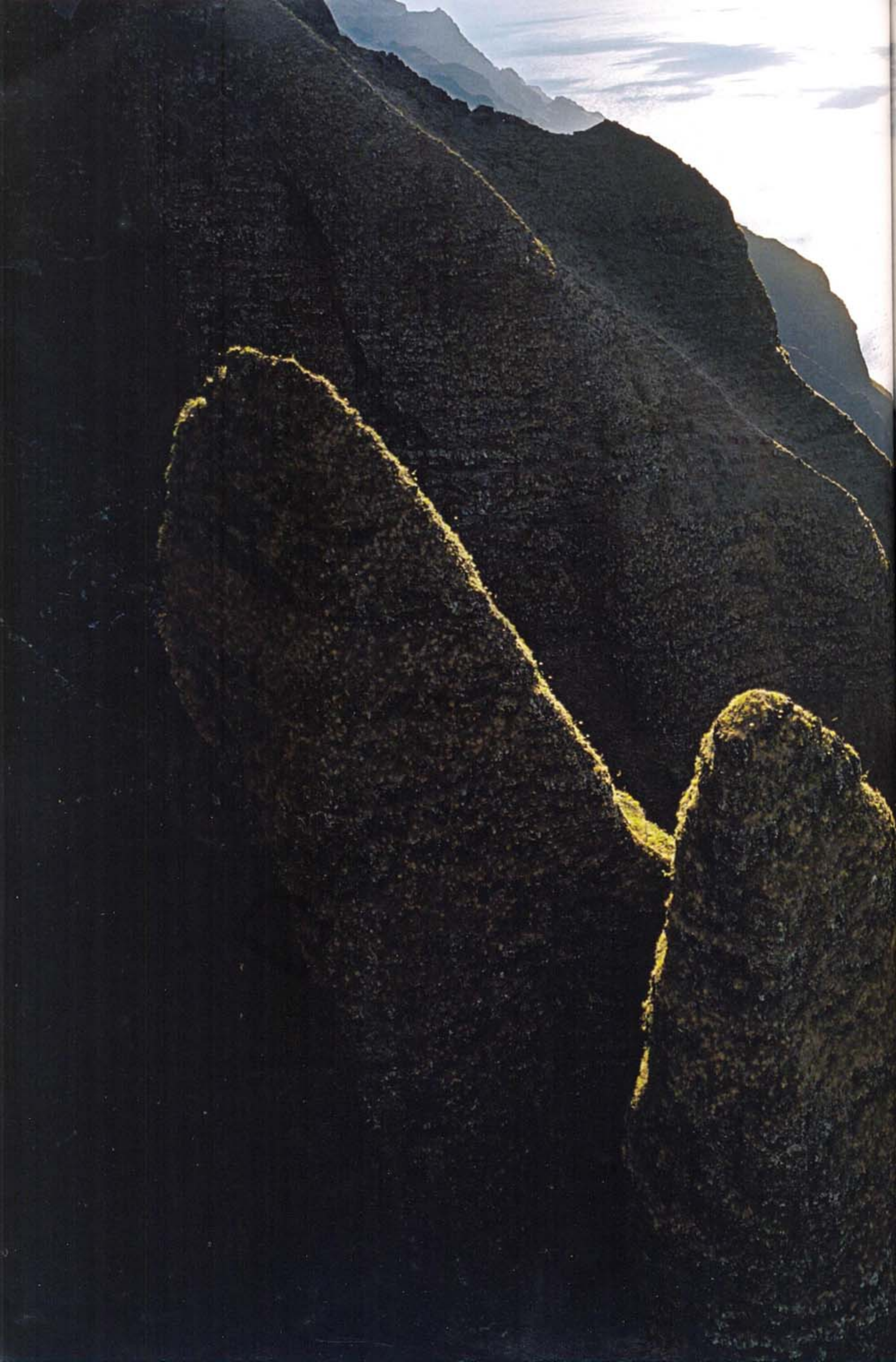
sites along the coast. "I have a board member who can't take Novocain," Kauka says. "So when he recently had a root canal, he just visualized himself here. I think his dentist was more nervous than he was."

Carpenter and Wichman take me to one of the platforms beneath the amphitheater of the cliff, and together we try to imagine the celebrations that occurred here centuries earlier. During *'awa* ceremonies—'awa, or kava, being the favorite ritual drink of Polynesia—high priests performed ritual sacrifices, hula dancers swayed to the beat of drums, and from the highest cliff, called Kamaile, young men hurled burning javelins like comets into the sea. These fireworks were so spectacular even King Kamehameha II made a special trip to view them.

Yet fireworks and celebrations were not enough to sustain these native Hawaiians. Perhaps they were cut down by Western diseases that ravaged the islands during the 1800s. Or maybe their traditional trading system no longer worked in the new money-based economy. No one knows for sure. But after more than 600 years of continuous habitation, the last permanent residents left the valley in the early 1900s for more populated parts of the island.

According to Carpenter, the parks archaeologist, Nu'alolo Kai is one of the more important archaeological sites on the islands. A decade of budget cuts, however, has created a maintenance backlog of 125 million dollars in the state's parks, making it tough to maintain even a picnic shelter and composting toilet at the site. Care of the area falls largely to volunteers and local watermen, with Carpenter and other archaeologists providing expertise and sharing in the sweat. It's tough work, clearing brush, rebuilding stone structures, and hauling trash. But for Sabra Kauka, it provides a personal connection to the landscape, one she hopes isn't lost on the many local students she brings here to help with the work.

"In Hawaiian there is a saying, *'Ma ka hana ka 'ike*—In the work is the knowledge,'" she says. "If you want to learn about this place, you



Razor-sharp ridges tower over the Pacific, inspiring legends of giant sculptors and children of the gods turned to stone. In reality, the basalt pillars are the fraying hem of the shield volcano that created Kaua'i, incised by more than a million years of nearly constant erosion.

have to take care of this place, and then it will reveal itself to you."

Her words echo in my ears a few days later as I slowly work my way across a crumbling pali (*nā pali* means "the cliffs" in Hawaiian) on the trail to the Kalalau Valley. Sweat falls in steady drops from my hat to the narrow trail, which wends a very fine line between a rock wall and a sheer 800-foot drop to the sparkling sea. Early Western visitors reported seeing Hawaiians running along these trails, sometimes two abreast. Today a parade of "flightseeing" helicopters buzz by like giant gnats.

Despite the difficulty of the trail, I pass several people coming and going, some of the half million visitors from all over the world who flock here each year. The ones I meet include some serious hikers, a few college kids in bathing suits and sandals, and one or two obvious "Kalalau outlaws"—bearded men in their 40s or 50s with ragged clothes and furtive looks. These modern-day hermits live in the remote valley, eluding occasional roundups to evict them.

With abundant water, rich soils, and plenty of papaya, coconut, and java plum trees, Kalalau has provided refuge for many outcasts over the years. In 1893 several Hawaiians with leprosy

AS I WATCH THE SUN MELT INTO THE SEA, A PASSING SHOWER UNCORKS A MAGNIFICENT RAINBOW. HOW COULD HUMANS TRASH SUCH A PARADISE?

moved their families to the valley to keep from being banished to the dreaded leper colony on Moloka'i. When the deputy sheriff of Waimea came to round up the sick ones, a well-known cowboy and crack shot named Ko'olau refused to go without his wife and son. The standoff lasted into the night, until shots rang out and the deputy fell dead. Hawaii's new provisional government, fresh from deposing Queen Lili'uokalani, feared an open revolt and sent the army after the cowboy. But Ko'olau evaded his pursuers in the cracks and crags of the valley, eventually dying there of his disease. "Ko'olau the Leper" became a modern folk hero of Hawaii.

Decades later another group of social outcasts sought peace in the valley—young hippies who spent years living off the land and communing with nature until eventually they were rousted

out by the law. At a bend in the trail I meet one hiker of that generation and ask him if he'd been to Kalalau. "I was there in the 1960s," he said with a warm smile. "It was pristine. Everybody ran around naked. But hey, it was the '60s!"

When I finally reach the magical valley with its folded cliffs and sinuous beach, the vibe is more frat party than nudist retreat. Dozens of campers, some apparently long-term, are scattered among the trees behind the beach. A group of college kids have a boombox blaring, and a woman with bright red hair is shaving her legs in the valley's famous waterfall. Bags of garbage, old coolers, and discarded tents are strewed about the campsites and sea caves, waiting for work crews to haul them out by helicopter—the greatest expense for the cash-strapped park.

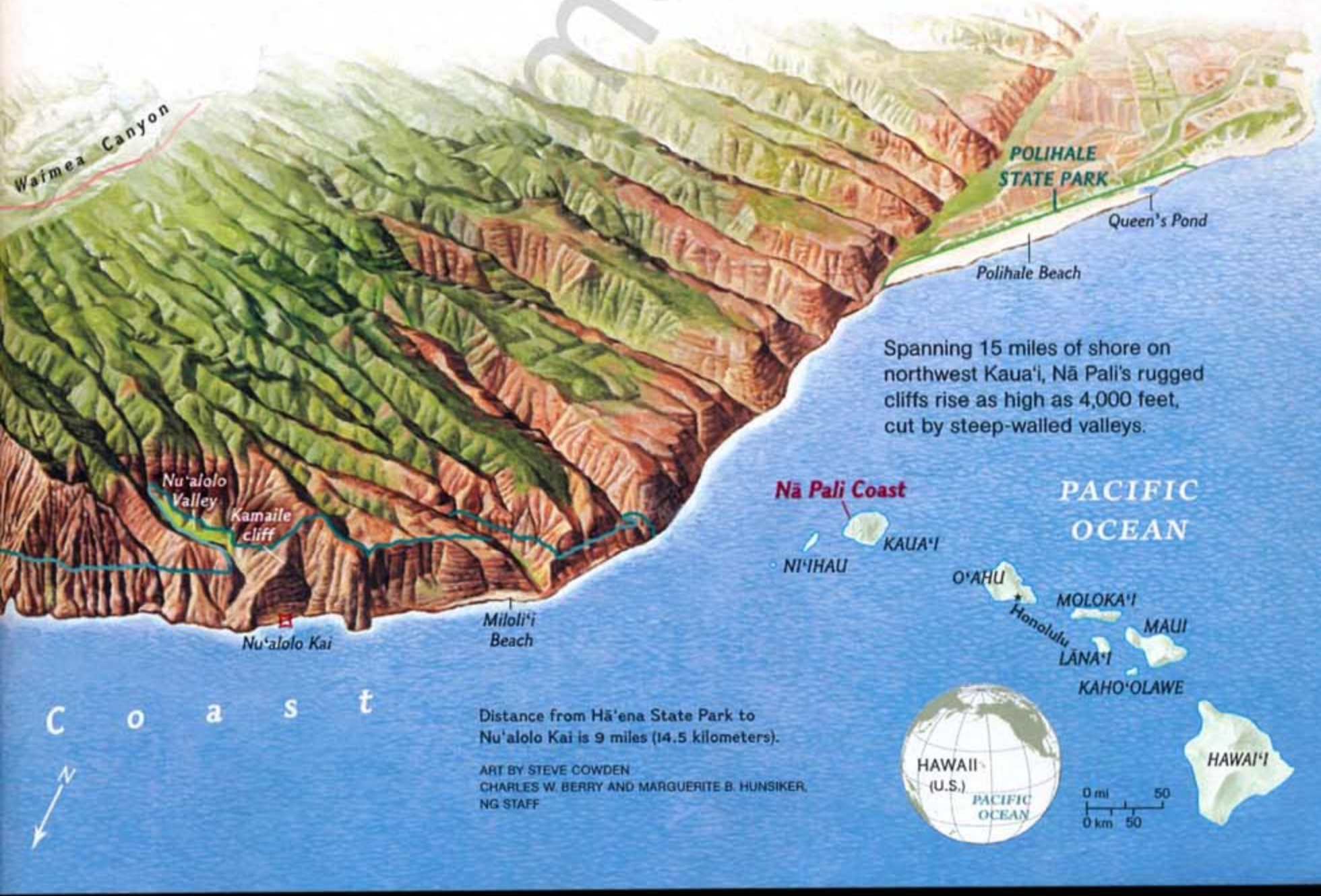
"The challenge of managing Kalalau is its isolation, which is also its attraction," state parks administrator Dan Quinn told me later. "If we'd get more people carrying out what they carry in, it would be a better experience for everyone."

As I watch the sun melt into the sea, a passing shower uncorks a magnificent rainbow. How could humans trash such an earthly paradise? The fictional Shangri-la, as portrayed in James Hilton's 1933 novel *Lost Horizon*, was inspired by the Buddhist concept of Shambhala, a mythical place of peace and tranquillity reached by enlightened beings. Maybe we aren't there yet.

