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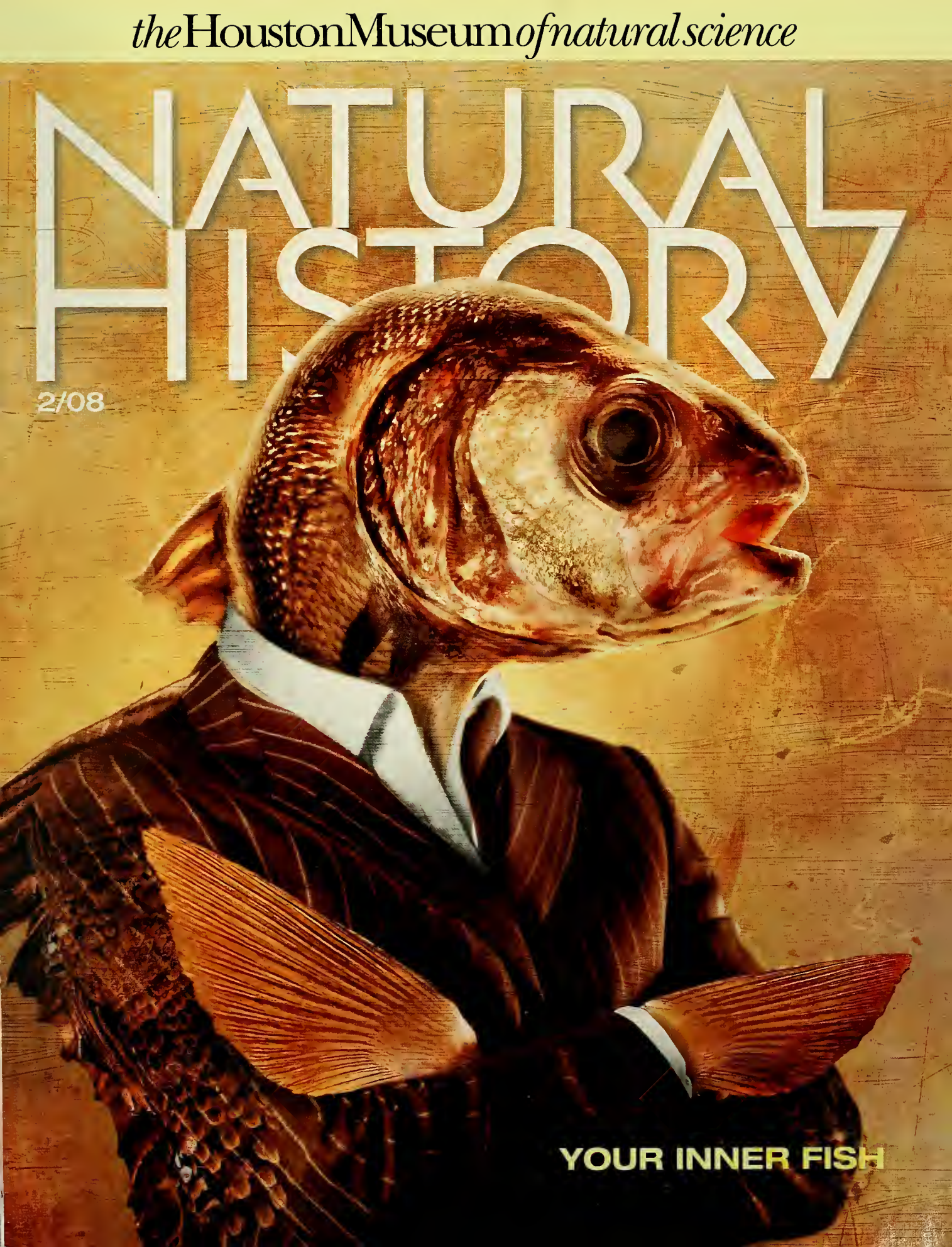

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FEBRUARY 2008 VOLUME 117 NUMBER 1

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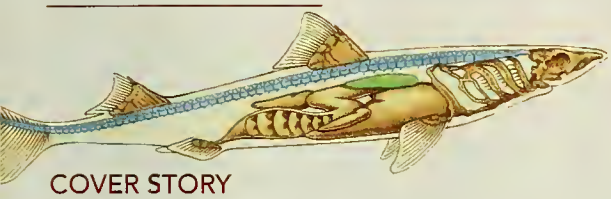
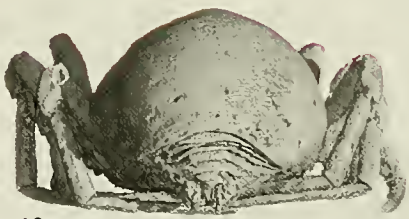
FEATURES



COVER STORY

ON THE COVER: Your Inner Fish
Illustration by Christos Magganas

DEPARTMENTS



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THE NATURAL MOMENT VEGETARIAN CARRION

Photograph by Michael Turco

◄ *See preceding two pages*


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Expect blow flies, flesh flies, coffin flies, and other kinds of carrion flies to come calling not long after death does. Female blow flies usually arrive first, driven to lay their eggs in the still-juicy flesh of a corpse. By homing in on telltale odors, such as those of sulfur and the aptly named putrescine and cadaverine, they can detect a dead body more than a mile away.

But how do the flies confirm such indirect signs of death? Well, they don't. Drawn by odors to an open, infected wound on an otherwise healthy animal, the flies will lay their eggs anyway. Upon hatching, the maggots, more discerning than their parents, eat only necrotic tissue—one reason why humans use them as alternatives to surgery and antibiotics.

The adult flies' morbid zeal has proved useful to several thousand plant species (and many kinds of fungi). The plants have evolved to smell remarkably like cadaverous flesh; some even resemble skin in color and texture. Most of the flowering species—such as the carrion flower pictured here, *Stapelia gigantea*—dupe flies into pollinating them, which leaves the maggots to starve on the petals in search of real meat.

As a forensic entomologist, Susan Gruner of the University of Florida often gets calls about blow flies. She studies the flies' growth patterns—for example how "maggot masses" grow faster than individual maggots by generating extra heat—in an effort to better pin down an animal host's time of death. Not surprisingly, the calls Gruner gets about carrion flies are rarely from her suburban neighbors in Gainesville, Florida.

But this summer a neighbor asked Gruner over to see some. The flies were attracted to a cactus-like plant with succulent stems and a stinky flower measuring about one foot across. (Strictly speaking, cacti are native only to the Americas; this plant hails from South Africa and is more closely related to milkweeds.)

Finding the fly scene prettier than the usual gore, Gruner called on her husband, photographer Michael Turco. And he too found the buzzing subjects to be amenable: mesmerized by the flower, oblivious to his camera and lighting softbox.

Gruner identifies the large fly in the featured photograph [*see previous two pages*] as a flesh fly, or "sarc"—short for the genus *Sarcophagidae*. But the eggs, which look like grains of rice, weren't laid by sarcs, since sarcs bypass the egg stage and deposit larvae directly. Instead, the eggs belong to a species of blow fly, *Chrysomya megacephala*, that Gruner also observed flying around the flower.

Turco described the noxious odor that drew so many visitors as "not very becoming, but not anywhere near as bad as a dead body." —*Erin Espelie*

Michael Turco found the fly shoot near his home in Florida to be a cakewalk in comparison to assignments he's had in Indonesia, Peru, Zambia, and elsewhere. His trips have been featured by the Florida Museum of Natural History, the National Geographic Society, and the National Wildlife Federation. Visit www.agpix.com/michaelturco for more of his images.

PROJECT HOPE
FOUNDED IN 1958

In 1983, at the invitation of China's Ministry of Health and university medical centers, Project HOPE became the first private international health organization to make a long-term commitment to improving that vast nation's healthcare system.

Recently, Project HOPE's China Diabetes Program was launched to increase both public and professional awareness of diabetes and improve the quality and availability of diabetes care. To learn more, visit www.projecthope.org.

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More than 30 million people in China are living with a disease they know little or nothing about. Diabetes, known for decades in many countries as the "silent killer," rapidly has become a major chronic disease for the Chinese.[1]

Project HOPE and its partners are combining education with public awareness campaigns to slow the spread of the disease.

The ultimate goal of the partnership is to train Chinese nurses, physicians, and dieticians so they, in turn, can train staff and medical professionals. To date, more than 170,000 individuals in 32 Chinese provinces have received training.

Since the development of the BD glass syringe for insulin delivery in 1924, BD has been a major provider of healthcare devices and educational programs for health professionals and diabetes sufferers. It was natural, then, for BD to partner with Project HOPE and share its expertise and financial support with the China Diabetes Program.

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[1] *Diabetes Care*, 2004; World Health Organization

[2] "America's Most Admired Companies" annual survey 2007, *FORTUNE* magazine, March 19, 2007

Fishy Picture

The legend for a photograph accompanying the article by Eleanor J. Sterling and Merry D. Camhi ["Sold Down the River," 11/07] identifies a large fish as the endangered Mekong giant catfish *(Pangasius, or Pangasinodon, gigas)*. It is actually a species of *Bagarius,* an unrelated and morphologically very different catfish. No one can protect species if they aren't properly identified; let's hope that fishers on the Mekong River don't use the photo to decide which species to haul on the bank.

Larry M. Page
Weerapongse Tangjitjaroen
University of Florida
Gainesville, Florida

THE EDITORS REPLY: The error was ours, not that of the authors nor of the fishmonger who was selling the fish. For future reference, the correct catfish is shown in the photograph below.

Follow the Water

As a rancher who works with soil and water conservation districts across the country, I was troubled by some of the statistics cited by Sharon P. Nappier, Robert S. Lawrence, and Kellogg J. Schwab ["Dangerous Waters," 11/07]. The authors write that "it takes more than fifty gallons of water to produce a single cup of milk" and give figures of 470 gallons for a quarter pound of hamburger and 520 gallons for a cotton T-shirt. Such statements imply that the water is "used up" in its agricultural applications. But a large part of the water used in agriculture remains in the ecosystem, where it is withdrawn and reused. Although there may be serious water quality issues involved, there is no net loss of the water quantity, simply a relocation and some increase in transpiration.

Johnny Sundstrom
Deadwood, Oregon

THE AUTHORS REPLY: We agree with Mr. Sundstrom's point that there is a minimal net loss of water when it is used for agriculture. Water does return to the global ecosystem, but in what condition? For example, after water is used to nourish a cotton plant it may contain residual nitrogen and pesticide particles, preventing it from being available for

Before releasing it, fisherman Michael Ward (left) and guide Mr. Noi (right) lift a 180-pound Mekong giant catfish caught in the waters of Bung Sam Lan, a lake in Thailand.

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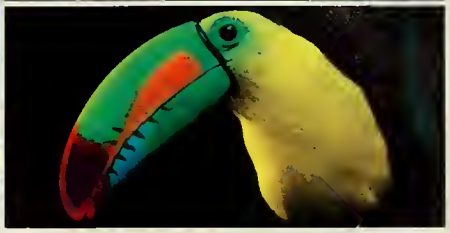

Clockwise starting top left: Caño Negro Wildlife Refuge; Tortuguero Park Canal Cruise; White Faced Monkey; Keel Billed Toucan; Manuel Antonio Park; Rainforest Hike

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The Blob

By Robert Anderson

Last summer, while cruising Alaska's fjords with the family, I kept an eye trained on the water in hopes of pointing out killer whales and dolphins to my children. We saw both, but passing by in the dark green, sunlit waters was, above all, an endless parade of large white blobs. Jellyfish appeared to be the dominant life form. In those waters and elsewhere around the world, the seas are experiencing massive jellyfish blooms, which some researchers believe are caused by overfishing. Please visit the magazine online (www.naturalhistorymag.com), where I review Web sites devoted to those alien-looking invertebrates and their role in marine ecosystems.

Robert Anderson is a freelance science writer who lives in Los Angeles.

WORD EXCHANGE

potable use. Similar scenarios exist worldwide with the production of other agricultural goods and industrial animal products, such as feedlot beef. People in high-income countries have access to advanced water treatment technologies and water distribution networks, but the same is not true for more than 1.3 billion people worldwide. Our statements challenge readers to consider the environmental and health impacts when water is redistributed to meet the high demands of agricultural production in a water-scarce world.

Follow the Money

The special issue "Water: The Wellspring of Life" [11/07] did a commendable job of highlighting a topic that deserves more attention. But let's confront financial and economic realities. Cash strapped governments don't have the resources to save wetlands or replace leaky pipes unless they raise taxes. Private water suppliers hesitate to invest unless they can recover costs quickly. Big water users won't use water-saving processes until the price of water gives them an incentive to do so.
Leonard S. Hyman
Sleepy Hollow, New York

Language Savers

I read Sarah Grey Thomason's "At a Loss for Words" [12/07-1/08] with great interest since I am familiar with an organization that shares similar goals. SIL International (formerly, the Summer Institute of Linguistics) was founded in 1934, originally with the purpose of translating the New Testament. Today SIL studies, documents, and assists in promoting the use of lesser-known and unwritten languages in more than seventy countries. Because the people who speak those languages often live in geographic, social, and economic isolation, studying their languages results in practical help for local people even as it contributes to a broader knowledge of linguistics, anthropology, and ethnomusicology. Thanks to organizations like SIL and Sarah Grey Thomason's Society for the Study of the Indigenous Languages of the Americas, native peoples are being given a chance to preserve their culture.
Gary Noel Ross
Baton Rouge, Louisiana

Erratum

Seventh-grader Sydney Moore in Vancouver, Washington, caught a factual error in Laurence A. Marschall's review of *The Pompeii Pop-Up* ["And for the Coffee Table," 12/07-1/08]. Mt. Vesuvius erupted in A.D. 79, not 79 B.C. as eyewitness Pliny the Younger well documented.

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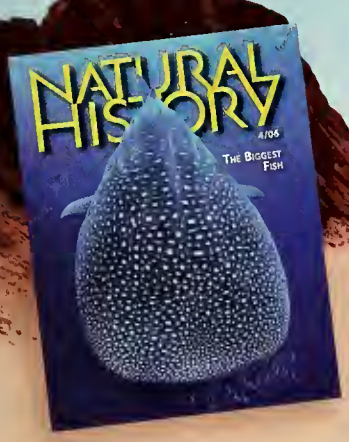

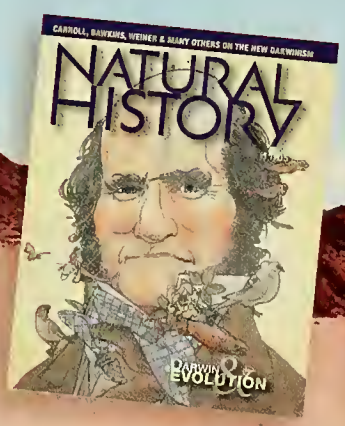

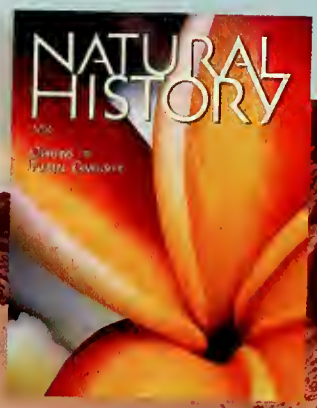

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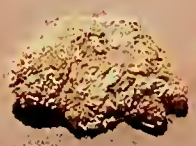


NATURAL HISTORY

Hybrid Headstart

The spadefoot toad, *Spea bombifrons*, makes a habit of the unthinkable: mating with members of another species. Interbreeding often produces few or no offspring, or offspring with reduced fertility, so biologists usually assume that interbreeding females have been forced to mate or have accidentally chosen the wrong male. But in the spadefoot toad's case, it seems to be no mistake.

The ranges of *S. bombifrons* and the related species *S. multiplicata* overlap in the American Southwest and Mexico, where both species reproduce in ephemeral ponds. *S. multiplicata* tadpoles develop faster, and so have better odds of escaping the drying pools than do *S. bombifrons* tadpoles. Occasionally, *S. bombifrons* females mate with *S. multiplicata* males (the females pick their partners), and the resulting hybrids, though less fertile, metamorphose about two weeks earlier than pure *S. bombifrons* tadpoles

DAVID PFENNIG

Do not forsake me, oh my darling: male S. bombifrons toad calls for a mate.

Karin S. Pfennig of the University of North Carolina at Chapel Hill suspected that female *S. bombifrons* toads decide whether to interbreed based on their pond's depth—and the need to give tadpoles a head start. So she placed some *S. bombifrons* females in an artificial pond with either shallow or deep water, and played them the calls of males of both species. Sure enough, the females approached and touched the speaker broadcasting calls of *S. multiplicata* males more often in shallow water than in deep water.

What's more, in shallow ponds robust females opted to hybridize less often than skinny ones did. That makes sense, says Pfennig, because a mom's condition affects her tadpoles' ability to metamorphose. Apparently, female spadefoots know just when to break the rules. *(Science)* —*Graciela Flores*

The Secret Life of Weeds

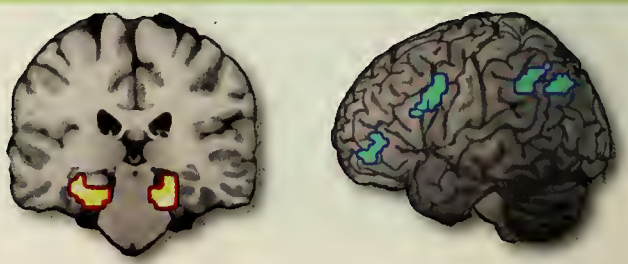
"I bend, and break not," the reed, in fable, tells the oak. Break not, indeed. During the past 150 years a European strain of the common reed, *Phragmites australis*, has spread throughout the northeastern United States. It pushes aside other plants, including the eleven native strains of the same species, and now threatens to dominate the region's marshlands. A recent study has unveiled the secret to the reed's success: *P. australis* poisons neighboring plants from the roots up.

