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NATURAL HISTORY

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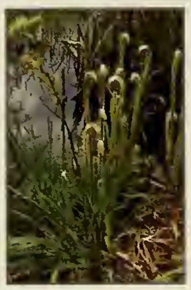
JULY/AUGUST 2008 VOLUME 117 NUMBER 6

Illustration of Enhydrocyon, the first bone-crunching member of the dog family, by Mauricio Antón

FEATURES

DEPARTMENTS



ON THE COVER: *Red fox (*Vulpes vulpes*) in the Formby National Trust reserve near Liverpool, United Kingdom*
PHOTOGRAPH BY ANDREW PARKINSON/CORBIS


THE NATURAL MOMENT
WALLFLOWERS
Photograph by Reinhard Dirscherl

nature.net by robert anderson

PALEOBOTANY

ALTHOUGH DARWIN FIGURED out that natural selection was the general force driving evolution, he knew there were difficult puzzles left to solve. For example, he called the sudden appearance of flowering plants in the fossil record an "abominable mystery." Popular accounts of evolution tend to focus on the animal kingdom, but Darwin looked equally to plants for insights into species diversification. In recognition of this, the New York Botanical Garden has produced *Darwin's Garden: An Evolutionary Adventure* (http://www.nybg.org/darwin/), which includes a self-guided tour of plants representing major developments in our planet's biological prehistory. For my guide to Web sites about paleobotany and "living fossil" gardens, please visit the magazine online (www.naturalhistorymag.com).

ROBERT ANDERSON is a freelance science writer who lives in Los Angeles.

◄ *See preceding two pages*

THE NATURAL EXPLANATION BY ERIN ESPELIE

REINHARD DIRSCHERL

Up against a wall—that's often precisely where you want to be when diving. An underwater wall can provide a peerless viewing experience, a full screening of colors, textures, and creatures in wraparound splendor (eat your heart out, IMAX). And any diver who has struggled to maintain a steady state of buoyancy can also appreciate the advantage of such a vertical display, where accidentally drifting down offers new perspectives rather than sea-urchin-scraped shins.

One world-class site, the Yellow Wall, attracted wildlife photographer Reinhard Dirscherl to Komodo National Park in Indonesia. Situated in Loh Dasami, a protected bay bounded by the islands Rinca and Nusa Kode, the wall supports a forest of yellow tree corals and much more, from sea apples to cat sharks and orange skunk clownfish. In shallow waters of the deep-reaching wall, Dirscherl came across the subjects of his photograph: a blue sea squirt, which filter-feeds by huffing water in and puffing it out, and a bevy of multicolored scuds, tiny amphipod crustaceans that devour any detritus they can paddle into their mouths with their shrimplike legs.

Despite years of diving experience, Dirscherl had to battle for stillness. Not only did he confront a north-moving current, but the "many strange, small critters" he saw on the Yellow Wall were either undulating or scurrying at different paces, which made them tricky to capture in focus.

Scuba diver, squirt, or scud, trying to stay put in the ocean can be tiresome. And that's likely why so many creatures embrace the lifestyle of a drifter—including salps, the pelagic cousins to the stationary sea squirts, as well as species of scud that successfully trawl open waters.

The scuds seen here belong to the family Cyproideidae, which tend to stay put by sticking close to sessile life-forms, such as sea fans or sea squirts. Even algae can be anchorages for them. Currently forty-three species have been identified worldwide. And an entirely new family was recently discovered in Iceland's groundwater, where scuds may have been thriving for more than 30 million years. Many others may yet be discovered—that is, if pollution or warming waters don't unmoor the extremely susceptible creatures first.

Born in Oberpfalz, a northeastern district of Bavaria, Germany, **Reinhard Dirscherl** now works out of Munich. His library of underwater subjects and settings has ballooned in the last decade to more than 30,000 photographs, several of which have won international awards. Visit his Web site www.ocean-photo.com to see reefs, rays, and more.

WORD EXCHANGE

Looking a Horse in the Mouth

Sandra L. Olsen's "Hoofprints," [5/08] was a stimulating summary of her groundbreaking research. I have an additional piece of evidence that supports her early date (3500–3300 B.C.) for horse domestication. My colleague Dorcas R. Brown and I have defined a distinctive kind of tooth wear that occurs when a horse chews on its bit: facets on the lower premolars. Those abraded areas on the front corner of the teeth are common on bitted horses and rare or absent on non-bitted horses. We found large wear facets on seven of fifty-four horses from Botai and Tersek, two sites occupied around 3500–3000 B.C. in the northern Kazakh steppes. It is clear from this finding that some of the horses at Botai and Tersek were bitted and ridden.

David W. Anthony
Hartwick College
Oneonta, New York

SANDRA L. OLSEN replies: I am quite familiar with the findings David W. Anthony refers to. However, the beveled teeth from Botai are in keeping with natural variation found in wild and domesticated horses. I personally have found several examples of beveled Ice Age horse teeth from North America. One 26,000-year-old horse tooth from Gold Run Creek, in the Yukon Territory, had an enormous bevel measuring a third of an inch. This was many millennia before people came to the Americas. Therefore, I do not feel comfortable adding bit wear to the list of evidence for horse domestication at Botai.

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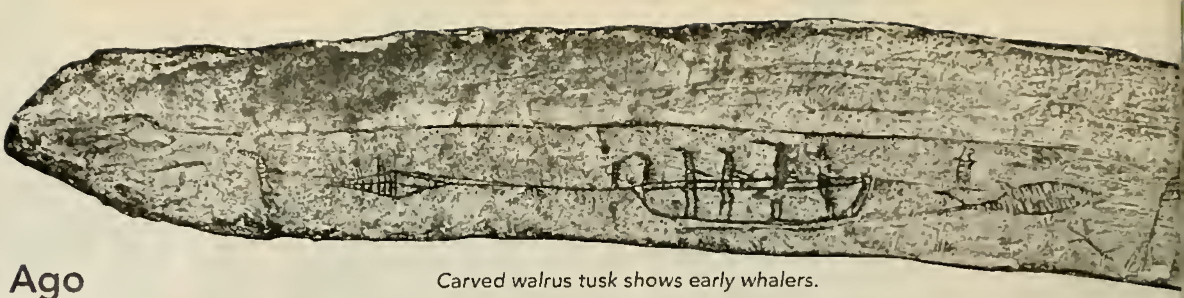


Carved walrus tusk shows early whalers.

TOP: UN'EN'EN EXCAVATION TEAM

Many Whales Ago

For many Arctic peoples, whales have traditionally been an important source of food and of bone for buildings and tools. But capturing such enormous quarry is no easy task—it requires a cooperative effort, multipassenger boats, and substantial weaponry. When did Arctic residents develop the requisite skills and technology? Until now the earliest evidence of whaling came from a 2,000-year-old site in Alaska, but a new finding moves that date back substantially in time.

A team led by Daniel Odess of the University of Alaska Museum of the North in Fairbanks collaborated with Russian colleagues to excavate a 3,000-year-old site called Un'en'en on the Chukchi Peninsula, Russia's northeasternmost tip. In addition to worked whalebone and heavy lance blades suitable for hunting large animals, the team unearthed an impressive carved walrus tusk. The tusk bears two scenes of men pursuing whales in multipassenger vessels called umiaks, with lines bearing sealskin floats connecting the vessels to the whales. The carving leaves little room for doubt that the communities were indeed whaling, and not simply scavenging bones from washed-up leviathans.

Other images on the carving include what appear to be men hunting polar bears with bows and arrows, a man stabbing another in the back, small doglike animals, and tents—a rare snapshot of Arctic life 3,000 years ago. (*Presented at the annual meeting of the Society for American Archaeology*) —*Lydia Bell*

American bullfrog

M. BERRONEAU

A Whiff of DNA

It's easy for small creatures to hide in a pond—what with all the murky water, vegetation, rocks, and logs—so biologists who want to catalog them must do a lot of mucking around. A new technique might make that task a lot easier: just collect half a tablespoon of pond water and examine the DNA therein. Bullfrogs, for starters, shed enough DNA into the water to enable their detection, according to a new study.

Ecologist Gentile Francesco Ficetola, now at the University of Milano–Bicocca in Italy, and three colleagues studied American bullfrogs (*Rana catesbeiana*), which have invaded European wetlands and displaced many native amphibians. Ficetola and others had already documented the invaders' distribution in France by surveying more than 2,500 wetlands. For the present study, Ficetola's team collected small water samples—just half an ounce each—from ponds known either to harbor bullfrogs or to be free of them. The team found bullfrog DNA in every sample from ponds with the animals, but never in samples from ponds without. What's more, the amount of detectable bullfrog DNA in a sample signalled whether a pond is teeming or only sparsely populated.

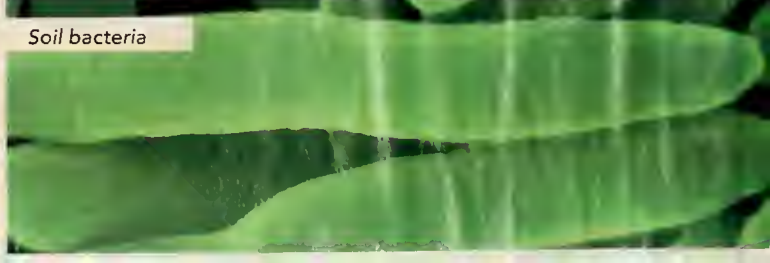
The free-floating DNA, Ficetola says, probably comes from mucus, feces, urine, or decomposing bodies. The next steps will be to extend the technique to additional species and to determine how long a species' DNA "calling card" persists after animals have left a pond—or been successfully eradicated. (*Biology Letters*) —*Stéphan Reebs*

Poison Control

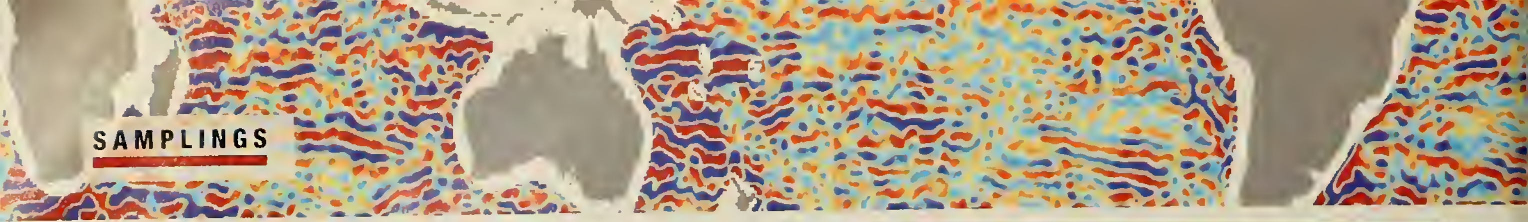
That so many bacteria have become drug-resistant is testimony to the microbes' toughness, but here's tougher: some bacteria actually eat antibiotics for breakfast. What's more, such super-tough bacteria are naturally widespread in the soil, according to a new study by Gautam Dantas, graduate student Morten O.A. Sommer, and two colleagues, all at Harvard Medical School.

To study bacteria with varying degrees of prior exposure to artificial antibiotics, the team sampled dirt from eleven disparate locations, including pristine wilderness, farms, and cities. Then they exposed the samples to eighteen antibiotics, including natural ones like penicillin and synthetics like ciprofloxacin. All eleven soil types sheltered bacteria that could grow on antibiotics—including commonly prescribed ones—as their only source of carbon. What's more, all but one of the antibiotics became fodder for bacteria in most soil types.

To be able to eat antibiotics, those bacteria must obviously have a high degree of resistance. Indeed, they tolerate antibiotics at levels fifty times more concentrated than do bacteria that are just conventionally resistant. The poison-munching bacteria aren't harmful to people, but some of them have close relatives that are, such as the agent of infection, *Pseudomonas aeruginosa*. Because bacteria swap genes freely, Dantas and Sommer warn that the soil dwellers might be able to transfer the genes for super-resistance to their infective cousins. (*Science*) —*S.R.*



Soil bacteria



Section of world map shows newly discovered oceanic currents.

Sea of Stripes

Sailors and scientists have been mapping ocean currents for centuries, but it turns out they've missed something big. How big? The entire ocean is striped with 100-mile-wide bands of slow-moving water that extend right down to the seafloor, according to a recent study.

Nikolai A. Maximenko of the University of Hawaii at Manoa and colleagues developed a precise new method for measuring the topography of the ocean surface by combining data from satellites and from the movements of more than 10,000 drifting oceanographic buoys. In doing so, the team generated detailed maps, in which they first noticed the peculiar striations. Some scientists initially dismissed the stripes as statistical artifacts, but Maximenko's team dug deeper, looking for a similar pattern in water temperature measurements from two test areas in the Pacific.

Indeed, though barely detectable, the striated currents are real. They flow past each other in opposing directions at 130 feet per hour—just one-tenth to one-hundredth the speed of major ocean currents—and subtle changes in temperature demarcate their boundaries.

Maximenko says a new computer model has corroborated some features of the observed striations, but his team is still mystified by their orientation, location, and strength. The discovery is important, he says, because even weak currents can have large effects on global climate and on the flow of food and creatures in the oceans. (*Geophysical Research Letters*)

—*Brendan Borrell*

Bugs Smell Funny

When an animal detects an odor, a flurry of activity ensues inside its sensory cells—whether they're in a dog's nose or a moth's antenna. Those cellular mechanisms are extremely complex and were thought to be universal. New research shows, however, that in a striking departure from the rest of the animal kingdom, insects smell things their own way.

The classical mechanism works like this: an odor molecule binds to a molecular receptor in the membrane of a sensory cell, which triggers a series of reactions inside the cell, which opens a gate that lets in ions, which sends off a message to the brain. The new research, by Koji Sato and Kazushige Touhara of the University of Tokyo, Leslie B. Vosshall of the Rockefeller University in New York City, and colleagues suggests that insects skip the intermediate steps. Instead, the odor molecule binds directly to the gate to open it.

It's not clear what, if any, advantage the insects' unique system might confer, but a rapid response to odors is one possibility. Among the insects the team tested was a species of mosquito that transmits malaria. The skeeters sniff out their victims; the new study may help find ways to block their sense of smell, and thus prevent the spread of disease. (*Nature*) —*S.R.*

Luna moth, antennae awaiting odors

The Petal Effect

Ah, roses. Their heady fragrance and delicate petals glistening with dew could soften the hardest heart. But take a sharper look at the dewdrops. They bead, rather than spread—and that's because the material composing the petal surface doesn't bond well with water. Yet the droplets don't roll off. What binds them to the petals?