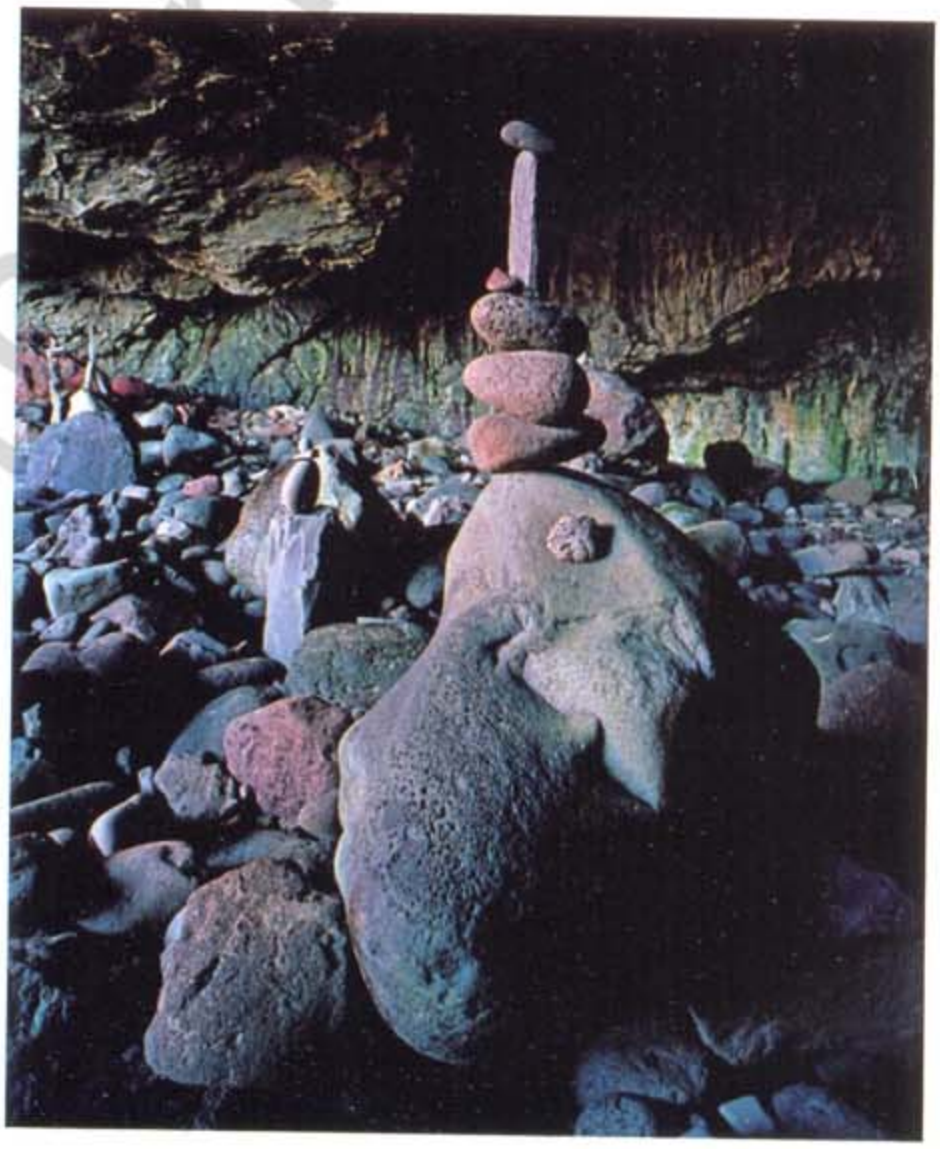
On my last day in Kalalau, however, I meet someone who seems well along the way. A young outlaw with a massive backpack bounds down the last stretch of trail as I'm starting the long climb out. He drops his burden at my feet, sprawls on the grass, and tells me his name is Eric. He's planning to stay for two months in a cave up the valley, foraging, meditating, and "getting centered" with the universe. "You go back up that valley and there are rock platforms, taro fields, sacred altars all the way up," he says. "It was a metropolis in there! It's the land of the menehune, the ancient ones. It's primal!"

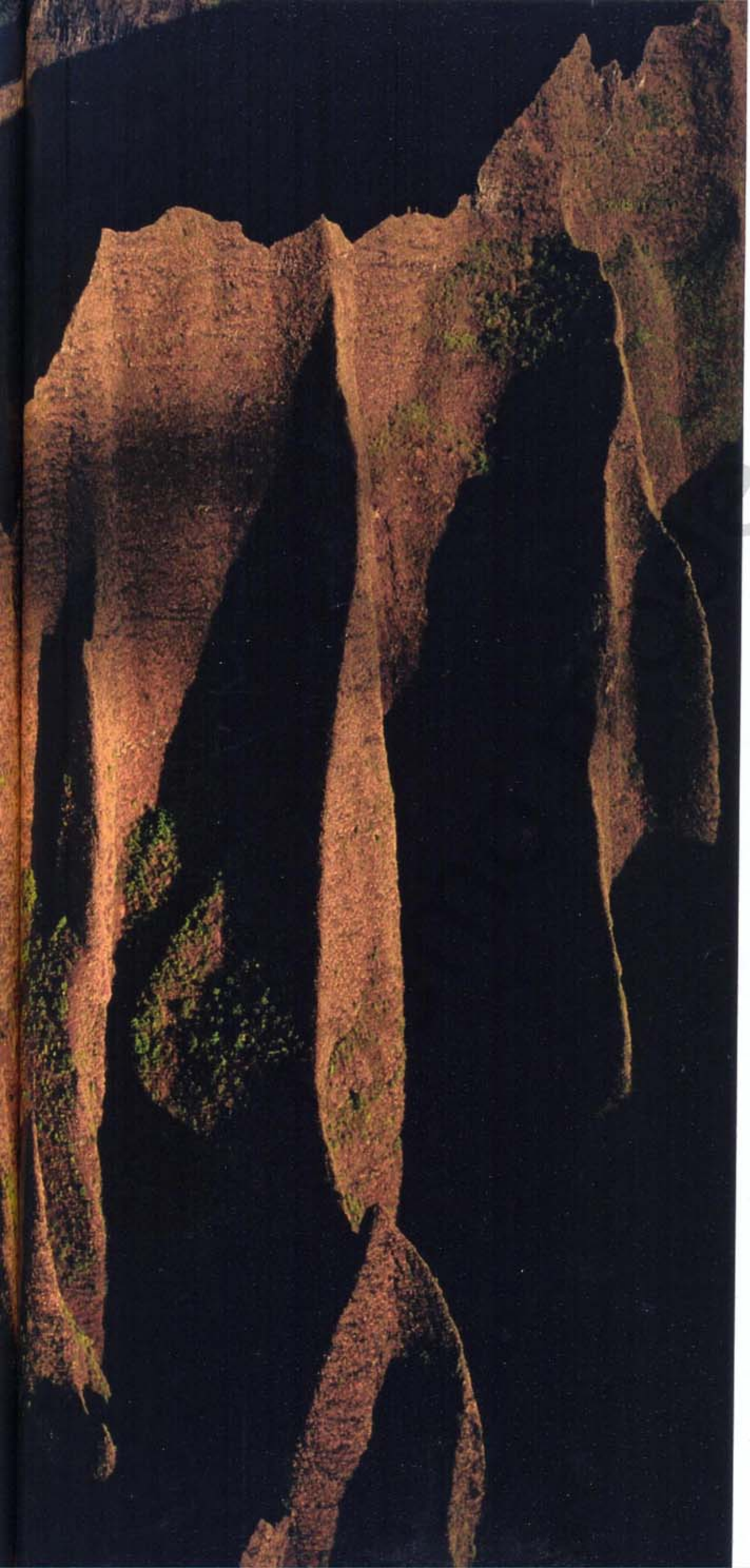
Eric is bright, articulate, and seems utterly at peace with himself and the world. We chat for a while, and then he picks up his 75-pound pack as if it were full of feathers and lopes down the trail, singing a joyful tune. "Enjoy your journey on planet Earth!" he shouts in parting. And for the rest of the day, I do.

Pacific Apertures Explore Nā Pali's magnificent beaches and vistas, and find out where the images were taken in an interactive map at **ngm.com.**

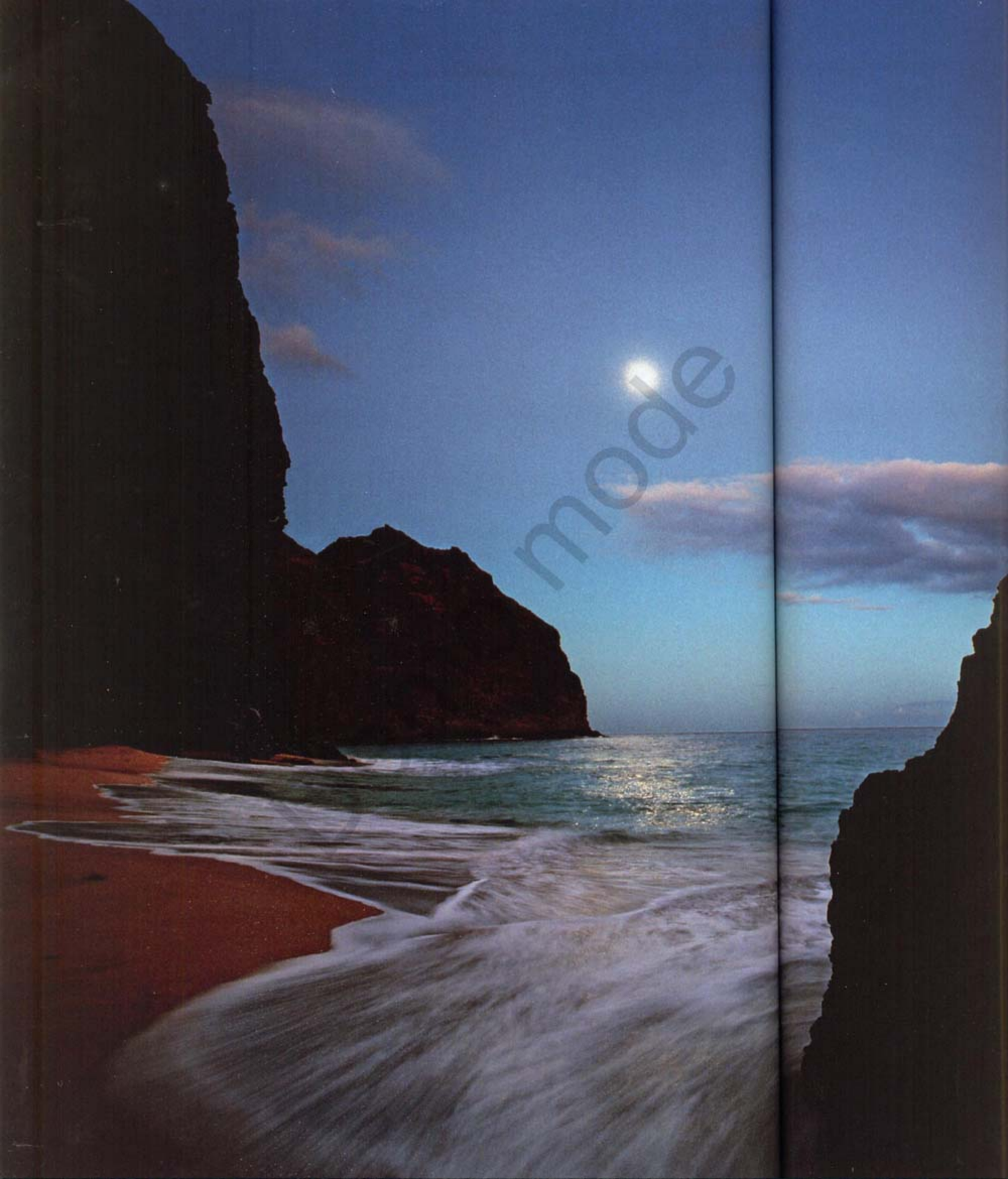


A banyan tree spreads its roots near a *heiau*, a sacred spot where early Hawaiians once made offerings. Many natural and cultural sites on Nā Pali Coast are threatened by non-native plants and misguided visitors. Some campers dismantle historic stone works to build fire rings, while others leave trash or traces of their visit, like the faux *ahu*, or altars (below) in a Kalalau sea cave.