Thimmaraju Rudrappa and Harsh P. Bais of the University of Delaware in Newark and three colleagues discovered that *P. australis* roots secrete a chemical brew containing gallic acid, a toxin. When they exposed test plants of various species to either straight gallic acid or the reed's secretions, the other plants' roots completely disintegrated. (The reed, it seems, is immune to its own poison.) The European strain of *P. australis* exudes gallic acid that is about sixteen times more concentrated than that of a sample native strain, they discovered, making the invader much more effective at knocking out competitors.

The team suspects that *P. australis* might have other concealed weapons: a deadly microbe in its root secretions, or enhanced resistance to ultraviolet light. Still, Rudrappa and Bais hope that future studies could yet uncover a weakness that will let biologists break—or at least control—the fabled reed. *(Journal of Chemical Ecology)* —*Lydia Bell*

Super weed: European strain of the common reed

DR. THIMMARAJU RUDRAPPA



HONGKEUN KIM/JRNL. OF NEUROSCIENCE

Brain scans show active regions during recollection of a true memory, above left, and a false memory, above right.

Of Two Minds

Ever remembered with certainty something that never actually happened? Most people have, but how the brain produces such devilishly convincing, yet false, memories has long eluded neuroscientists.

During recall of an event, the brain simultaneously processes information in at least two regions: the medial temporal lobe, which specializes in specific details, and the fronto-parietal network, which handles the overall gist of the event. To determine how the two regions participate in the recall of true and false memories, Roberto Cabeza of Duke University and Hongkeun Kim of Daegu University in South Korea gave volunteers a test of real versus false memory while scanning their brains using functional magnetic resonance imaging, or fMRI—a technique that shows which areas of the brain are active.

The test required the volunteers to memorize lists of related words and later to identify, in new lists, those they had already seen. When volunteers correctly and confidently recognized words from the original lists, they showed increased activity in the detail-oriented medial temporal lobe. In contrast, when they recalled, with similar conviction, words that were not on the original lists, they showed increased activity in the fronto-parietal network—the region that traffics in generalities.

True memories tend to be rich in sensory details, while memory illusions feel familiar but are less vivid. The distinction isn't fail-safe, says Cabeza, but in principle it's wise to be suspicious of vague memories. *(The Journal of Neuroscience)* — *G.F.*

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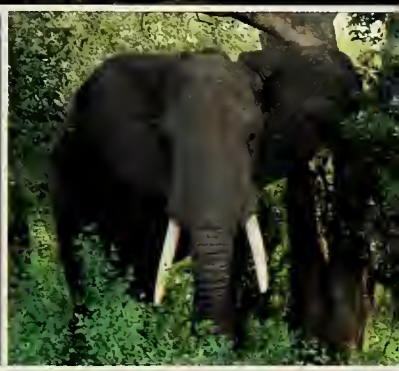

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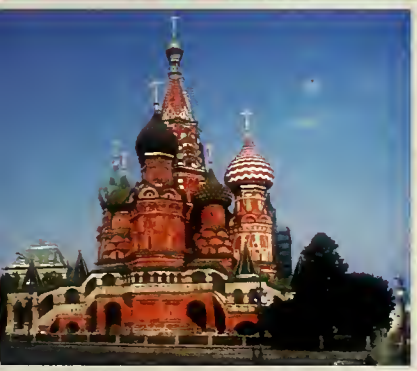

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Good Morning, Honey

Messmate pipefish, *Corythoichthys haematopterus*, form strong monogamous pairs that normally endure from year to year. In most other long-term monogamous fish species, couples live together year-round, but not the messmate pipefish; mates of that species live apart, both during and outside the May-through-September spawning season. A new study describes how they keep in touch: couples meet each morning throughout the year for a brief bout of dancing, thus renewing their vows.

Atsushi Sogabe and his graduate advisor, Yasunobu Yanagisawa, of Ehime University in Japan, watched the pipefish perform their morning salutations along the Japanese coast. Each pair met in a particular spot, usually within an hour of sunrise, to swim side by side, sometimes arching their bodies and crossing one another's paths. The dances lasted about three minutes then each fish went its separate way for the rest of the day. The short daily greeting is enough to keep pipefish couples together between breeding seasons: barring the death or disappearance of one partner, couples never broke up.

TOMONORI HIRATA

Eggs coat the belly of a male messmate pipefish (left) with his mate after spawning.

Males usually arrived first at the meeting site. In an as-yet unpublished experiment, Sogabe—playing the anti-Cupid—detained a number of females to see how the males would respond. He says the males waited about a day before starting the search for a new love. *(Journal of Ethology)*

—*Stéphan Reebs*

Emergency Broadcast System

Marine iguanas may not be big talkers—in fact, they don't vocalize at all—but at least they're good listeners. A new study shows that the wary reptiles tune in to the alarm calls that Galápagos mockingbirds broadcast (for the benefit of their own kind) when they spot a common enemy, the Galápagos hawk.

On the island of Santa Fe in the Galápagos archipelago, Maren N. Vitousek, a graduate student at Princeton University, and three colleagues recorded two kinds of mockingbird vocalizations: an alarm call and a territorial song. The team then played back both sounds to groups of iguanas. Nearly half the iguanas raised their heads or ran away when they heard the alarm call. In contrast, fewer than a third reacted to the song.

JONATHAN GREGOR

Marine iguanas: expert eavesdroppers

Various birds and mammals are likewise known to heed the warnings of other species. Those eavesdroppers all make alarm calls of their own, prompting biologists to suggest that alarm calls may share acoustical features that provoke reactions across species. But the responsiveness of the mute iguanas requires other explanations: either the iguanas instinctively know what the bird calls mean, or they can learn over time, in Pavlovian fashion, that the calls announce the imminent arrival of a dreaded predator. *(Biology Letters)*

—*S.R.*

Spider Insider

Examining the guts of fossil spiders millions of years old sounds far-fetched, but a technique originally developed for medical diagnostics has been repurposed to do just that—and with strikingly clear results.

THE UNIVERSITY OF MANCHESTER/GHENT UNIVERSITY

Scans show, from top to bottom, a fossil spider from below, from the back, and in lateral section.

Like a medical CAT scan, Very High Resolution X-Ray Computed Tomography, or VHR-CT, works by taking X-ray images along multiple axes. A computer collates the images to depict the specimen both inside and out. David Penney of the University of Manchester in England and a team of colleagues in Belgium applied VHR-CT to a 53-million-year-old male spider encased in amber that had been discovered in France. In spite of the spider's small size—less than a twentieth of an inch long—Penney and his team could subject it to a "digital dissection." He easily identified the spider's taxonomic family as one with living members and recognized that it was a species new to science, which he named *Cenotextricella simoni*.

VHR-CT leaves specimens intact, even as it reveals internal organs and structures, and it can "see" through amber more clearly than lower-tech light microscopy can. Those are substantial advances for the study of minute fossils. *(Zootaxa)*

—*S.R.*

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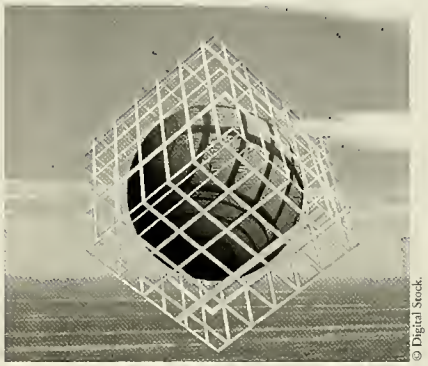

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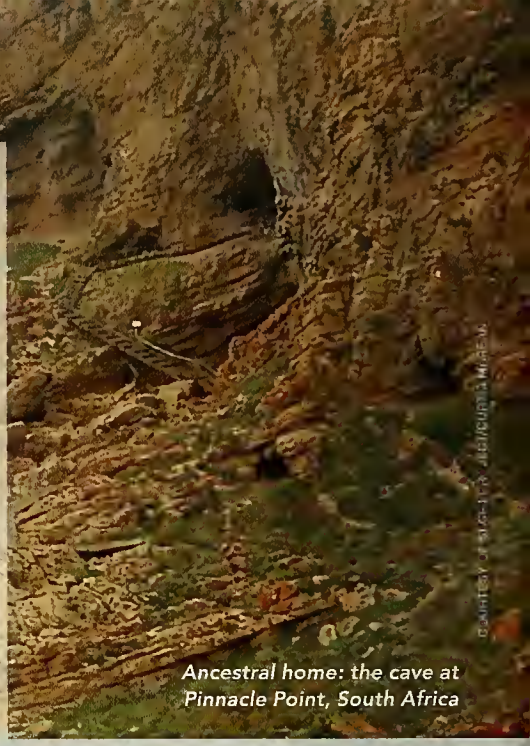
Seafood Shack

Today more than half the world's population lives near an ocean, but what about our ancestors? The remains of shellfish dinners dispatched 164,000 years ago and recently discovered in a South African cave show that early *Homo sapiens* had adapted to a coastal lifestyle hard on the heels of their evolutionary debut, estimated at around 200,000 years ago. The shells predate other evidence of a seafood diet by some 50,000 years.

While excavating the cave, which overlooks the Indian Ocean at Pinnacle Point, a team of archaeologists led by Curtis W. Marean of Arizona State University in Tempe unearthed numerous shells from a variety of species, including brown mussels, snails, and limpets. A whale barnacle turned up, too, suggesting that the cave's inhabitants had scavenged blubber from a beached carcass. The team also discovered pieces of red ocher, probably used as a decorative pigment, and small, flaked stones, or bladelets. Both the ocher and the bladelets are among the oldest artifacts of their kind.

It's been difficult for archaeologists to determine when humans began exploiting the marine environment because from 195,000 to 130,000 years ago, sea level was as much as 400 feet lower than it is today, a result of glaciation. Rising seas later erased most traces of early coastal occupation. Happily, Pinnacle Point passed the ages well above the water line. *(Nature)* —S.R.



Ancestral home: the cave at Pinnacle Point, South Africa

COURTESY OF KYLE S. BRAUN, ARIZONA STATE MUSEUM

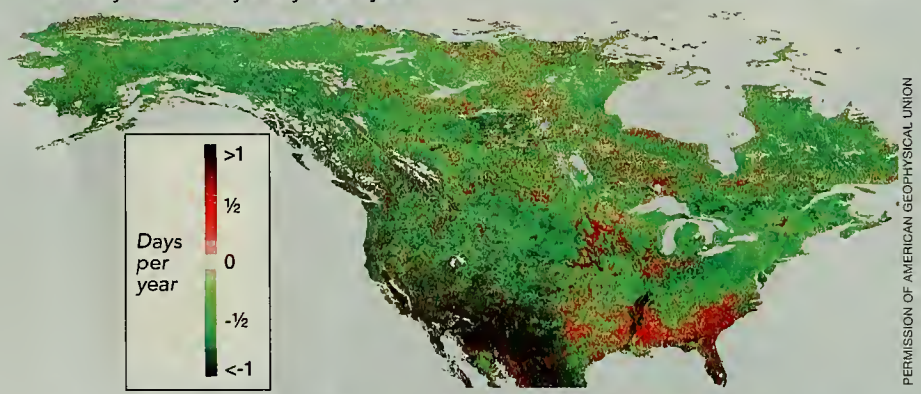
THE WARMING EARTH

Spring Timing

Spring green-up—when plant buds burst open at winter's end—has been arriving ahead of schedule in the northern United States for the past twenty-five years, as a result of global warming. In fact, spring has been springing progressively earlier by about a day every three years, according to Xiaoyang Zhang and two colleagues at the National Oceanic and Atmospheric Administration in Camp Springs, Maryland, who examined records of lilac-bloom dates and satellite images of vegetation to reach their conclusions.

But the trend applies only to plants up north. In southern states, the reverse is true: spring green-up has been arriving later by about a day every seven years. What's going on? Aren't southern states experiencing global warming, too?

Absolutely, Zhang's team says, just a little differently. The effect stems from the fact that most plants going dormant in autumn must remain just so cold for just so long before they can fully respond to the warmth of spring. Northern winters, though truncated, are still cold enough for long enough that plants can leaf out once balmy weather returns. But down south, cool days—already few to start with—have diminished so much that plants' chill requirements aren't always met. When that happens, only additional spring warmth can wake them; hence southern states' progressively later green-up. *(Geophysical Research Letters)* —S.R.



PERMISSION OF AMERICAN GEOPHYSICAL UNION

Map shows the average change, from one spring to the next, in the onset of bud burst between 1982 and 2005. The green scale indicates how much earlier (in days) buds burst, the red scale shows how much later.

Warm and Fuzzy

For thirty years, study after study has shown that doubling the atmospheric concentration of carbon dioxide (CO_2) by the burning of fossil fuels should ultimately raise average global temperatures between 3.5 and 8 degrees Fahrenheit. That's a wide range—with the effects scaling from serious to severe—yet a wealth of research has failed to narrow it much since the 1970s. A new study explains the source of the uncertainty.

The world's climate systems are full of feedback loops that amplify the errors inherent in any estimate, say Gerard H. Roe and Marcia B. Baker of the University of Washington in Seattle. For example, rising CO_2 levels raise air temperatures directly, through the greenhouse effect, as well as indirectly, as when snow and ice melt, letting the ground absorb extra heat that further warms the air. Even a small gap in scientists' understanding of how the components of climate systems affect one another can result in widely differing temperature predictions. Roe and Baker worked out a mathematical description of how such uncertainties compound, which shows that future predictions probably won't be any more precise than the ones we've got now.

Policymakers should find a message in the math: there's no point delaying action to reduce emissions in hopes that more studies will provide a clearer picture of future temperatures. *(Science)* —S.R.

SPECIAL RESEARCH REPORT

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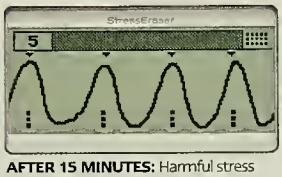

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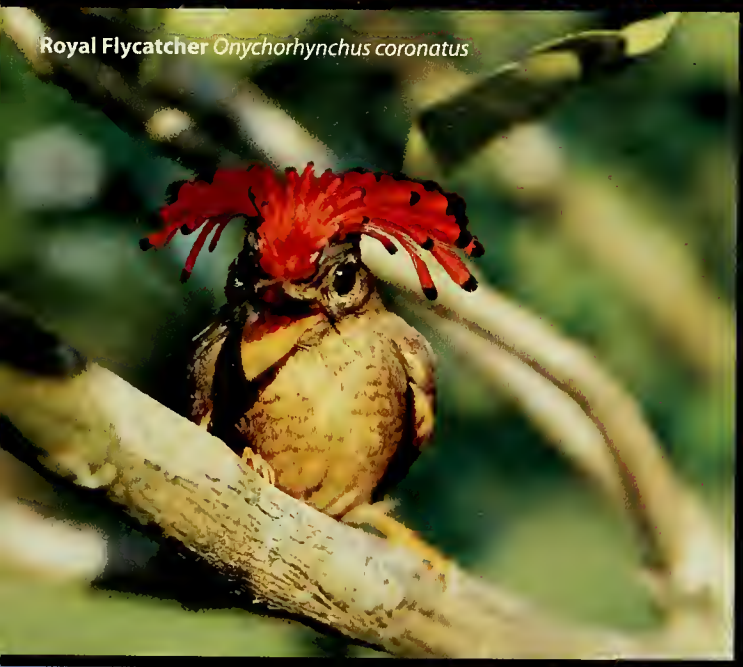

Royal Flycatcher *Onychorhynchus coronatus*

"Tres Chimbadas" Lake, Madre de Dios

Birdwatchers in Machu Picchu

Cock-of-the-Rock

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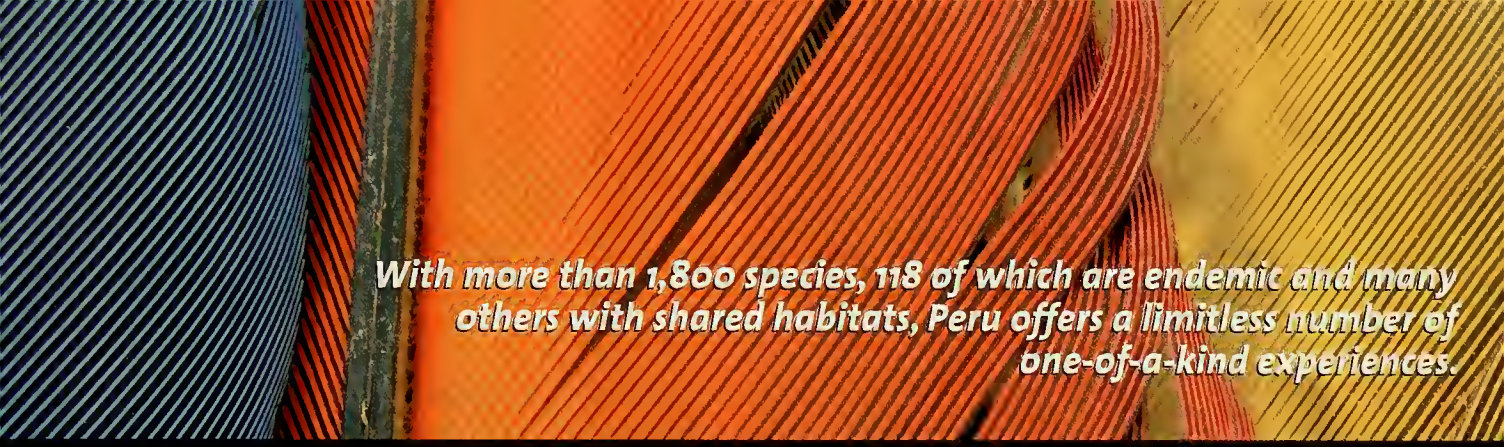

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Lulu's Pygmy-Tyrant *Poecilotriccus luluae*

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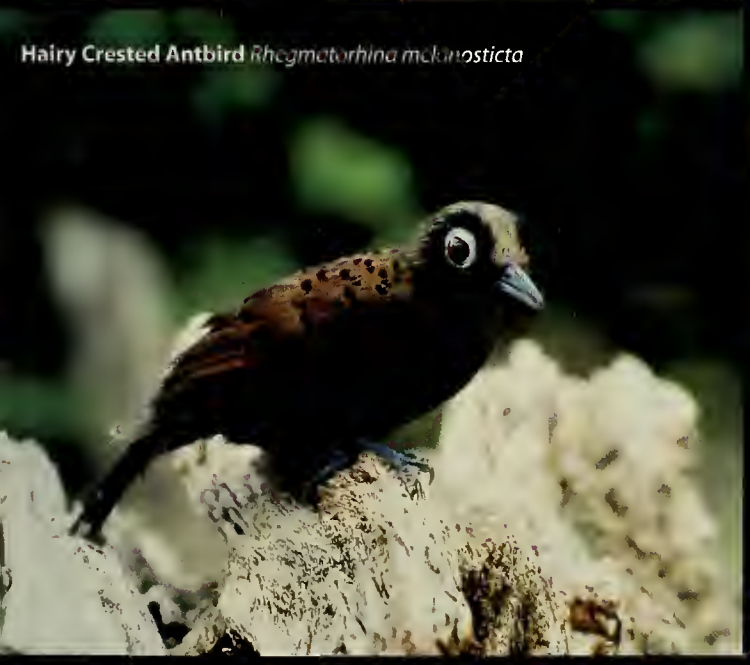

Hairy Crested Antbird *Rhegmatorhina melanosticta*

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Hearts and Flowers

The herbal remedy foxglove joined the ranks of modern medicine, thanks to its eighteenth-century champion, Dr. William Withering. Would we be better off without it?