To find out, a team of chemists led by Lin Feng of Tsinghua University in Beijing peered at the petals with a scanning electron microscope. What they saw was a carpet of minuscule bumps covered with even tinier ridges. To confirm that those structures—and not the chemical makeup of the petals—are what grip the water droplets, Feng's team made a plastic cast of the petal surface. As with the original petal, water droplets stuck to the cast, even when it was turned upside down.

LIN FENG

Above: surface of a rose petal, magnified 800×

It's the texture, then, that does the trick. Texture is also important in the so-called "lotus effect," which causes water to bead up and roll off many plants' leaves and petals, clearing away dust and debris. The difference: on drop-shedding surfaces, the tiny bumps have wax-coated tips and are separated by narrower troughs, so they make less contact with water. Feng thinks that the rose's waxless "petal effect" might help flowers attract pollinators by holding glistening dewdrops.

Casts like Feng's could be cheaply manufactured, should any commercial uses be found for the unusual properties of rose petals. But romantics needn't worry—even a dozen casts won't convey love messages like the real thing. (*Langmuir*) —*S.R.*

BOTTOM (PETALS) ROSEMARY CALVERT; MIDDLE: © VOLKMAR BROCKHAUS/ZEFA/CORBIS; TOP: OLEO MELNICHENKO (IPRC/UH)

SAMPLINGS

Clouds and Mirrors

The space surrounding a black hole at a galaxy's center normally radiates lots of X-rays, yet the vicinity of the black hole called Sagittarius A that lies at the hub of our own Milky Way is unusually dim. It wasn't always so: 300 years ago, astronomers now say, Sagittarius A flared up with X-rays, blazing out a million times more radiation than it does today.

How were the astronomers able to peer back in time? Apparently, through a clever trick with mirrors. Next to the black hole, at a distance of 300 light-years, is a cloud of gas and dust that reflects X-rays. Because radiation takes 300 years longer to travel from black hole to cloud to Earth than directly from black hole to Earth, the cloud now shows black-hole radiation as it would have appeared 300 years ago, say Tatsuya Inui and three colleagues, all from Kyoto University in Japan.

Another possibility is that the cloud emits its own X-rays as charged particles collide with it—but then the emissions would remain constant from year to year. By combining years of observations from several X-ray telescopes, Inui's team discovered a steep drop in radiation coming from the cloud over a ten-year period. Such instability is a sign of Sagittarius A's waning X-ray flare.

Magic tricks aside, the black hole still holds mystery. Nobody knows why it's quiescent now—or whether it will spring to life again someday. (*Publications of the Astronomical Society of Japan*) —*S.R.*

GETTY IMAGES

Brain Freeze

No one likes making mistakes on the job, but it's easy to lose focus when you're stuck doing the same thing over and over. What if you could predict—and prevent—such errors? A new study shows that the brain begins to wander as long as thirty seconds before the body makes an error, a departure signaled by changes in the brain's blood-flow patterns.

Tom Eichele of the University of Bergen in Norway, Stefan Debener of the Institute of Hearing Research in Southampton, England, and several colleagues used functional magnetic resonance imaging (fMRI) to monitor the brains of thirteen subjects as they undertook the "flanker task." In that classic psychological test, subjects select one of two buttons depending on the direction of arrows displayed on a screen. Analyzing the brain's blood-flow patterns, the team found that a subject tended to blunder after the brain simultaneously activated a set of regions associated with rest, and reduced activity in a different area associated with staying on task. Intriguingly, the change began up to half a minute before an error occurred, and the brain seemed to refocus after the subject caught the mistake.

The study challenges a long-standing theory that the brain flubs simple tasks because of fleeting, random errors in neuron firing. With the new information in hand, it may be possible to build a device that warns us when we're drifting off. (*PNAS*) —*B.B.*

THE WARMING EARTH

Six-Legged Agents of Change

Red-leafed trees in background photograph of a Canadian forest indicate damage by the mountain pine beetle, below.

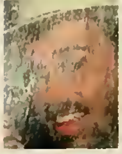
Hordes of mountain pine beetles are decimating British Columbian forests. Rising temperatures due to global warming have boosted the beetles' numbers by increasing their reproductive rate and reducing their winter die-off. Now, in a perverse twist, a new study shows that in a few years, the pests will have turned the once climate-friendly forests into net emitters of carbon dioxide (CO_2).

Since 2000, the beetles have killed off more than 32 million acres of forest, according to Werner A. Kurz and a team of scientists from the Canadian Forest Service. Kurz and colleagues say the current outbreak is an order of magnitude larger than any previous mountain-pine-beetle explosion, and they predict it will take another twelve years or so to taper off. That's a lot of dead trees, which release CO_2 as they decompose. Meanwhile, there are fewer healthily growing trees left to absorb the greenhouse gas through photosynthesis.

Using a computer model, Kurz's team calculated that by 2020, the beetles will have killed so much forest that their net effect will be the equivalent of five years of CO_2 emissions by all the cars and trucks of Canada.

Kurz and his team are the first to account for large-scale insect outbreaks in an analysis of forest carbon balances—and to show the positive feedback loop between climate change and insect pests. They're unlikely to be the last, however, given the risk of more boreal forests falling prey to warmth-loving insects. (*Nature*) —*S.R.*

BEETLE: KLAUS BOTTE, NATURAL RESO



Battered Expectations

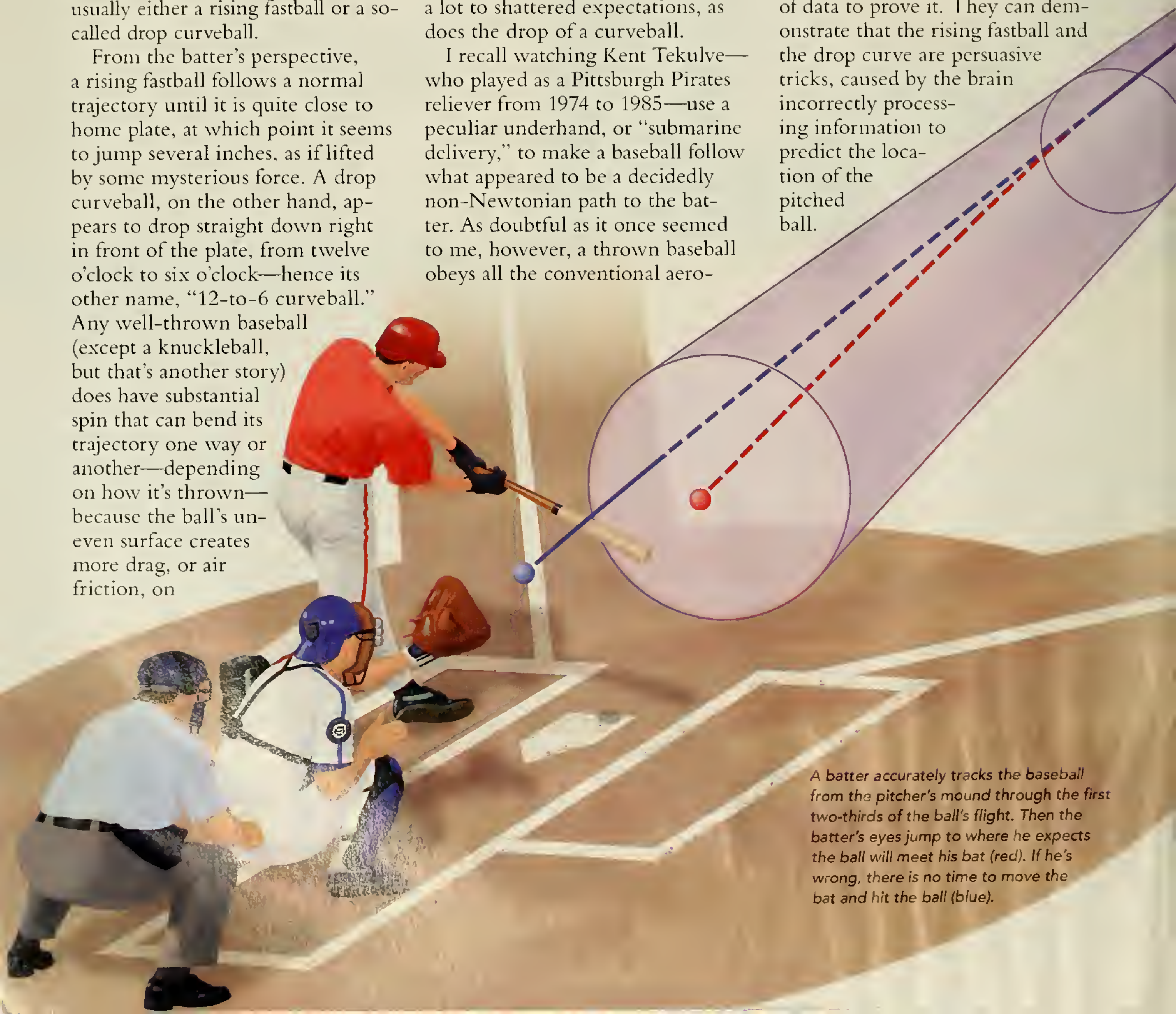
Do baseballs obey the conventional laws of physics?

Illustration by Tom Moore

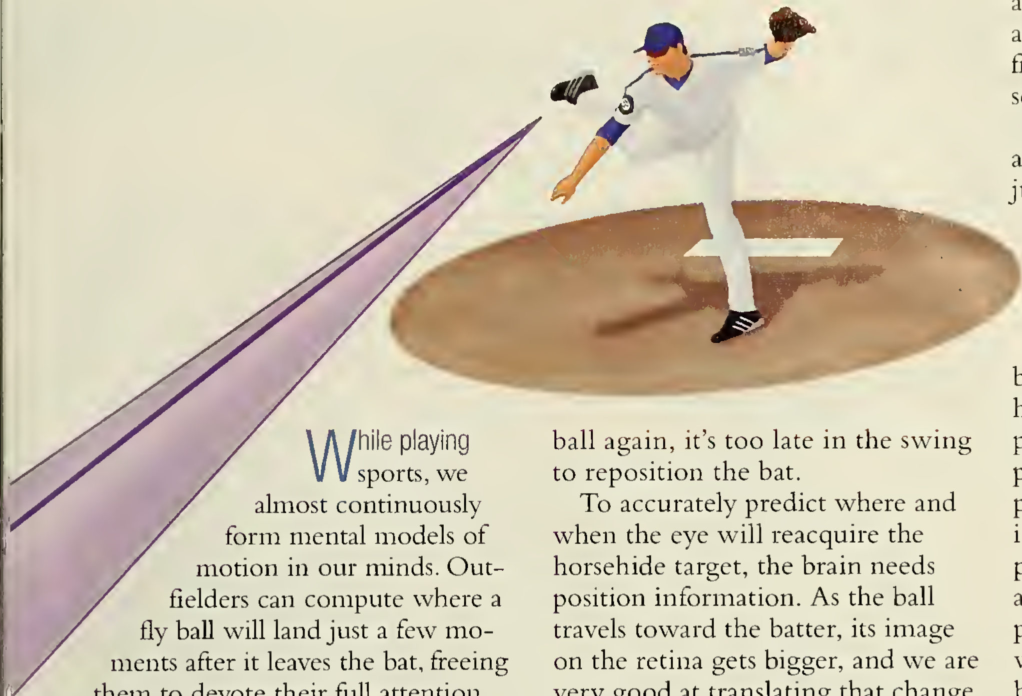
On fields of dreams, the duel between the batter and the pitcher at times assumes aspects of humiliation and farce. And never more so than when a batter misses a pitch, swinging so forcefully as to nearly sprain something. The culprit in such cases is usually either a rising fastball or a so-called drop curveball.

From the batter's perspective, a rising fastball follows a normal trajectory until it is quite close to home plate, at which point it seems to jump several inches, as if lifted by some mysterious force. A drop curveball, on the other hand, appears to drop straight down right in front of the plate, from twelve o'clock to six o'clock—hence its other name, "12-to-6 curveball." Any well-thrown baseball (except a knuckleball, but that's another story) does have substantial spin that can bend its trajectory one way or another—depending on how it's thrown—because the ball's uneven surface creates more drag, or air friction, on one side of the ball than the other. A ninety-mile-an-hour fastball, for example, should drop nearly three feet owing to gravity, yet it falls less than two feet thanks to backspin-generated lift. It doesn't rise, though. The perceived pop owes a lot to shattered expectations, as does the drop of a curveball.

I recall watching Kent Tekulve—who played as a Pittsburgh Pirates reliever from 1974 to 1985—use a peculiar underhand, or "submarine delivery," to make a baseball follow what appeared to be a decidedly non-Newtonian path to the batter. As doubtful as it once seemed to me, however, a thrown baseball obeys all the conventional aerodynamic laws of physics. A. Terry Bahill, a systems engineer at the University of Arizona, and colleagues including David G. Baldwin, a former major-league relief pitcher with an engineering degree and a Ph.D. in genetics, have reams of data to prove it. They can demonstrate that the rising fastball and the drop curve are persuasive tricks, caused by the brain incorrectly processing information to predict the location of the pitched ball.



A batter accurately tracks the baseball from the pitcher's mound through the first two-thirds of the ball's flight. Then the batter's eyes jump to where he expects the ball will meet his bat (red). If he's wrong, there is no time to move the bat and hit the ball (blue).



While playing sports, we almost continuously form mental models of motion in our minds. Outfielders can compute where a fly ball will land just a few moments after it leaves the bat, freeing them to devote their full attention to running to the correct spot on the field. Similarly, you might think a batter could guess where a pitch would be likely to cross home plate.

By equipping players with special glasses that precisely track eye and head movements, Bahill has shown that a batter's attention is fixed on the ball as it is released, and for the first two-thirds of its flight path his eyes smoothly track the motion of the ball. During this focused tracking, the eyes gather data that the brain busily assembles into a model of where the ball will be when it gets within hitting range, and when that will be.

About the time the batter starts to swing—when the ball is about nineteen feet from home—the batter's eyes suddenly jump to where he anticipates the bat–ball meeting will take place. Why? Because it's the only way the eye can move fast enough to keep up with the incoming ball. Now that mental model comes into play. Across that brief gap, the ball's arc is computed by the brain without further reference to the real world. By the time the batter's eyes pick up the actual ball again, it's too late in the swing to reposition the bat.

To accurately predict where and when the eye will reacquire the horsehide target, the brain needs position information. As the ball travels toward the batter, its image on the retina gets bigger, and we are very good at translating that change in size into a time of arrival for the ball. For a fastball taking about two-fifths of a second to travel to the plate, the average person can predict its time of flight to within twenty-five thousandths of a second. Although impressively close, that spread in timing would result in a spray of foul balls and misses; there is only a window of plus or minus nine-thousandths of a second for fair balls. Bahill has shown the pros do considerably better at this timing task, estimating the time of arrival to within plus or minus five-thousandths of a second.