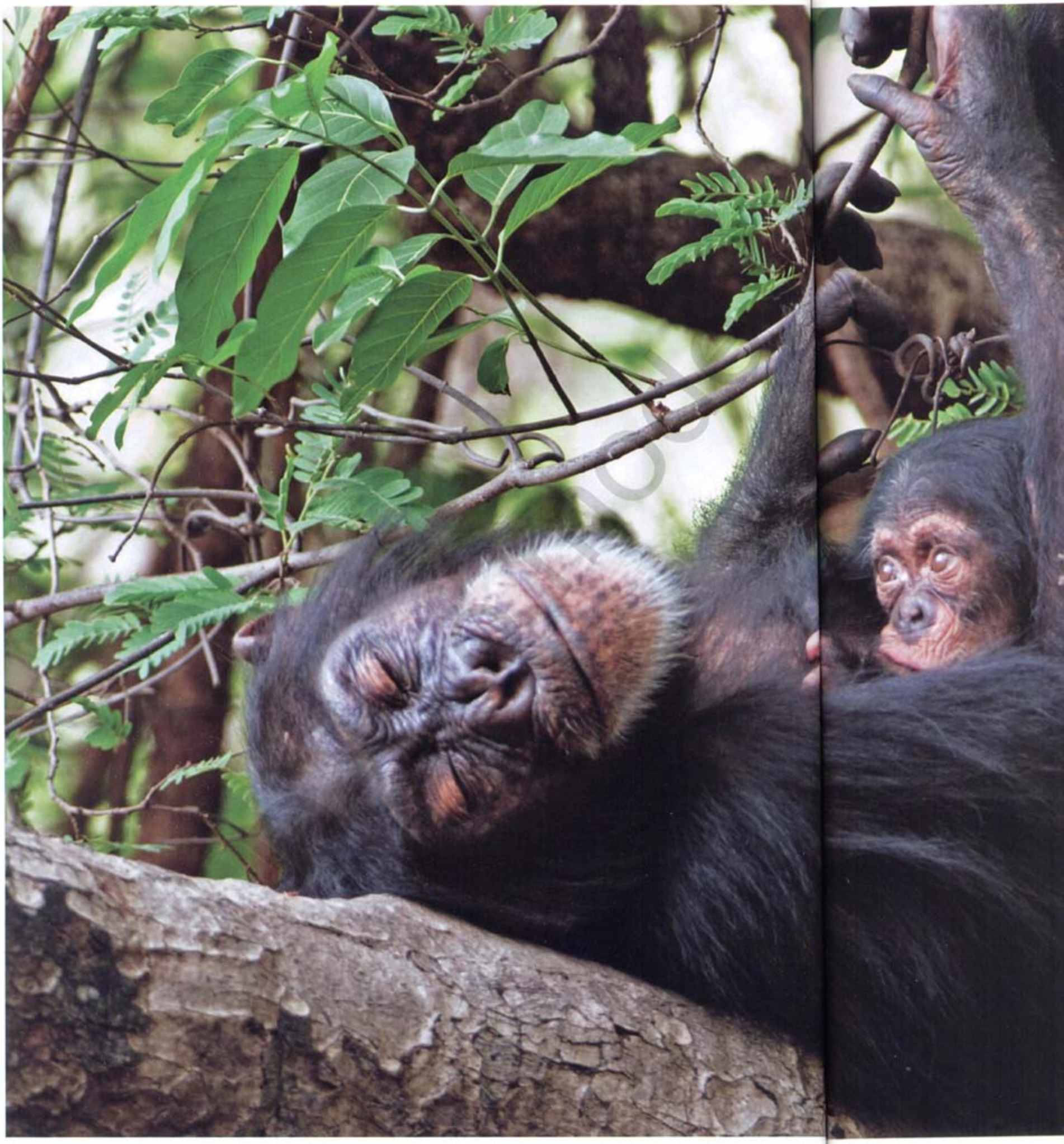




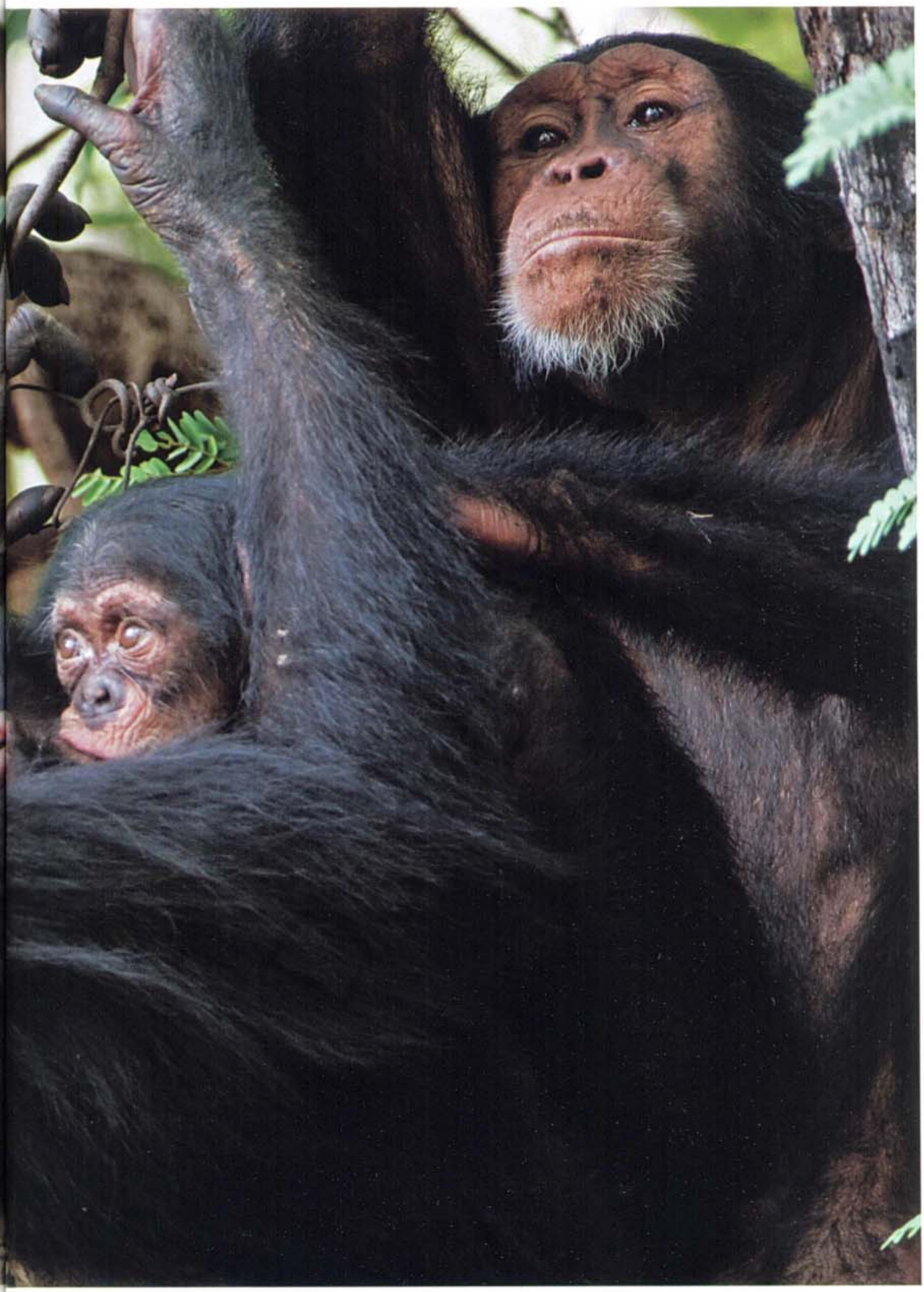
Sunset bathes the battlements of Kalalau, the largest valley on Nā Pali Coast. The famous fluted walls are the result of varying rates of weathering and erosion. The valley is accessible only by boat, when the seas are calm in summer, or by way of a dizzying 11-mile trail that hugs the cliffs.

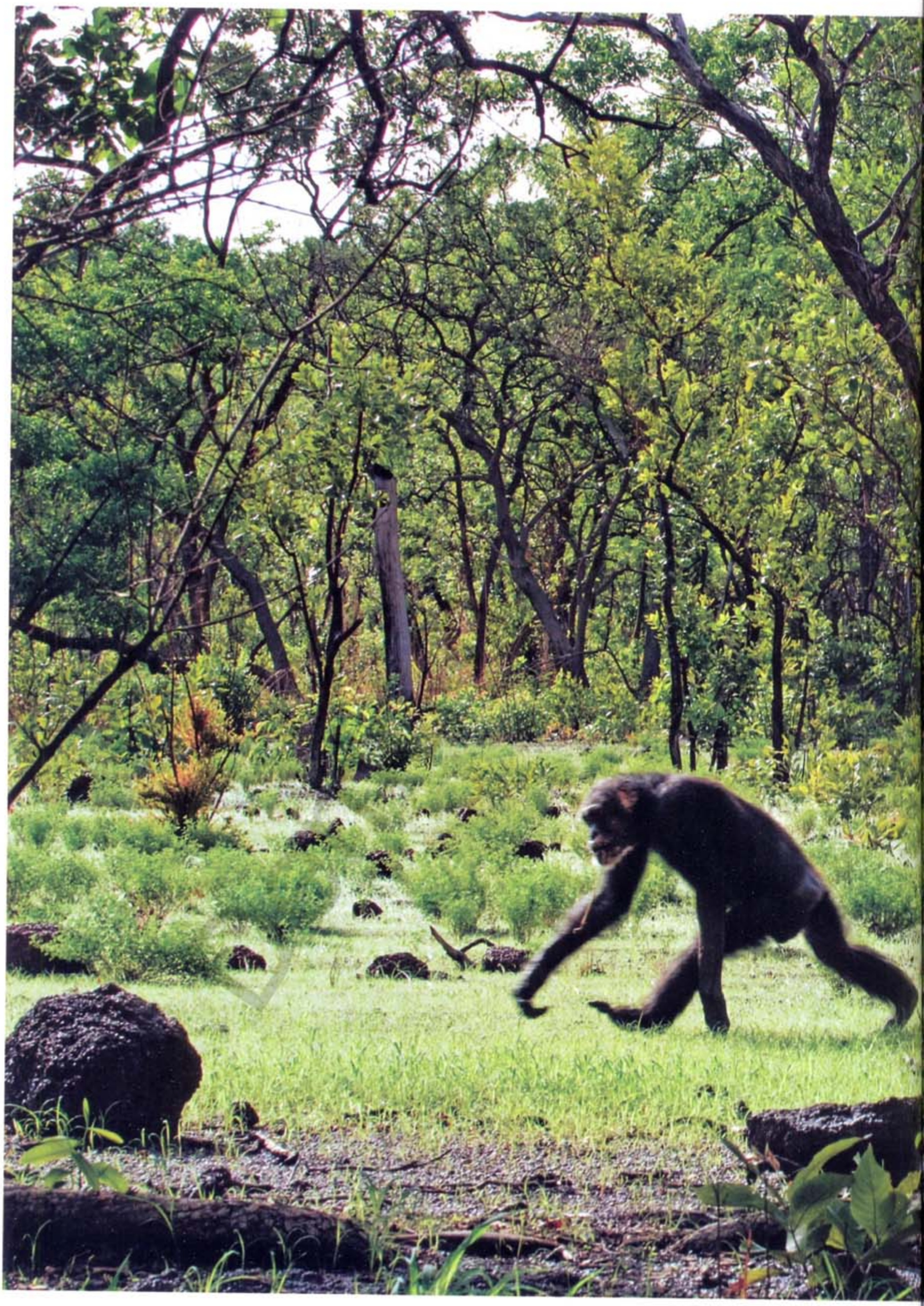


Just before setting, the moon silvers the waves washing Kalalau Beach. An old Hawaiian legend tells of Pele, goddess of fire, coming to this coast in search of a home, but she was driven away by a goddess of the sea. Their contest continues today, with the sea winning bit by bit. □



First-time mom Nickel reclines with her newborn, Teva, one of the newest members of the chimp group being studied at Fongoli. All the chimps clamored to groom the baby, but Nickel let Mike (at right), an orphan, get close. She avoided adult males, prone to noisy fits of branch shaking.





Savanna-woodland chimps, unlike their rain forest brethren, spend most of their waking time on the ground searching for food and water. Fongoli's mix of grassland, low trees, and a hot dry season mirrors the environment that eventually propelled early humans to hunt and use tools.

by **Mary Roach** *photographs by* **Frans Lanting**

DAYBREAK IS SUDDEN and swift, as though an unseen hand had simply reached out and raised a dimmer switch. Cued by the dawn, thirty-four chimpanzees awaken.

They are still in the nests they built the previous night, in trees at the edge of an open plateau.

A wild chimpanzee does not get out of bed quietly. Chimps wake up hollering. There are technical names for what I'm hearing—pant-hoots, pant-barks, screams, hoos—but to a newcomer's ear, it's just a crazy, exuberant, escalating racket. You can't listen without grinning.

These are not chimps you've seen in these pages before. They're savanna-woodland chimps, found in eastern Senegal and across the border in western Mali. Unlike their better-known rain forest kin, savanna-woodland chimps spend most of their day on the ground. There is no canopy here. The trees are low and grow sparsely. It's an environment very much like the open, scratchy terrain where early humans evolved. For this reason, chimpanzee communities like the Fongoli group—named for a stream that runs through its range—are uniquely valuable to scientists who study the origins of our species.

By 8 a.m. my chintzy key-chain thermometer says it's 90 degrees. Our shirts are marked by the same white salt lines that appear on people's boots in winter. Here it's salt from sweat. The plateau we're crossing is a terrain of nothing, of red rocks and skin cancer, with no trees to break the fall of equatorial sun. In our backpacks we each carry three liters of water. It was cool when we set out. By noon it will be hot enough to steep tea.

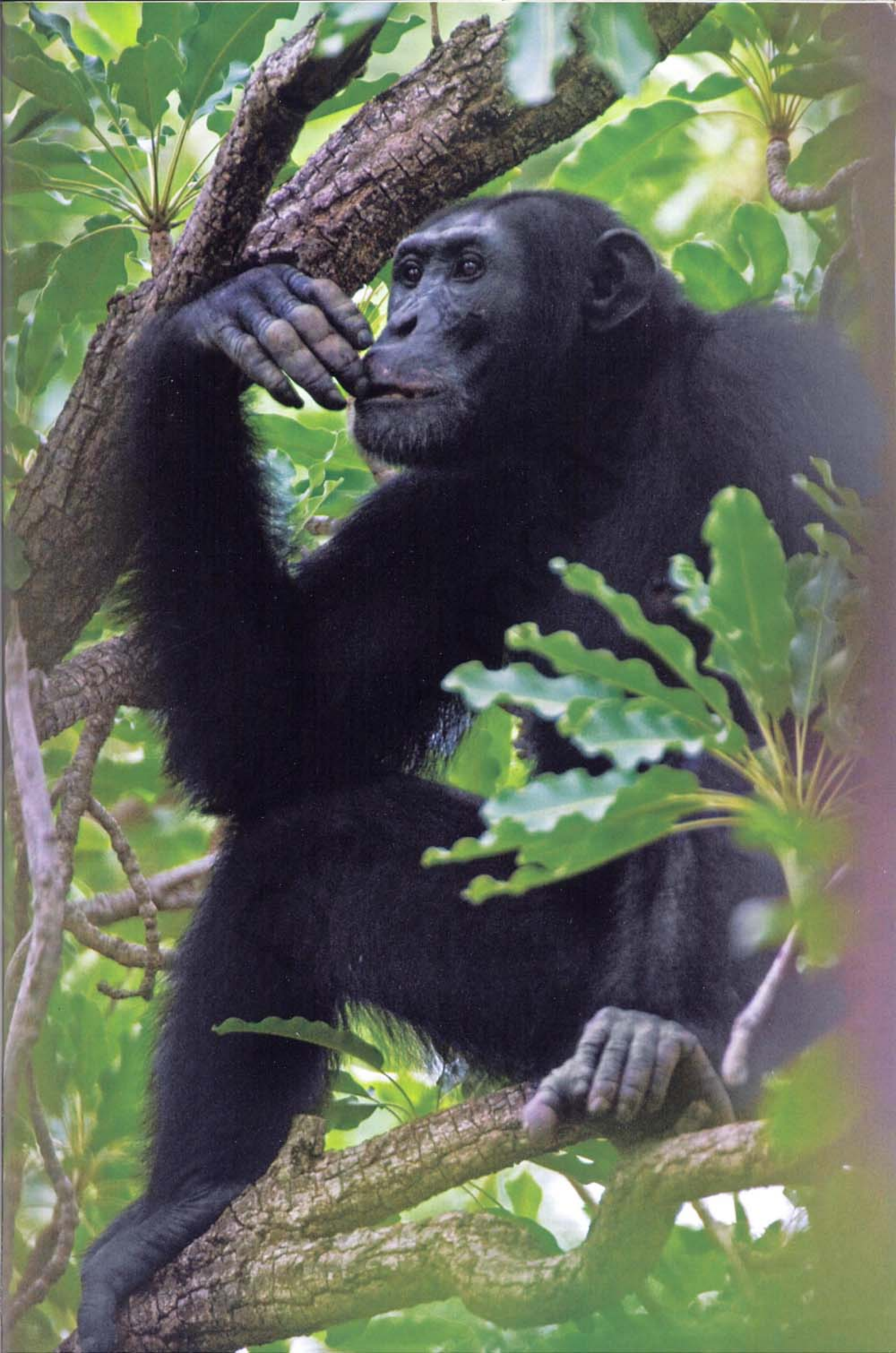
I'm not complaining. I'm making a point. Life on the savanna—even so-called mosaic savanna, tempered by patches of lusher gallery forest along the streambeds—is exceptionally harsh. If you are a primate used to greener terrain, you must adjust your behavior to survive. Our earliest hominin (meaning bipedal ape) ancestors evolved more than five million years ago during the Miocene, an epoch of extreme drying that saw the creation of vast tracts of grassland. Tropical primates on the perimeter of their range no longer had plentiful fruits and year-round streams and lakes. They were forced to adapt, to range farther in their search for food and water, to take advantage of other resources. In short, to get creative.