By Druin Burch

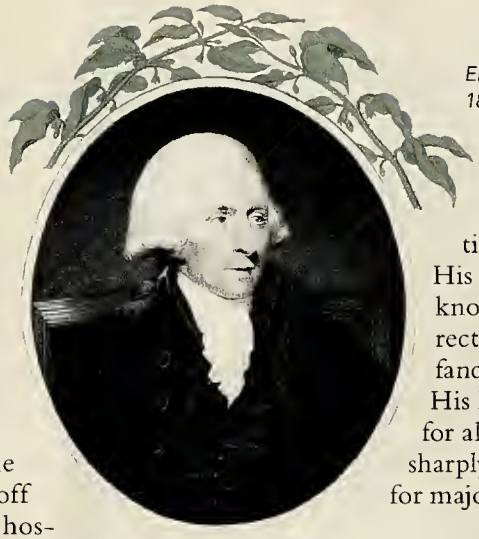
Dropsy is an old word for an older problem. Afflicted, you begin to swell—first your ankles, then your legs. Walking gets difficult, even sitting becomes painful. Then the swelling gets so bad your skin splits open.

The commonest cause is heart failure. Think of the revolving door of an office building. As the door gets older it turns more slowly. Eventually people have to queue, spilling out onto the street. As your heart gets feebler, your blood queues up in the same way. Under that pressure, your veins leak fluid, which builds up between cells, pooling wherever gravity directs.

Because we have a double circulation system, there's a double problem. Unable to get into a weakly pumping right ventricle, ready to go to the lungs, deoxygenated blood backs up in your extremities, and fluid collects in your tissues. You swell from the feet upwards. And instead of being pumped out to the body from your left ventricle, oxygenated blood backs up, and fluid gets squeezed into your lungs, filling the spaces where air should be. You get breathless.

Doctors used to try to relieve dropsy, which today we call edema, by making holes in people's bloated legs to let the fluid out. That could help, a little. Anything that reduced the amount of fluid in your body, even leeches and bloodletting, could make you feel better.

Welcome to the world of medicine that Dr. William Withering knew in the late eighteenth century, a scintillatingly brilliant time that crackled with new discoveries, political revolutions, and the excitement generated by the birth of the Enlightenment. Yet



Engraving of Dr. William Withering made in 1801, two years after his death.

Withering lacked the charisma of his era. He was raised in a medical family in Shropshire, England, in 1741, and after four years' apprenticeship to a local physician, he went to Edinburgh to get his degree. There were the typical diversions: he golfed, published bad poetry, and learned to play the bagpipes. He loathed, in particular, the botany he was forced to study. Nevertheless, he completed his degree, then set off on a professional pilgrimage to hospitals around Europe.

Unfortunately, Withering's trip ended early. His traveling companion, a healthy young man of his own age, developed a skin infection in Paris. "An abscess grew upon his shoulder, a fever came on, the wound gangren'd and yesterday he died," wrote Withering, who lived in a time when death came suddenly and doctors were impotent.

In 1767 Withering began to practice. One of his first patients was seventeen-year-old Helena Cooke. She liked drawing flowers. While she lay sick in bed, Withering scoured the countryside to find her fresh subjects, apparently moved by her charms to overcome his antipathy toward botany. It turned out to be the start of two lifelong relationships: Withering married his patient and acquired a lasting fondness for plants.

In 1775 worldly opportunity called on the young couple, arriving in the overwhelming shape of Erasmus Darwin, pockmarked, rotten-toothed, and enormous. He had as great an appetite for food and free love as for science and verse. (Famous in his time for his fertile mind and his poetry about the sex lives of plants, he is best known these days for his grandson Charles.) Darwin recognized the young Withering's intellect and helped him secure the position of town physician for Birmingham.

Combined with Darwin's friendship, the post brought membership in a remarkable club: the Lunar Society, named for its habit of meeting at full moons to make traveling home safer. The Lunaticks, as they called themselves, men like Matthew Boulton, Joseph Priestley, and Josiah Wedgwood, were the leading British scientists and entrepreneurs of the day.

Hand-colored illustration of a foxglove species, Digitalis purpurea, *drawn by James Sowerby. It appeared in the six-volume collection* Flora Londinensis, *published in the late eighteenth century—around the time of Withering's experiments with foxglove as a human drug.*

While his friends manufactured Britain's industrial revolution, Withering lived conservatively. His son described him as methodical, known more for "steady sense and correct judgement than for the flights of fancy or the eccentricities of genius." His letters are fabulously dreary. But for all his lack of glitter, Withering was sharply observant. When his opportunity for major discovery came, he jumped:

> In the year 1775, my opinion was asked concerning a family receipt for the cure of the dropsy. I was told that it had long been kept a secret by an old woman in Shropshire, who had sometimes made cures after the more regular practitioners had failed. . . . This medicine was composed of twenty or more different herbs; but it was not very difficult for one conversant in these subjects to perceive that the active herb could be no other than the Foxglove.

Any of some twenty plants in the genus *Digitalis*, foxglove had been used as a medicine by hosts of people, from ancient Greeks to medieval Welsh. During the Middle Ages in Western Europe, it was believed to cure a whole range of diseases for which it is actually useless. In the mid-1600s, for example, the herbalist Nicholas Culpeper recommended foxglove for treating epilepsy. It doesn't.

Foxglove also had obvious problems. In the sixteenth century, a botanically misguided Dutch chef fed his guests a foxglove omelette. Their consequent diarrhea and vomiting were a good demonstration of the plant's milder side effects; too much of it, and you die. In the seventeenth century, forty years before Withering, a Frenchman investigated foxglove's effects on a turkey. "He did not attempt to perch," ran his poignant report on the poultry, "he uttered plaintive cries." The bird stumbled drunkenly for a few days, refused to eat, and died.

At medical school I was taught the blunt truth that only inactive drugs are without side effects. Taking a pill is like thumping the side of a misbehaving television: you might bang the right piece into place, but you might make things worse. Withering knew this (minus the television analogy), worrying that "the lives of men" could be "hazarded" by his new drug. His understanding of medical science evoked the modernity of the Lunar

Dropsy Courting Consumption *is the title that artist Thomas Rowlandson gave to this illustration, published in 1810. The corpulent man on bended knees could have been among the many who suffered from heart problems; his body contrasts with the shapely statue of Hercules in the background.*

Society. It was not enough, he realized, to compile only encouraging stories.

> It would have been an easy task to have given select cases, whose successful treatment would have spoken strongly in favour of the medicine, and perhaps been flattering to my own reputation. But Truth and Science would condemn the procedure. I have therefore mentioned every case in which I have prescribed the Foxglove, proper or improper, successful or otherwise.

Altogether Withering wrote up 163 cases of dropsy in which he used the plant, and the majority of those patients (no doubt the ones whose dropsy was caused by heart failure) got better. Swollen legs reduced in size, breathing was eased. Noting that patients produced copious amounts of urine as they began to improve, Withering suspected that digitalis extract worked as a diuretic, causing excess fluid to be lost as urine and so reducing the amount of work the heart needed to do. "It charms the shapeless monster into man," Erasmus Darwin wrote in his poem about it. Praise even came from the other side of the world: a physician from New Hampshire wrote congratulating Withering and asking for help in seeding the flower in America.

In 1790, with the Revolution raging in France, Withering diagnosed himself with tuberculosis. Over the next several years, consumption sucked his life away. A friend was struck by how weak he became: "The flower of English physicians is indeed withering." (Medicine has progressed over the centuries, but puns are as bad as ever.) In October 1799 he died. His memorial tablet was carved with a plant of the genus *Witheringia* on one side and, separated by a terrifically bad poem, a foxglove on the other.

HEARTS ARE WELL EVOLVED, but not miraculous. That means compromise and ultimate failure. Let's say that you hope to manufacture something with a lifetime guarantee, a watch, for example; you would engineer it to last a hundred-odd years, not a thousand. Evolution is equally careful about not wasting resources. Therefore no body part outlasts the rest, or not by much. Even our solid skeleton weakens and fails as we reach old age.

Modern medicine follows a similar aim, hoping to keep any organ from failing too far ahead of the rest, thus extending our healthy lives and compressing our decay into the fewest possible days. The heart, however, often proves difficult to save, as muscle cells don't divide—at least, not abundantly enough to regenerate healthy tissue. If you exercise them, heart muscle cells might get bigger, but few or no new ones will be made. So as you age, they can die off gradually—particularly under the stress of high blood pressure, diabetes, or coronary artery disease—or, in the case of a heart attack, die off suddenly and potentially catastrophically. Either way, the heart never grows back.

Foxglove—or digitalis, as the pharmaceutical compounds derived from it are commonly called—works

not by directly causing increased urination, as Withering thought, but by making the heart beat more strongly and efficiently. The trouble is, drugs that increase the strength of the heart's beats don't make it grow new muscle; they only drive what's left a little harder. And any coach will tell you that if you push any athlete too far, you risk collapse.

When an aging heart fails and begins to pump less blood, our bodies make a mistake. They notice the reduced flow, but presume we're bleeding or dehydrated. Evolutionarily, surviving blood loss and dehydration is more critical than extending old age. So, when the body detects a lack of blood flow, it assumes that a lack of blood is to blame. In response we get thirsty and our kidneys reduce urine output. By drinking more and peeing less, our bodies compensate for a loss of fluid that has not occurred—as a result, we end up with too much. Having to pump more fluid is exactly what a failing heart needs least. Withering correctly observed that digitalis made people feel better, yet could it have been killing them just the same? Neither Withering nor anyone long after him took a systematic look.

In 1997, nearly two centuries after Withering's death, a medical trial came back with the answer. Almost 7,000 people were randomly allocated to digitalis or a placebo for more than three years. The results: for every thirty-nine people taking digitalis for a year, one avoided a hospital admission. The effect on mortality? Zero. Digitalis is neither the lifesaver people had imagined nor the killer some suspected.

IT HAS TAKEN TWO CENTURIES to go from hailing digitalis as a miracle cure to wondering if using it makes any sense at all. Some doctors feel that the harms are hardly worth the benefits. Others continue to prescribe it liberally, as though it really is a lifesaver. Yet for certain patients, digitalis remains modestly effective, making them feel and function better than any razzle-dazzle new synthetic drug. And that, even if they don't live longer, is no small thing.

Druin Burch is a medical resident and a tutor at the University of Oxford. His first book, *Digging Up the Dead* (2007), profiles the pioneering surgeon, body snatcher, and revolutionary democrat Astley Cooper, who incidentally trained John Keats as a surgeon. Burch lives in a village in the Cotswalds with eight ducks and 500 of his countrymen.

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

Jaws Two

Moray eels grab scientific attention—and more—with their jaws.

By Adam Summers ~ Illustration by Melisa Beveridge

Moray eels, to my certain knowledge, will bite if provoked. They belong to a family of elongated bony fishes with an impressive dental battery (Muraenidae), and my right hand has distinct impressions to prove it. My scars came from an encounter on the Great Barrier Reef with a hungry eel chomping at the chopped fish I was feeding to a group of groupers. The moray's bite beached me and left me with one good hand to gingerly eat my meals for the next month.

Not only do bony fishes lack hands or gripping forelimbs of any kind to reposition their meal, they are also deprived in the food-processing department by the total absence of a tongue. That leaves the fishes' jaws to do all of the work of converting whole prey into edible morsels. Some bony fish simply skip playing with their food and eat it whole; others, like bluefish, use cutting teeth to reduce the prey size, then swallow each piece whole. But the vast majority of bony fishes use a set of tools deep in their throat: a second pair of toothy jaws that can split, slice, tear, or crush food as it goes down the gullet.

The back-of-the-throat choppers are called pharyngeal jaws, and they come in an astonishing array of sizes, shapes, and functions—all derived from gill arches, which hold in place the bright-red respiratory structures that lie behind the cheeks of most fishes. Pharyngeal jaws are equipped with their own set of teeth and move completely independently of the oral jaws. Still, the problem persists of how to move prey back from the mouth jaws to the throat set. Suction usually works. But moray eels, it turns out, have a way to use their pharyngeal jaws that's pretty shocking, right out of the movie *Alien*.

Rita Mehta, currently based at the University of California in Davis, is an expert on snakes' feeding behavior, so when she teamed up with fish biomechanist Peter Wainwright, also at Davis, she focused on the snakiest of fishes. For their body size, moray eels can eat extremely large prey, such as octopus, making Mehta think there might be an interesting story in how they manage to choke down such huge meals. Snakes have a mobile upper jaw

which can ratchet from left to right, allowing a snake to "walk" its head down the length of its prey without ever releasing it from the grip of at least one side of the jaws. What about the eels?

Mehta started by using high-speed video to record adult reticulated morays (*Muraena retifera*) as they ate pieces of squid. The movies allowed her to really slow down the action, which showed that the food was hauled into the eel's mouth rather jerkily. That was hard to understand, but the mystery deepened when an eel ate with its mouth particularly wide open—and the camera caught a flash of something moving, something that seemed to come out of the throat and grab the prey. The pharyngeal jaws seemed unlikely candidates, since in moray eels they are set very far back in the body, well behind the back of the skull.

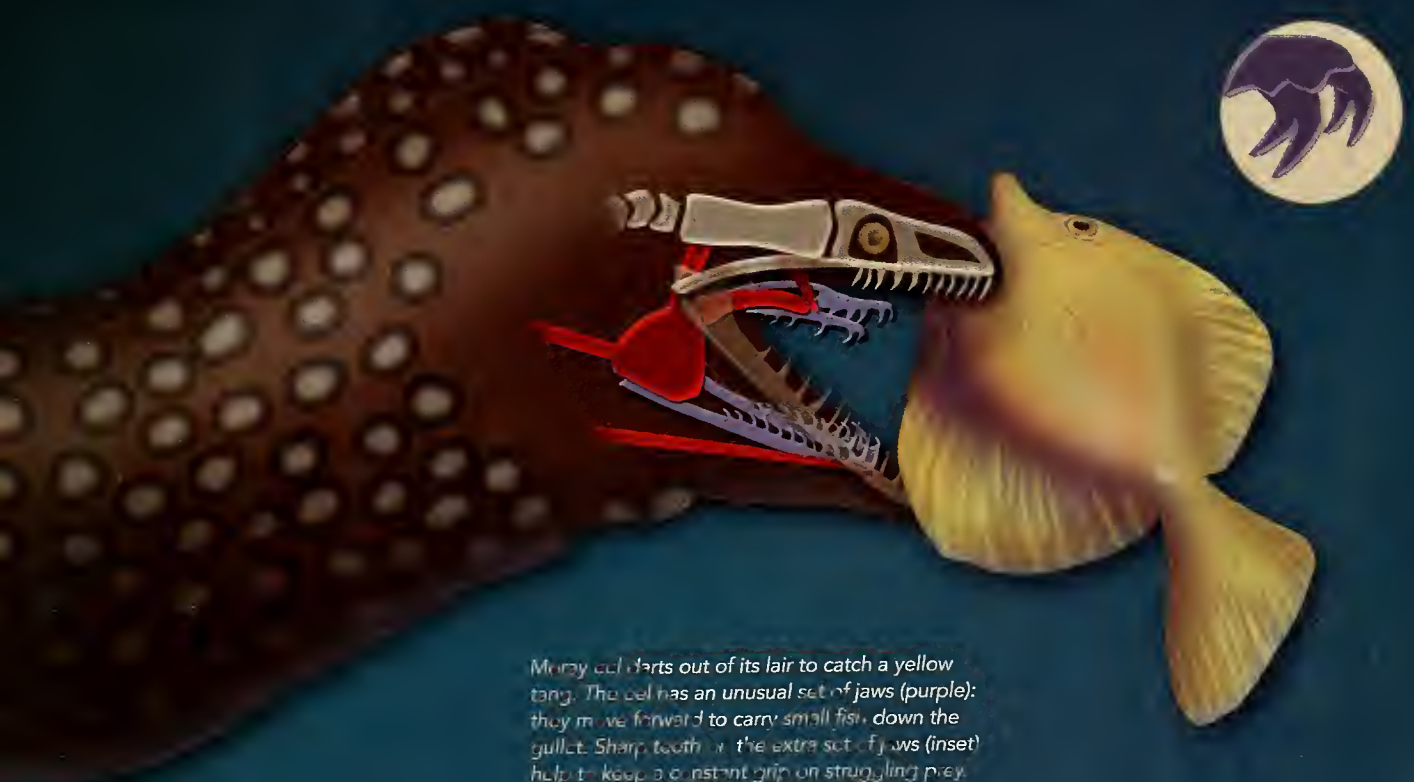
Mehta set to finding out by using a fluoroscope, an X-ray machine that allows movies to be taken of moving bones. In a small glass tank that minimized the difficulty of filming through water, she fed a reticulated moray a live fish. The video showed something a little intimidating. After the moray grabbed lunch in its mouth, the pharyngeal jaws started sliding forward, all the way up the throat, until their sharp teeth were even with the eel's eye.