It's an oddity of the way our visual system works that batters can accurately model the "when" of the ball's arrival by directly observing it, but the "where" is another matter. That variable depends on knowing things that are hard to estimate visually: the ball's distance from the batter, and the rate and direction of its spin. To put these parameters into a mental model, the batter relies on cues such as the pattern of the moving ball's gray-and-red blur (different angles of spin look different); the posture of the pitcher, especially his arm and hand; the point at which the pitcher releases the ball; and expectations of ball speed derived from previous pitches. Herein lies the secret to that hoppin' fastball.

If the pitcher can fool the batter about the speed of the pitch, even just a little bit, the effect is a startling difference between where the batter expects the ball and where it actually appears. For example, a few ninety-mile-an-hour fastballs set up the batter to expect more of the same heaters. If the next pitch is 5.5 percent faster, at ninety-five miles per hour, the ball will appear at its point of impact with the bat three inches above where the slower pitch would have. A batter using a mental model to follow the ball perceives that as a sudden leap upwards as the ball comes back into his region of focus.

That perceptual jump can also explain the phenomenon of the diving curve. While a curve ball certainly does curve, there is a particular pitch that appears to the batter to behave quite badly. Players often say "that one rolled off a table" to describe a ball that drops, or "breaks hard," just before the plate. Bahill and his colleagues report that in this case, the pitcher has fooled the batter into thinking the ball is moving faster than it is, leading to a perceptual drop when the ball appears below where the batter expects it.

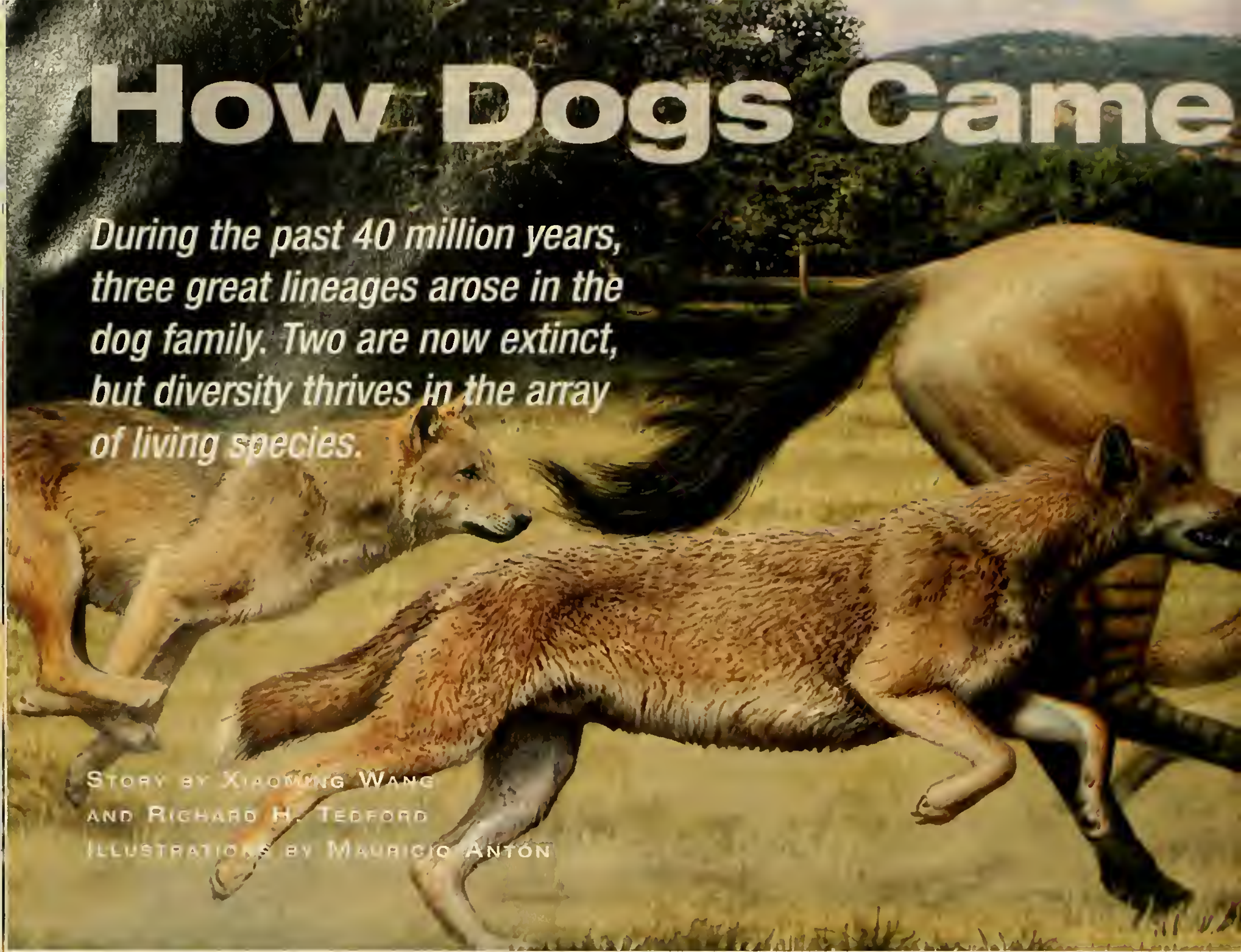
Faced with such deceit, maybe batters would be better off just closing their eyes. Then again, if they keep them open, they can learn the specific tricks a pitcher employs to throw off their clear perception of the ball's flight. That could explain why some hurlers have great success early in their careers, but then lose their mystique as batters catch on to them.

ADAM SUMMERS teaches bioengineering at the University of California at Irvine, home of the Anteaters, participants in the 2007 NCAA College World Series!

How Dogs Came

During the past 40 million years, three great lineages arose in the dog family. Two are now extinct, but diversity thrives in the array of living species.

STORY BY XIAOMING WANG AND RICHARD H. TEDFORD
ILLUSTRATIONS BY MAURICIO ANTÓN



The downfall of the dinosaurs 66 million years ago gave mammals an incredible opening, and they ran for it, rapidly becoming the dominant land vertebrates. Among those to emerge were the earliest carnivorans (members of the order Carnivora), whose living representatives include the cats and closely allied families, such as hyenas and mongooses, as well as dogs and closely allied families, such as bears, weasels, and seals. As their name implies, most carnivorans eat meat, and even those that aren't carnivorous—such as the giant panda—can be recognized by the last upper premolar and first lower molar on each side of the mouth. Those teeth are specially adapted for shearing, and are known as carnassials. Only in some species, such as seals and sea lions, have the carnassials evolved into simpler forms.

Back when mammals got their big break—during the Paleocene epoch, which lasted ten million years—conditions around the globe were warm and humid. And the epoch that followed, the Eocene, was marked by a warming trend so great that even the polar regions were quite hospitable to life. Surging into prominence, flowering plants diversified and created lush forests all over the Earth. In North America, where tree canopies sheltered a growing number of primates and other forest-dwelling mammals, the earliest carnivorans arose. From there they spread to Eurasia, over land bridges that then existed to Europe or near the present-day Bering Strait. Mostly the size of small foxes, or smaller, the carnivorans were adapted to life in and around trees, probably preying on invertebrates and small vertebrates. They lived in the shadow of the generally much larger hyaenodonts, a group of mammalian predators that had come on the scene earlier but which later became extinct.

When did the carnivorans split into their catlike and doglike divisions? No one knows exactly; it may have been 50 million years ago or even earlier. By 40 million years ago, however, the first clearly identifiable member of the dog family itself, the Canidae, had arisen in what is now southwestern Texas. Named *Prohesperocyon wilsoni*, the fossil species bears a combination of features that together mark it as a canid. Fittingly enough, these include

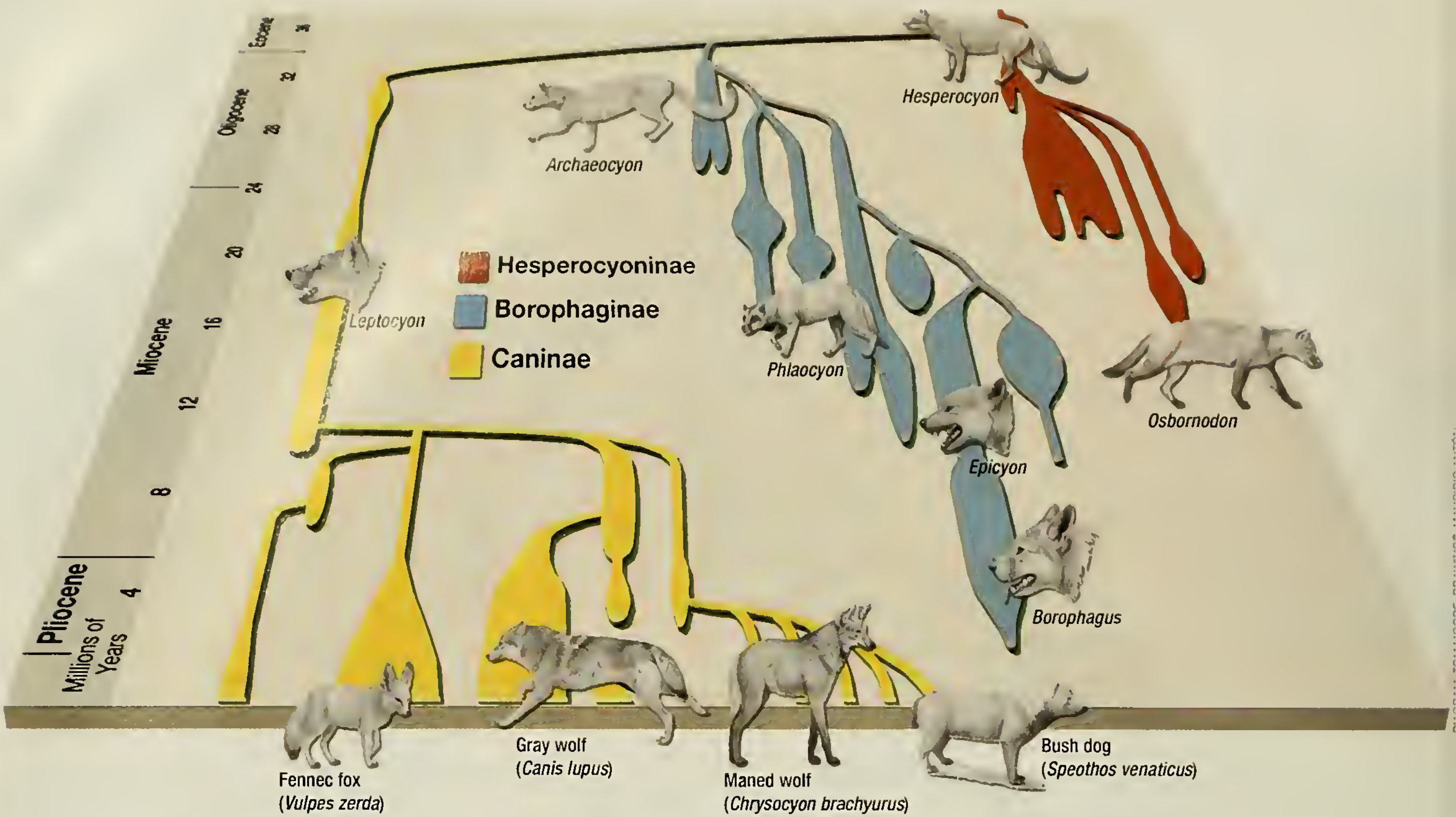
to Run the World

In an artist's reconstruction of a savanna in western North America about 15 million years ago, a pack of Aelurodon ferox *(in the canid subfamily Borophaginae) pursues a three-toed horse of the genus* Neohipparion. *In such an open landscape, both predator and prey were driven to evolve stamina and speed.*

features of the teeth—including the loss of the upper third molars, part of a general trend toward a more shearing bite—along with a characteristically enlarged bony bulla, the rounded covering over the middle ear. Based on what we know about its descendants, *Prohesperocyon* likely had slightly more elongated limbs than its predecessors, along with toes that were parallel and closely touching, rather than splayed, as in bears.

The dog family thrived on such limb adaptations, which helped support a cursorial, or running, lifestyle in response to a changing environment. And none too soon, for the subsequent epoch, the Oligocene, between 34 million and 23 million years ago, started a long trend of climatic deterioration. Ice sheets appeared on the Antarctic continent for the first time, while in mid-latitude North America, conditions became progressively dryer and seasonal variations more pronounced. The lush, moist forests of the late Eocene gave way to dry woodlands and then to wooded grasslands, with large areas of open grassland developing by 30 million years ago. Mammalian herbivores began to evolve teeth adapted to eating grass (so-called high-crowned teeth, which continue to erupt as the chewing surfaces are worn down). For both predators and prey, the ability to run and survive in an open, exposed landscape became crucial. To a large extent, the history of the dog family is a story of how a group of cursorial predators evolved, through speed and intelligence, to catch changing prey in a changing landscape.

The canids are one of three modern families of carnivorans notable for including top predators, species capable of hunting down prey several times their own size. The other two are the cat family (the felids) and the hyena family (the hyaenids). On land, at least, there appears to be a body-size threshold of around forty-five pounds beyond which a mammalian predator must begin to tackle larger prey in order to get enough energy. Chris Carbone, a senior research fellow in biodiversity and macroecology, and colleagues at the Institute of Zoology, the research division of the Zoological Society of London, have suggested that small predators can sustain themselves on invertebrates



Soon after its beginnings 40 million years ago, the dog family (Canidae) diverged into three main subfamilies, each of which dominated in turn. The figure illustrates major branching points, with the width of each lineage representing its species diversity through time. All three subfamilies coexisted for a long time. Two (the Hesperocyoninae and the Borophaginae) became extinct in turn, but the Caninae, with thirty-six species, is going strong. (Portraits of the selected species shown above are not drawn to the same scale.)

and small vertebrates because of their low absolute energy requirements.

In 1871, pioneer vertebrate paleontologist Edward Drinker Cope formulated the principle that in animals, small body sizes tend to evolve into large body sizes. With the help of our colleagues Blaire Van Valkenburgh, a functional morphologist at the University of California at Los Angeles, and John Damuth, a biostatistician at the University of California, Santa Barbara, we have examined the canid fossil record with that idea in mind. We have concluded that, indeed, larger and larger species have repeatedly evolved in many lineages. Consequently, many species have independently passed the threshold where they needed to take down large prey. Features of their jaws and teeth show that the larger canid species have also tended to become hypercarnivorous, that is, more purely meat-eating.