In 2007 Jill Pruetz, an anthropologist at Iowa State University, reported that a Fongoli female chimp named Tumbo was seen two years earlier, less than a mile from where we are right now, sharpening a branch with her teeth and wielding it like a spear. She used it to stab at a bush baby—a pocket-size, tree-dwelling nocturnal primate that springs from branch to branch like a grasshopper. Until that report, the regular making of tools for hunting and killing mammals had been considered uniquely human behavior. Over a span of 17 days at the start of the 2006 rainy season, Pruetz saw the chimps hunt bush babies 13 times. There were 18 sightings in 2007. It would appear the chimps are getting creative.

There are individuals who are uncomfortable with Pruetz's tales of spear-wielding chimps, and not all of them are bush babies. Harvard professor of biological anthropology Richard Wrangham, who has studied chimpanzee aggression in Uganda's Kibale National Park, has been skeptical. Wrangham is widely known for his "demonic male" theory, which holds that the savage murders carried out by male chimps while policing their turf are suggestive of a violent nature at the core of man. Primatologist Craig Stanford, author of *The Hunting Apes,* also downplays the importance of Pruetz's findings. "This behavior is fascinating, but the observations are so preliminary that it merits only a short note in a journal."

The report ran in the major journal *Current Biology,* and people seemed to find it interesting. In the week that followed, Pruetz's findings were featured in more than 300 news and science outlets, including *New Scientist,* the *New*

Plotting his move? Lupin, a large teenage male, seems to have alpha ambitions, but chimp politics require more than brute strength—winning friends is critical.



York Times, the *Washington Post,* and NPR's *Science Friday.* The Smithsonian Institution requested one of the spears. In short, it was the most widely talked about primatology news since the reports of infanticide and cannibalism at Jane Goodall's site at Gombe in the 1970s.

Pruetz and I watch the chimps climb from their nests. A large male hangs from a low branch by one arm, swinging gently, in no hurry. The silhouette is utterly erect, arrestingly humanoid. He lets go, drops to the ground, and moves off across the plateau. The symbolism is impossible to miss. Here is a chimpanzee, thought by many to be the closest thing we have to a living model of our early hominin ancestors, literally dropping from the trees and moving out into the open expanses of the savanna. It is as though we are watching time-lapse footage of human evolution, the dawn of man unfolding in our binoculars.

CHIMPS THAT LIVE on the ground, rather than in the safety of treetops, tend to be wary of large strangers.

Jill Pruetz spent four years getting the Fongoli chimpanzees accustomed to the presence of humans—what primatologists call habituating them—and the past three summers observing them. Six days a week, from dawn to dusk, she follows the chimps.

It is not glamorous work. It's hot and filthy and exhausting. Home is a mud-walled hut and a drop toilet shared with 30 Fongoli villagers. Dinner is peanut sauce over rice, except when it's peanut sauce over millet. If the chimps wander unusually far, Pruetz gets back to the village so late that her portion has long ago been fed to the dogs. Sometimes, rather than hike the five miles back to camp, she curls up and sleeps on the ground (or takes a nap in an abandoned chimp nest). She has gotten malaria seven times.

Mary Roach is the author of Stiff *and* Bonk: The Curious Coupling of Science and Sex, *due out this month. Frans Lanting is a wildlife photographer whose most recent book is* Life: A Journey Through Time.

Yet you rarely meet people who love what they do as much as Pruetz does. Right now she is sitting on the ground, jotting notes with one hand and slapping sweat bees with the other. Blood from a blister has soaked through the heel of her sock. To listen to Pruetz, we might as well be in Paris. "Sometimes," she says, scratching a bite, "I think I'm going to wake up and it's all a dream." The payoffs have been dramatic. In addition to using tools to hunt, Fongoli chimps have been exhibiting some other novel behaviors: soaking in a water hole, passing the afternoon in caves.

At 24 square miles, Fongoli is the largest home range of any habituated chimpanzee group ever studied. (Jane Goodall's Gombe chimps, by comparison, roam over five square miles.) Craig Stanford likens foraging over a large range to knowing one's way around an enormous supermarket. Like Pruetz, he believes the chimpanzees are not foraging at random, but moving with foresight and intent. "You don't stroll down the aisles hoping to catch a glimpse of the broccoli. You know where each item is, and in which months seasonal foods are likely to be in stock." The same, he thinks, holds true for chimpanzees.

"Ecological intelligence" is the name of the theory that some primates, including those of our lineage, have evolved larger, more complex brains because it helped them adapt to the challenges of surviving in a less giving habitat. "The first push toward a larger brain," writes Stanford, "may have been the result of a patchily distributed, high-quality diet and the cognitive mapping capabilities that accompanied it."

High-quality, meaning: meat. The shift toward eating more meat may have played an important role in the evolution of a larger, more sophisticated brain. Here's how the thinking goes. Brains are, to use terminology coined by researchers Leslie Aiello and Peter Wheeler, "expensive tissue." To keep a bigger brain functioning, some other organ or system needed to become more streamlined. A chimp doesn't have to eat nearly as much of an energy-rich food like meat as he would of low-nutrient plant matter. Expending less energy on digestion means you can afford to apply it

elsewhere, perhaps to power an expanded brain.

As if on cue, a female named Tia appears in our sight lines 20 feet ahead, sitting on a boulder pulling raw flesh off a limb like a picnicker with a comically huge drumstick. Pruetz raises her binoculars, then lowers them again. "Holy crap! It's a bushbuck." She can tell from the white markings on the hide, a long strip of which hangs from the leg. "That's the biggest animal I've seen them eat." She surmises it was a fawn. Gombe chimps have occasionally killed bushbuck fawns as well. They are the largest prey on record for a chimpanzee.

Hunting at Fongoli coincides with the rainy season, and Pruetz has some theories about why this is. As water holes fill and shoots and other greenery become more plentiful with the rain, the land provides enough sustenance to support a sizable group of chimps on the move. There are advantages to traveling in a large group. A single chimp or small group that heads out on its own can easily lose track of the community for days at a time. For a chimp, sociability is important. Pruetz points to an estrous female named Sissy, her pink swelling bobbing behind her like a bustle. "Otherwise you miss out on that." She means, of course, the chance to mate, to pass along your genetic material.

Right now, two rains into the rainy season, there's enough water and food for the group to travel together, but just barely. Pruetz believes it is this scenario—large crowd competing for limited resources—that has pushed certain members of the community to try their hand at novel things.

Things like sharpening sticks to spear bush babies. It is a different kind of hunting than the organized colobus monkey raids documented at other sites. A chimp who comes across a dead, hollow tree limb—promising real estate for day-sleeping bush babies—will sometimes break off a branch from a nearby tree, remove the leaves and the flimsy ends, and then use its teeth to whittle one end to a point. This tool is then stabbed into an opening in the tree limb until the animal inside is out of commission. Whereupon it is eaten, head first, Pruetz says, "like a Popsicle."

Adult female and juvenile chimps—the low rankers—have been seen hunting bush babies most often. This makes sense. Dominant males are not generous with food they find, and no one can force them to share. Fongoli females appear to have taken matters into their own hands.

Now here comes Farafa, her baby Fanta on her back and a bushbuck haunch in her jaws. It's a complicated, messy piece of anatomy, with sinew and hide hanging off one end. Tia sees her and stands up to move away. My last glimpse of Tia is with her now bare bone brandished above her head, standing erect, as though reenacting the "dawn of man" scene from *2001: A Space Odyssey*. Fongoli chimps have a flair for the dramatic.

THE MEDIA RUCKUS spurred by Pruetz's report of spear-wielding chimps made her absence as a speaker at last year's Mind of the Chimpanzee conference perplexing. She was in the audience but wasn't invited to present a paper. On top of that, Pruetz's postdoc adviser, Cambridge University primatologist William McGrew, made a passing reference to the Fongoli hunting behaviors but did not credit her with the work. He credited her coauthor and former student Paco Bertolani, now a student of McGrew's. Bertolani witnessed the first—of now 40—observed instances of the behavior, but scientific etiquette would call for the principal investigator to be mentioned. McGrew apologized afterward. Some primatologists took Pruetz to task for overstating the bush-baby-spearing behavior. When your prey is smaller than your hand, are you really hunting? Male primatologists tend to make the distinction along gender lines: The traditional view has been that chimpanzee hunting—along with aggression and murder—is the domain of the male. "Small mammals that females and juveniles obtain are 'gathered,'" Pruetz says, "while males 'hunt.'" Females, the thinking goes, don't hunt because they don't need to; male chimps are thought by some to trade meat

Primatologist Jill Pruetz holds one of the first known "spears" used by a chimp. She made headlines with her report of chimps hunting bush babies by jamming modified sticks into tree-hole burrows (right). The technique appears to be used most often by females and the young, which may engineer new foraging methods when food is scarce and males refuse to share.

for sex, but Pruetz hasn't seen this at Fongoli.

I'm going to weigh in, for what it's worth. One day while accompanying Pruetz, I watched a young chimp named David at a bush baby tree hole. We heard him well before we saw him: a resounding *THONK* that caused Pruetz to stop in her tracks and go, "Hold on, hold the phone, that sounds like a spear!" We looked around, and there he was, standing on a branch in a kino tree, holding on with one hand and waving a thick, three-foot-long stick over his head. He slammed it down into the hole, then examined the tip. Concluding that no one was home, he took off, leaving the spear protruding from the hole. The violence and foresight with which he undertook his task did not suggest an animal quietly foraging. His aim was unmistakable: to kill, or at least incapacitate, whatever was in there.

Many of Pruetz's reviewers tripped over the word spear. For one thing, it suggests a projectile and a more Cro-Magnon-esque technique: something aimed and thrown. (Pruetz says she had spearfishing in mind when she chose the noun.) Stanford suggested bludgeon. But bludgeons are blunt, not sharpened. Another offered dagger. Someone else wanted bayonet. In the end, Pruetz took spear out of the title and worded her text more cautiously, making reference to a tool "used in the manner of a spear." (The press picked up on it anyway. "Spear-Wielding Chimps Snack on Skewered Bushbabies" ran the giddy *NewScientist.com* headline.)

I asked Pruetz if perhaps she's been the victim of an alpha male primatologist conspiracy. She laughed it off. "Yeah, maybe I'm not pant-grunting enough." (The pant-grunt is an expression of submissiveness; a chimp that encounters a higher ranked peer and fails to pant-grunt is asking for trouble.) It's also possible that humans are simply resistant to the notion that anyone other than a human makes weapons for killing.

You would think that primatologists, more than other scientists, would be comfortable with the shifting boundaries between chimpanzee and human. Their gene sequences are around 95 to 98 percent the same. (This is less meaningful than it sounds. Humans share more than 80 percent of their gene sequence with mice, and maybe 40 percent with lettuce.) A recent exploration of the human and chimpanzee genomes, undertaken by David Reich and colleagues at

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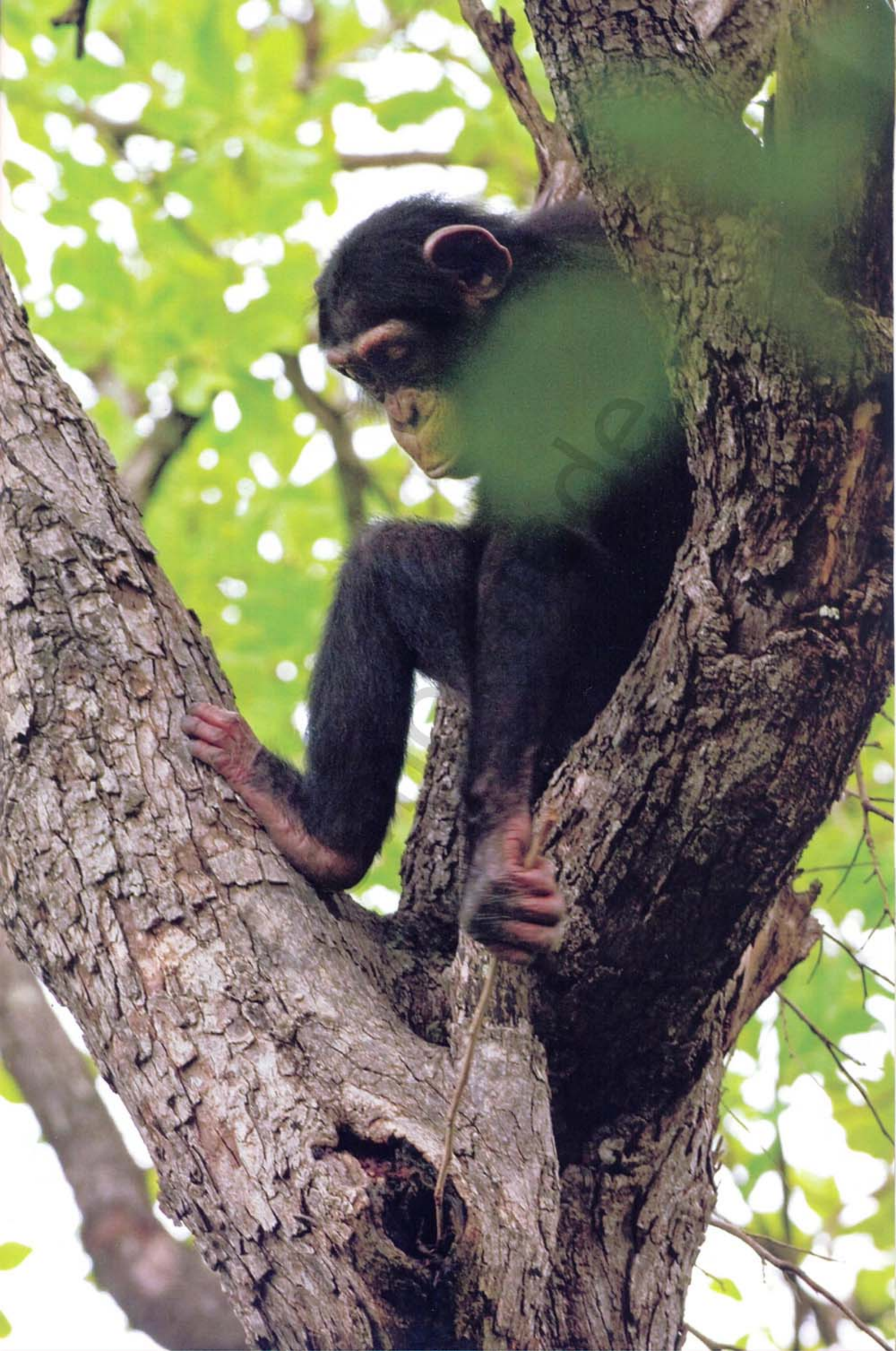