Dissection revealed that muscles connect the moray's upper pharyngeal jaws to the skull just behind the eyes, and also run from the lower pharyngeal jaws to the point of the eel's chin. When the eel contracts those muscles, the throat jaws open and slide forward, almost out of the mouth of the eel [*see illustration across these two pages*]. The pharyngeal jaws then close on the part of the prey that is most deeply in the mouth and drag it back towards the stomach. The eels seem to use their secondary jaws about 90 percent of the time.

A moray eel has another method of dealing with large prey. It will loop its body around a victim, similar to the way a python does; but rather than constricting its prey, a moray pulls its head through the loop, holding the victim in a knot while ripping off bite-size chunks of flesh. For the vast majority of prey species, which are too small for that, the morays use the *Alien* method, ratcheting them down the hatch without letting go. The strategy is like a snake's, but morays evolved to ratchet front to back, rather than left to right.

In looking at my scar, I now suppose that I am lucky a second set of tooth marks isn't inside the first, reducing the utility of my already sad-looking *digiti minimi*.

Adam Summers (asummers@uci.edu) is an associate professor of bioengineering and of ecology and evolutionary biology at the University of California, Irvine. His daughter is named Eleanor Elektra Lehman (EEL) in part to memorialize that snaky fish that chomped down on him.



Moray eel darts out of its lair to catch a yellow tang. The eel has an unusual set of jaws (purple): they move forward to carry small fish down the gullet. Sharp teeth on the extra set of jaws (inset) help to keep a constant grip on struggling prey.

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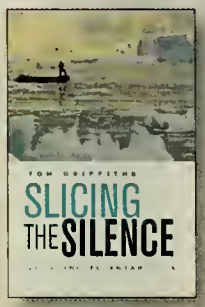

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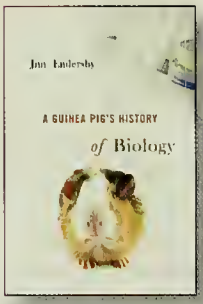

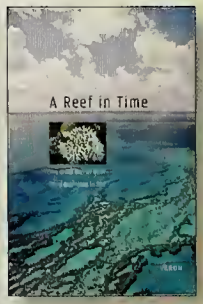

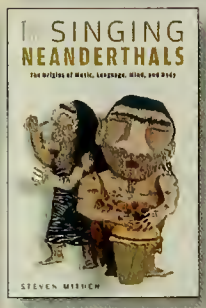

HISPANIOLA

A Photographic Journey through Island Biodiversity
Biodiversidad a Través de un Recorrido Fotográfico

ELADIO FERNÁNDEZ

FOREWORD BY EDWARD O. WILSON
INTRODUCTION BY PHILIPPE BAYARD, SOCIÉTÉ AUDUBON HAÏTI

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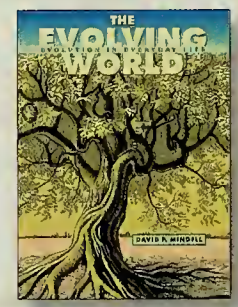

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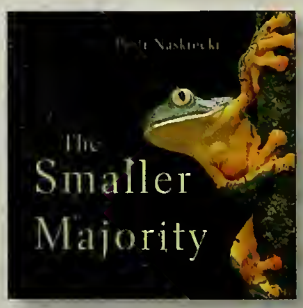

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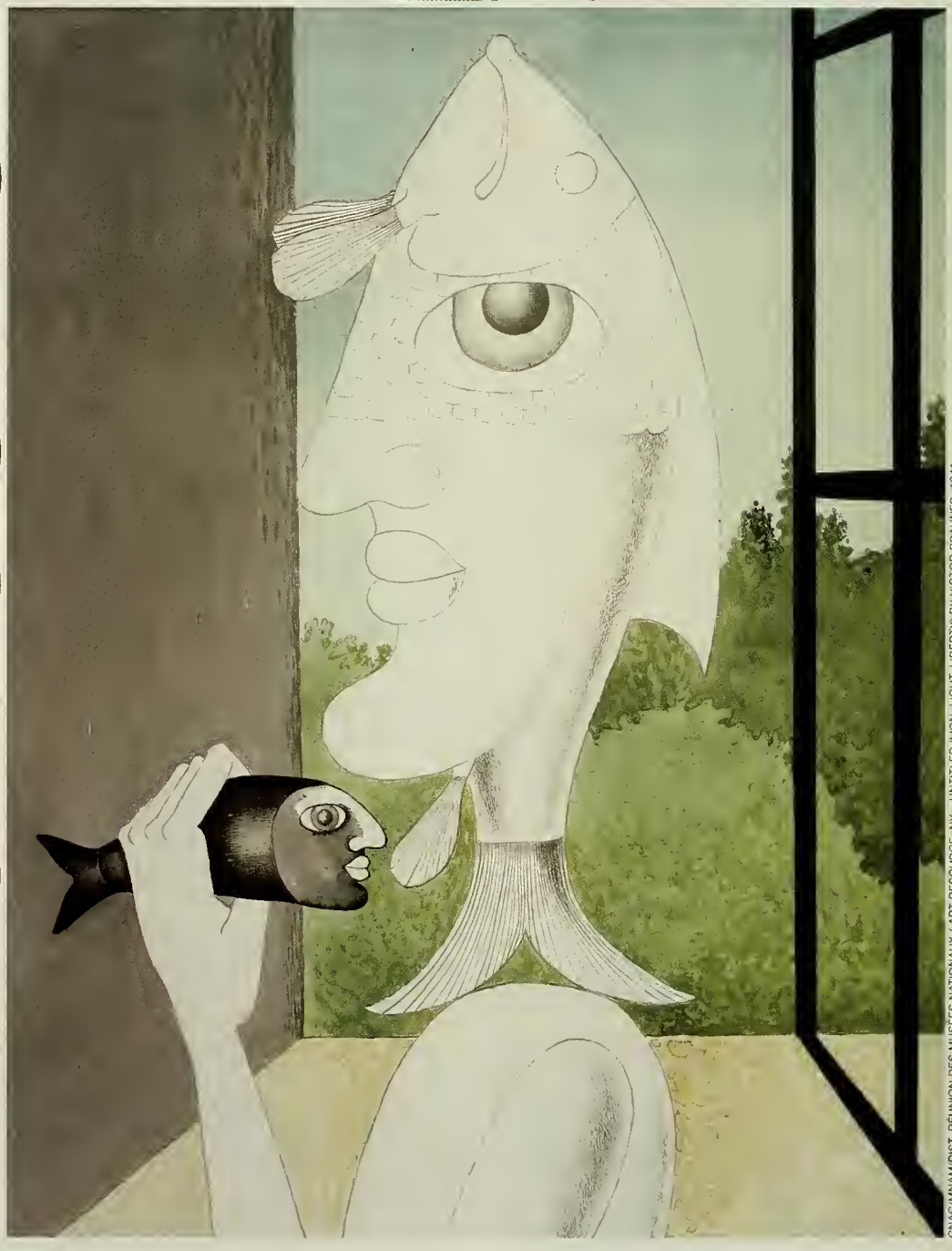
FISH OUT OF WATER



CNAC/MNAM/DIST. RÉUNION DES MUSÉES NATIONAUX / ART RESOURCE, NY – UNTITLED (LION, LIGHT, LIBERTY) BY VICTOR BRAUNER, 1941

Human ailments as varied as hernias, hiccups, and choking are a legacy of our "fishy" ancestry.

BY NEIL SHUBIN

HUMANS MAKE MUCH of what distinguishes us from the apes, but we actually share so much with fish that the comparison with apes feels almost trivial. Once you see our similarities to fish, all mammals start to look alike. And our very ancient evolutionary kinship with other animals has an impact on our lives today. The exceptional combination of things we do—talk, think, grasp, and walk on two legs—comes at a cost, the inevitable result of the tree of life inside us.

Imagine trying to jury-rig a vintage Volkswagen Beetle to travel at speeds of 150 miles per hour. In 1933, Adolf Hitler commissioned Ferdinand Porsche to develop a cheap car that could get forty miles per gallon of gas and provide a reliable form of transportation for the average German family: the result was the Volkswagen, a car that remained substantially the same throughout its many years of production. Its original design placed constraints on the ways it could be modified—engineers could only tweak it so far before major problems arose—and it ultimately was replaced by a completely new Beetle.

In many ways, humans are the fish equivalent of an old Beetle turned hot-rod. Take the body plan of a fish, reconfigure it to be a mammal, then tweak and twist that mammal until it walks on two legs, talks, thinks, and has superfine control of its fingers—and you have a recipe for trouble. In a perfectly designed world—one with no evolutionary history—we would not have to suffer from hemorrhoids or easily-damaged knees. Indeed, virtually every illness we suffer has some historical component that can be traced back from mammals to amphibians to fish and beyond.

You can dress up a fish only so much without paying a price.

SPEECH COMES AT JUST such a price: sleep apnea and choking are high on the list of problems we have to live with in order to be able to talk. We produce speech sounds by controlling motions of the larynx, the back of the throat, and the tongue. All those structures are relatively simple modifications to the basic design of a mammal or a reptile. The human larynx, for example, is made up mostly of cartilages that correspond to the gill arches of a shark or fish [*see diagram on page 29*]. But in humans, the back of the throat, extending from the last molar tooth to just above the voice box, has flexible walls that can be widened and narrowed by relaxing and contracting a number of muscles. The human tongue, too, is woven of multidirectional muscle fibers that give it a remarkable range of movement. By changing the size and shape of the mouth cavity and the softness or rigidity of the throat, we are able to modify sounds from the larynx.

Unfortunately, that flexible throat, so useful in talking, makes us susceptible to a form of sleep apnea that results from obstruction of the airway. During sleep, the muscles of the throat relax. In most people, this does not present a problem, but in some, the passage can collapse so that relatively long stretches pass without a breath. This, of course, can be very dangerous, particularly in people who have heart conditions. Snoring is a symptom of the same underlying problem.

Another trade-off of speech is choking. Our mouths lead both to the trachea, through which we breathe, and to the esophagus, so we use the same flexible passage to swallow, breathe, and talk. Those functions can be at odds, for example when a piece of food "goes down the wrong pipe" and gets lodged in the trachea; our fishy ancestors had no such worries. Other mammals, and reptiles too, use the same structures for eating, breathing, and communicating but the back of the mouth does not need to be so vertically spacious and flexible as ours. The basic mammalian structures are arranged so that nonhuman animals can safely swallow while breathing. Tweaking the engineering to enable us to talk has left us peculiarly vulnerable.

THE ANNOYANCE OF HICCUPS also has its roots in our fish and amphibian past. If there is any consolation, we share that misery with others. Cats and dogs, like many other mammals, also get hiccups. A small patch of tissue in the brain stem is thought to be the center that controls that complicated reflex.

The hiccup reflex is a stereotyped twitch that involves a number of muscles in the body wall, diaphragm, neck, and throat. A reflexive firing of one or two of the major nerves that control breathing causes those various muscles to contract. This results in a very sharp inspiration of

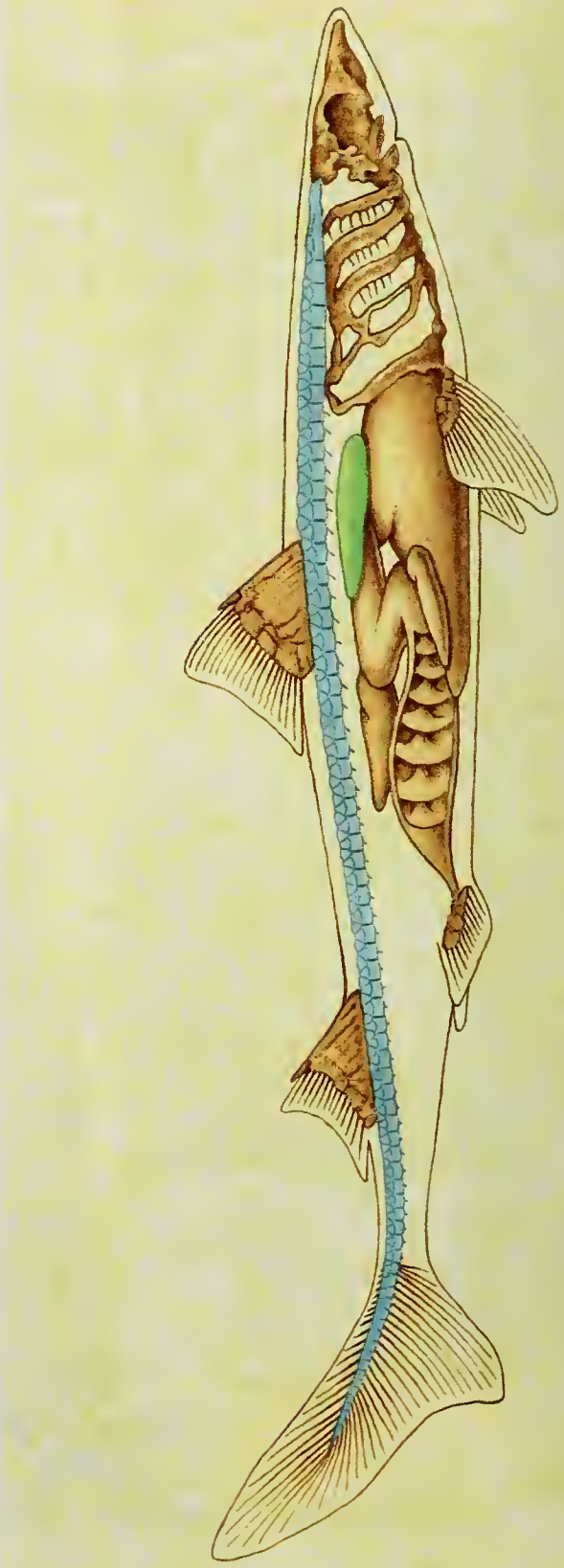
air. Then, about thirty-five milliseconds later, a flap of tissue in the back of the throat (the glottis) closes the top of the airway. The fast inhalation followed by a brief closure of the air tube produces the "hic."

Our tendency to develop hiccups is another influence of our past. There are two issues to think about. One is what causes the reflexive firing of nerves that initiates the hiccup. The other is what controls that distinctive hic—the abrupt inhalation and the glottis closure. The nerve action is a product of our fish history, while the hic is an outcome of the history we share with tadpoles.

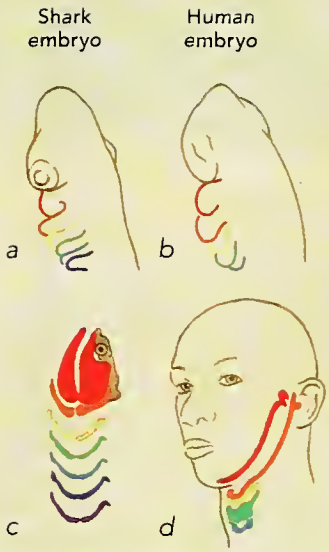
Fish first. Our brains can control our breathing without any conscious effort on our part. Most of the work takes place in the brain stem, at the boundary between the brain and the spinal cord. The brain stem sends nerve impulses to the main breathing muscles. Breathing happens in a pattern: muscles of the chest, the diaphragm (the sheet of muscle that separates chest from abdomen), and the throat contract in a well-defined order. Consequently, the part of the brain stem involved is known as a "central pattern generator." It can produce rhythmic patterns of nerve and, consequently, muscle activation. A number of such generators in the brain and spinal cord control other rhythmic forms of behavior, such as swallowing and walking.

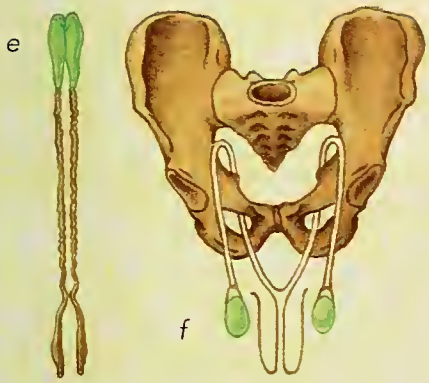
The problem is that the brain stem, originally controlling breathing in fish, has been jury-rigged to work in mammals. Sharks and bony fish respire using muscles in the throat and around the gills. The nerves that control those areas all originate in a well-defined portion of the brain stem. We can even detect that nerve arrangement in some of the most primitive fish in the fossil record. Imprints of ancient ostracoderms, from rocks more than 400 million years old, preserve casts of the brain and cranial nerves, and just as in living fish, the nerves that control breathing extend from the brain stem.

That works well in fish, but it is a lousy arrangement for mammals. In fish, the nerves that control breathing do not have very far to travel from the brain stem. The gills and throat generally surround that area of the brain. We mammals have a different layout; our breathing is carried out by muscles much farther away. For example, the major nerve that controls contraction of the diaphragm—the phrenic nerve—exits the brain stem from the base of the skull, just as it does in fish. Then, however, it extends all the way down through the neck and the chest cavity to reach the diaphragm. That long path through soft tissue is exposed and vulnerable; a rational design would have the nerve travel through the protective spinal column and

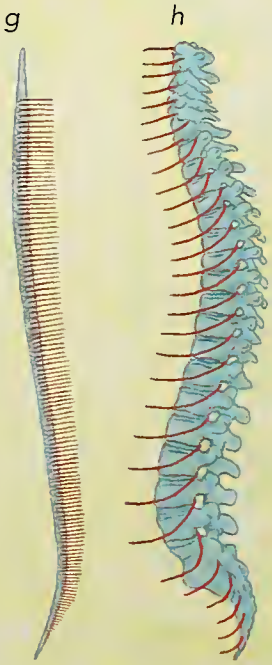


Both shark and human embryos (a, b, at right) have similar gill arches (brightly colored elements). In sharks, the cells in these arches become bones, nerves, arteries, and muscles that support the gills (c); in humans, they form the jaw, ears, larynx, and parts of the throat (d).