The cat family and the hyena family similarly evolved hypercarnivorous top predators. (One might think the bear family, the ursids, should be added to this list, but only the polar bear is hypercarnivorous, and it is a rather atypical member of the family. Most bears are omnivores.) It's only a slight oversimplification to say that felids almost invariably approach their prey in stealth and try to pounce on it in surprise attacks. Modern canids, by contrast, have a decidedly different tactic, one suited to their ancestors' lifestyle on the open plains. In that setting, surprise attack is seldom achieved; it is less important to subdue the prey in the shortest possible time than to outrun and exhaust the quarry. Lacking retractable claws, a powerful weapon for most felids, canids rely more on social hunting when confronting large prey—using sheer numbers and coordinated hunting strategies rather than sophisticated weaponry to overwhelm them.

Hyaenids are more closely related to cats, yet they more strongly resemble canids, both

A young adult Eucyon davisi, *about the size of a living coyote, approaches one of its parents in a submissive attitude. The large social groupings in several species of the subfamily Caninae may have arisen when such youngsters remained in their parents' territory and helped raise pups. The genus* Eucyon *lived in North America from about 9 million to 5 million years ago.*

behaviorally and anatomically. They kill their prey by consuming them alive, rather than by delivering a killing bite on the neck as felids do. They too are persistent pursuers rather than stalkers that ambush prey, and they tend to be highly social hunters. The similarities are a good example of convergent evolution, an understandable outcome when one realizes that for much of their evolutionary history, the two groups were not direct competitors but were facing similarly open environments. Canids were at first confined to North America, whereas hyaenids arose in Eurasia.

When did canids become so diverse? From *Hesperocyon,* a descendant of *Prohesperocyon,* the family experienced its initial radiation in the early Oligocene, about 34 million years ago, splitting into three major subfamilies: the Hesperocyoninae and the Borophaginae (both extinct lineages known only from fossils), and the Caninae, whose descendants survive today. But it is at first only among the hesperocyonines that we see some really dominant dogs, capable of hunting prey larger than themselves. They were the size of small wolves and equipped with teeth specialized for ripping into raw meat, comparable to those of modern African hunting dogs. The early borophagines, on the other hand, were all smaller and tended toward less predatory lifestyles. And biding its time was the Caninae subfamily, comprising only a few inconspicuous species (we'll avoid calling them "canines," a term that is usually used in a narrower sense).

Altogether, by about 30 million to 28 million years ago, twenty-five species of canids roamed western North America, a peak of diversity within a continent unequaled before or since by any single family of carnivoran. The dog family was making its mark. Meanwhile, the hyaenodonts and other archaic predators had begun to decline, and they were eventually overtaken by the successful carnivorans.

North American herbivores, the potential prey for canids, steadily diversified during the first half of the following epoch, the Miocene, which lasted from 23 million to 5 million years ago. That was thanks not only to evolution but also to immigration of Eurasian native species via land bridges. The herbivores reached an all-time peak of diversity around 15 million years ago, and perhaps not coincidentally, canids experienced a second peak of diversity (some twenty species) at the same time. But now mostly the borophagines were the ones to flourish. The hesperocyonines were on the verge of extinction, while the Caninae continued to keep a low profile.

Among the factors driving canid evolution was the increasing speed of the grazing herbivores, which in turn was a response to being preyed upon in open habitats. The well-known illustration of this process is how members

An adult Hesperocyon gregarious, *a canid species that could have been ancestral to all three major canid subfamilies, watches over her two pups in front of their den. The scene is set in western North America between 40 million and 34 million years ago, when early canids, like most other members of the order Carnivora, were still evolving in a forested environment.*

of the horse family essentially came to run on the tips of their toes, evolving longer toe bones and eventually losing their lateral digits. Even though canids were getting faster, they also had to adjust to competition from new carnivoran immigrants, including members of the cat family; false saber-tooth cats (which were catlike but not true felids); large mustelids; and giant bear dogs (family Amphicyonidae). Bone-cracking became a specialty of the new borophagine species that arose at the time, suggesting that they regularly scavenged carcasses—a kind of resource that is easier to locate in a more open environment. The ability to consume bones may have arisen as a byproduct of group feeding among social predators, in which individuals, trying to consume as much food as quickly as possible, ate bone (or swallowed meat plus bones indiscriminately).

The Caninae lineage, present from the early Oligocene, finally made its big move during the late Miocene, as the open grasslands continued to expand. One distinctive feature of the subfamily, which had slender, elongated limbs, is that the front and hind big toes became progressively smaller, and ceased to be functional. This cursorial feature, not found in the other two canid subfamilies, became an advantage when the landscape opened up. By the late Miocene, early precursors of the modern "true" foxes (tribe Vulpini) had emerged, as well as a genus, *Eucyon,* that was ancestral to the tribe Canini. The latter group comprises the "canines" in the narrow sense of the term, and includes dogs, wolves, coyotes, jackals, certain foxes, and other species.

A key development in Caninae history was the spread of the subfamily out of North America, beginning about 7 million years ago, when some groups crossed the Bering land bridge into Asia. With the exception of a single species in the middle Miocene of China, hesperocyonines never escaped the dog family cradle, nor did any borophagines. Records of the Caninae appeared in Europe first, and almost immediately thereafter in Asia and Africa. The first member of the genus *Canis*—to which the gray wolf, coyotes, jackals, and the domesticated dog belong—loped onto the scene about 6 million years ago.

During the subsequent epoch, the Pliocene (5.3 million to 1.8 million years ago), a further opportunity opened up for the Caninae. About 3 million years ago, the Panamanian Isthmus formed, linking North and South America. Carnivorans that arrived in South America generally trumped the native predators, and the Caninae were part of that success story, radiating explosively out of a few lineages in Central America and southern North America. Members of the subfamily constitute the largest group of carnivoran predators in South America today. Indeed, with eleven species, South America is home to almost one-third of the entire canid diversity on the planet.

Just as the intercontinental flux led to a new peak of diversity among the canids—one that continues through the Pleistocene epoch and down to the present time—so, too, did it influence the array of prey. Ancestral horse species, which had lost their two outer digits but retained three, were eclipsed in North America by single-digit horses. By

A solitary Borophagus diversidens defends its prey from a pack of Canis lepophagus. Such a confrontation, whose outcome could go either way, may have been common a few million years ago. A bone-crushing species, B. diversidens was the last of the borophagines, whereas the would-be robbers were members of the ascendant genus Canis, whose living examples are the coyote, gray wolf (including the domestic dog), red wolf, Ethiopian wolf, black-backed jackal, golden jackal, and side-striped jackal.

Pliocene to early Pleistocene times, the modern horse genus, *Equus*, had spread to Eurasia and South America, along with members of the camel family (mostly llamas and their extinct relatives), which, like canids, had been confined to North America during much of their existence. While the Caninae subfamily thrived, however, borophagines dwindled to one or two species of highly specialized bone-cracking dogs, which became extinct by the end of the Pliocene.

The third canid expansion brought dogs into contact with hyaenids, which, with one brief exception during the Pliocene, had never expanded into North America. By the Pliocene, however, the competitive landscape had changed significantly for both families, and their members weren't fighting for the same fare. The foxes and jackal-like dogs that arrived in the Old World were much smaller than most hyaenids, which by now were all large, bone-cracking animals.

A dire wolf (Canis dirus) calls for its pack as a herd of mammoths ambles past. The scene is based on fossils found in the Rancho La Brea tar pits, which trapped animals between 20,000 and 10,000 years ago.

If we look around today at the major terrestrial carnivoran families—canids, felids, ursids, mustelids, and others—we see that each has a balanced spectrum of small and large species, but not the hyaenids. Apart from the aardwolf, which is a highly specialized termite-eater, there are only three living species of hyenas, all large carnivores. In the major carnivoran families, if the large-size species become extinct in the future, smaller forms could evolve to replace them. But if the large hyenas one day become extinct, their great evolutionary lineage will end.

Climate change kicked into high gear during the Pleistocene epoch, whose alternating cold, dry ice ages and warm, humid intervals was a tumultuous time for all animal and plant evolution. Many mammal species on the northern continents (North America and Eurasia), particularly herbivores, attained giant sizes as an adaptation to extreme cold. Large body size helped not only to conserve heat, but also to store more fat to cope with winter weather. Woolly mammoths, giant deer, and woolly rhinos roamed Eurasia, and the woolly mammoth, mastodon, giant ground sloth, large saber-tooth cat, and dire wolf reigned supreme in North America. Most such megafauna became extinct at the end of the Pleistocene, about 10,000 years ago. But the gray wolf, *Canis lupus*, is one of the few exceptions, and remains one of the most successful large canids in the world.

From about the beginning of the Pleistocene the genus *Canis* has had a continuous presence in Eurasia, along with various species of fox and raccoon dog. Gray wolves are present beginning about 1 million years ago. Early humans—*Homo erectus, H. neanderthalensis,* and *H. sapiens*—must have competed with some larger species of canids, because they shared a broadly similar hunting (and scavenging) lifestyle. By the end of the Pleistocene, the inevitable close encounters between modern humans and wolves—in the Middle East or Europe, or possibly China—resulted in the first domestication of a canid. If one counts the domestic dog as a highly specialized adaptation for cohabiting with humans, then canids have achieved ultimate success in occupying nearly every corner of the world—in all sizes, shapes, and speeds.

Xiaoming Wang (near right) began researching the evolution of the canid family for his doctoral dissertation and then spent several years at the American Museum of Natural History in New York, studying canid fossils under the guidance of **Richard H. Tedford** (above right). Wang produced a monograph on the canid subfamily Hesperocyoninae, and the two, along with paleontologist Beryl E. Taylor, produced another on the Borophaginae. The three will soon complete one on the Caninae. Wang is a curator in the Department of Vertebrate Paleontology at the Natural History Museum of Los Angeles County. Tedford, one of the foremost authorities on the evolution of the Carnivora, is now a curator emeritus in the Department of Vertebrate Paleontology at the American Museum.

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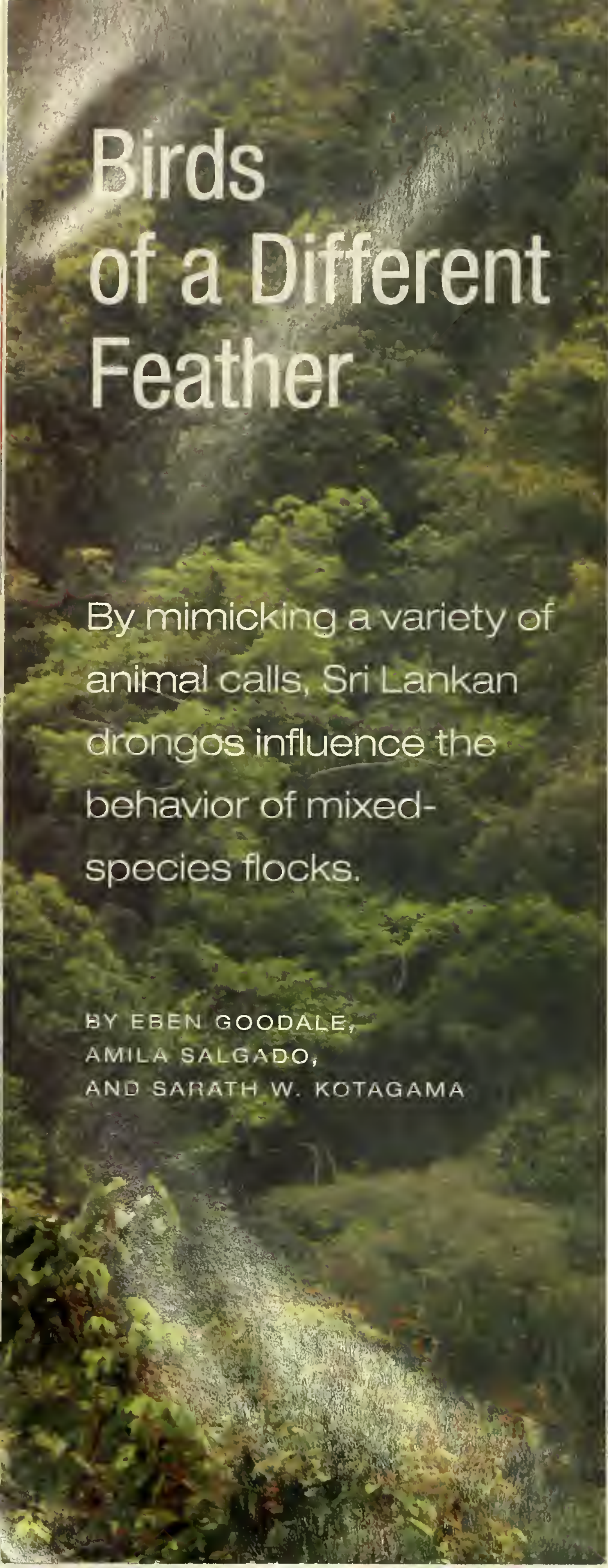
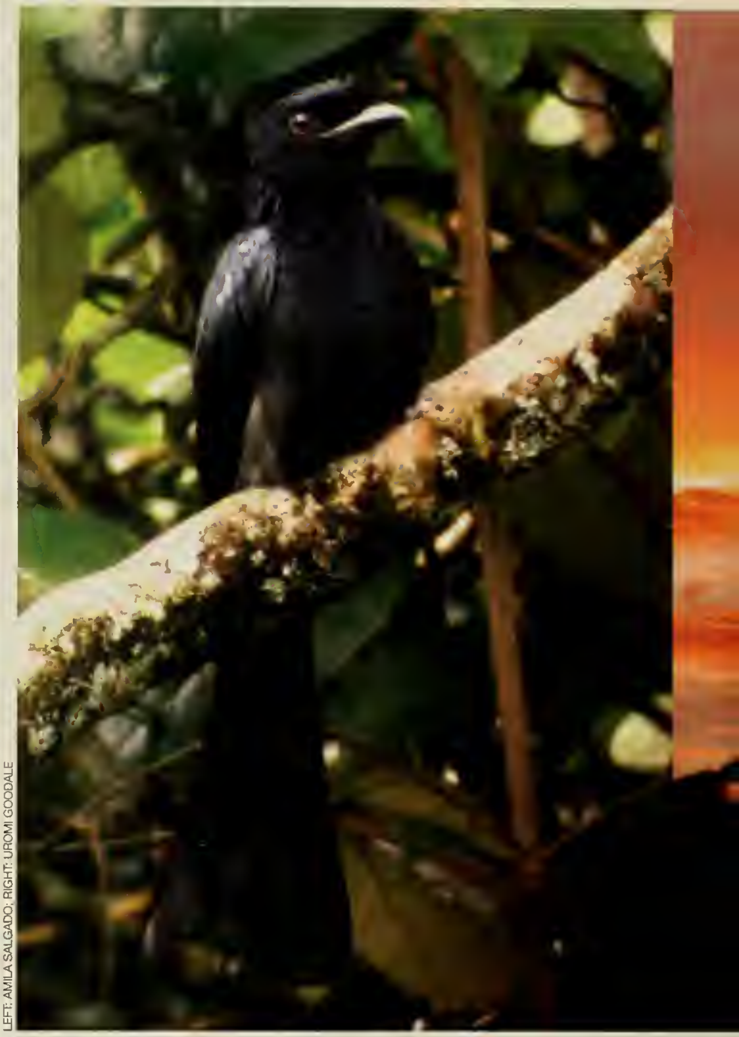


Birds of a Different Feather

By mimicking a variety of animal calls, Sri Lankan drongos influence the behavior of mixed-species flocks.