CHIMP CULTURES

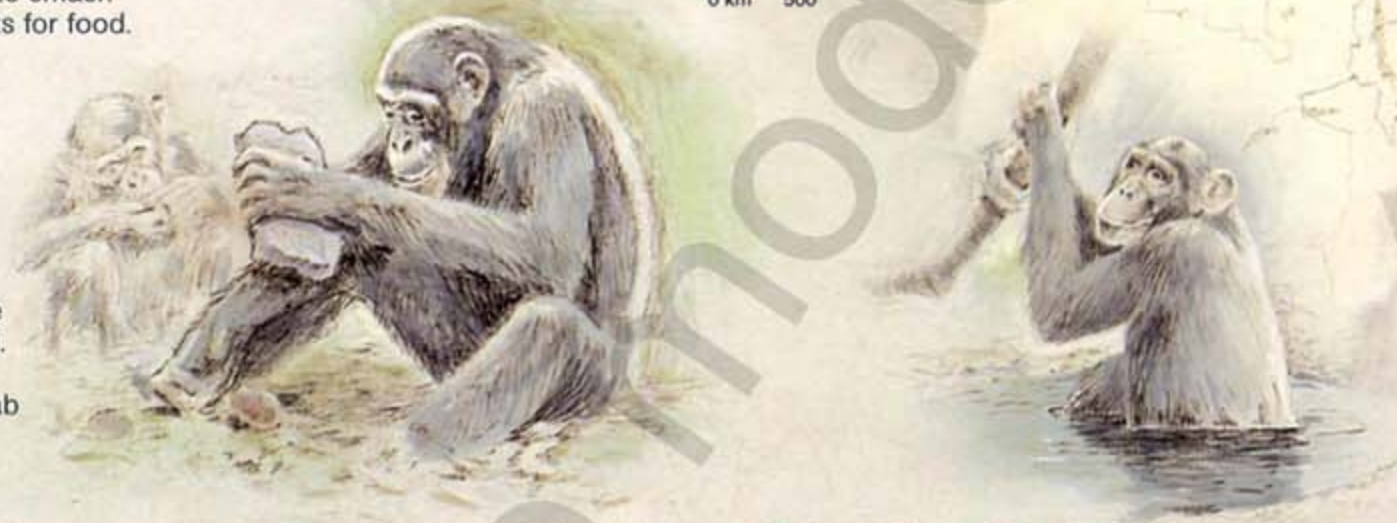
Just as humans use chopsticks in one culture and forks in another, scientists now realize that chimpanzees also develop different cultural practices depending on where they live. Chimpanzees in ten well-studied sub-Saharan communities have devised the following variations on common behaviors.

► Use of hammer and/or anvil

Chimps use rocks to smash open nuts and fruits for food.

WHERE
- Fongoli
- Assirik
- Bossou
- Gombe
- Taï

VARIATION
Taï chimps also use wood to crack nuts. Fongoli and Assirik chimps slam baobab fruit against rocks.



▼ Leaf sponge

Chimps chew leaves into spongy wads to soak up water for drinking.

WHERE
All sites except Mahale–K

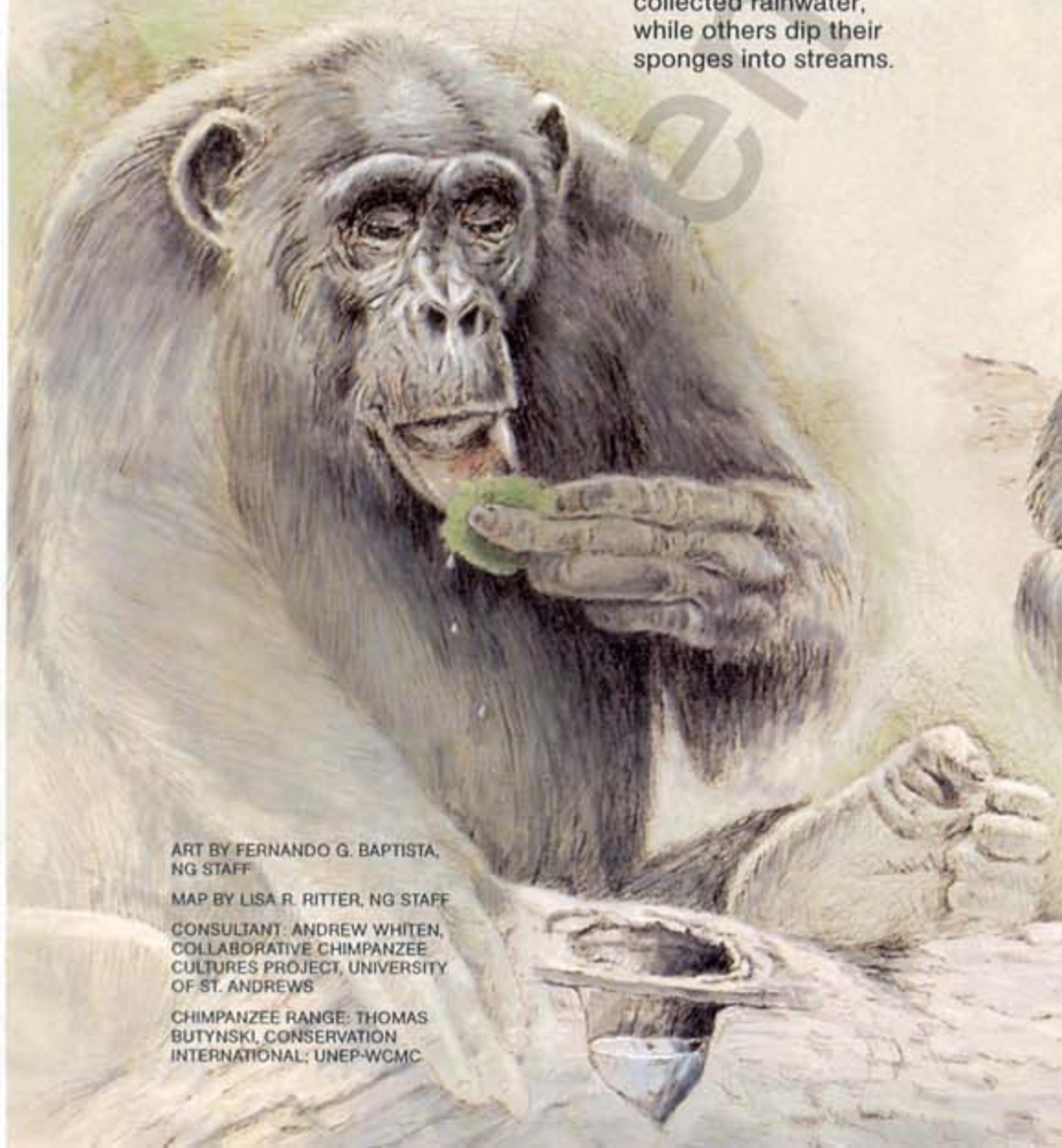
VARIATION
Chimps in some groups poke leaf sponges into tree holes to absorb collected rainwater, while others dip their sponges into streams.

▲ Going into water

Chimps in most communities avoid major contact with water, but three groups enter streams or pools.

WHERE
- Fongoli
- Bossou
- Mahale–M

VARIATION
At Fongoli chimps sit in waist-high water or lie in shallow pools. Bossou chimps wade but don't sit down. Mahale chimps display by splashing.



▲ Termite fishing

Chimps often use twigs, grass, or vines to fish termites from mounds.

WHERE
- Fongoli
- Gombe
- Goualougo
- Mahale–K

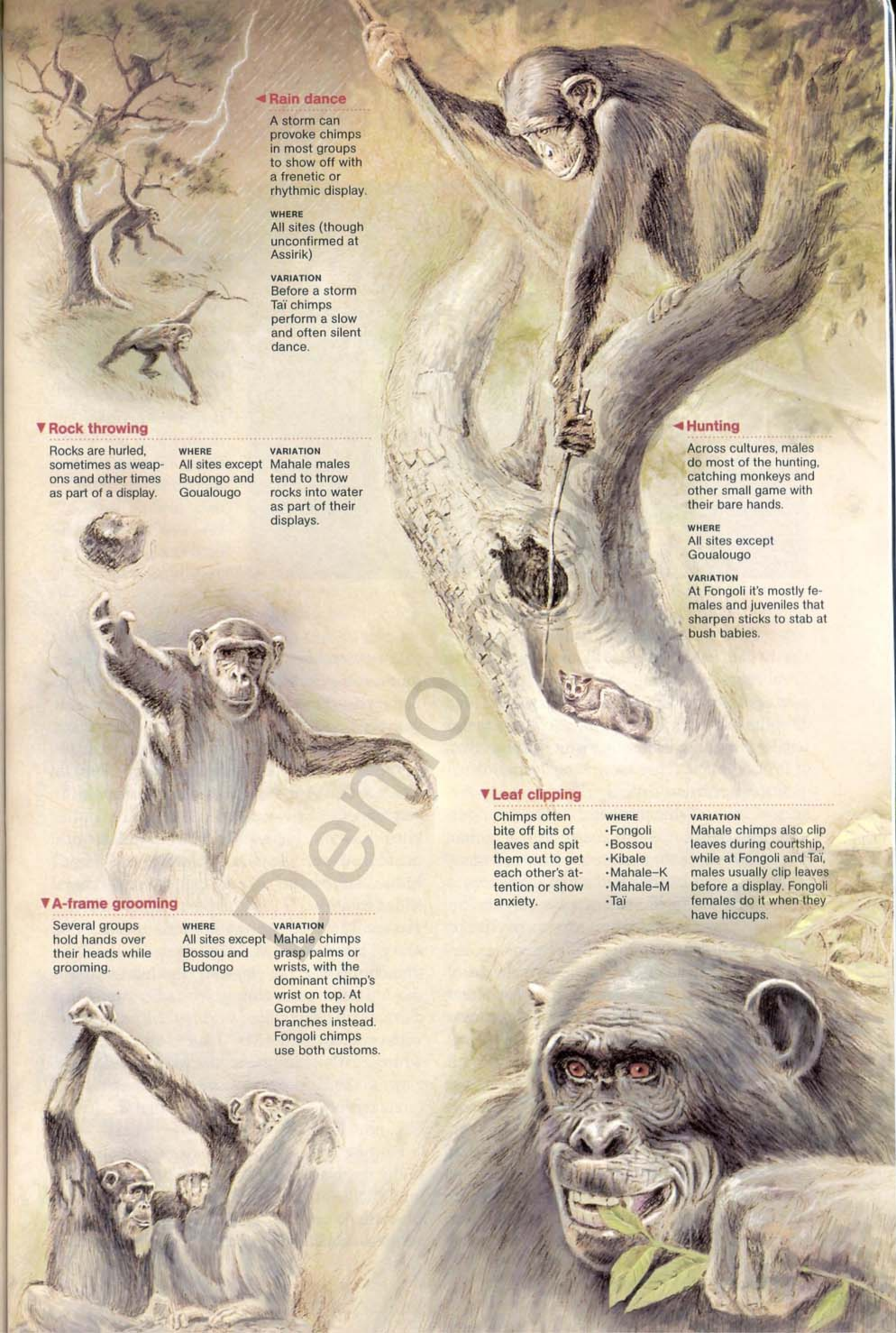
VARIATION
Apes get larger helpings of termites at Fongoli and Goualougo by first fraying the end of their fishing tools to create more surface space to snag the bugs.

ART BY FERNANDO G. BAPTISTA, NG STAFF

MAP BY LISA R. RITTER, NG STAFF

CONSULTANT: ANDREW WHITEN, COLLABORATIVE CHIMPANZEE CULTURES PROJECT, UNIVERSITY OF ST. ANDREWS

CHIMPANZEE RANGE: THOMAS BUTYNSKI, CONSERVATION INTERNATIONAL; UNEP-WCMC



◀ Rain dance

A storm can provoke chimps in most groups to show off with a frenetic or rhythmic display.

WHERE
All sites (though unconfirmed at Assirik)

VARIATION
Before a storm Taï chimps perform a slow and often silent dance.

▼ Rock throwing

Rocks are hurled, sometimes as weapons and other times as part of a display.

WHERE
All sites except Budongo and Goualougo

VARIATION
Mahale males tend to throw rocks into water as part of their displays.

◀ Hunting

Across cultures, males do most of the hunting, catching monkeys and other small game with their bare hands.

WHERE
All sites except Goualougo

VARIATION
At Fongoli it's mostly females and juveniles that sharpen sticks to stab at bush babies.

▼ Leaf clipping

Chimps often bite off bits of leaves and spit them out to get each other's attention or show anxiety.

WHERE
- Fongoli
- Bossou
- Kibale
- Mahale–K
- Mahale–M
- Taï

VARIATION
Mahale chimps also clip leaves during courtship, while at Fongoli and Taï, males usually clip leaves before a display. Fongoli females do it when they have hiccups.

▼ A-frame grooming

Several groups hold hands over their heads while grooming.

WHERE
All sites except Bossou and Budongo

VARIATION
Mahale chimps grasp palms or wrists, with the dominant chimp's wrist on top. At Gombe they hold branches instead. Fongoli chimps use both customs.

The only infant born in the Fongoli group last spring, Teva is the first baby scientists were able to track within a week or two of her birth. Closely monitoring her development will provide valuable insights into how chimps pass on behaviors. "Her mother is one of the most prolific hunters," says Pruetz. "It will be interesting to see if Teva picks it up."

the Broad Institute of MIT and Harvard in Cambridge, Massachusetts, suggests that chimpanzees and early hominins may have interbred after the two lines initially split. Yet there seems to be a lingering discomfort with findings that, as Pruetz puts it, "chip away at our superiority."

Since the earliest days of primatology, discoveries of chimp behavior that threaten to undermine the specialness—the apartness—of human beings have met with rancorous resistance. Many anthropologists bristled at the first references to chimpanzee "culture"—a concept widely accepted today. Jane Goodall's first reports of chimps making tools (for termite fishing) were as contentious in their day as more recent claims of teaching chimps to use language. At the Great Ape Trust, in Des Moines, Iowa, a bonobo named Kanzi has learned to communicate through symbols. Kanzi commands about 380 symbols and shows signs of understanding their meaning. When he was frightened by a beaver, an animal for which he had no symbol, he selected the symbols for "water" and "gorilla" (an animal that scares him). Critics say the communications are purely conditioned behavior. Novel uses of symbols—e.g., "water gorilla"—are dismissed as coincidence.