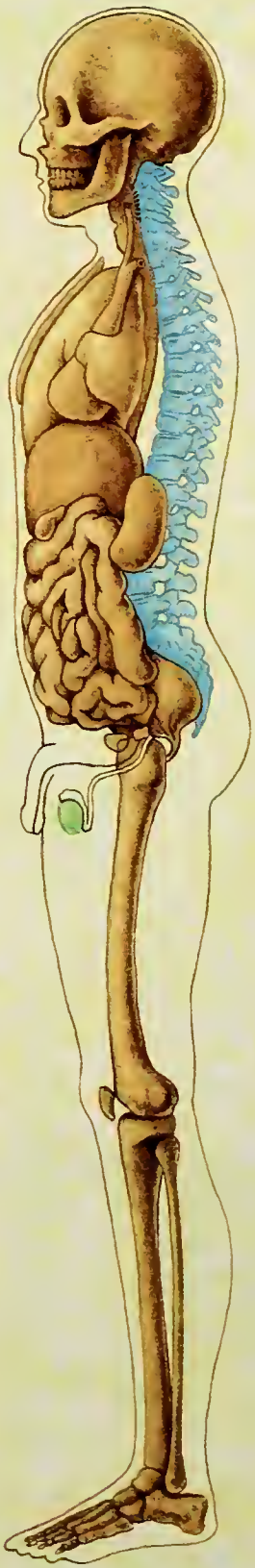




Shark gonads (testes shown here, e) extend above the liver toward the front of the animal, as they do in early human fetuses. In male humans, and other male mammals, the testes (f) descend during further development; the spermatic cords take a detour to loop over the pelvic bone, and the scrotum emerges as an extension of the body, making a weak spot where hernias can form.



Nerves that control sensation and movement exit the spinal cord between the vertebrae in both sharks (g) and humans (h). This arrangement works fine in a fish, which is largely supported by water, or in an animal that walks on four legs, so that the body's weight is dispersed among front and back limbs. Humans, who walk on two legs, often experience severe pain or loss of movement when vertebrae in the lower back shift, or when the disks between the vertebrae change shape or rupture with age and/or disease.



TIM GUNTHER / WWW.GUNTHERGRAPHICS.BIZ

THE FREQUENT KNEE INJURIES PEOPLE SUFFER ARE CLEAR EVIDENCE OF THE PITFALLS OF HAVING AN INNER FISH.

emerge nearer the diaphragm. Unfortunately, anything that interferes with one of these nerves, such as a tumor in the chest cavity, can block their function or cause reflexive firing.

If the odd course of our nerves is a product of our fishy past, the hiccup itself is likely the product of our history as amphibians. Hiccups seem to be controlled by their own pattern generator in the brain stem: stimulate it, and you stimulate hiccups. It turns out that this pattern generator is virtually identical to one found in amphibians—and not in just any amphibians, but specifically in tadpoles. Tadpoles use both lungs and gills to breathe, and this pattern generator is active when they breathe with gills. In that circumstance, a tadpole needs to pump water into its mouth and throat and then out across the gills, but it must also prevent the water from entering its lungs. To keep out the water, it closes the glottis, the flap that can seal off the breathing tube. The central pattern generator in the tadpole brain stem ensures that an inspiration is followed immediately by a closing glottis. They can breathe with their gills thanks to an extended form of hiccup.

There are additional parallels between gill breathing in tadpoles and our hiccups. Gill breathing can be blocked by carbon dioxide, just as hiccups can (one home remedy, breathing into a paper bag, helps concentrate carbon dioxide). Experimentally stretching the wall of a tadpole's chest is another way to block gill breathing, just as inhaling deeply and holding one's breath can stop hiccups. Perhaps we could even block gill breathing in tadpoles by having them drink a glass of water upside down.

THE HAZARDS OF TAKING a fish body and morphing it into a mammal show up in other specific ways. One is our propensity for hernias, at least for hernias near the groin.

If you were to slit the belly of a shark from mouth to tail, the first thing you'd see is liver, a lot of it. The liver of a shark is gigantic. Some zoologists believe that a large liver contributes to the buoyancy of the shark. Move the liver away, and you'll find the gonads extending up into the "chest" area, near the heart [*see diagram, page 28-29*]. This arrangement is typical of most fish: the gonads lie toward the front of the body. In mammals, the location of the gonads is quite different, and therein lies the problem.

This article was adapted from *Your Inner Fish: A Journey into the 3.5-Billion-Year History of the Human Body*, by Neil Shubin, ©2008. Reprinted with permission of Pantheon Books, a division of Random House, Inc. All rights reserved. On sale in bookstores in January.

Now, it is a very good thing that our gonads are not near our hearts (although it might make reciting the Pledge of Allegiance a different experience). If our gonads were in our chests, we wouldn't be able to have babies. For males in particular, it would be a disaster. Males continuously produce sperm throughout their lives. Sperm are finicky little cells that need exactly the right range of temperatures to develop correctly for the three months they live. Too hot, too cold, and they die or become malformed. Male mammals have a neat little device for controlling the temperature of the sperm-making apparatus: the scrotum.

As we know, the male gonads sit in a sac. Inside the skin of the sac are muscles that can expand and contract as the temperature changes. Hence the cold shower effect: the scrotum will tuck close to the body when exposed to cold. The whole package rises and falls with temperature. This is all a way to optimize the production of healthy sperm. The dangling scrotum also serves as a sexual signal in many mammals. The problem with this arrangement is that the plumbing that carries sperm to the penis is circuitous. Sperm travel from each testis through a spermatic cord. The cord leaves the scrotum, travels up toward the waist in front of the pelvis, loops rearward over the pubic bone, and doubles back and down through the pelvis to reach the ejaculatory duct, which empties into the urethra. The reason for this absurd roundabout route lies in our developmental and evolutionary history.

Our gonads begin their development in much the same place as a shark's: up near the liver. As they grow and develop, our gonads descend. In females, the ovaries descend from the midsection to lie near the uterus and fallopian tubes. This ensures that the egg does not have far to travel to be fertilized. In males, the descent goes farther.

The descent of the gonads, particularly in males, creates a weak spot in the body wall. To envision what happens when the testes and spermatic cords descend to form a scrotum, imagine pushing your fist against a stretched rubber sheet. In this example, your fist becomes equivalent to the testes and your arm to the spermatic cords. The problem is that where once the rubber sheet was a simple wall, you've now made another space, between your arm and the rubber sheet, where things can slip. This is essentially what happens in many types of inguinal hernias in men. Some inguinal hernias, or hernias of the groin, are congenital, created when a piece of the gut travels with the testes as they descend. Inguinal hernia

can also be acquired: A weak spot in the body wall—the muscular wall of the abdomen—can be breached, if pushed by a strong muscle contraction, and a loop of gut can be squeezed to lie next to the spermatic cord.

Females are far tougher than males, particularly around that part of the body. Because females do not have a giant tube running through the abdominal wall, it is much stronger than a male's. That is a good thing, when you think of the enormous stresses that female body walls go through during pregnancy and childbirth.


CHRISTOS MAGGANAS

HURT YOUR KNEE, and you will almost certainly injure one or more of three structures: the medial meniscus, the medial collateral ligament, and the anterior cruciate ligament. So frequent are injuries to those three parts of the knee that they are known among doctors as the "unhappy triad." They are clear evidence of the pitfalls of having an inner fish. Fish do not walk on two legs.

Rocks about 380 million years old preserve the first knees—in the pelvic fins of fish. They look like a simple hinge made of three bones. The animals that had them were mostly aquatic, so their "knees" didn't bear much weight. Consequently, the fin is relatively flat and shaped almost like a paddle. Our legs look the same way when we are in the womb, at six to seven weeks of age. After about eight weeks of development, a remarkable thing happens: our knees rotate so that they face forward, flexing backwards. We can see evidence of this shift even in our adult bodies, where many of the nerves that supply the lower leg wrap backward at the knee.

What does this mean in our daily lives? That rotation of our knees is essential to our ability to walk: imagine trying to amble about with your kneecap facing to the rear. It is also a prescription for disaster. Most of the weight of our body when we walk, run, and jump gets borne on a simple hinge. To make matters worse, the hinge is held together by a handful of strap-like ligaments, with two cartilage pads inside. Our "unhappy triad" is another example of the revenge of our inner fish.

LOOKING BACK THROUGH BILLIONS of years of change, we see that everything innovative or apparently unique in the history of life is really just old stuff that has been recycled, repurposed, or otherwise modified for new uses. Human hands are a modified version of mammalian ones, which are ultimately modified fish fins. Bones in our ears originally helped ancient sharks and reptiles chew. The genes that control all of this structure were originally used to build the bodies of ancient worms, flies, and fish. Every part of us tells this story: our sense organs, our heads, even our entire body plan.

While the evolutionary history we carry within us causes problems, it is also a treasure trove of potential solutions. Answers to fundamental questions we have—about the inner workings of our organs, about possible cures for disease—will come from understanding how our bodies and minds have emerged from parts common to other living creatures. Already, the study of a little worm called *Caenorhabditis* has led to the discovery of a new mechanism for gene regulation. That discovery, for which the Nobel Prize was awarded in 2006, has spawned some of the most promising technology for tumor suppression and reduction ever discovered. If a cure for cancers is to be found, it will likely be derived from that little worm. I can imagine few things more beautiful or intellectually profound than finding the basis for our humanity, and remedies for many of the ills we suffer, nestled inside some of the most humble creatures that have ever lived on our planet.

A paleontologist, **Neil Shubin** has found fossils, such as *Tiktaalik*, "a mosaic of primitive fish and derived amphibian," that throw new light on key transitions in evolution—from water to land, from reptile to mammal—and that clarify the origins of salamanders, dinosaurs, and their relatives. His expeditions have taken him to Greenland, the High Arctic of Canada, Argentina, China, Morocco, Nova Scotia, and the deserts of the United States. Shubin is the provost of Chicago's Field Museum as well as the associate dean and Robert R. Bensley Professor of Anatomy at the University of Chicago. *Your Inner Fish: A Journey into the 3.5-Billion-Year History of the Human Body*, is his first book for a popular audience.

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A Change in the Weather

For generations Inuit have survived by closely observing the natural world. As the Arctic environment changes, their insights are informing science.

BY SHARI GEARHEARD

Dogsled—one in a group carrying the author and her research team—skirts an unseasonable patch of open water in the sea ice off Greenland. The Arctic is warming about twice as fast as the rest of the world. Inuit and other Arctic residents report wide-ranging environmental changes, including early break-up and late freeze-up of sea ice.

ANDY MAHONEY

Toku and I sat silently on the wooden sled, listening to the swish of snow under the runners and the panting of happy sled dogs. Whiteout conditions and blowing snow made for poor visibility. It was the end of March, and we were traveling across sea ice from the village of Qaanaaq on Greenland's northwestern shore to the most northerly community in the world, Siorapaluk, about thirty-five miles away.

We and the other members of our research team had been traveling most of the day, the fifteen of us divided among seven dogsleds. The journey was part of a project to study sea-ice changes in three Arctic communities: Qaanaaq in Greenland, Barrow in Alaska, and Clyde River in Canada. Inuit elders and hunters from each community, along with scientists from Canada, Greenland, and the United States, made up the team. The trip to Siorapaluk was a chance to see changing patterns of sea ice that the people from Qaanaaq, the Qaanaarmiut, had been describing to us.

The dogs pulled our sled in the tracks of other dog teams well ahead, moving slowly but steadily through freshly fallen snow. I was enjoying the ride and friendly conversation with Toku, a hunter and fisher from Qaanaaq, when I happened to look down at the snow. My heart skipped a beat. Mixed with the fresh imprints of dog paws, I saw dark, water-filled holes. The dogs were falling through the ice, which was only about two inches thick.

But, falling through sea ice in March? Normally the ice is much thicker at that time of year and doesn't begin to break up for at least another two months. Back in Qaanaaq, the Qaanaarmiut had told us that dur-

TERRY GARCHINSKI

Portraits of Baffin Island in Nunavut, Canada, near the Inuit town of Clyde River. Teenagers pass a July day fishing on sea ice in the town's protected bay, above. The ice, which lasts a few weeks longer in the bay than on the ocean, has begun to break up and flood, but is still several feet thick. In August, local waters are ice free, above right.

ing the last decade they've had to shift certain travel routes from sea ice onto land and stop sea-ice travel in some areas in May instead of August because of such conditions.

There on the sled it seemed we were experiencing the changes first hand. Toku encouraged her dogs to keep moving. I realized that now was not the time to ask for a pee break or jump off and run along to warm up. I had traveled sea ice enough, and with my own dogs, to keep from panicking, but it took some focus to remain calm. Toku smoked another cigarette. I busied myself with examining her dog whip and willed the dogs to keep pulling.

Finally we arrived safely at Siorapaluk. Everyone helped to unload sleds and get the dogs tied up for the night. The chatter soon turned to the thin ice, and one of the drivers said he had been pretty nervous when his dogs' legs started punching through. Most of the Inuit on our team had experienced similar thin-ice conditions before; for them, it was all part of being hunters and traveling in the Arctic. Everyone agreed, however, that it was much too early in the spring for such thin ice.

SHARI GEARHEARD

Inuit elders and hunters in Barrow, Alaska, host their counterparts from Qaanaaq, Greenland, and Clyde River for a discussion of changing environmental conditions in the three communities.

On the trip back to Qaanaaq the next day, the weather was clear and we traveled under blue skies [*see photograph on preceding two pages*]. With perfect visibility, we could see where we had sledded the day before. Unsettlingly close to our route lay huge gray patches of thin ice and black patches of open water. For years I'd been working with Inuit to document changes in the Arctic environment, but that was the first time I'd personally faced one of the new hazards those changes often bring.

Inuit, on the other hand, are frontline observers of the changing Arctic, confronted regularly by its new and shifting demands. The Arctic—ecologically defined, the region north of the tree line, roughly latitude 60 degrees north, about 450 miles south of the Arctic Circle—has been gradually warming since the early 1970s, and today air temperatures are, on average, about 2 degrees Fahrenheit warmer than they were three decades ago, twice the global average rise in temperature. As has been widely reported, many Arctic glaciers and the Greenland ice sheet are melting at unprecedented rates and permafrost is thawing in

Near Clyde River sea ice typically persists from November into July. Cracks in it, such as the one shown above, often form in the same places from year to year. Lately, however, local Inuit report that cracks have been forming in unusual locations, perhaps as a result of shifting ocean currents and winds.

some places for the first time. This past summer Arctic sea ice receded to a record minimum, covering just 61 percent of the area it covered, on average, between 1979 and 2000 [*see map on page 33*].

The Arctic climate has always fluctuated, according to studies of ice cores that date back some 400,000 years, from which past temperature and atmospheric conditions can be deduced. But the overwhelming majority of climate scientists agree that the recent changes are almost certainly attributable to global warming. Inuit, too, recognize the Arctic's inherent variability—which they've observed keenly and adapted to over the centuries—and they say that something is indeed very different today. Changes in snow and sea-ice conditions, shifts in the seasonal calendar, unusual animal behavior—all exceed the familiar range of variability, they say. As a result of their intensive use of the environment, Inuit and other Arctic residents pick up on many subtle changes and intricate connections that scientific instruments cannot detect, and that scientists are just beginning to appreciate and understand.

Inuit, a broad term—Inuk being the singular—includes many Arctic groups, from the Yup'ik in western Alaska and Russia to the Kalaallit in Greenland. All were once known as Eskimos, a term no longer used in most regions, and they speak related languages or dialects in the Eskimo-Aleut language family. In total, approximately 155,000 Inuit live in the Arctic, mainly in northern Alaska, Canada, Greenland, and northeastern Russia [*see map on page 33*]. (Other indigenous groups inhabit the Arctic, too, including the Dene and Athabaskans in North America, the Sami in northern Scandinavia, and a dozen or so other ethnic groups in northern Russia.)

I live and base most of my studies in Clyde River, or Kangiqtugaapik, a small Inuit community of about 850 on the northeastern shore of Baffin Island in the Canadian territory of Nunavut. Nunavut—which means "our land" in Inuktitut, the language of the region's Inuit—split from the Northwest Territories to become Canada's newest territory in 1999. Nunavut is huge, encompassing 770,000 square miles—about three times the size of Texas. Some 29,500 people, 85 percent of them Inuit, live there, spread between twenty-six communities. The territory boasts a diverse landscape, from flat tundra and lakes to dramatic mountains, fjords, and cliffs. Ten months out of the year, from October through July, snow, ice, and cold weather prevail in most places.

In the 1950s and 1960s, Inuit in the region moved—some willingly, some under compulsion—into settled communities created by the Canadian government. But before that they were nomadic, following the rhythms of the seasons and the migrations of animals as they moved between summer and winter camps. Today, many Inuit still spend a great deal of time out on the land and at camps and cabins, but most live primarily in settlements. As with many northern indigenous groups, elders belong to the last generation to have lived most of their lives in the traditional way and to retain the specialized knowledge, language,

and skills needed to live on the land.

My work has focused on the Nunavut communities of Baker Lake, Clyde River, and Igloolik, but has recently taken me to Alaska and Greenland as well. Working closely with resident researchers and interpreters, I meet with elders and other local experts to discuss environmental changes. Often we use maps to chronicle travel routes and the locations of various changes, such as thinning ice, dried-up ponds, and receding glaciers. I also spend a great deal of time accompanying Inuit as they travel, hunt, and fish, to learn about what they observe and how they make decisions within their environment.