BY EBEN GOODALE, AMILA SALGADO, AND SARATH W. KOTAGAMA

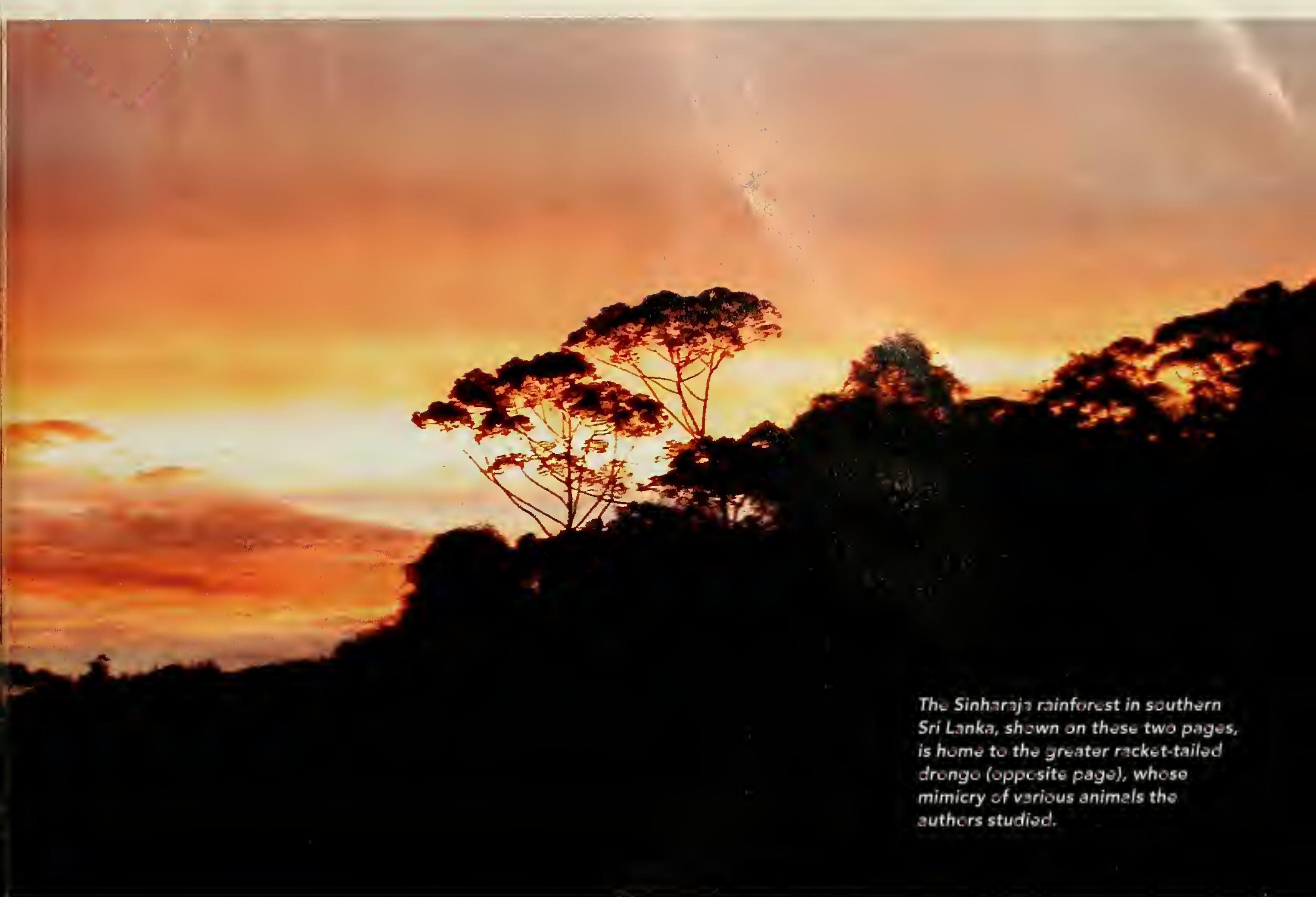


LEFT: AMILA SALGADO; RIGHT: UROMI GOODALE

We were losing the flock. A thicket of bamboo in the Sri Lankan rainforest blocked a clear line of pursuit, and we hadn't heard any birdcalls for several minutes—only the sawmill whine of cicadas. Suddenly a black bird appeared, flying back toward us. It was a greater racket-tailed drongo (*Dicrurus paradiseus*), a handsome bird with an elegantly forked tail that is almost always found in flocks of mixed species. It perched close by, about ten feet away, facing us. Clearly intent on what we were doing, it made direct eye contact and began to call with a series of loud, strident notes—a call typical of drongos announcing a stationary predator. That behavior, a form of "mobbing," probably warns other birds of danger or informs the predator it has been seen.

What happened next was more surprising than the drongo's mobbing of us. Mixed in with calls of its own species, we heard the calls of other voluble species that fly in flocks alongside the drongos: the staccato chatter of the orange-billed babbler (*Turdoides rufescens*), the high-pitched call of the ashy-headed laughingthrush (*Garrulax*

UROMI GOODALE



The Sinharaja rainforest in southern Sri Lanka, shown on these two pages, is home to the greater racket-tailed drongo (opposite page), whose mimicry of various animals the authors studied.

cinereifrons), and the trilled ring-a-ling, reminiscent of an old-style telephone, of the Sri Lanka scimitar babbler (*Pomatorhinus melanurus*)—all coming from the one drongo [*see photographs on pages 26 and 27*]. But they were not just any calls, tossed in for effect: they were specifically the calls that those species make when mobbing. Like a person speaking in a second (and third and fourth) language, the drongo was making the very calls the other species would have made if they had been present.

Finally, before it flew away, the bird mimicked the call of a common predator in the rainforest, the crested serpent eagle (*Spilornis cheela*). Then it took off in the direction of its flock. We were left speechless. What had we just observed, and why had the drongo behaved in that way?

More than twenty known drongo species make their homes over a vast range, from northeastern Australia through temperate and tropical Asia to sub-Saharan Africa and Madagascar, yet they are not a particularly well studied group. Nor are they much beloved by birdwatchers (indeed, calling someone a drongo is a term of abuse in Australia). Perhaps that is because the birds are not visually striking—they are uniformly black and gray—though they more than make up for their lack of dramatic color with the wide variation of their calls, which run the gamut from grating, clamorous shrieks to melodious whistles. And drongos are far from shy about making noise; they are in fact aggressive, often chasing or mobbing predators, even those much larger than themselves.

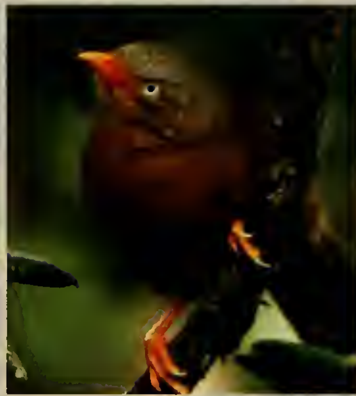
Some drongo species are open-country birds, others dwell in forests, but all forage for insects they catch on the wing. They spend much of their stationary time perched upright, turning their heads back and forth, scanning for prey. Anything that might cause insects to jump into the air attracts them, such as a rowdy troop of monkeys or a racing wildfire. Flocks of birds with certain foraging methods can likewise rouse insects as they move through the forests. The greater racket-tailed drongos found in the Sinharaja rainforest of southern Sri Lanka, where we conduct most of our drongo research, often join such flocks. The flocks on average comprise a dozen different species and forty or so individuals, with two to four

ANIMALS MIMICKED BY DRONGOS SOUNDING AN ALARM

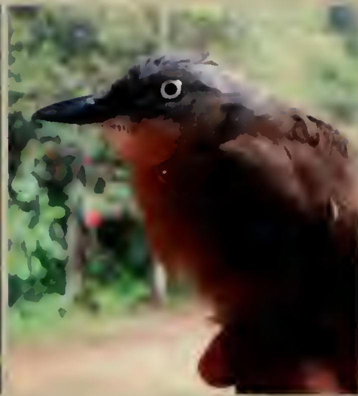
FIRST, SECOND, AND FOURTH PHOTOS FROM LEFT: AMILA SALGADO; THIRD PHOTO: VIMUKTHI W... ATHUNGHE

CRESTED SERPENT EAGLE

SRI LANKA BLUE MAGPIE



ORANGE-BILLED BABBLER



ASHY-HEADED LAUGHINGTHRUSH

FIRST AND SECOND PHOTOS FROM LEFT: AMILA SALGADO; THIRD PHOTO: WEN-HSIN HUANG

GRIZZLED GIANT SQUIRREL

TOQUE MACAQUE

BESRA SPARROWHAWK

When alarmed, drongos mimic a variety of sounds associated with danger: the calls of aerial attackers (the crested serpent eagle and Besra sparrowhawk) or nest predators (the Sri Lanka blue magpie and toque monkey), or the alarm calls of other species in the forest (the orange-billed babbler, the ashy-headed laughing-thrush, and the grizzled giant squirrel). Groups on this and opposite page are shown in order from most to least imitated.

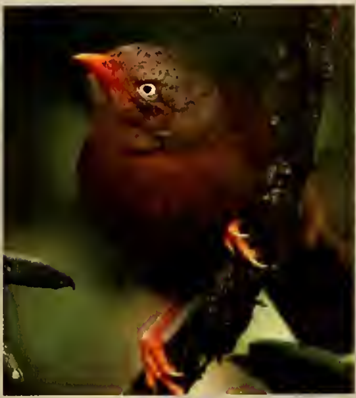
drongos among them. While leaf-gleaning birds do the dirty work, drongos wait to grab the insects that the other birds flush into the air. Being a flock member certainly pays off: a greater racket-tailed drongo in a flock gets approximately 40 percent of its food from creatures disturbed by its flockmates, and will eat at three times the rate of a racket-tail unfortunate enough to be outside of a flock.

At first glace, drongos appear to be parasites on their travel partners. Beyond taking advantage of any insects sent flying, the birds will occasionally steal food—or "kleptoparasitize," in the more polite scientific terminology—directly from other members of the flock. Still, their role in mixed-species flocks is one of the more complex questions we have encountered in our long-term studies of flock ecology and organization in Sri Lanka. In "playback" experiments that simulate the presence of drongos by playing their vocalizations on speakers, we found that contrary to what one might expect, other bird species are actually attracted to drongo calls. Birds seem to be gaining some benefit from joining drongos, a benefit that outweighs the costs of kleptoparasitism.

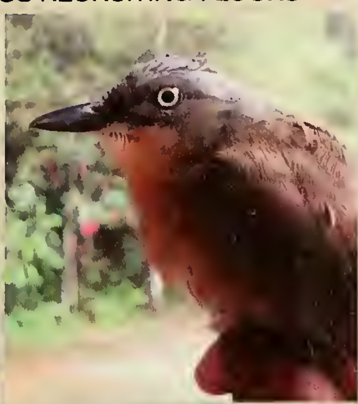
Most likely, the drongos' vigilance against predators makes up for their transgressions. The leaf-gleaning species have their view blocked by the leaves they are inspecting, whereas drongos may spy danger, such as eagles, more quickly. And true to their vocal nature, upon detecting a threat, drongos make loud alarm calls. Although other birds in Sri Lankan flocks also broadcast alarms, theirs seem to be less reliable than drongos': we have found that they miss true threats more frequently, and they make a higher percentage of false alarms, warning of such fast-flying or large, but nonthreatening, birds as parrots or hornbills. Drongo alarms, as tested in playbacks, spur other species to move quickly for cover. Thus the overall relationship between drongos and other flock participants seems to be a mutual give-and-take, whereby both parties gain.

But that is not all. The drongo's mobbing of us was an important moment because it was then that we first realized just how sophisticated the birds' mimicry is. Before that, however, we'd been duped on several occasions into thinking that we were near a mixed flock when in fact close observation revealed only a drongo or two sitting motionless above us. Those drongos displayed a particular style of non-alarm mimicry in which they rotate through imitations of other flocking species, mixing in their own species-specific calls. But why do they do it? Our observations suggest that drongos use such mimicry to attract birds for their own purposes. They choose different sounds

BIRDS MIMICKED BY DRONGOS RECRUITING FLOCKS



ORANGE-BILLED BABBLER



ASHY-HEADED LAUGHINGTHRUSH

YELLOW-BROWED BULBUL

COMMON IORA

FIRST PHOTO FROM LEFT: VIMUKTHI WEERATHUNGHE
SECOND AND THIRD PHOTOS: AMILA SALGADO
FOURTH PHOTO: MARTIN CREASSER / ALAMY

In situations free from danger, drongos imitate the songs and "contact calls" of various other bird species, particularly those they join in flocks. Such mimicry serves to recruit flocks and manipulate their behavior, all to the drongos' benefit.

WHITE-FACED STARLING

SRI LANKA SCIMITAR BABBLER

BLACK-NAPED MONARCH

AMILA SALGADO

to sing for particular functions. In one study, by monitoring the location of drongos using radio transmitters, we showed that drongos perform the majority of their mimicry when they are without a flock, and benefit by attracting other birds.

As turns out, drongos don't like to travel far. They have home ranges of about one mile in diameter at most. If a drongo's flock moves outside of the home range, the drongo stays behind and begins to vocalize, and mimic, heavily. On four such occasions, we clearly saw the flock turn around and move back in the direction of the calling drongo.

To test the idea that drongo mimicry does indeed attract other birds or flocks, we conducted another playback experiment. We made two types of recordings of drongo non-alarm vocalizations: one with mimicry and the other edited to include only drongo species-specific notes. When we played the tapes back to birds, we found that more than twice as many species responded to the tapes that included mimicry. Thus, through mimicry drongos can re-form flocks or manipulate flock movements—all for the sake of extra food, it seems.