An exception to these attitudes has long been found at the Primate Research Institute at Kyoto University. Japanese primatology is consistent with the Buddhist precept that humans are a part of the natural world, not above or separate from it. At the Mind of the Chimpanzee conference in Chicago last year, Tetsuro Matsuzawa spoke of primatology's early years, when scientists "didn't know how much close we are." He added, with unabashed awe: "So close, like horse and zebra." In the background of one Japanese researcher's slides was what looked to be a chimp wearing glasses. I turned to the man next to me. "I'm sorry," I said. "I must be losing my mind. Was that chimp wearing glasses?" The man told me the Japanese primatologists had noticed the chimp was nearsighted and had him outfitted with prescription lenses. (I later learned he was wrong: This chimp was just playing with the glasses. There once was a research chimp whose caretakers ordered her glasses, but that was in the U.S., not Japan.)

No one around Fongoli is sending chimps to the optician, but the animals are accorded a remarkable amount of respect by locals. Kerri Clavette, Pruetz's intern, interviewed villagers about their beliefs regarding chimpanzees and

whether they hunted them. Among the region's main tribes—the Malinke, Bedik, Bassari, and Jahanka—chimps, compared with monkeys, have an elevated, almost human status. "Chimpanzees came from man, as they have similar hearts," a villager told Clavette. Behaviors normally associated with a baser nature—such as walking on all fours—were given a respectful spin: "Chimpanzees walk on their knuckles to keep their hands clean to eat with." Chimpanzee origin myths feature humans running off into the woods for some reason—war, fear of circumcision, fear of being punished for fishing on Saturday—and staying there so long that they turn into chimpanzees.

Despite a local history of killing chimpanzees for medicinal reasons—the meat laid on a person's arm or eaten for strength, the brains prepared with couscous to treat mental illness—villagers rarely hunt chimpanzees in eastern Senegal today. Sadly, the taboo against eating one's almost kin has broken down in central Africa, where turmoil has worsened dire economic circumstances and chimps are sold as bush meat.

Attitudes in the West have been shifting gradually over the past few decades. The sequencing of the chimp genome, completed in 2005, has focused attention anew. New Zealand, the Netherlands, Sweden, and the United Kingdom have all passed legislation limiting experimentation on great apes, and the Balearic Islands in Spain passed a resolution in 2007 granting them basic legal rights. In 2006 an Austrian animal rights organization submitted an application to a district court in Mödling to appoint a legal guardian for a chimp named Hiasl. The strategy was to establish "legal person" status for the hairy defendant. (The judge was sympathetic but refused.) It is perhaps less problematic to view the situation as does *The Third Chimpanzee* author Jared Diamond: not that chimps are a kind of human, but that humans are a kind of chimp.

THE CHIMP NAMED SISSY sits motionless and hunched at a low termite mound twenty feet from us.

Only her right arm moves, pushing a saba vine probe into a hole and gently withdrawing it, with termites clinging to it. She raises it carefully to her mouth like a pensioner spooning soup. The mound is across an open lay of pebbly, brick-colored laterite that gives the ground the look of a clay tennis court.

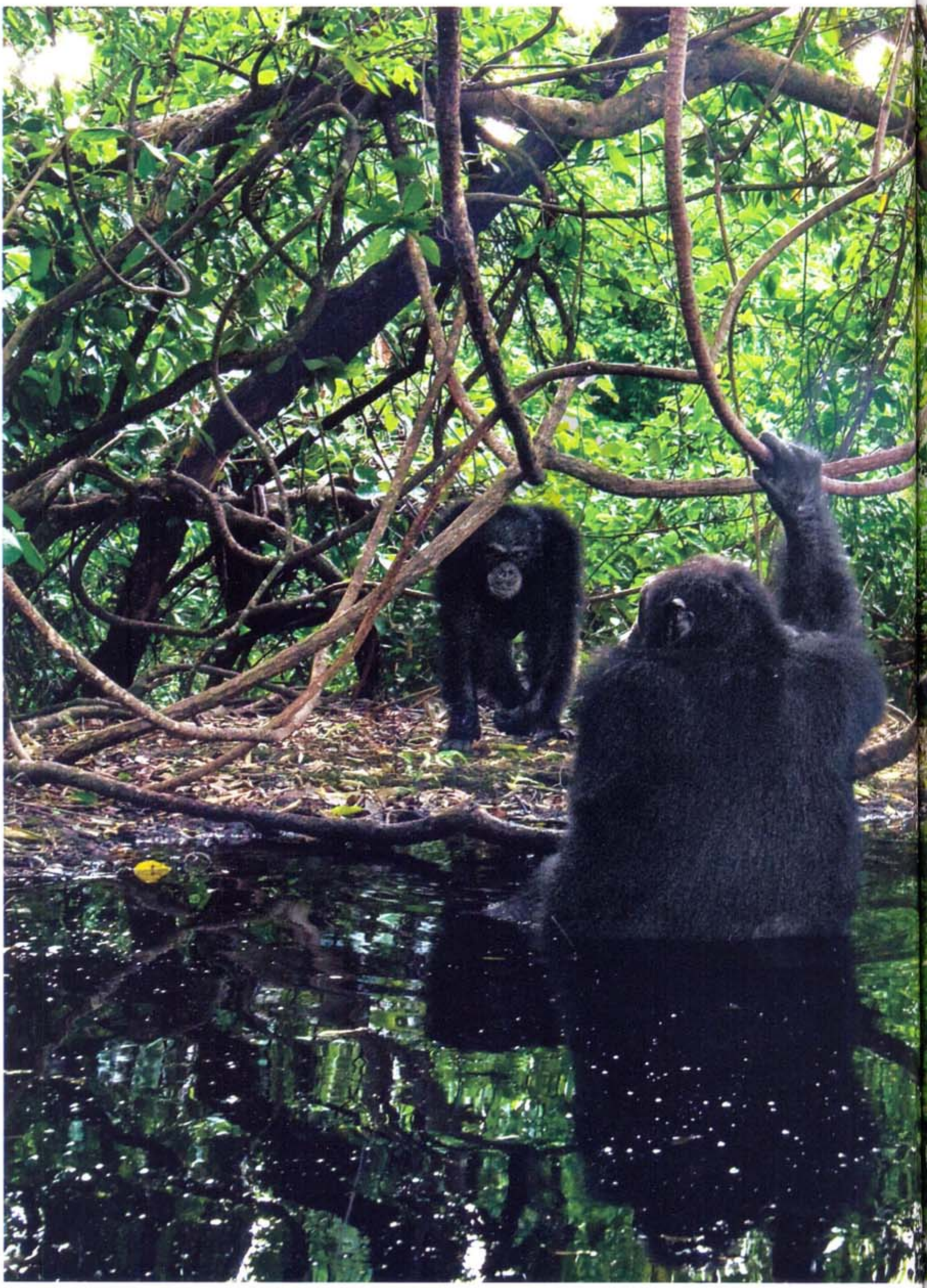
Like fly-fishing, termite fishing is a meditative, deceptively nuanced activity. I tried it a few times and could not even find an active hole. My probe never sinks farther than an inch or so; the chimps regularly bury theirs a foot or more. They can find active holes by smell, inserting a probe and then sniffing the end of it for the smell of soldier termite pheromone.

Fongoli chimps eat termites year-round, not just in the dry season, when other foods are scarce. Termites make up, at bare minimum, 6 percent of the Fongoli chimps' diet. We know this because most evenings at six o'clock research assistant Sally Macdonald sits down with a set of sieves and buckets, and one or two ziplock bags of the chimp feces that the researchers bring back most days. She scans the fruit seeds, estimates the percentage of fiber from leaves and shoots, and takes note of bones and termite pincers. "Science in all its glamour," deadpans Macdonald, whose mother sends ziplock bags but does not know their fate.

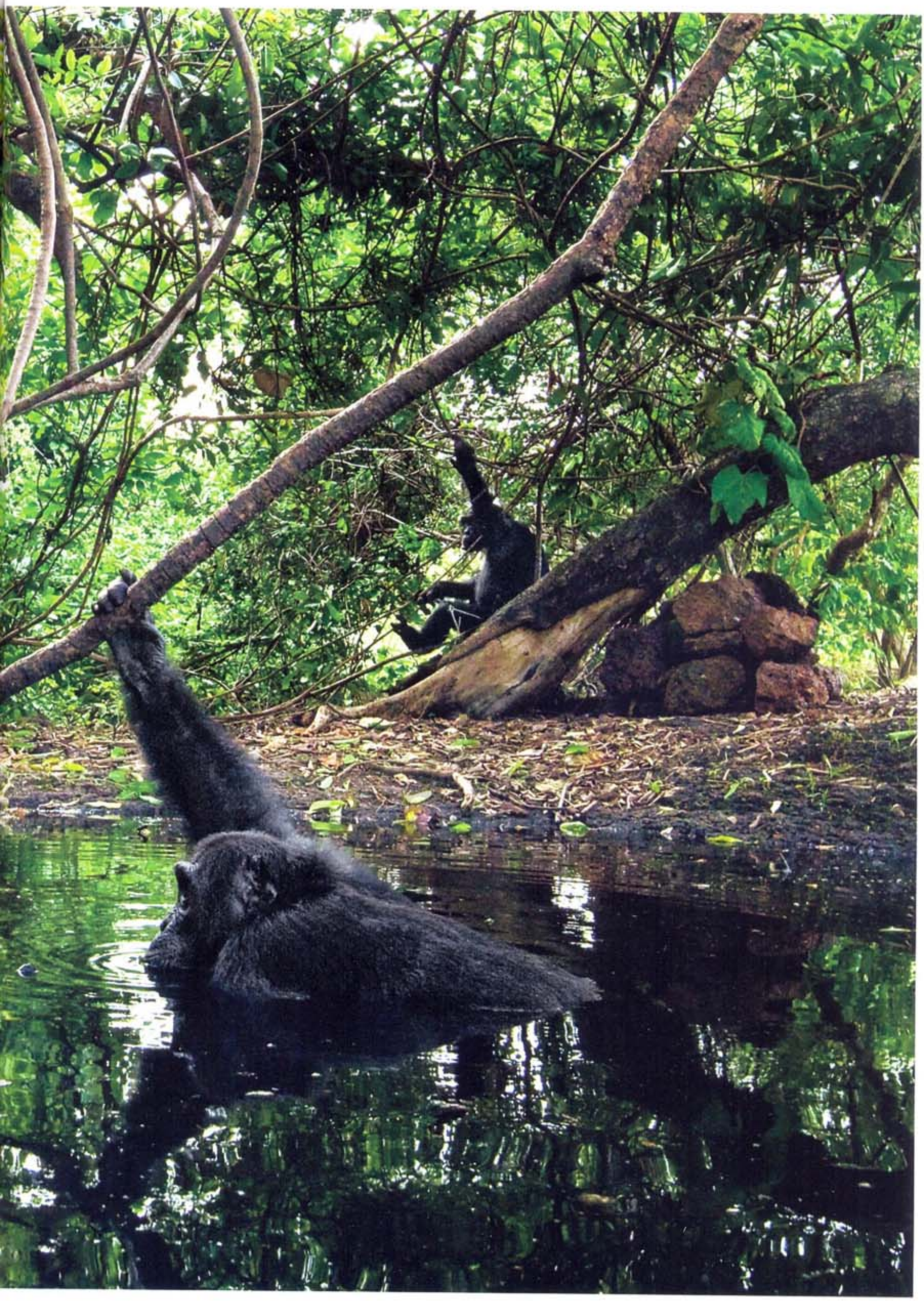
A quick glimpse into the bucket reveals that saba fruit is the chimps' mainstay this time of year, an adult averaging 30 to 40 a day. The Fongoli record for saba seeds in a single fecal sample—499, compared with an average of 75—probably belongs to a male named Mamadou. Which may explain why Mamadou is, quoting Pruetz, "especially gassy."

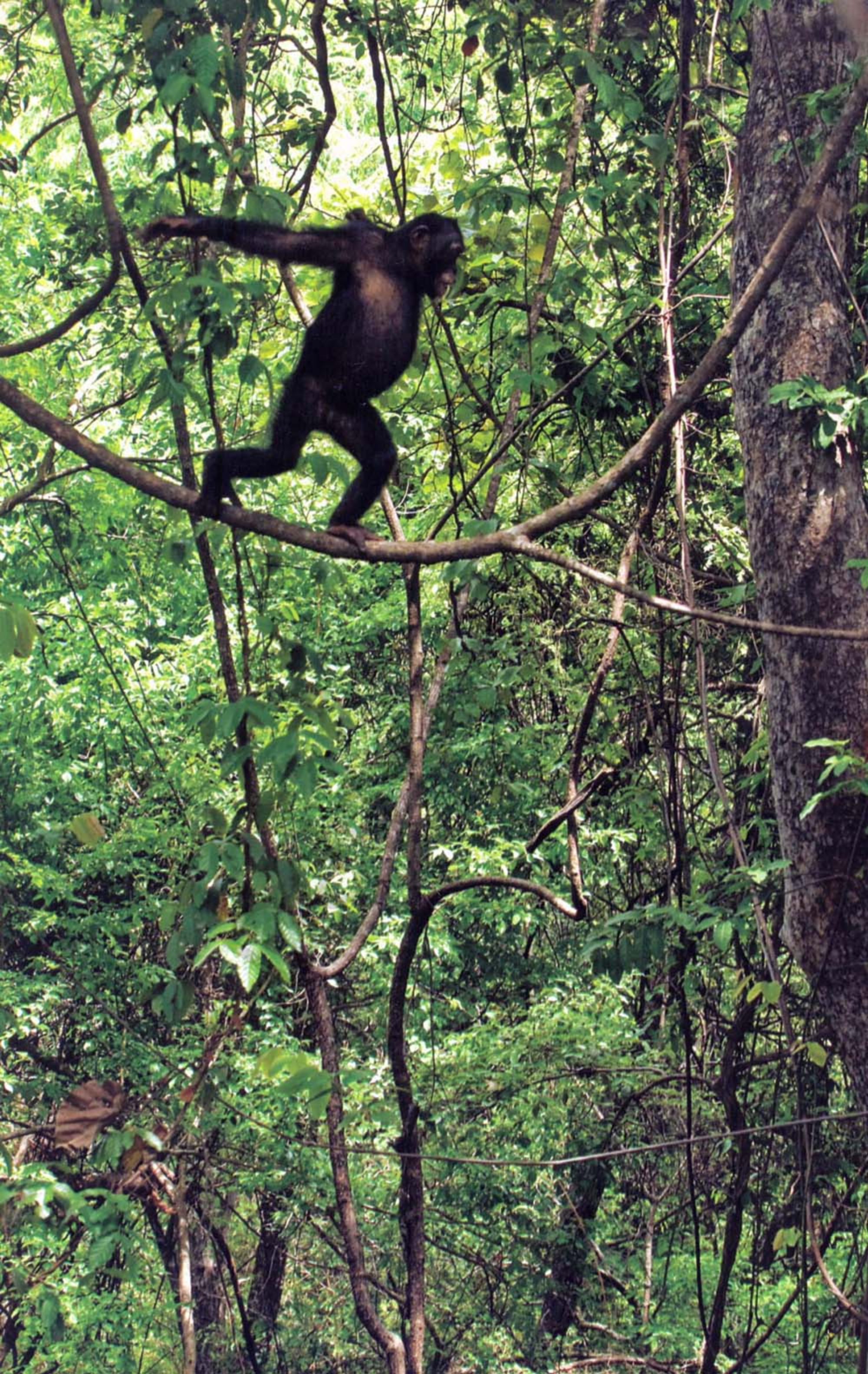
Pruetz's Ph.D. student Stephanie Bogart says part of the reason chimps fish termites is that they're an exceptionally calorific food. A 3.5-ounce serving of termites has 613 calories, compared with chicken's 166. But 3.5 ounces of soldier termites is hundreds of insects, fished piecemeal from a mound. It's like eating cake one crumb at a time. The chimps must really like them.