SHARI GEARHEARD

Inuksuk *(the plural is* inuksuit*) near Clyde River: such humanlike figures of rock mark travel routes, indicate important resources, or aid in hunting.*

Years ago, it was often difficult to get scientists to take traditional knowledge seriously. But increasingly, climate scientists and other researchers have been incorporating indigenous knowledge and observations into their research. A notable example is the prominent role of Arctic indigenous communities in the International Polar Year of 2007 to 2008, in which thousands of scientists are engaged in more than 200 research projects in the Arctic and Antarctic. Indigenous communities are contributing to studies on biological diversity, birds, caribou and reindeer, and human health, among other topics.

Several of the projects I help lead bring Inuit and scientists together. One example is the sea-ice study in Clyde River, Barrow, and Qaanaaq—called the Siku-Inuit-Hila Project, for "sea-ice people weather" in a mix of Inuit dialects—which contributes to several international studies. In another project, I work with Inuit hunters and my colleagues at the National Snow and Ice Data Center at the University of Colorado at Boulder to document changing sea-ice off the east coast of Baffin Island, using both remote sensing data and Inuit knowledge. Remote sensing via satellites provides an overview of sea-ice extent and some data on its characteristics going back to the 1970s. Inuit knowledge goes back further, to the early 1900s, and provides insight into finer-scale changes, including sea-ice texture and stability, and into changes in the environmental processes that drive sea ice, such as currents, snowfall, and winds. Such work is driven by the belief that linking multiple methods, scales, and ways of knowing increases confidence in individual observations, broadens the information base, and helps explain the various changes.


SHARI GEARHEARD

Puppies of the breed known as the Canadian Inuit dog, or qimmiq*, explore the world around their doghouse, behind them. They will join the author's sled team when they mature.*

After almost thirteen years, my work in Nunavut tells a story repeated by many communities around the North: the Arctic is changing, and changing fast, on a number of fronts. Among the most striking changes, observed by locals from Alaska to Finland, is that the weather is increasingly unpredictable. Since weather determines the day's activities for most hunters, it is a critical part of everyday life, and closely watched. Skilled Inuit forecasters observe cloud patterns and wind conditions to predict weather through the next day.

Since around the mid-1990s, however, those techniques haven't been working so well [*see sidebar on opposite page*]. Winds kick up and die down unexpectedly, they come from unusual directions, and they shift direction several times a day. Although conditions may indicate a clear day ahead, an unexpected storm might arrive. As Norman Attungala, an elder from Baker Lake, explained to me in 2001, "Inuit have a traditional juggling game. The weather is sort of like that now. The weather is being juggled; it is changing so quickly and drastically."

The increased risk of running into bad weather has pushed Inuit hunters and travelers to change their travel habits. Some pack extra supplies, just in case. As for the traditional forecasters, many have lost confidence in their prediction skills and have stopped advising hunting parties about when and where to travel. That has wrought an emotional change for some, who miss having an advisory role in their families and communities.

Inuit have been observing many other environmental changes, too. During the past decade, for instance, Inuit in Nunavut have noted strengthening winds, which can pack snow much harder than usual. The hard snow can prevent people from building igloos for temporary or emergency shelter, leaving them vulnerable to that

Uqarumajakka "What I have to say"

By Ilkoo Angutikjuak

Translated from Inuktitut by Nellie Iqalukjuak and Geela Tigullaraq

I am sixty-five years old and I have been living in Clyde River, Nunavut, almost my entire life. When I was young, we hunted by dog team for seal, fish, fox, rabbit, and sometimes caribou in the winter, and we hunted narwhal and fished for halibut in the summer. I hunt by Ski-Doo these days, and I enjoy going out on the land when it's not too windy.

In the past, we would watch the dogs to learn about the wind. If it was windy and the dogs started walking around instead of lying curled in one spot, we'd know it was going to calm down. I don't have dogs anymore, but I use rawns today. Like dogs, they try to get into a sheltered spot if it's going to get windy. When you're always outside, you notice little things like that. In the old days, even as children, we had to go outside first thing in the morning to look at the weather, to learn. It's still the same for me today, even though I sometimes look through a window. But it's more difficult to predict the weather now, especially the wind. It seems to get windy suddenly these days. And there are many other changes, too.

For example, the sea ice isn't the same anymore. It seems like it's forming only from water, meaning it's much less salty now. You can even see through the sea ice. In the past it wasn't clear, it was whitish. It also breaks up sooner in the spring than it used to, and the winters don't feel as cold. Narwhals seem to come sooner than before. When the sea ice was here longer, they didn't come as early; they would pass us by, swimming north.

The snow has changed, too. It used to be really white but now it seems yukiwish, as if it has some fine sand or dirt on it. The sky used to be clear blue on a nice day but now it seems reddish. It's just a guess, but I think it's redder for the same reason the snow is yukiwish: there is a smoky or dirty substance in the air. That might explain why the nights seem darker, too—the snow is dirty, not as reflective of light, and the sky is hazy.

I know that before our time the world was very warm, even around here. When the glaciers started to recede people found woolly mammoth tusks, so we know things were different long ago. Many years from now, it might be like those old days. Inuit used to say that one day the Arctic would melt, that things would reverse and there would be snow down south, but none up here. We see weird weather in many places on the television these days, and it is warmer here, so maybe that's what is happening.

If the changes continue, I will learn to live with them. The seals and other animals that depend on the sea ice will move to the shores; the animals will adapt. I've heard that because they depend on sea ice, polar bears will go extinct, but I don't believe it. They are very adaptable. As the sea ice changes, polar bears might get skinnier and some might die, but I don't think they will go extinct.

The only way to react to the changes we are seeing is to be positive. The people and animals will adapt. At the same time, it is very important to get the information out there about what is changing, so others can understand what is happening.

unpredictable bad weather. Some Baker Lake residents told me they blamed the extra-hard snow for the deaths of several travelers out on the land.

Weather and wind changes, in turn, have affected sea ice—and not just its thickness. In Nunavut, all but one of the twenty-six communities lie on the coast. Their inhabitants rely intensively on sea ice for hunting and traveling, so their understanding of it is quite complex. How does the sea ice feel when you walk on it? How does it respond to being kicked or struck with a harpoon? How does it taste at different times of the year: too salty? Not as salty as it should?

As with the Qaanaarmiut in Greenland, many Nunavummiut, or people from Nunavut, report that the ice is thinner in places, forms later, and breaks up earlier—observations that mirror findings from numerous scientific studies. Clyde River Inuit note that familiar cracks in the sea ice are not appearing even as new ones open in unusual locations; they say the sea ice seems to be softer, not as solid as it used to be; and they say the currents have shifted in certain areas, combining with wind changes to affect ice movements. In response, Inuit in northern Quebec and parts of Nunavut are reviving the traditional practice of dogsledding. Dog teams are more reliable than snowmobiles in the changing environment, because they can help navigate dangerous sea-ice conditions and can find their way home during storms—not to mention that they don't run out of gas or need new spark plugs.

Dogsledders have helped to identify seasonal changes. The month of June, according to Clyde River Inuit, no longer lives up to its name, Qiqsuqqaqtuut, which refers to the top layer of snow melting during the day and refreezing at night. During the spring dogsledders usually prefer to travel at night, when the refrozen surface lets sleds' runners glide quickly over the snow and the temperature is cooler than during the day for the dogs. Now the crust no longer forms at night. Moreover, many Inuit communities report that fall freeze-up of sea ice comes between two and three weeks late and spring break-up is

SHARI GEARHEARD

Naqsaq is a year-round hunting and fishing camp about forty-five miles southwest of Clyde River. Beyond the cabins, a retreating glacier leaves a cascade of gravel in its wake. Many local glaciers have been receding recently; the meltwater has eroded riverbanks and destroyed some campsites.

between two and three weeks early, making for an extra month or more of the open-water summer season.

Changes in the environment are bound to affect other organisms, and indigenous people throughout the Arctic have reported changes that range from subtle to striking in a variety of species, including birds, caribou, fish, insects, polar bears, walrus, and whales, as well as plants and lichen. In many cases, species are turning up in unexpected places or at unexpected times of the year, often following the shifts in seasonal timing. But many of the observed changes are even more complex.

At Clyde River, for instance, the most important animal for Inuit is the ringed seal, which provides food and skins for clothing. Seals normally molt in spring, and they scrape off old fur as they lounge and move around on sea ice, basking in the spring sunshine. But hunters and women who work with skins note that seals caught in summer sometimes appear still to be molting. With earlier sea-ice break-up, seals are forced into the water before their molt is complete. Inuit still use the seals' meat for food, but the skins are too uneven to be useful.

Notably, not all Arctic communities are experiencing the same changes. Parts of western North America are warming dramatically; some communities there are experiencing severe coastal erosion and thawing permafrost is damaging or destroying infrastructure. Temperatures elsewhere in the Arctic remain stable. Yet wherever environmental changes occur, they intersect with social, cultural, economic, and political changes, often brought about by the forces of modernization and globalization.

Apak Qaqqasiq, a Clyde River elder, told me a few years ago that the changes are "not that scary, yet." Indeed, it's often not the changes per se that are unusual: the sea ice has occasionally broken up early, the weather has gone wonky at times. *At times.* But the sea ice never used to break up early six years in a row, and the weather has never changed as frequently or as unpredictably as it does today.

And more change is yet to come. The Intergovernmental Panel on Climate Change projects that by the year 2100 the Arctic will have warmed by between 5 and 12 degrees above current average temperatures, already 2 degrees higher than they were in the 1970s. What will happen to the Inuit? Undoubtedly, they will face serious challenges. Like many hunters I work with, I have concerns for the future; but like them I also have hope and a strong faith in the ingenuity and resiliency that have enabled Inuit to thrive in one of the harshest and most unpredictable environments on Earth.

In spite of the changing sea ice, Toku continues to be a successful hunter, combining the knowledge her father and brother have passed on to her with her own observations of new conditions. And the community of Clyde River is tackling climate change head on, partnering with scientists and the Canadian government to develop an adaptation plan. Many Inuit have told me that regardless of how their environment changes, they will always remain Inuit—connected to their land by love and respect, no matter what the weather may bring.

Shari Gearheard is a research scientist with the National Snow and Ice Data Center at the University of Colorado at Boulder. She works with Inuit to document their knowledge of the environment and develops collaborative projects to link Inuit and scientific knowledge. Shari lives with her husband Jake, their dog Umik, and their sixteen sled dogs in Clyde River, Nunavut, where she bases her studies.

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AS HEARD ON PAUL HARVEY NEWS

New advanced portable heater can cut your heating bill up to 50%

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End of interview.

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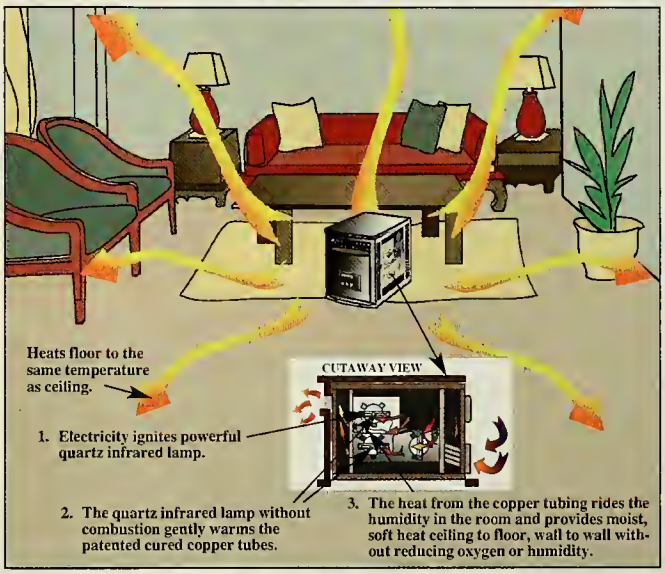

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Far from the forests of the night

*In spite of their staggering liabilities as pets, **tigers** and other **"exotics"** have become hefty commodities in the United States, in part because of inconsistent state laws.*

BY JOSIE GLAUSIUSZ

Ming, a Bengal-Siberian tiger, was found living in a New York City apartment in 2003, along with an alligator that measured over five feet. Their illicit caretaker, Antoine Yates, served several months in jail for reckless endangerment—of humans, not the animals.

PHOTOS (OPPOSITE) MATTHIAS CLAMER; (BELOW) AP PHOTO/NYPD

Three times a year the small town of Mount Hope, Ohio hosts a three-day sale of exotic animals. For a modest entrance fee of five dollars, visitors can meander among the crates, shopping for bearded dragons, Fennec foxes, and wallabies. Or they can ponder the merits of purchasing a black bear, a cougar, a sugar glider, or a zebra. For a seventeen-year-old boy and his eager-to-please, divorced dad, a two-week-old African lion was the winner. In April 2005, they plunked down $900 in cash for the cub, whose eyes were not yet open. No permit and no "owner's manual" included. (Ohio law did not require a permit, and still didn't at press time.)

The very next day the boy and his furious mother turned the lion, Alex, over to Tiger Mountain Refuge in Rainelle, West Virginia. John Forga, who runs the sanctuary with his wife, Myreda, asked the teenager where he had intended to keep Alex, as he and his mother lived in an apartment. Forga recalls the boy's answer: "'I was gonna train him to be friendly and he could have stayed in my room.' He was going to grow up in a child's bedroom watching TV and eating Cheetos!"

Alex now weighs 585 pounds, lives in a 2,500-square-foot enclosure, and dines well on a daily diet of twenty pounds of fresh beef, one adult tame rabbit, and two vitamin-infused chicken legs. Tiger Mountain shelters a bevy of other unwanted, abused, neglected, and confiscated big cats, including a blind African caracal lynx, a black leopard that was nearly euthanized by a private zoo in Ohio, and a cross-eyed, 350-pound Bengal tigress abandoned by a small zoo in Missouri.

No one knows exactly how many exotic pets live in the United States, or how many foreign animals are brought into the country every year. Hundreds of millions, from tropical fish and butterflies to lab monkeys, enter legally, making the U.S. the largest importer of live, wild animals in the world. Add to that a lion's share of the illegal international trade in wildlife, valued by the U.S. State Department in 2007 at $10 to $20 billion worldwide—a business that has been compared to drug and people trafficking, and that uses many of the same criminal networks and smuggling routes. Each of the 120 U.S. Fish and Wildlife Service inspectors must assess thousands of animals crossing U.S. borders every day of the year.

Tigers and other endangered big cats fall on the illegal-import list, but there is little point in smuggling wild tigers into the U.S., since those already present reproduce easily in captivity. And few federal regulations govern ownership or breeding of big cats, even though those are some of the most difficult exotics to care for properly. Cheetahs, cougars, lions, tigers, leopards, and more are often raised in cages

too small for them to turn around in, and fed insufficient or inappropriate food, such as canned dog food.

Tigers are among the most popular: 7,000 to 15,000 of them live in private roadside zoos, circuses, sanctuaries, farms, and backyards in the U.S. Owners are often deluded into thinking that they can tame the creatures, treating them like house cats, perhaps attracted by the challenge. Yet even house cats, which have been domesticated for thousands of years, will reach out and swat their human companions. What happens when a six-month-old, sixty-pound beast with claws and flesh-slicing incisors takes a

swipe? At that moment, a would-be tiger trainer must realize that the animal is wild, not some docile furball. Captivity does not equal domesticity.

Today wild tigers inhabit just 7 percent of their original range, a territory that once stretched from the Caspian Sea to the island of Bali in Indonesia. Their range has shrunk by 41 percent in the last decade alone. Most wild tigers subsist by hunting wild cattle, deer, and pigs in isolated pockets of forest in India, Sumatra, eastern Russia, and southern China. The dwindling of their natural habitat and poaching for pelts and tiger parts—used in traditional Chinese medicines such as tiger-bone wines and tiger-penis soups—compounds the tigers' risk of extinction. The wild tiger population has plummeted from an approximate count of 100,000 at the beginning of the twentieth century to less than 5,000 today. That means thousands more tigers live in captivity in the U.S. than in the wild.

Private owners often cite such statistics as reasons for supporting a growing population of caged tigers. In captivity, large exotic cats breed easily as long as they are given a steady supply of fresh meat and a minimum of space. The *Animal Finders' Guide*, a newsletter published eighteen times a year by Pat Hoctor, a former breeder in Prairie Creek, Indiana, shows that there is no shortage of both cubs and adults up for grabs in the U.S. A seller in Texas, for example, offers "free—two male tigers 2 ½ years old, like women; one female tiger, 6 years old, likes men and women; cages with cats." Another advertisement, from a breeder in Oregon, offers a "Barbary lion and caracal kittens;" a third, in California, is selling a "rare Asian leopard cat female, nine weeks old, bottle raised." More startling still: the price tag of a tiger cub—between $300 and $900—is comparable to that of a poodle puppy registered with the American Kennel Club.

Year-old tiger eats out of a handler's hand at Amazing Exotics, a self-styled "educational facility" in Umatilla, Florida that gives "tiger encounter" tours. A bill was introduced into the House of Representatives in 2007 that, if passed, would ban direct contact between the public and big cats. The bill was dubbed "Haley's Act," after Haley Hill Yurbrand, who was mauled to death in 2005 while posing with a tiger.

PHOTO: DAWN ANDREW SULLIVAN

The astonishing ease with which you can buy, sell, or give away a tiger—or other big cat—attests to the mess of laws covering exotic cat ownership in the United States. The 1973 Endangered Species Act bars the import of tigers into the country, but does not forbid private ownership of those bred here. The USDA issues licenses to exhibitors of wild and exotic animals, but pet owners are not eligible to apply for one. In 2003, a watershed federal law was passed: the Captive Wildlife Safety Act bans the interstate shipment of lions, tigers, and bears for the pet trade. However, the law does not forbid the breeding and intrastate delivery of the animals for non-commercial purposes. State and local laws vary widely and contain numerous loopholes that can confuse even the most earnest pet owners. Some states have banned exotic cat ownership completely, while others don't even require the animals to be registered [*see sidebar on opposite page for more information*].