DRONGOS, PARROTS, AND PORPOISES ARE THE ONLY ANIMALS CLEARLY SHOWN TO IMITATE OTHER SPECIES' VOCALIZATIONS IN CONTEXT.

Another extraordinary feature of drongo mimicry is that it varies depending on context. Many of the world's songbird species are known to mimic, but often their choice of what to copy appears random, ranging from car alarms to chainsaw roars. Well-known imitators, such as males of the northern mockingbird and the European starling, appear to use mimicry to expand their repertoire of songs, evidently to impress females of their own species.

In contrast, drongos put their mimicry skills to different uses in different contexts. When alarmed—with predators sighted nearby—drongos imitate the alarm calls of other species or the calls of predators themselves. An astounding example of that is their mimicry of the blood-curdling scream of the grizzled giant squirrel (*Ratufa macroura*). They even distinguish between the calls other bird species make while mobbing a terrestrial predator, such as a snake or a mongoose, versus a perched aerial predator, such as a hawk. When drongos are not alarmed,

LEFT: NICK GARBUTT/NHPA; RIGHT: JAN ŠEVČÍK

The shikra, above left, and the crested goshawk, above right, both prey on drongos and their flockmates. Because drongos perch upright and scan the air around them for insects, they identify predators more reliably than do birds that hunt insects on the ground and in the foliage. That may be why the other birds tolerate the drongos' presence, despite the fact that drongos sometimes steal their food.

they imitate other species' songs and so-called contact calls—the calls made by a group of birds to keep in contact during foraging. It's as if drongos are multilingual.

There is danger in being the main mobber for a flock: after all, a mobber inevitably draws the attention of predators. Like the drongo, an American bird called the phainopepla (*Phainopepla nitens*) mimics the calls of predators and the alarm calls of other species. Ornithologist Miyoko Chu studied the phainopepla when she was a graduate student at the University of California, Berkeley, and found that the bird's mimicry increases the mobbing activity of other species. So it seems that the birds may seek safety in numbers when undertaking mobbing. We expect that drongo alarm mimicry performs the same function, but we have not yet done the playback experiments to test that idea.

Since drongos participate in mixed flocks from the time they are fledglings through maturity, they probably learn other species' calls directly, associating certain call types with certain distinct contexts. But if drongos need to learn their repertoire of alarm calls, a class of vocalizations usually considered innate, aren't young, naïve birds at risk of not responding correctly in life-threatening situations? We plan to explore that question next.

The flexible and complex mimicry of drongos has been a revelation to us. They not only make both alarm and non-alarm calls of other species, but also use the calls in different, appropriate contexts. Parrots and porpoises are the only animals besides drongos clearly shown to imitate other species' vocalizations in a contextually correct manner. In parrots and porpoises, the behavior has been studied almost exclusively in laboratory settings, and it hasn't been entirely clear how they use their remarkable abilities in the wild. Observing drongos in their natural environment, on the other hand, we've been able to suggest reasons why imitation of other species might be adaptive.

The influence drongos have on their flock compatriots may not represent an equal cross-cultural dialogue—drongos, silver tongued, have the obvious advantage—but it certainly offers a starting place to understand how a mix of species interact. Ultimately, we are also gaining insight into the complexity of the once maligned "bird brain"—and finding a need for more cross-cultural communication between birds and humans.

Eben Goodale (near right) has been studying mixed-species flocks since 1995. His doctoral work focused on communication in those flocks, which he continues to study in Sri Lanka, India, and Papua New Guinea. **Amila Salgado** (above center) is a devoted birdwatcher and photographer. He founded Birdwing Nature Holidays, a Sri Lankan tour company, and visits the Sinharaja rainforest often. **Sarath W. Kotagama** (above right) began to study the mixed-species bird flocks of the Sinharaja rainforest in 1981, and his research helped convince the government to protect the forest. He is a professor of environmental science at the University of Colombo and a former director of the Sri Lankan Wildlife Department.

Web links related to this article can be found at www.naturalhistorymag.com

THIS LAND BY ROBERT H. MOHLENBROCK

Water Sprites

Diverse wetlands rub shoulders in Michigan.

Spring growth of cinnamon fern uncurls in the Rose Lake bog.

In 1938, the Michigan Department of Conservation purchased 765 acres of farmland, swampland, and small lakes about twelve miles northeast of Lansing, and the Rose Lake Wildlife Experiment Station was established. Additional land has been added since to make a total of 4,140 acres of diverse habitats. It is now known as the Rose Lake Wildlife Research Center. Operated by the Wildlife Division of the Michigan Department of Natural Resources, the property is managed for a variety of purposes, including research, education, and conservation. Hunting is permitted in designated areas during the hunting season (generally September 15 through March 31); other recreational uses are hiking, biking, and target practice.

Rose pogonia

WOODFALL/PHOTOSHOT

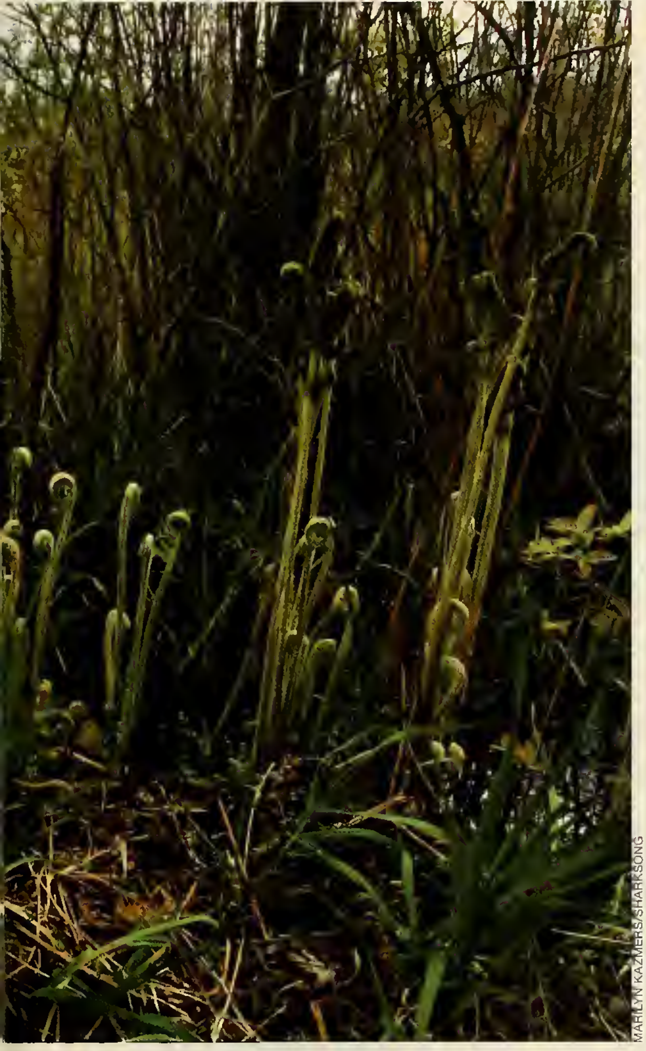
To make the area more attractive to wild birds, beginning in the mid-1940s the upland areas (most of which had been woodlands before being cut down) were planted with autumn olive, bush honeysuckle, European highbush cranberry, and other non-native berry-producing shrubs. Since then the birds have distributed those exotic shrubs into previously pristine areas, since the seeds pass through birds unscathed and readily germinate when they fall on suitable terrain. Nonetheless, there are still some fine native habitats; most of these are extremely wet areas where the previous landowners were unable to farm and where the exotic shrubs have had little impact.

Three wetland habitats within one mile of each other—a swampy wood along Clark Road and a fen and a bog near the Rose Lake headquarters on Stoll Road—provide a lesson in similarities and contrasts. The swampy wood has a dense canopy overhead, whereas the bog has few trees and the fen none at all. The water in the swampy wood, which stands up to a foot deep in places throughout the year, is slightly acidic. The underlying water in the bog is more strongly acidic, while the underlying water in the fen is basic. The majority of wetland plants show an affinity for just one or two of the

HABITATS

Swampy wood American elm, box elder, green ash, red maple, and swamp white oak form the tree canopy. Red-osier dogwood, silky dogwood, swamp dewberry, swamp red currant, and swamp rose are common shrubs. Common sedges are fowl manna grass, fringed sedge, lake sedge, and spongy sedge. Wildflowers include fringed yellow loosestrife, late goldenrod, marsh marigold, skunk cabbage, swamp aster, swamp saxifrage, and tufted loosestrife. Ferns are abundant, including cinnamon fern, intermediate wood fern, royal fern, and sensitive fern, along with at least three members of the fern-related genus *Equisetum*, which includes the horsetails and scouring rushes. Upland species that grow on small rises include black haw, Canada mayflower, starry false Solomon's seal, white lettuce, and wild geranium.

Bog American larch, whose branches bear clusters of deciduous needles three-quarters to one inch long, is the dominant tree, though poison sumac is common. Small shrubs include dwarf birch, highbush blueberry, hoary willow, leatherleaf, meadowsweet, shrubby cinquefoil, swamp dewberry, swamp red currant, and swamp rose. Sphagnum moss abounds,



MARILYN KAZMERS/SHARKSONG

wetlands; only swamp dewberry, a shrub with trailing, bristly stems, appears consistently in all three.

The bog is dominated by acid-loving plants belonging to the heath

Bog bean

MARILYN KAZMERS/SHARKSONG PHOTOGRAPHY

family, while the fen and swampy wood lack species in that family. The bog is also unique in harboring pitcher plants and sundews (both carnivorous) as well as orchids. Sphagnum moss, absent from the fen and swampy wood, is plentiful in the bog, often forming large spongy mounds in which many of the other bog species grow. In places, the bog contains a floating mat of vegetation, so that if one gently bounces up and down, the entire mat begins to pulsate.

Huge plants of royal fern and cinnamon fern are found in both the bog and the swampy wood, as are swamp rose, skunk cabbage, and marsh marigold, but none of these occurs in the fen. Red-osier dogwood and fowl manna grass are inhabitants of the fen and the swampy wood, but are not present in the bog. Plants common to both the bog and the fen are shrubby cinquefoil, marsh cinquefoil, meadowsweet, dwarf birch, perfoliate boneset, and hoary willow.

Although the upland areas at the Rose Lake Wildlife Research Center were cleared in the past, a fairly attractive secondary wood now covers the slopes above the fen. The dominant species are American basswood, black oak, black walnut, northern red oak, shagbark hickory, white oak, and wild black cherry. Among the shorter trees are chokecherry and serviceberry, two members of the rose family with attractive flowers.

The fen ends abruptly at its eastern border, where the water becomes deeper and provides an ideal habitat for an unbroken stand of narrowleaf cattail. And between the northern edge of the bog and Rose Lake itself, one stretch of shoreline is lined with swamp loosestrife, a plant whose arching woody stems bear hundreds of pink flowers during the summer. Climbing over the swamp loosestrife are the prickly stems of a vine known as tearthumb.

JOE LEMONNIER

VISITOR INFORMATION
Rose Lake Wildlife Research Center
8562 East Stoll Road
East Lansing, MI 48823
517-641-4903

www.dnr.state.mi.us/publications/pdfs/wildlife/viewingguide/slp/103Rose/

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

forming a substrate for many other plants, including pitcher plants, sundews, and two wild cranberries. Orchids that bloom in May are grass-pink, rose pogonia, and showy lady's slipper, while August features three species of fringed orchids in the genus *Platanthera*. A low-growing plant with clusters of white to creamish flowers and large leaves divided into three leaflets is bog bean, a species related to gentians. Sedges include brownish sedge, narrow-leaved woolly sedge, and three-way sedge. Among the wildflowers are bog goldenrod, marsh bellflower, marsh cinquefoil, marsh marigold, perfoliate boneset, and skunk cabbage. Cinnamon fern and royal fern are common.

Fen Dwarf birch, hoary willow, meadowsweet, red-osier dogwood, shrubby cinquefoil, and swamp dewberry are among the shrubs. The wetter part of the fen is covered by an abundance of sedges that include Crawe's sedge, fowl manna grass, hard-stem bulrush, Mead's sedge, sterile sedge, three-square, tussock sedge, twig rush, and two kinds of cotton sedges. The delicate Kalm's lobelia, marsh cinquefoil, marsh Saint-John's-wort, mountain mint, perfoliate boneset, Riddell's goldenrod, and willow aster are among the wildflowers.

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BOOKSHELF BY LAURENCE A. MARSCHALL

Beach Reading

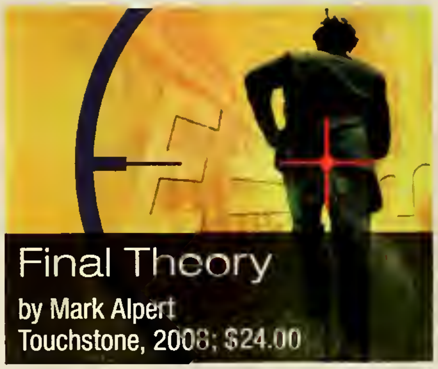
Reading may not be sweat-inducing, but something about the dog days of summer makes one want to go light on mental exercise. July and August reading choices should require only a comfortable beach chair, a generous coating of SPF-30 lotion, and a few lazy hours. Here are some recent offerings whose authors add a little bit of science and natural history to the mix.

Something strange has been happening in the graviton laboratory of Yariko Miyakara, a physicist at the University of Creekbend, South Dakota. Although the chamber that holds her apparatus is sealed and airtight, beetles are randomly turning up inside. Stranger still, when removed from the chamber they vanish from their jars within days. When she calls on Julian Whitney, the university's paleontologist, for advice, he tells her that the beetles have been extinct for 65 million years.

Several pages into this fast-paced novel, you just know what's going to happen next: Miyakara and Whitney, along with another physicist, a security guard, and a German shepherd, enter the graviton chamber and—boom!—find themselves "translocated" into the age of dinosaurs. Something unforeseen in the graviton apparatus is transporting objects back and forth through time. Beetles were small stuff. Now this motley crew is stuck in a world of giant carnivores, with only a few tools and no return ticket.

Of course, there is a way back, since the disappearing beetles presumably made the return trip. But unfortunately for our heroes, and fortunately for us readers, it involves an adventure-filled journey through a thousand miles of Cretaceous landscape. Since the brother-and-sister authors of the book are both Ph.D. scientists (in oceanography and neuroscience), this gives them plenty of opportunity to discourse on the behavior of dinosaurs and the ecology of ancient North America. It's not hard to imagine the authors consulting journal articles on Cretaceous biology and ecology to flesh out their story, converting research on dinosaur diets, for instance, into descriptions of the foul stench of ankylosaur turds.