Sissy gets up from her spot at the termite mound to select a new tool. She breaks off a length of vine, inspects it. Satisfied, she sticks it in her mouth and carries it back to the mound



Most chimps avoid getting in water, but Fongoli males seek out pools to escape the 110-degree heat. "Pools are like the North Star for finding the chimps," says Pruetz. "They use them as a base and radiate out from them when they forage." The pile of rocks at right hides a camera.





Nellie, a young female, grips a limb with her feet as she tightropes some 30 feet above the forest floor. Chimps feature curved toe bones (right) that help them grasp trees and vines as they navigate the forest canopy. Observing apes walking on branches has led some scientists to speculate that bipedalism may have actually arisen in trees rather than on the ground.

like a seamstress holding pins between her lips. Pruetz and others argue that female chimps are not only more skilled than males at crafting and using tools, but also more diligent. Craig Stanford agrees that it might well have been our female ancestors who first steered the culture toward tool use. Early tools for foraging, he imagines, gave way to tools for scavenging meat from carcasses killed and abandoned by large carnivores. These tools in turn may have paved the way for implements for killing prey. Which makes Pruetz's observations of chimps sharpening sticks and using them to whack bush babies all the more arresting: Fongoli's females seem to have skipped ahead to the killing tools. Barbecue tongs can't be all that far behind.

PRUETZ AND I are sitting along a forested ravine where the chimps rest during the day's hottest hours.

The vegetation is thicker here. We watch a slender green vine snake move through the grass. Birds are calling over our heads. One says *cheerio;* one actually says *tweet.* A third says *whoop whoop whoop whoop whoop,* like Curly of the Three Stooges. (When I ask what that one is, Pruetz replies, not at all sarcastically: "a bird." She is a woman of singular interests.)

Pruetz directs my gaze to a tangle of saba vines. Where I see a dark mass, she is able to distinguish six animals. The woman has chimp vision. (It's a condition that lingers long after she gets back to Iowa. "I get home and I'm looking for chimps on campus.") The animals can be so well hidden and so quiet that even Pruetz has trouble finding them. She sometimes locates them by smell—"chimp" being a potent variant of B.O. "Yesterday I thought I smelled chimp," Pruetz says, "but it was me."

The scene in the vines is one of drowsy, familial contentment. Yopogon is grooming Mamadou. Siberut is leaning against a tree trunk, rubbing his two big toes together, as he often does. A pair of youngsters swing on vines, flashing in and out of an angled shaft of sun. One uses a foot to push off from a tree trunk, spinning himself around. The other swings from vine to vine,

Next of Kin Witness Fongoli chimpanzees in action as they make and use sharpened sticks to hunt for bush babies in video clips at **ngm.com.**

Tarzan-style. They are almost painfully cute.

A chimp called Mike lies on his back in a hammock of branches, legs bent, one ankle crossed atop the opposite knee. One arm is behind his head, the other is crooked at the elbow, the hand hanging slack from the wrist, in the manner of a cowboy slouched against a fence. We stare at each other for a full ten seconds. Partly because his pose is so familiarly human and partly because of the way he holds my gaze, I find myself feeling a connection with Mike.

I confess this to Pruetz, who admits to similar feelings. She cares about the Fongoli chimps as one cares about family. She sends excited emails when a baby is born and worries when the elderly and nearly blind Ross disappears for more than a week. But she does not reveal this side of herself at conferences. There it's all lingo and statistics, pairwise affinity indexes and "blended whimper pouts." "Especially with male chimp researchers," she says.

One of the first things primatology students are taught is to avoid anthropomorphism. Because chimps look and act so much like us, it is easy to misread their actions and expressions, to project humanness where it may not belong. For example, I catch Siberut looking toward the sky in what I take to be a contemplative manner, as though pondering life's higher meaning. What he's actually pondering is life's higher saba fruits. Pruetz points some out in the branches above Siberut.

YET IT IS IMPOSSIBLE to spend any time with chimpanzees and not be struck by how similar they are to us.

I've been keeping a list of things I have seen or read or heard Pruetz say that drive home this point in unexpected ways. I had not known that chimpanzee yawns are contagious—both among each other and to humans. I had known that chimps laugh, but I did not know that they get upset if someone laughs at them. I knew that captive chimps spit, but I hadn't known that they, like us, seem to consider spitting the most extreme expression of disgust—one reserved, interestingly, for humans. I knew that a captive ape might care for a kitten if you gave one to it, but had not heard of a wild chimpanzee taking one in, as Tia did with a genet kitten. The list goes on. Chimps get up to get snacks in the middle of the night. They lie on their backs and do "the airplane" with their children. They kiss. Shake hands. Pick their scabs before they're ready.

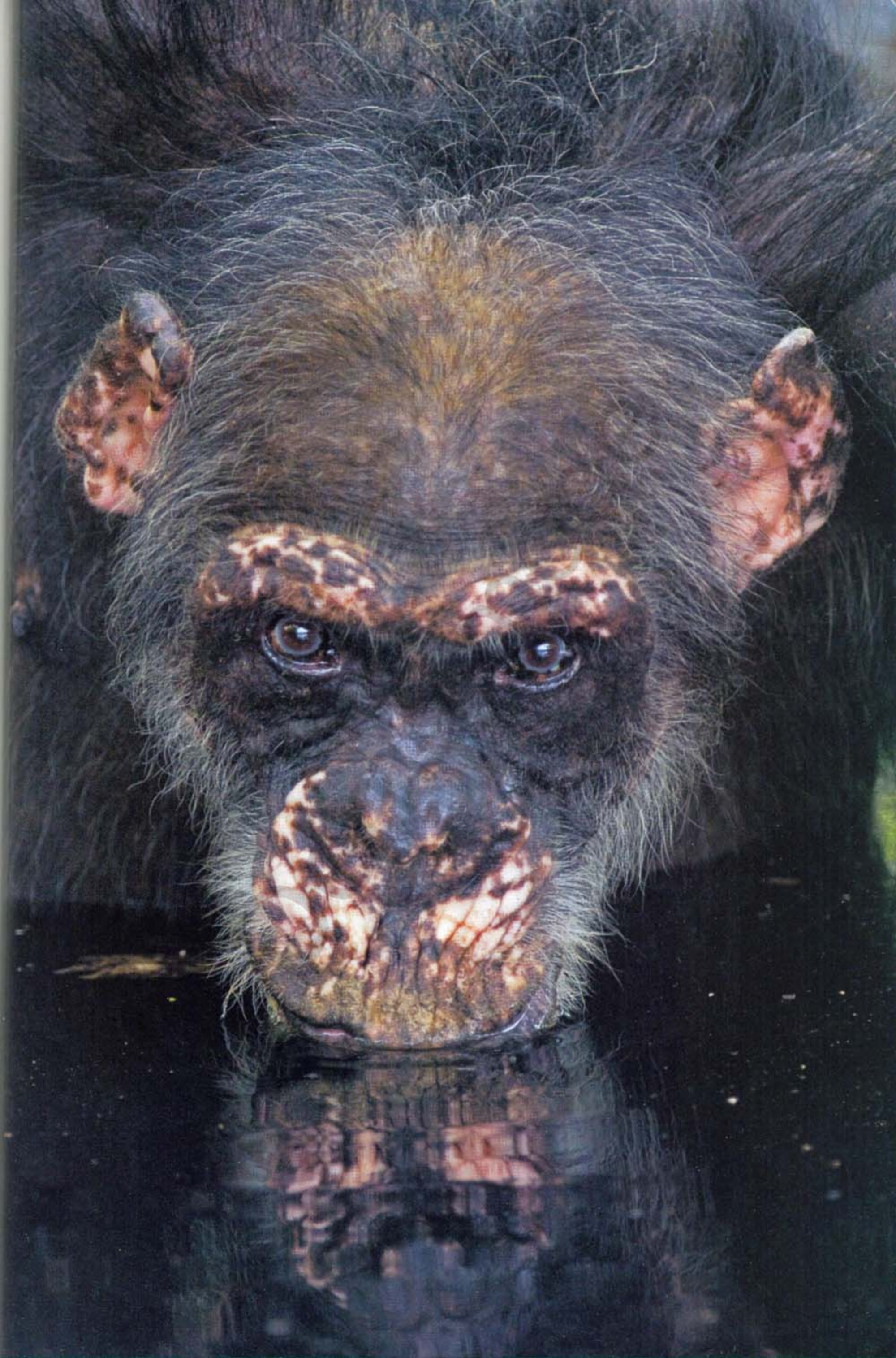
The taboo on anthropomorphizing seems odd, given that the closeness—evolutionary, genetic, and behavioral—between chimpanzees and humans is the very reason we study chimps so obsessively. Some thousand-plus studies have been published on chimpanzees. As a colleague of Pruetz's once said to her, "A chimp takes a crap in the forest, and someone publishes a paper about it." (No exaggeration. One paper has a section on chimpanzees' use of "leaf napkins": "This hygienic technology is directed to their bodily fluids (blood, semen, feces, urine, snot).... Their use ranges from delicate dabbing to vigorous wiping."

As for the chimps, they are not nearly as intrigued by the ape-human connection. While we've been observing them, they have largely ignored us, occasionally shooting a glance over one shoulder as they move through the brush. There is no fear in this glance, but neither is there curiosity or any sort of social overture. It is a glance that says simply, Them again.

Even Mike. He just turned away from my gaze and pointedly, or so it seemed, rolled over to turn his back on me. In hindsight I would have to say that the reason Mike had been looking at me was that I happened to be in his line of vision.

The chimps begin making their nests, breaking off leafy branches and dragging them into the treetops. Pruetz will wait until all are bedded down before turning to head back. We sit and listen to their "nest grunts"—soft, breathy calls that seem to express nothing more than the deep contentment one feels at the end of a day, in a comfortable bed. □

Almost blind, deaf, and toothless, Ross is probably in his 40s and too old to hunt. He survives by pounding open fruits—proof that innovation isn't just for the young.



HOW TO HELP

Doctors in Niger reconstructed Noufou Tapsoba's face after the boy's bout with noma.

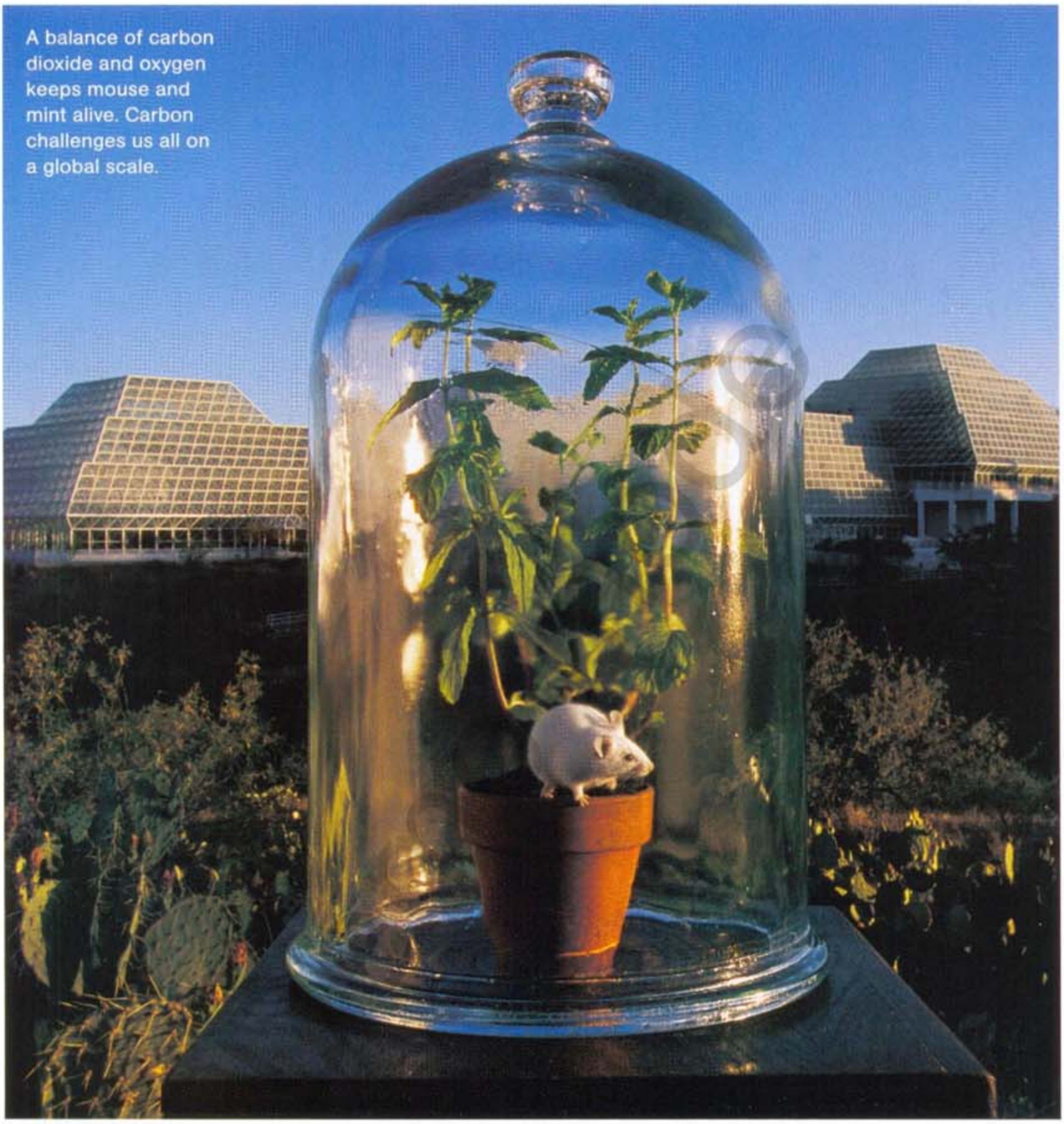
THE SAHEL, PAGE 34 **Stopping Noma** It starts as a sore in the mouth. Then, quickly, noma—a gangrenous infection that thrives where poor sanitation and malnutrition are common—eats through facial muscles, cartilage, and skin, leaving a wound that often gapes open to the bone. More than 100,000 children worldwide have noma; the rate in sub-Saharan Africa is as high as 1 in 1,000 a year. Most victims are children, and over 70 percent die from the disease. Photographer Pascal Maitre met 12-year-old Noufou Tapsoba (above) in Niamey, Niger. Sentinelles, a Swiss NGO specializing in noma care, had brought the boy to a hospital there for reconstructive surgery; more operations followed Maitre's visit. Though no one knows exactly what causes noma, the disease is treatable if caught in time—and preventable with proper nutrition and health care. These groups are trying to stop its spread:

- **Sentinelles** works to prevent noma and expedites surgery for disfigured children. Checks made out to the group should include its account number (CCP 10-4497-9) and be sent to Sentinelles, Les Cerisiers, Route de Cery, 1008 Prilly, Switzerland. For more information go to *sentinelles.org* (the site is only in French).