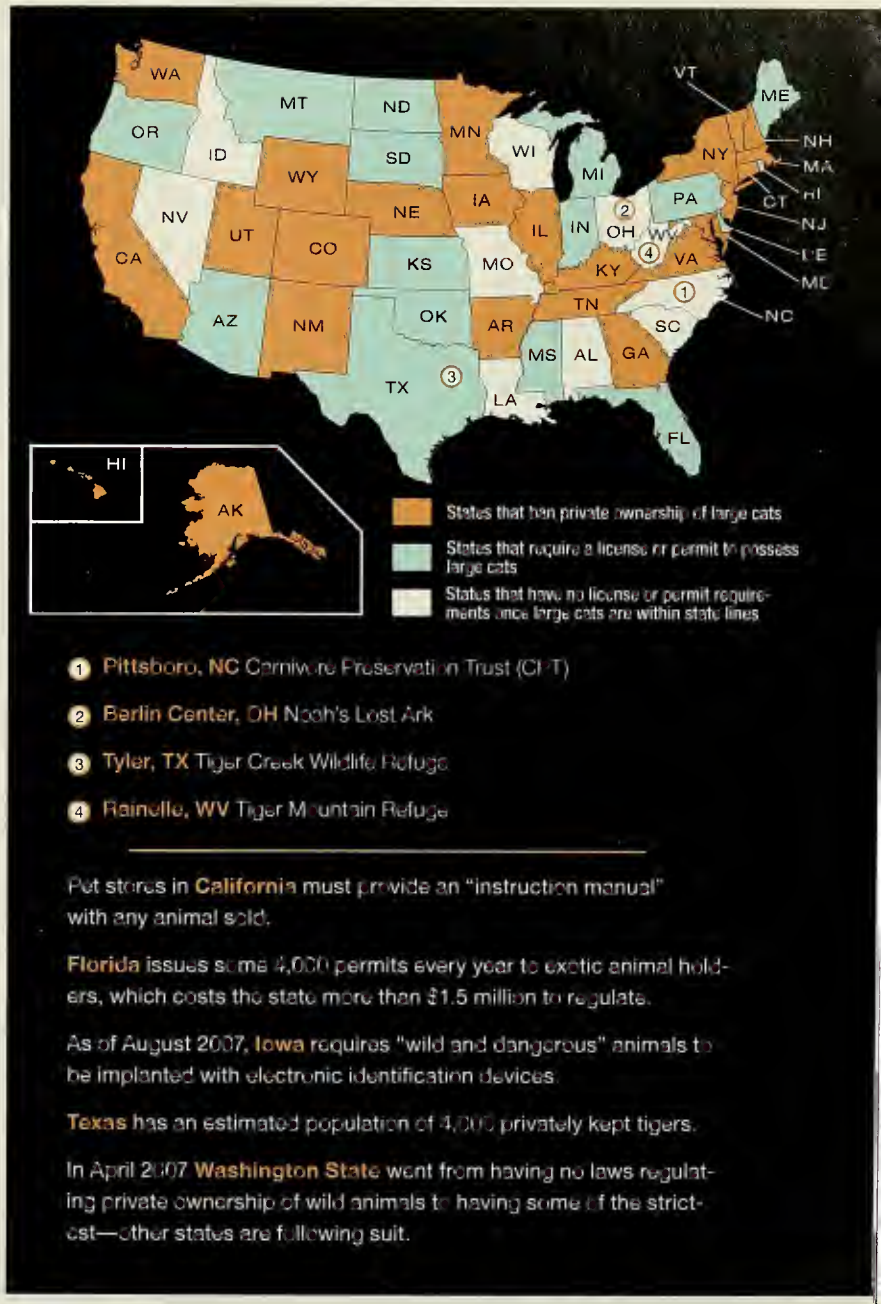
So confusing and inconsistent are the laws that many people are ignorant of them. Paris Hilton found out that her pet kinkajou—a small rainforest-dwelling mammal related to the raccoon—was illegal in California only after it bit her at 3 A.M. one morning in August 2006 and she required a trip to the hospital. Breeders and self-styled conservationists also appear unconcerned about the rules banning interstate shipment. "How many tigers do you want? I'll send them to you," Brian Werner jokingly offered when I interviewed him by phone from New York. Werner is the executive director of the Tiger Missing Link Foundation, which operates Tiger Creek Wildlife Refuge in Tyler, Texas, and vice president of the Feline Conservation Federation (FCF), an advocacy group that represents private owners. "It's legal for me to send tigers to you as long as I'm not selling them. I am licensed by the USDA, by the way. But even if I weren't, I could give them to you." In fact, a USDA-licensed facility can only transport an exotic cat across state lines to another licensed facility, or to an organization exempt from the prohibitions of the Captive Wildlife Safety Act, such as a nonprofit sanctuary. Violation carries a prison term of up to five years, but this does not deter many people. Tiger checks at state lines aren't exactly common.

In the past few years, states have started moving toward more control. In 2004, for example, the New York State legislature amended its environmental conservation law to ban the breeding of any wild cat species or the sale of wild felines as pets—a precaution likely taken in the wake of the 2003 case of Ming, a 400-pound tiger confined to a Harlem apartment [*see photograph on previous page*]. Ming now lives at Noah's Lost Ark, a nonprofit exotic animal

sanctuary in Berlin Center, Ohio. Other states have followed suit and tightened laws after lions and tigers have mauled owners, the grandchildren of owners, or bystanders.

Matt Joseph keeps ten exotic felines on his thirty-acre ranch in Lisbon, Ohio: four cougars; two male lions; one lioness; two female ligers (a cross between a male lion and a female tiger), and one female Siberian tiger. He bought all of them from breeders, ranging from Georgia to Minnesota, New York, Ohio, and Pennsylvania, and houses the cats in 1,800- to 3,200-square-foot enclosures. "I go into cages with them, I lay with mine, I sleep with mine," Joseph says. "A lot of people who've seen me do what I do say I'm crazy." He appears to believe that he is immune from serious attack, despite statistics showing that exotic cats do injure owners and bystanders. In 2003—the same year that a 600-pound white tiger named Montecore dragged Las Vegas showman and tiger trainer Roy Horn across the stage and mauled him in front of a live audience—eighteen people were injured by captive tigers and four were killed. Even Joseph, who says he has seen other collectors confine tigers in cramped quarters, believes that nobody should own the animals, "not even myself, much as I love them and enjoy them."

So what happens when pet owners find themselves threatened, attacked, or simply bored by their large pets? Many people abandon them. To prevent this, the Florida Fish and Wildlife Conservation Commission created an annual Non-Native Pet Amnesty Day. The free event, which will have its third anniversary on February 23, 2008 at the Miami Metro Zoo, gives remorseful owners the chance to turn over their animals without penalty—thus saving the local ecosystem from more strain. Other alternatives are scarce. Most zoos require strict pedigrees for their animals, and they likely have an already-filled quota of tigers, lions, and other exotics. The consequences can be seen in the numerous sanctuaries—some for real, some in name only—that have popped up around the country. At the more luxurious end of the spectrum is the Carnivore Preservation Trust (CPT), a spreading expanse of woodland dotted with spacious enclosures, nestled on a remote country road in Pittsboro, North Carolina. Vultures swoop overhead in the humid southern air, searching for scraps of meat, as keepers rove around the site, tossing chunks of goat meat and dead chickens—rejects donated by a local meatpacking plant—over the high fences of the enclosures to the thirteen pacing tigers. Pam Fulk, executive director of the CPT, says the cats were found dumped in parking lots, deserted in trailers, or tethered half-starved at a junkyard where passersby could pose. "When they're cubs, they're cute, they're cuddly," says Fulk. But at the critical age of six months, many are abandoned or killed.



Private tiger owners often claim that by rescuing these forsaken felines, they are preserving them from extinction. It's an argument that makes little sense to wildlife ecologist Ron Tilson, director of conservation at the Minnesota Zoo and the coordinator of the Tiger Species Survival Plan, a breeding program designed to maintain genetic diversity among zoo tigers in America

by mating only the most distantly related individuals with each other. Tilson argues that captive tigers are so inbred that they could not survive if released into their native habitat, as some people advocate. "They've lost a whole lot of genetic tools that may be real important to them and their offspring to survive—for example, resistance to certain kinds of diseases, the ability to tolerate extreme heat or cold, the ability to know how to hunt and kill."

Tilson also emphasizes the importance of protecting wild tigers, pointing to programs set up by the World Wildlife Fund and Wildlife Conservation Society to conserve vast swaths of landscape in Asia. He cites a successful scheme in the Russian Far East that rescued Siberian tigers from the brink of extinction. Twenty years ago, he says, just 150 tigers remained in the wild in Russia; in the last ten years, however, the tiger population there has doubled or even tripled, thanks to hard-nosed intervention efforts: aggressive patrolling for poachers' trucks inside protected areas, roadblocks, inspections, arrests, and stiff sentences.

In an attempt to cut down on such poaching, breeders in China have set up over a dozen "tiger farms," housing about 4,000 felines. Parts harvested from those magnificent beasts are destined for the Asian medicinal market [*see photograph below*]. Raising a farmed tiger is about 250 times as expensive as hunting a wild one, however, so illegal trading remains alluring to poverty-stricken poachers—especially as it is impossible to distinguish farmed tiger organs from those illicitly obtained.

Could the inbreeding of large cats as pets in the U.S. be equally damaging to the individual felines—if not to the species at large? Because big cats in captivity are often accidentally or intentionally mated with close relatives, many of their offspring are born with genetic disorders—immune deficiencies, cleft palates, epilepsy, and kidney or heart problems. One recently deceased tiger housed at the CPT was so "mentally retarded," says Pam Fulk, that he ignored an entire family of rabbits living under his den box.

As the disparate state laws in the United States continue to adjust and extend to cover exotic animals treated as pets, the need to redefine what it means to be wild may become more urgent. Breeders are not making that easy: they are crossing tigers and lions to produce ligers or tiglons, as well as crossing smaller wild cats with small breeds domesticated long ago. For example, the Bengal cat is a cross between an Asian leopard cat and a domestic cat; the striped "toyger," the offspring of a Bengal cat and a domestic, resembles a miniature tiger; and a new "designer" breed, the $20,000-plus spotted Ashera, is a serval crossed with an Asian leopard cat and domestic breeds.

Not unlike those hybrids, captive and inbred tigers in the U.S. have clearly drifted far from their wild roots; they are both thousands of miles and many generations away from their native state. Certainly they should not be used as an excuse for complacency about the need to conserve a natural, native habitat for their wild-dwelling brethren—if anything, the opposite. For though exotic cat collectors may yearn for a taste of the wild in their daily lives, they also—paradoxically—squelch the spirit of these fierce predators. Even so the large cats, captive or otherwise, will never be completely domesticated, as Ellen Whitehouse, the executive director of Noah's Lost Ark, insists. "People live in this fantasy world where they think that the tigers and lions actually, truly love them." She says, "They honestly cannot ever be tamed. They cannot be controlled. They're always wild. I have raised some here, and every single one of them would eat me."

Josie Glausiusz is a journalist and editor; her articles have appeared in *Discover*, *Nature*, *Wired*, *New Scientist*, *OnEarth*, *The Forward*, *The Jerusalem Post*, and more. She is the co-author, with photographer Volker Steger, of *Buzz: The Intimate Bond Between Humans and Insects* (Chronicle, 2004).

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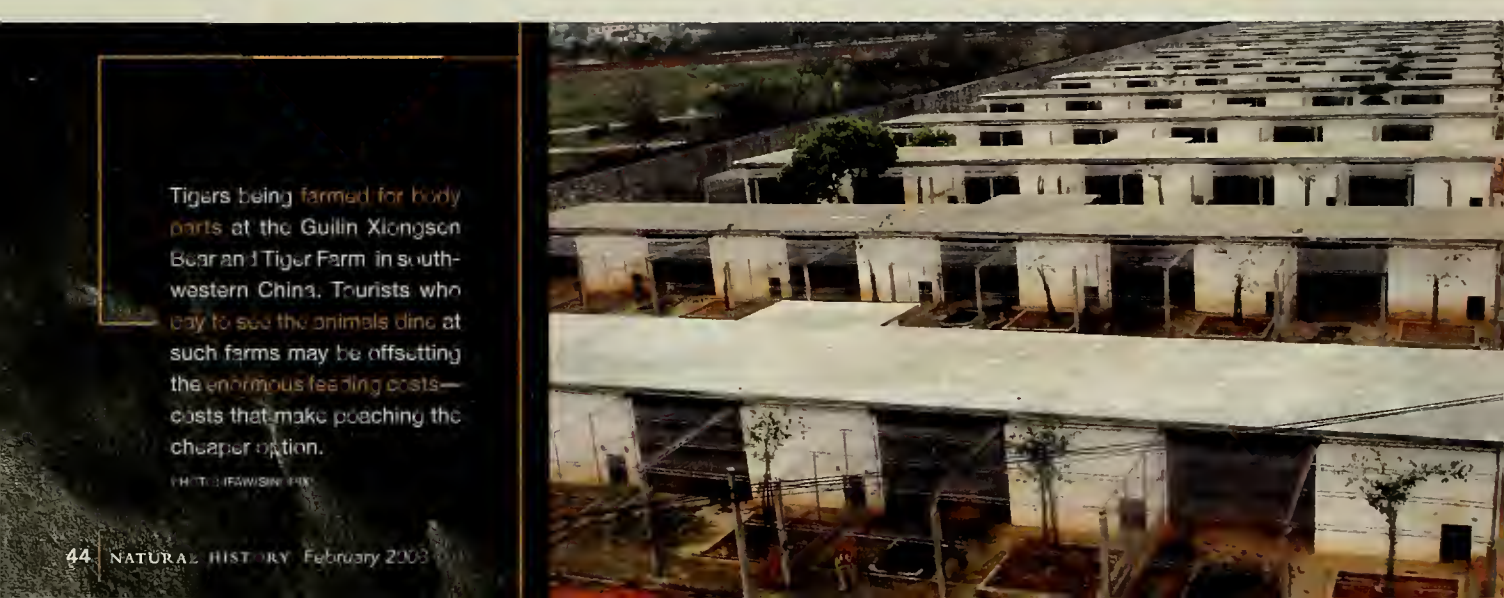

Tigers being farmed for body parts at the Guilin Xiongsen Bear and Tiger Farm in southwestern China. Tourists who pay to see the animals dine at such farms may be offsetting the enormous feeding costs—costs that make poaching the cheaper option.

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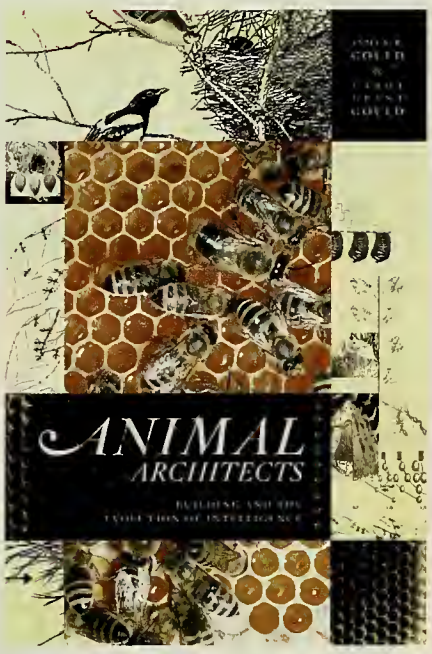
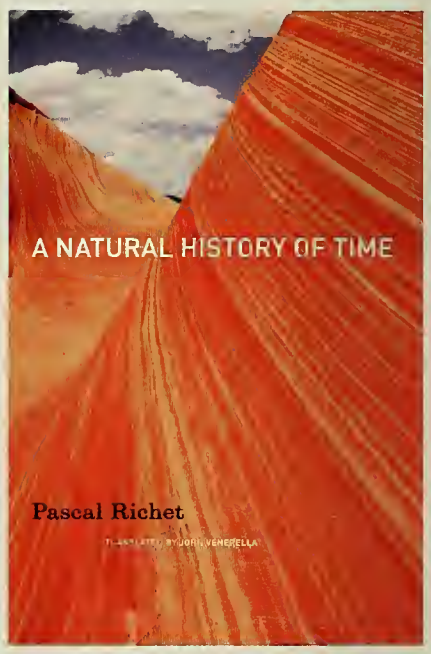


Citrus

A HISTORY

Pierre Laszlo



Animal Architects:
Building and the Evolution of Intelligence

by James L. Gould and
Carol Grant Gould,
Basic Books, 2007; $26.95

Consider the steel and glass towers of Dubai or Singapore, the spare elegance of Frank Lloyd Wright's Fallingwater, or the convoluted curves of Frank Gehry's Guggenheim Museum in Bilbao, Spain. Consider even the most mundane big-box store, for that matter, and it is clear that we humans are master builders, able to create artificial environments orders of magnitude larger and far more elaborate than those of any other species on earth.

Still, the architectural achievements of other creatures are nothing to sniff at, as the ecologist James Gould of Princeton University and the science writer Carol Grant Gould amply demonstrate in their stimulating study. Beavers, the most familiar animal builders, exhibit levels of engineering and organization that might challenge the Army Corps of Engineers. L.H. Morgan, an amateur naturalist who studied beaver dams near Lake Superior in the 1860s, described one that was 261 feet long, 6.5 feet high, and eighteen feet thick at its base. It was made up of tree trunks, limbs, branches, and stones, cemented together by vast amounts of mud and braced by sharpened stakes driven vertically into the ground. And if that sounds impressive, consider the mother of all recorded beaver dams, on Montana's Jefferson River, which stretched nearly ten times farther—2,200 feet—from end to end.

If brain mass were correlated with architectural skill, one would expect most animal architects to be mammals. The truth is quite the reverse. Most mammals are content to sleep outdoors, use existing caves as dens, or at most, dig. The real masters of the building arts are birds and insects, whose nests and hives display an uncanny ingenuity in both design and creation.