In spite of its references to hard academic science, however, *Cretaceous Dawn* is a first-class adventure story, an effortless read as engaging as vintage Jules Verne. The descriptive prose is both evocative and illuminating, and the plot has enough twists and cliff-hangers to keep readers traveling on to the inevitable translocation back to the present.



Given the centuries-old literary tradition of the Holy Grail and the more recent blockbuster success of *The Da Vinci Code*, it's not surprising that new versions of the grail quest story continue to appear. This latest contribution, however, is about the holy grail of theoretical physics: the Unified Field Theory. The pursuit of a single set of equations knitting together quantum mechanics and relativity occupied Einstein for much of his later life, but he did not solve the problem, nor has anyone since.

What if Einstein actually had succeeded, but because the military implications of the theory appalled him, he decided to keep it to himself? Well, not quite to himself . . . what if he had spilled it to his most trusted collaborators with the understanding that they would remain forever silent? And what if, many years later, someone learned of Einstein's secret and set about to extract it from the few surviving confidants . . . by whatever means necessary? Then suppose that an innocent person, say an unassuming historian of science, was called to the deathbed of a former mentor, an old physics professor who had been tortured by a mysterious assailant . . . and suppose the professor asked him to memorize a seemingly random sequence of numbers—keys to the Unified Field Theory.

David Swift, the hero of this first novel by *Scientific American* editor Mark Alpert, is abruptly swept into a nightmare of violence and intrigue by just such a chain of events. Pursued by police, federal agents, and a terrorist of diabolic depravity, he allies himself with a stunning Princeton string theorist named Monique, an autistic teenager named Michael, and a snake-handling fundamentalist named Graddick, to rediscover Einstein's notes and to foil the forces of evil. That's all you need to know—other than a warning: do not begin this book less than several hours before a dinner or other social engagement. You will probably not be able to stop reading until (I'm not giving much away here) the world is safe and David Swift is in the arms of Monique at last.

This isn't exactly science fiction, though it does feature a lot of space travel and a world in which people are genetically engineered to stay as young as they choose. Nor is it exactly lesbian lit; yet the central love theme is an affair between a beautiful renegade government employee named Billie Crusoe and a "drop-dead gorgeous" fembot named Spike (according to the book, the first "Robo *sapiens*").

At first, this does not even appear to be a novel, but rather three short stories. The first begins on the high-tech planet Orbus, dying because humans have exhausted its natural resources. The hope is that as Orbus dies, humans will be able to start all over on a newly discovered blue planet light-years away, where the only inhabitants are animals in a much earlier evolutionary state, including dinosaurs. Billie and Spike join a group of prospective colonists who land on the planet, but things do not quite develop as planned: dark clouds gather over paradise, and they face their own extinction as well as that of the blue planet's native inhabitants.

The second story takes place on Earth in the eighteenth century A.D., when a member of Captain Cook's crew, named Billy, finds himself marooned on Easter Island, witnesses the destruction of the island's last tree, and becomes enmeshed in a tragic cycle of tribal warfare. The third and final story is a vignette of an Earth after a nuclear war. Engineers have developed a robot—only a head, also named Spike—to help bring about a lasting peace. The robot, however, makes other plans.

What connects the three stories only becomes apparent in the final section, when seemingly unrelated motifs come together and the narrative resolves into a meditation on how humans relate to each other and to the natural world. That may be a bit more weight than is advisable for light summer reading, but the humor and sheer intelligence of Winterson's prose more than offset the novel's underlying darkness.

You can almost see the smoke and hear the calls to prayer as author Jenny White guides you through the narrow streets of Istanbul. The year is 1887, and Kamil Pasha, a magistrate under the Ottomans, is trying to keep the city from going up in flames. Muslim refugees from wars in the Balkans are flooding the neighborhoods, straining relief agencies and stirring already tense relations between Christians, Muslims, Jews, and a variety of smaller sects. To make matters worse, treasured relics have been disappearing from churches, mosques, and synagogues, and each group is blaming the others, and the sultan's government, for the robberies. The Middle East, you might conclude, hasn't changed much.

The measure of a mystery set in the past lies in its command of details and of character. White, a Boston University anthropologist who has written widely about Turkish culture and politics, gets those just right. Her hero, Kamil, in his second outing (the first was in *The Sultan's Seal*), embodies all the contradictions of the Eurasian metropolis in which he lives. He is a thoughtful, literate man in a violent line of work, a Cambridge graduate who carries his grandfather's worry beads along with a revolver through the mean streets of the city. Equally memorable is Malik, the patriarch of an exotic Abyssinian sect, who enlists Kamil's help in investigating the theft of a silver box believed to contain proof of the existence of God. With a supporting cast of jaded police officers, ruthless crime lords, resourceful street urchins—and especially the green-eyed beauty, Saba—this book will leave you convinced you have traveled to an exotic time and place, if only for a few breathless hours.

ALSO WORTHY OF MENTION

Flatland: A Journey of Many Dimensions; The Movie Edition

by Edwin A. Abbott with Thomas Banchoff and the Filmmakers of *Flatland*
Princeton University Press, 2008; $15.00

Originally published in 1884, this wonderful fantasy—written three decades before Einstein's general theory of relativity and a century before string theory—explores the world of many dimensions by imagining a world of only two. When its protagonist–narrator, A Square, is visited by a sphere, his mind is stretched, and ultimately his placid world is turned inside out. The book is the companion piece to a 2007 animated movie, but whether you see the movie or not, the book is a must-read. If you've never thought much about why we inhabit only three dimensions, it may turn *your* world inside out.

Laurence A. Marschall is W.K.T. Sahm Professor of Physics at Gettysburg College in Pennsylvania, and director of Project CLEA, which produces widely used simulation software for education in astronomy.

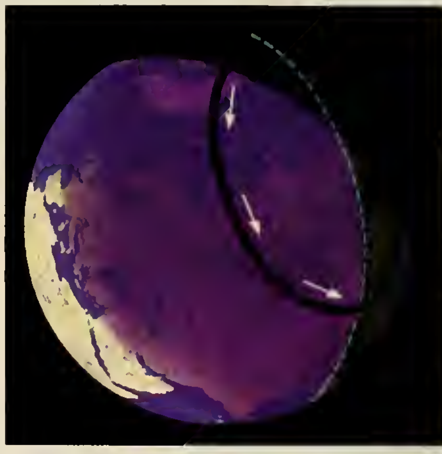
SKYLOG BY JOE RAO

The "star" of the summer is Jupiter, shining bright within Sagittarius, the Archer—above and to the left of the constellation's most prominent star pattern, popularly known as the Teapot. In early July, when Jupiter swings into opposition (that is, when it's on the opposite side of the Earth from the Sun), the planet rises at sunset, ascends highest in the south around 1 A.M. local daylight time, and sets at sunrise. Later in July and throughout August, it will be prominent in the southeast as dusk fades and will remain visible for most of the night.

The first total solar eclipse in nearly two and a half years takes place the morning of August 1. The Moon's umbra, or full shadow, will first fall north of the Arctic Circle in Canada, where Earthlings positioned to get the earliest view of totality will see the Sun eclipsed as it rises. The umbra will then sweep northeastward, giving a glancing blow to northern Greenland, before heading southeast out of the Arctic Circle, through Siberia and western Mongolia and into China. Viewers about 400 miles southwest of Beijing will get the last glimpses of the total eclipse as the Sun sets. Many eclipse watchers are expected to gather at Novosibirsk, the largest city in Siberia. Weather permitting, they will witness a total eclipse lasting two minutes twenty seconds. Many regions will experience a partial eclipse.

The Perseid meteor shower, which peaks during the night of August 11–12, will probably offer the best meteor spectacle in 2008, since the December Geminids will be washed out by a full Moon. The waxing gibbous Moon will set around 1:30 A.M. local daylight time, leaving a dark sky for the next three hours. The constellation Perseus, from where these shooting stars appear to radiate, will be climbing the east-northeastern sky during the predawn hours.

The Perseids appear each summer as Earth crosses the orbit of comet Swift-Tuttle, brushing past dusty debris the comet has left in its wake. Following a long elliptical path, the comet shows up in our neck of the solar system about every 130 years. Although its most recent visit was in 1992, most of the meteors we see result from debris the comet left behind hundreds or even thousands of years ago. The Perseids peak over just a few hours; this year viewers in the Pacific time zone who scan the sky after the Moon sets may enjoy the best show. However, the shower remains substantial for about three days.



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Total solar eclipse, August 1: The moon's umbra, or full shadow, will sweep from Canada into China (thin black path); neighboring regions will experience a partial eclipse (purple shading). Earth's night side is shown for the beginning of the eclipse; dotted line shows where it will be two hours later, when the eclipse ends.

JOE RAO (hometown.aol.com/skywayinc) *is a broadcast meteorologist and an associate and lecturer at the Hayden Planetarium in New York City.*

JULY NIGHTS OUT

1 Mercury approaches its greatest elongation (apparent distance) west of the Sun—a separation of 22 degrees. Look for the planet low near the east-northeast horizon about an hour before sunrise. An hour or so after sundown this same day, low in the western sky, yellow-orange Mars will appear to hover just above the bluish star Regulus. Though equally bright, they are easily distinguished through binoculars. To the upper left of the pair, golden and twice as bright, is Saturn.

2 The Moon becomes new at 10:19 P.M. eastern daylight time (EDT).

5 Low in the western sky, about an hour after sundown, a crescent Moon, the bright star Regulus, and the planets Mars and Saturn form a straight line from lower right to upper left.

9 Jupiter arrives at opposition to the Sun (see story above).

9–11 The faster-moving Mars—situated about 1 degree below Saturn on the 9th—passes noticeably to Saturn's left by the 11th.

10 The Moon waxes to first quarter at 12:35 A.M. EDT.

18 The Moon becomes full at 3:59 A.M. EDT.

25 The Moon wanes to last quarter at 2:42 P.M. EDT.

AUGUST NIGHTS OUT

1 A total solar eclipse sweeps from northern Canada across the Arctic Circle and Siberia into China (see story above). The Moon becomes new at 6:12 A.M. EDT.

8 The Moon waxes to first quarter at 4:20 P.M. EDT.

11–12 The Perseid meteor shower peaks (see story above).

15 The planets Mercury, Saturn, and Venus will be closely bunched together close to the western horizon just after sunset. Unfortunately, only Venus may stand out against the Sun's glow—but viewers with binoculars could luck out.

16 The Moon becomes full at 5:16 P.M. EDT. A partial lunar eclipse will favor much of Europe, Africa, and Asia beginning at 19:36 and ending at 22:44 Greenwich Mean Time.

23 The Moon wanes to last quarter at 7:49 P.M. EDT.

30 The second new Moon this month arrives at 3:58 P.M. EDT.

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Quaint villages, festivals, scenic biking and hiking. Antique shops, country inns, fine restaurants.

23. CHESAPEAKE BAY MARITIME MUSEUM
Located in historic St. Michaels, the Museum boasts ten waterfront exhibits, working boat yard, and the largest collection of Bay boats.

24. DORCHESTER COUNTY
Home to Blackwater National Wildlife Refuge; explore the heart of Chesapeake Country.

25. FREDERICK COUNTY
Maryland's Crossroads of History. Antiques, battlefields, covered bridges, parks, wineries and more close to Gettysburg and DC.

26. KENT COUNTY
A scenic peninsula on the Chesapeake Bay, offering fishing, boating, kayaking, small beaches, great shopping, and museums.

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

28. MONTGOMERY COUNTY
Experience transportation history along the C&O Canal and the National Capital Trolley Museum. So many things to do.

29. ST. MARY'S COUNTY
Potomac River lighthouses, Chesapeake Bay seafood, and maritime history. Cozy inns, waterside dining and fantastic festivals.

30. WORCESTER COUNTY
Maryland's only seaside county. Visit Assateague Island National Seashore. Kayak, canoe, bird watch, golf, bed and breakfast inns.

MISCELLANEOUS

31. ATHENA REVIEW
Athena Review, journal of archeology, history and exploration, invites you to send for more information on a free issue.

32. ENDLESS POOLS
Swim or exercise in place against a smooth current adjustable to any speed or ability. Installed indoors or outdoors. Request a free DVD.

33. HERITAGE AUCTION GALLERIES
Heritage Auction Galleries' September Natural History auction features a comprehensive Private Collection of exceptional mineral specimens from around the world.

34. MASHANTUCKET PEQUOT MUSEUM AND RESEARCH CENTER
The Pequot Museum brings to life the Native American and Natural History of New England through engaging interactive exhibits.

35. ROSETTA STONE
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36. ARIZONA. THE GRAND CANYON STATE.
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37. DELAWARE TOURISM OFFICE
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38. TUCSON
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39. WASHINGTON STATE
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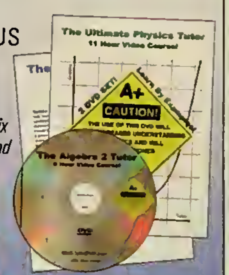

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Historic Summit Aims to Improve Science Education

In early April 2008, an eminent group of nationally recognized leaders in education, business, philanthropy, science, media, and government gathered for a dynamic summit convened by the American Museum of Natural History intended to expand and accelerate action to remedy America's science education crisis. The 37 speakers at *Science Generation: A National Imperative* represented a wide variety of sectors, from the President of the Federal Reserve of New York to a middle-school science teacher from New York City. They addressed a number of pressing issues: national science education goals and standards, improving science teaching, creating a re-energized family base that is motivated to embrace science, and others.

Ellen V. Futter, President of the American Museum of Natural History, set the stage with her opening remarks by saying, "We are in real danger in this country of getting used to the public not understanding science, our students continuing to have poor achievement in science, and our competitiveness in a global society continuing to erode. Yet, in this vital area, we simply do not have the luxury of 'getting used to it.' The consequences for our children, our society, our future competitiveness and position in the world—indeed, for our planet—are unimaginably serious."

© AMNH/D. FININ

Museum President Ellen V. Futter addresses the need for improved science education nationwide.

More than 300 attendees from 28 states, representing science centers, education policy institutes, school districts, and government agencies, as well as parents and students, agreed that the United States must move forward on a number of fronts to improve science education. Consensus was reached on several key needs:

- the need for national, or "common," standards to achieve excellence and equity
- the need for cross-sector, cooperative action
- the need to identify promising, effective practices that can be brought to scale
- the need for science-rich institutions (such as museums, botanical gardens, zoos, and science centers) to work more closely with formal K–12 education
- the urgent need for leadership and advocacy, especially regarding fully funding and implementing the America COMPETES (Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science) Act
- the need to engage parents and students in embracing the imperative of educating a "science generation"

A number of promising programs across the country demonstrated success in improving science education, including the Alabama Math, Science, and Technology Initiative, Ohio's STEM (science, technology, engineering, and mathematics) Learning Network, and the Boston Museum of Science's "Engineering Is Elementary" curriculum. New York City's Urban Advantage Consortium (being replicated in Chicago, Miami, and Denver), a public-private partnership with the New York City Department of Education that brings the resources of eight science-rich cultural institutions to bear on science teaching and learning in the schools, is a prime example of tying together formal and informal education.