- **The University of Maryland Dental School** offers dental care to noma-prone kids in Africa. Contributions (payable to UMB Foundation, Inc., specifying "Noma Research and Treatment Fund") should be directed to the University of Maryland Dental School, Office of the Assistant Dean of Finance, 650 W. Baltimore St., Baltimore, MD 21201.

PHOTO: PASCAL MAITRE

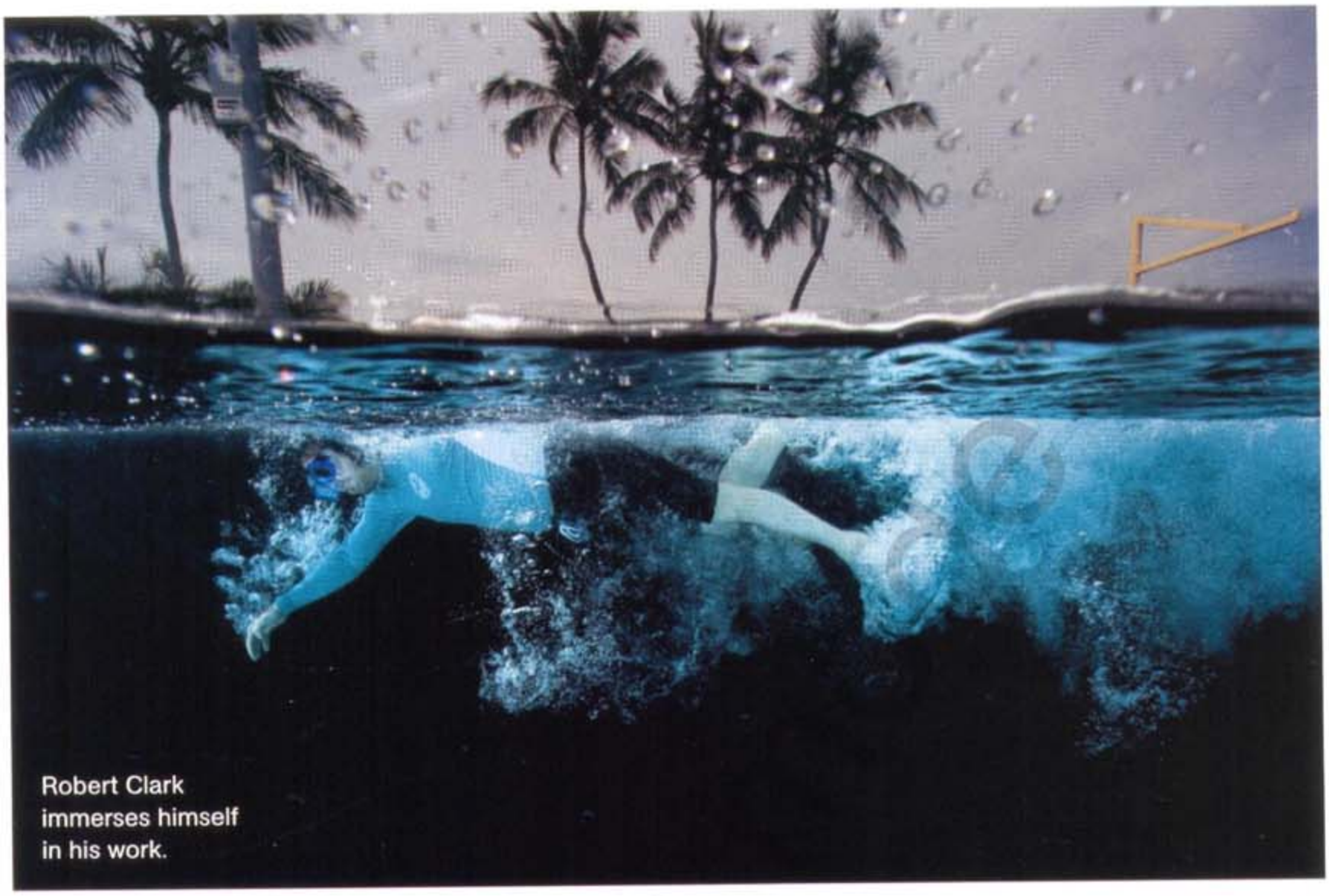
INSIDE GEOGRAPHIC



A balance of carbon dioxide and oxygen keeps mouse and mint alive. Carbon challenges us all on a global scale.

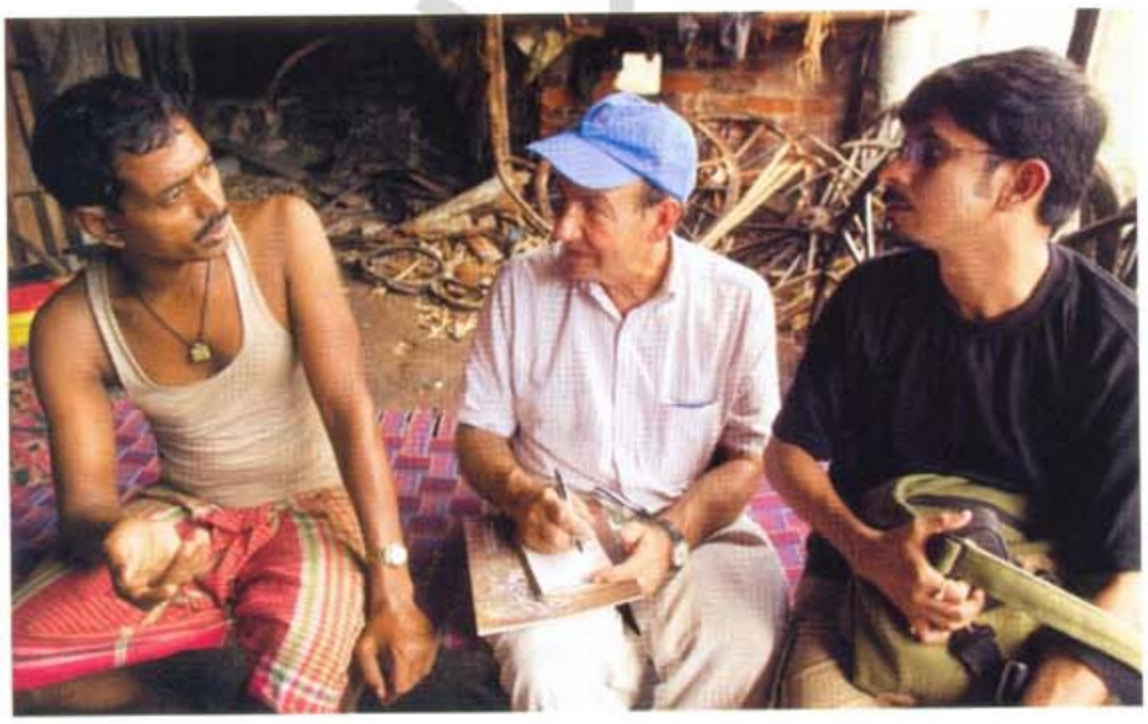
SPECIAL REPORT **Changing Climate** Earth's climate is in flux, but according to a new *National Geographic* special issue, it's not too late to do something about it. The publication looks at the changes happening around the world, explains the science, and offers solutions. A pullout section—to stick on your energy-efficient refrigerator—suggests ways to shrink your carbon footprint. The report also points to broader sustainable solutions, such as wind or solar power, that can help meet the world's rising energy needs. *Changing Climate,* available April 1, is for sale on newsstands for $4.95, or call 1-800-777-2800. For more information, visit *ngm.com.*

PHOTO: PETER ESSICK



Robert Clark immerses himself in his work.

ON ASSIGNMENT **Splashy** Robert Clark arrived at the Key West, Florida, pool at 9 a.m., though his shoot with Olympic swimmer Gary Hall, Jr. (see pages 84-5), wasn't scheduled until sunset. It took that much time to get ready. Clark's assistant, Christopher Farber, swam competitively in college; he did most of the test-picture swimming. But the photographer also jumped in. "Unfortunately, I don't look quite like Gary Hall," says Clark, who showed this shot to the Olympian. Hall's feedback: "You might want to keep your hips up."



Trillin (center) and interpreter Apu Bandyopadhyay (right) visit a *dera* owner.

ON ASSIGNMENT

Rickshaw Writer

While in Kolkata, India, to write about rickshaws, Calvin Trillin visited the *dera*, or rickshaw garage, of Mohammed Tahir (left). Rather than use rickshaws, Trillin got around mostly in the city's cabs, which are inexpensive but often get snarled in traffic. He did try out the subway, which is supposed to have eased traffic woes, but says, "It's hard to realize that the traffic used to be worse, because it's pretty bad."

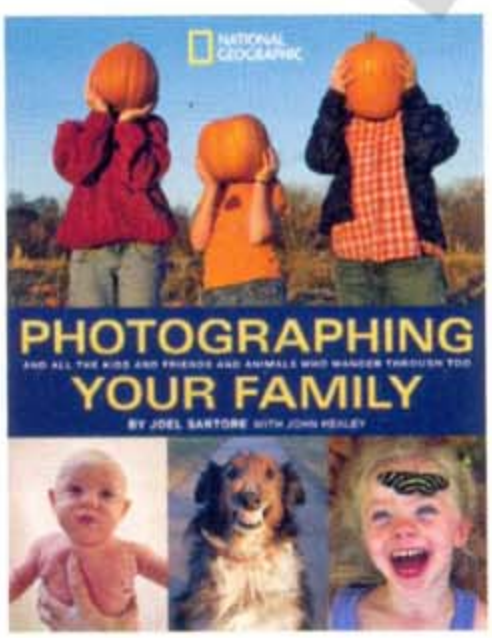
PHOTOS: CHRISTOPHER FARBER (TOP); AMI VITALE

INSIDE GEOGRAPHIC

NATIONAL GEOGRAPHIC CHANNEL

Human Footprint Take a shower a day and in 77 years you will have soaped up more than 28,000 times—and sent a lot of water down the drain. Airing April 13 at 9 p.m., the National Geographic Channel's *Human Footprint* shows symbolically just how much average Americans consume. Rows of 28,433 rubber ducks represent the showers; 12,888 oranges, 43,371 soda cans, and 3,796 disposable diapers also star. But rest assured: The show's producers used recycled material and expired food when possible.

NG Books



Photographing Your Family
As longtime *National Geographic* photographer Joel Sartore makes clear in his new book, if there's one thing you should be able to get good pictures of, it's your family. You have the time, the access, and—as long as you can figure out how to get the camera to work—the ability. Sartore offers lessons on lighting, backgrounds, and composition using images of his own family. Whatever you do, he says, don't line the relatives up, order them to smile, and blind them with the flash. Some of his suggestions:

- Practice photographing sleeping people—until they wake up and get mad.
- Think twice about shooting births and funerals.
- Floors make excellent backgrounds, and standard indoor lightbulbs give great light.
- Children's cooperation can be bought with ice cream.

Photographing Your Family is in bookstores now for $24.95.

PHOTO: ROY GUMPEL, TOUCH PRODUCTIONS, LTD

FLASHBACK

Scale to Fit Fish scales stood in for sequins on a dress that was "the latest to be worn by women," according to notes accompanying this photo. The image arrived at the *Geographic* in June 1921 but was not published. It may have been acquired for the magazine's January 1922 story "Certain Citizens of the Warm Sea," in which author Louis L. Mowbray noted: "The writer has seen an evening gown made wholly of bonefish scales which was indeed a thing of beauty. The scales were bored and laid on a fabric base like shingles on a roof. The resultant effect was like that of the natural body of the fish." *—Margaret G. Zackowitz*

Flashback Archive Find all the photos at **ngm.com.**

PHOTO: KADEL AND HERBERT, NATIONAL GEOGRAPHIC IMAGE COLLECTION

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Mitsuaki Iwago.
A Splashing Good Time.

Fed by groundwater that seeps down from nearby Mount Kilimanjaro, the famous marshes of Kenya's Amboseli National Park provide drinking water for thousands of animals, including African elephants that can drink up to 200 liters (50 gallons) of water every day. Although it appears that there is still plenty of water for now, it was obvious to photographer Mitsuaki Iwago that the once mighty glaciers atop Kilimanjaro were shrinking with every passing year. The sight troubled him, not just because of the potential loss of such a magnificent natural wonder, but because the water from those glaciers was so important to the animals that lived in the savannah below. He could only hope that this spectacular world and its diverse inhabitants would last forever.

Shot in Amboseli National Park in Kenya, on July 19, 2007, at 5:54 p.m., with the Olympus E-3, Zuiko Digital ED 300mm, f2.8, 1/400sec.

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Now featuring Mt. Kilimanjaro in Africa
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Mitsuaki Iwago, born in Tokyo in 1950, is an internationally renowned wildlife photographer whose work has won many awards and has appeared in and on the cover of *National Geographic*.

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