In a session moderated by NBC's Tom Brokaw and Frank Luntz, a dozen students from the World Journalism Preparatory School in Queens (a public middle school) and their parents emphasized the importance of parent involvement and the role of museums in capturing their attention and nurturing their fascination with science. Many of the students agreed that weekend trips to various New York cultural institutions broadened their interest in science topics that may or may not have been covered in the classroom.

The cross-disciplinary approach of this unprecedented meeting mirrors the conclusions that nurturing a "science generation,"—bringing equity across socioeconomic divisions, fostering enthusiasm, promoting standards—requires the participation not just of education and government, but also philanthropy, business, media, cultural organizations, community services, and perhaps most importantly, parents and students themselves.

The American Museum of Natural History gratefully acknowledges support for this event from presenting sponsor The Goldman Sachs Foundation and from principal sponsors Carnegie Corporation of New York and the GE Foundation, as well as additional support from Shell Oil Company.

Other key partners in the development of this summit were NASA, NOAA, the National Science Foundation, the New York City Department of Education, the American Association for the Advancement of Science, the National Science Teachers Association, and the Council of the Great City Schools.

Island-Hopping for Malaria's Evolutionary Path

© ANN PETERSEN

Dr. Susan Perkins on the island of Saint Barthélemy

Who doesn't dream of turquoise waters, verdant backdrops, and scarlet birds? Susan Perkins has taken the archetypical vacation one step further: her research on the evolution of malaria "forces" her to island-hop in the Caribbean.

Perkins, Assistant Curator of Microbial Genomics in the Museum's Division of Invertebrate Zoology and the Sackler Institute for Comparative Genomics, has been studying malaria parasites in lizards and other animals for 13 years. In fact, while in graduate school, she discovered a cryptic species of this protozoan, the third known lineage that infects lizards in the Lesser Antilles. Malaria parasites are found throughout vertebrates: there are more than 400 described species that infect birds, reptiles, and mammals and that are transferred into their hosts by a range of vectors from black flies to mosquitoes.

Years of research and analysis are paying off. Perkins and colleagues published a paper this year that places different genera and species of malaria parasites into a well-supported evolutionary tree. They found that bird parasites gravitate toward the base of the tree when compared to the parasites found in other vertebrates and that vector switches are the major drivers of evolutionary change in this group.

Perkins will continue to refine her analysis of malaria evolution over the next few years, and she plans to broaden her collection of lizard blood to hammer out the old divisions between the parasites of lizards and birds. So now it's on to new locales such as the Philippines, Japan, Panama, and Guyana for more lizards and their parasites.

Web Extra: The Story behind *The Horse*

www.amnh.org/horse

The development of any exhibition holds unique challenges and that was certainly true of *The Horse*, the current show exploring the evolution of this animal and the ensuing enduring bond between horses and humans that truly changed the world.

For a window into the process of developing an exhibition, especially one in which conceptual information must be brought to life in a tangible way, visit www.amnh.org/horse, where an audio slide show takes you behind the scenes with the scientists, writers, and designers who created this fascinating show.

One of the questions addressed in the eight-minute slide show is, how does one literally illustrate the diverse factors involved in the domestication of wild horses? "It's actually quite abstract; it's not just about breeding for specific shapes and purposes, it's also about behavior," explains one of the narrators, Ross McPhee, Curator of Mammalogy, AMNH, and co-curator of *The Horse* (with Sandra Olsen, Curator of Anthropology, Carnegie Museum of Natural History). "We had to toy around with several things." In the end, a combination of models, videos, and interactive computer stations makes the abstract concrete.

Throughout this web exclusive, you'll see various stages of the exhibition coming together, from large developments like the dioramas re-creating Nebraska ten million years ago and an archaeological dig site active in Kazakhstan, to smaller ones, no less thrilling, such as deciding on individual items. "One of the objects I really love is that ceramic horse from India," says Lauri Halderman, Director of Exhibition Interpretation, explaining how it expresses the symbolic rather than the physical, mundane role horses play in that country's culture. "The object itself is phenomenal. It's so big and ornate and fragile."

© AMNH/D. FINNIN

Alan Walker, Senior Production Manager (right), shows the hand-painted diorama backdrop to (left to right) Lauri Halderman; David Harvey, Vice President of Exhibition; and Ross MacPhee.

The same could be said of the fine balancing act that makes *The Horse*—or any of the Museum's exhibitions—the engaging blend of science, art, and technology it is.

At the Museum

American Museum of Natural History

www.amnh.org

EXHIBITIONS

The Horse

Through January 4, 2009

This trailblazing exhibition explores the origins of the horse family, extending back more than 50 million years; examines early interactions between horses and humans that led to horse domestication; and shows how horses have, over time, changed warfare, trade, transportation, agriculture, sports, and many other facets of human life.

The Horse is organized by the American Museum of Natural History, New York (www.amnh.org), in collaboration with the Abu Dhabi Authority for Culture & Heritage; Canadian Museum of Civilization, Gatineau-Ottawa; The Field Museum, Chicago; and the San Diego Natural History Museum.
The Horse at the American Museum of Natural History is made possible, in part, by the generosity of Rosalind P. Walter and the Eileen P. Bernard Exhibition Fund. Additional support has been provided by an anonymous donor.

© AMNH/H. DAVIES

Green Basilisk Lizard

Lizards and Snakes: Alive!

Through January 5, 2009

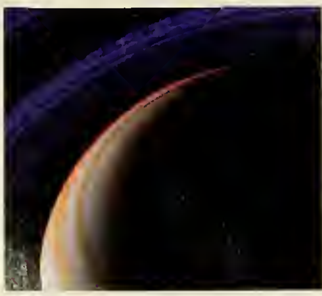
With over 60 live lizards and snakes from five continents, *Lizards & Snakes: Alive!* introduces visitors to the remarkable adaptations of these legged and legless lizards, such as projectile tongues, deadly venom, amazing camouflage, and sometimes surprising modes of locomotion.

Lizards & Snakes: Alive! is organized by the American Museum of Natural History, New York (www.amnh.org), in collaboration with the Fernbank Museum of Natural History, Atlanta, and the San Diego Natural History Museum, with appreciation to Clyde Peeling's Reptiland.

Saturn: Images from the Cassini-Huygens Mission

Through March 29, 2009

This stunning exhibition reveals details of Saturn's rings, moons, and atmosphere with images sent over half a billion miles by the *Cassini* spacecraft. Pictures from the largest moon, Titan, the first ever taken on the surface of an alien moon, are displayed alongside images of the giant geyser discovered on the smaller moon Enceladus.



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This false-color image taken from high above Saturn's north pole shows the Sun illuminating the rings.

The support of the National Aeronautics and Space Administration is appreciated. Special thanks to the Cassini imaging team, especially those scientists at Cornell University's Department of Astronomy, along with the staff of Cornell University photography. The Eastman Kodak Company of Rochester, New York, printed the images.

On Feathered Wings

Through May 25, 2009

This photography exhibition showcases the majesty of birds in flight: the controlled chaos, the acrobatic wizardry, the mysterious aerodynamics.

The presentation of both *Saturn* and *On Feathered Wings* at the American Museum of Natural History is made possible by the generosity of the Arthur Ross Foundation.

Unknown Audubons: Mammals of North America

Through August 2008

The stately Audubon Gallery showcases gorgeously detailed depictions of North American mammals by John James Audubon, best known for his bird paintings.

Major funding for this exhibition has been provided by the Lila Wallace-Reader's Digest Endowment Fund.

Public programs are made possible, in part, by the Rita and Frits Markus Fund for Public Understanding of Science.

GLOBAL WEEKENDS

Indigenous Peoples Day

Saturday, 8/9, 1:00–5:00 p.m.

Performers from the Halau I Ka Wekiu hula school in Hawaii headline this afternoon of cultural presentations, panel discussions, and films.

Cosponsored with the NGO Committee on the United Nations International Decade of the World's Indigenous Peoples.

COURTESY OF THE KAUAKOKO FOUNDATION

Halau I Ka Wekiu hula school in Honolulu

Global Weekends are made possible, in part, by the City of New York, the New York City Council, and the New York City Department of Cultural Affairs. Additional support has been provided by the May & Samuel Rudin Family Foundation, Inc., the Tolan Family, and the family of Frederick H. Leonhardt.

LECTURES

Global Kitchen: Mint Julep

Tuesday, 7/22, 6:30 p.m.

Taste a bit of history—the mint julep, official drink of the Kentucky Derby—with master mixologist Chris McMillian and cocktail historian David Wondrich.

FIELD TRIP

Bat Walks

Friday, 7/18 (rain date 7/19), 7/25 (rain date 7/26), 8:30 p.m. (Not for children under 5)

Rose Center for Earth and Space

Sets at 6:00 and 7:30 p.m.

Friday, July 4, and Friday, August 1

Visit amnh.org for lineup.

Join the New York Bat Group for a walk through Central Park to learn how bat watchers are cataloging the species that live in New York City.

AMNH ADVENTURES: SUMMER CAMPS

Each session includes hands-on investigations, behind-the-scenes tours, and visits with Museum scientists. For further information, please call 212-769-5315.

Water Camp
Monday–Friday, 7/7–11 (For children entering grades 2 or 3)

Robotics Camp
Monday–Friday, 7/7–11 (For children entering grades 6 or 7), Monday–Friday, 8/4–8 (For children entering grades 4 or 5)

Fossils and DNA Camp
Monday–Friday, 7/14–18 (For children entering grades 2 or 3), Monday–Friday, 7/28–August 1 (For children entering grades 4 or 5)

Meet the Beetles
Monday–Friday, 7/21–25 (For children entering grades 4 or 5)

Leapin' Lizards
Monday–Friday, 7/21–25 (For children entering grades 2 or 3)

Astrophysics Camp
Monday–Friday, 7/14–18 (For children entering grades 2 or 3), Monday–Friday, 7/28–August 1 (For children entering grades 4 or 5)

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AMNH summer campers are intrigued by science.

HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME

Virtual Universe

Things That Go Bang
Tuesday, 7/1, 6:30 p.m.

Journey through the Milky Way
Tuesday, 8/5, 6:30 p.m.

Celestial Highlights
Near and Far
Tuesday, 7/29, 6:30 p.m.

Searching Out Deep Space Wonders of the Galactic Plane
Tuesday, 8/26, 6:30 p.m.

These programs are supported, in part, by the Sant'Angelo/Koval Family and Val and Min-Myn Schaffner.

HAYDEN PLANETARIUM SHOWS

Cosmic Collisions

Journey into deep space to explore the hypersonic impacts that drive the formation of our universe. Narrated by Robert Redford.

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

IMAX MOVIES

Sea Monsters: A Prehistoric Adventure

Travel back 82 million years to a time when strange creatures filled the seas that once covered what is now the middle of North America.

INFORMATION

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

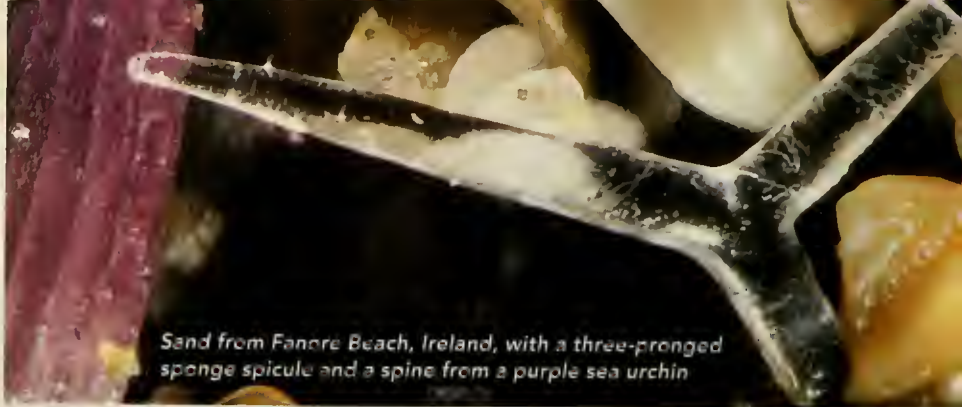
TICKETS AND REGISTRATION

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

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

Fine Grain

Story and Photographs
By Gary Greenberg



Sand from Fanore Beach, Ireland, with a three-pronged sponge spicule and a spine from a purple sea urchin

I started looking at sand under my microscope in 2001, when my brother sent me a can full of sand from Maui as a subtle hint to come visit him there. Expecting to see a bunch of tiny brown rocks, I was astonished at the spectacular colors, shapes, and textures! I have been collecting and examining sand from all over the world ever since.

Each beach has a unique signature written in its sand, a signature that speaks of the region's geology, mineralogy, and oceanography. The typical white to tan sandy beach is composed of silica, usually in the form of quartz (clear) and feldspar (orangey), because most continental landmasses are made of granite, which breaks down predominantly into those two minerals. The variety of Hawaiian beaches showcases their volcanic origins: Maui has red sand beaches, rich with oxidized iron; South Point on the Big Island glimmers green from pure olivine crystals; and numerous black sand beaches reveal grains of basalt or obsidian.

Some of the world's most beautiful sands are composed not of weathered rock or lava but of calcium carbonate. These sands, remnants of marine organisms, may come from shells, bones, spines, and teeth. Or they may be formed from the precipitation of minerals in solution. *Halimeda*, for instance, a type of seaweed, contains calcium that can solidify, creating as much as 90 percent of the sand on certain coral atolls.

And even human-hewn objects break down to become grains of sand, as on the Greek island of Delos. There, temples built from imported stone eroded over the years and filled the local beaches with nonnative bits of marble. (Plastic pellets are a much more alarming example of artifactual "sand grains" that can be found on beaches worldwide.)

Here are a few of my images with stories to tell.

GARY GREENBERG, *who now lives in Maui with his brother, is a visual artist with a Ph.D. in biomedical research from University College London. He holds seventeen patents for high-definition 3-D light microscopes. His book* A Grain of Sand: Nature's Secret Wonder *(from which these pictures are taken) was published in April 2008 by Voyageur Press.*

Clockwise from left: Star-shaped "foram"—the shell of a microscopic organism—from a beach in Japan; olivine crystals from South Point, Hawaii; garnet (red) and quartz from Plum Island, Massachusetts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