Weaverbirds, for instance, natives to Africa, India, and Southeast Asia, not only weave, but seem to understand knots as well. Male weaverbirds begin construction by looping a thin strip of leaf or grass over a tree branch, then securing it by tying a knot. The bird suspends its nest from this secured strip, interweaving more strips of vegetation until it has stitched together a large ovoid dwelling, resembling a giant ball of twine. A narrow entrance discourages predators, and a comfortable nesting chamber opens up inside.

Tailorbirds, less industrious but even more resourceful, assemble arboreal hideaways out of leaves that hang adjacent to each other on branches. True to their name, they sew the leaves together with strands of spider silk. The birds even prepare the leaves by punching holes in both edges of each leaf and drawing them together with the silk until a snug hanging sack is formed. Once they fill the sack with moss and other soft plant materials, they have a comfortable and naturally camouflaged place to cradle their young.

The strangest and most wonderful animal structures, according to the Goulds, are the ones constructed not as nesting places, but rather for what amount to aesthetic reasons. Male bowerbirds, the

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crowlike creatures native to Australia and New Guinea, erect bizarre sculptures deep in the forest to appeal to the females, much as male peacocks display a fan of decorative feathers. The Vogelkop bowerbird, for instance, clears an area a yard or more across, then constructs a tower in the center of the clearing out of hundreds of small sticks. Depending on where he lives, he'll build a thatched hut over his tower or leave it in the open. Finally, around the edge of the clearing, he assembles ornamental piles of contraband, such as colored stones, moss, and snail shells.

Do animal builders understand what they're doing? Earlier investigators envisioned beavers, bees, and bowerbirds carrying out the steps of construction as if they were robots. But the studies cited by the Goulds reveal levels of social organization and conceptualization that can't be explained that easily. How, for instance, to explain birds' ability to repair damage to nests already under construction, or the weaverbird's ability to create features on the inside of a structure that complement the ones on the outside. As with so many other traits that supposedly distinguish man from beast, architectural superiority turns out to be not a matter of kind, but only of degree.

Can one describe a work of nonfiction as being happy? Well, this one is. Pierre Laszlo, a retired chemistry professor turned science writer, has approached the lore of citrus fruit with the *élan* of a master chef (the man is French, after all), mixing history, economics, biology, and chemistry to produce a book that will bring a smile to readers of every taste. Until reading *Citrus*, in fact, I had not realized just how many tastes the title implied: lemon, lime, orange, and grapefruit, of course, but also citron, tangerine, kumquat, calamondin, and the self-descriptive Ugli, not to mention such variants as bergamot, mandarin, Valencia, ortanique, and Honey Murcott. Laszlo's literary method is to present them as characters in an unfolding story. He begins with the domestication of the citron in Persia and the early history of citrus horticulture, then moves to the establishment and

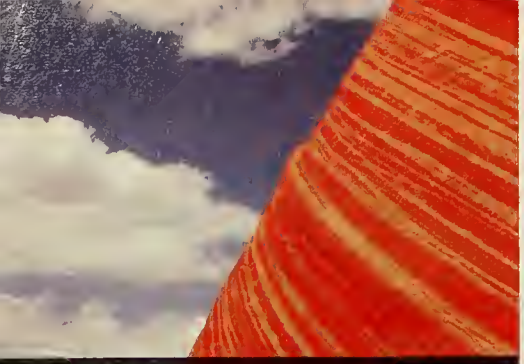
growth of the citrus industry in Florida, California, and Brazil, and finally, after many diversions and digressions, arrives at a final section that explores the place of citrus in literature, art, religion, and the culture of cuisine.

There are many surprises along the way. For instance, orange juice seems such a natural way to imbibe the fruit that it is difficult to imagine a breakfast without it. Yet until the 1920s, there were no efficient methods of bacterial disinfection, preservation, or distribution for such a perishable product. As a consequence, for those outside the citrus belt, fresh orange juice was a rare and expensive treat. According to Laszlo, it was an adman, Albert D. Lasker, who created the orange juice market almost single-handedly during a season when growers were saddled with a glut of excess fruit. At the time, new technologies had been developed that made it possible to pasteurize juice and transport it around the country far more efficiently. Lasker pounced: he launched a "Drink an Orange" campaign, which prompted the American public to adopt OJ as a tasty and healthy start to the day. The golden liquid got an added boost in the 1940s when growers learned to turn it into concentrate and flash-freeze it into compact cylinders. Open the freezing compartment in virtually any American refrigerator back in the 1950s and you'd find at least one can of Sunkist, Minute-Maid, or Tropicana.

Did you know that citrus peels are as ubiquitous in the modern household as the juicy fruit inside? The peels, it turns out, are filled with essential oils that can be turned into a wide variety of products. Limonene, for instance, found in most citrus peels, serves as the raw material for the molecular synthesis of many drugs. And since one variety of the limonene molecule invokes the sensation of oranges, while another variety is lemony, the two molecules are also used to impart flavor to a wide variety of soft-drinks. It's probably safe to say that, just as American breakfasts usually include orange juice, American lunches, at least of the fast-food variety, often include orange peel in the form of limonene-flavored soda.

Lest prospective readers worry that Laszlo has composed a paean to fast-food and industrial agriculture, note that he also includes a sampling of elegant citrus recipes that may induce readers to head for the kitchen. Among them is one for a wonderful Brazilian cocktail, the caïpirinha, another for sea bass with tangerine juice, and a third for an elegant *tarte au citron*. Good reading, good eating, and good humor make for happy reading. One might sum it up with a *bon mot* best resisted: If you love citrus, this is a book with appeal.

Continued on page 50



A Natural History of Time

by Pascal Richet, translated by John Venerella. The University of Chicago Press, 2007; $29.00

Looking at the sandy New England pond outside our summer house, I can readily imagine the glacial remnant that lay there some 12,000 years ago, melting in the warming rays of the Holocene sun. I know, too, that a few hundred million years ago, before continental drift split us apart, Europe and this bit of North American real estate were joined. And I'm well aware that 5 billion years ago, this sand and this water, indeed the Earth itself and everything on it, were part of an interstellar cloud that was condensing into our solar system. Deep time is just one of those things I take for granted.

But as geophysicist Pascal Richet demonstrates in this readable popular history of chronology, the geologic calendar implicit in today's view of nature was not shared by earlier generations. Written accounts from ancient civilizations depict prehistory as a foggy dreamtime. Most authors made little attempt to assign dates or durations other than "in the beginning."

To be sure, a few bold speculators such as Aristotle tried to attack the problem with pure logic. He asserted that the world was eternal, because it was impossible to imagine a beginning in which something arose from nothing. Nearly 2,000 years after Aristotle, Isaac Newton, the very emblem of the scientific revolution, used the new tools of astronomy to try to fit all of known history into a time frame beginning on page one of Genesis.

Only in the later 1700s did "natural philosophers" begin to learn how to read the dates nature has written in rocks. One of the most influential of those pioneers was the French polymath Georges-Louis Leclerc, Count of Buffon, who published his *History and Theory of the Earth* in 1749. Buffon devised a procedure that later investigators would find most fruitful: he measured or estimated the rates of natural processes that he was convinced had shaped the Earth, assumed those processes continued at a relatively steady pace, and thus calculated the time needed to transform the primordial Earth to its present state.

The best-known example of his method is a series of experiments he conducted on steel balls, from a half inch to six inches in diameter. Heating them to incandescence in a furnace, he measured how long they took to cool enough to be touched comfortably with the fingertips. Buffon knew from miners' reports that the Earth's internal temperature rises with increasing depth, and he interpreted this phenomenon to mean that the Earth was still cooling from a once-molten state. Extrapolating his results with small balls to a sphere the size of the Earth, he calculated the time it would have taken for the planet to cool to its present surface temperature: about 75,000 years. It was an audacious result—far longer than the biblical chronologies of a few millennia—but it carried the weight of experimental evidence.

Buffon's cooling model, of course, was oversimplified, and his age for the Earth was a gross underestimate, but he was clearly on the right track. When later investigators determined the ages of mountains and canyons from erosion rates, or when they estimated the age of the oceans from their current salinity and the input rates of freshwater from inflowing rivers, they got periods longer than Buffon's. But they were following his lead.

By the late nineteenth century, William Thomson, Lord Kelvin, had developed a refined version of Buffon's cooling model and, with it, estimated

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By John Fleming

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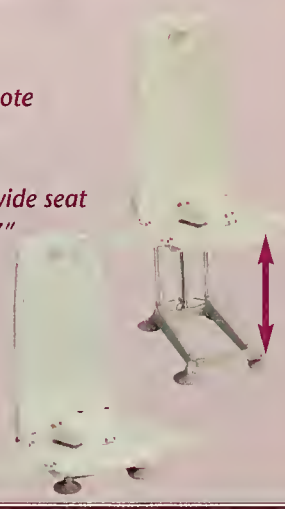

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20 to 100 million years as the age of the Earth. Lord Kelvin's was regarded as the most reliably determined value for the Earth's age scarcely more than a century ago.

What Lord Kelvin and everyone else had neglected—because they knew nothing about it—was natural radioactivity. The interior of the Earth, it turns out, is heated by trace amounts of radium and uranium in its rocks, energy enough to keep the Earth warm for billions, not millions, of years. The discovery of radioactivity at the turn of the twentieth century not only raised the possibility of a much older Earth, but also made it possible to measure the ages of rocks. It was only necessary to determine the ratios of radioactive "parent" elements to their stable "daughter" elements in a rock.

Once radioactivity entered the picture, the pieces of the chronological puzzle all began to fall into place. Rocks from the Earth, meteorites, and moon rocks all yield ages of about 4.6 billion years. Strata bearing the scars of great geological events and the remnants of long extinct creatures have been mapped and dated. Only the fine details of the Earth's timeline are matters of contention any more.

Yet precisely because the current well-grounded chronology seems so natural to most scientifically literate people, Richet's authoritative review of Earth's history is particularly welcome. Rather than fret about polls that show how many citizens still hold to the chronology of the Holy Book, he invites us to marvel at the efforts of science to read the book of nature itself.

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

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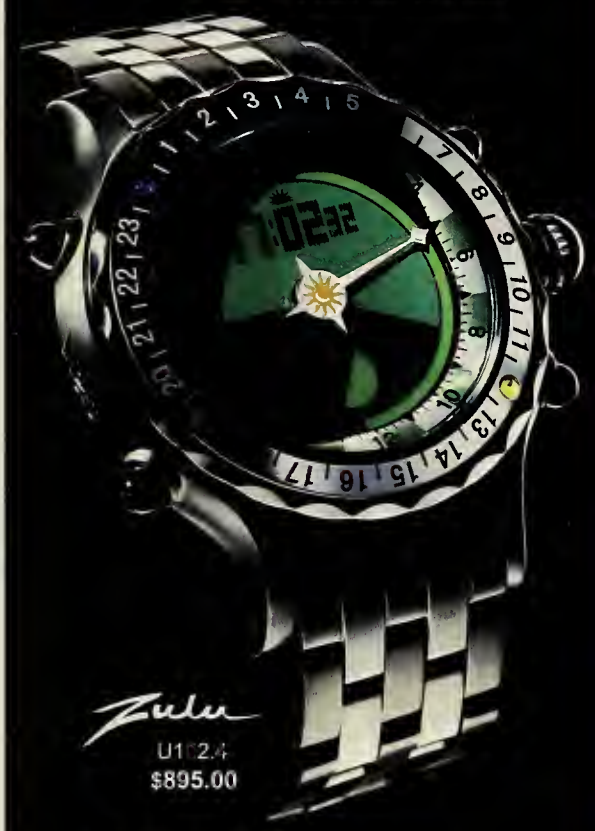

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By Joe Rao

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Annular eclipse in January 1992, from La Jolla, California

An annular solar eclipse takes place February 7, visible within a 3,500-mile-long, 360-mile-wide swath that sweeps through the Southern Ocean and Antarctica. The Moon, which was at apogee (its farthest point from Earth) on January 30, is still too far away to completely cover the brilliant disk of the Sun, creating instead an annulus, or ring, effect. The partial eclipse will be visible from New Zealand, eastern Australia, and a handful of South Pacific islands.

Sky watchers in the Western Hemisphere will have better seats for a total eclipse of the Moon, the night of February 20–21. The Moon first dims as it enters Earth's penumbra, when, from the point of view of a lunar inhabitant, only part of the Sun's disc would appear obscured by Earth. For viewers in the eastern standard time (EST) zone, the "real" shadow, the umbra, takes its first bite into the Moon at 8:43 P.M. Totality, when the entire face of the Moon is within the umbra, lasts 51 minutes, from 10:00 to 10:51. Then the Moon begins to edge out of the umbra, emerging from it completely at 12:09 A.M. During the total phase, the Moon will be passing through the southern portion of Earth's umbra, whose center is always dark but whose edges tend to be lighter and more colorful, owing to sunlight that is refracted into the shadow by Earth's atmosphere. When viewed from north of the equator, the upper part of the Moon should be a dark gray or chocolate hue, while its lower edge will appear brighter and splashed with tones of orange or red (for viewers south of the equator, top and bottom are reversed). As a bonus, the Moon will form a broad triangle with the bright blue star Regulus and the planet Saturn.

In the western portions of Europe and Africa, viewers will see the eclipse in the wee hours of morning, before the Moon sets in the west. Meanwhile, along the western coast of the United States and Canada, the eclipse will begin as the Moon rises in the east.

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

February Nights Out

1 Venus stands just above and to the left of Jupiter, the two separated by just a little more than the apparent width of the Moon (Venus is the brighter of the two planets). This striking duo beckons in the southeast as the night shades into the first light of dawn, about an hour and a half before sunup.

6 The Moon reaches its new phase at 10:45 P.M. EST.

7 The Antarctic witnesses an annular solar eclipse (see above).

11–17 As seen from near latitude 27 degrees north (southern Texas, central Florida), Mars passes directly overhead at about 8:00 P.M. local time. During this week the Red Planet is well placed for Northern Hemisphere observers in general.

13 The Moon reaches first quarter at 10:33 P.M. EST.

20 The Moon becomes full at 10:31 P.M. EST, and undergoes a total eclipse (see above).

24 Saturn arrives at opposition to the Sun (on the opposite side of Earth from the Sun), and is visible all night long.

27 Venus—a small but dazzling dot telescopically—stands just below Mercury low in the east-southeast. The two appear above the horizon just one hour before the Sun.

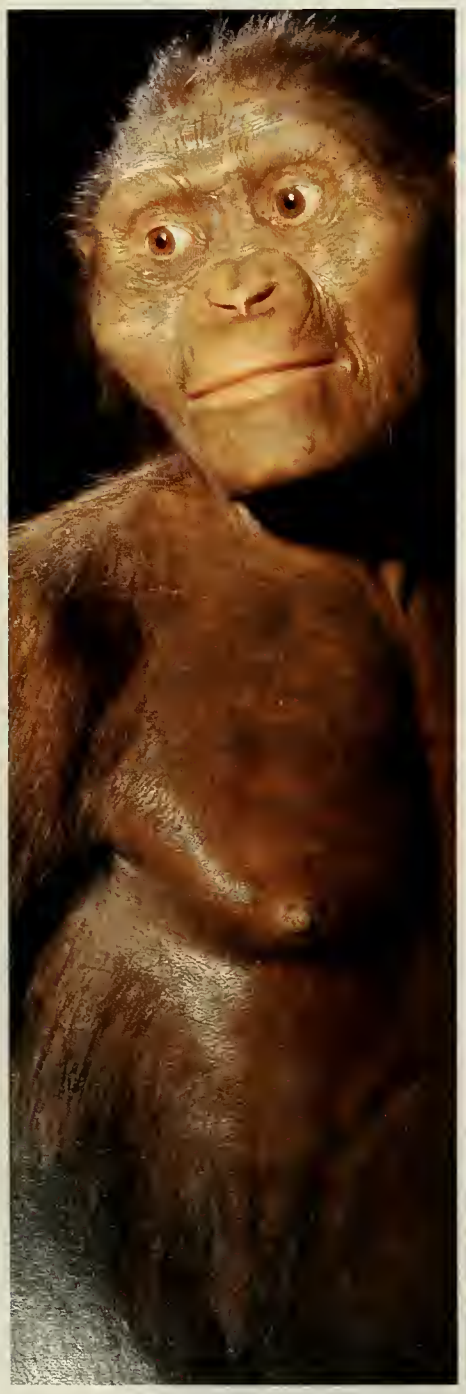
28 The Moon's last quarter occurs at 9:18 P.M. EST.

29 Leap day helps keep our calendar in sync with the seasons. The rule is to add a leap day if the year is divisible by four (2008 qualifies), but not in a century year—unless it is divisible by 400.

EXPLORER GUIDE

LUCY'S LEGACY

THE HIDDEN TREASURES OF ETHIOPIA



A sculpture, three-dimensional model of what Lucy might have looked like, stands over her actual fossilized remains in the final gallery of the exhibition.

Exhibition inspires thought-provoking questions

By Dirk Van Tuerenhout, Ph.D., Curator of Anthropology

Since the world premiere of Lucy's Legacy: The Hidden Treasures of Ethiopia opened at the Houston Museum of Natural Science on Aug. 31, 2007, tens of thousands of people have seen the original fossilized remains of Lucy, an Australopithecus afarensis who died over 3 million years ago – and remains one of the oldest and most complete members of the human family tree yet discovered.

During his tours of the exhibition and through his anthropology blog, Dr. Dirk Van Tuerenhout, the Museum's curator of anthropology, has received many interesting questions from both visitors and the general public about what this fossil means to us today, 33 years after it was discovered and millions of years after she lived. Here are a few of the most common questions, and Dirk's answers.

Is Lucy the "missing link?"

While it retains a place in the popular imagination, the term "missing link" is misleading. It implies a chain of species, one passing into extinction as another rises to carry on evolving. But the true story is actually much more complicated.

The mechanism that supports evolution resides in the genetic changes that occur as a result of mutations. We are all unique because of a small number of mutations that set us apart from our parents. When these small changes are allowed to accumulate over vast amounts of time – say millions of years – the results can be significant. The fossil record tells us that these results were, in fact, very significant: hundreds of thousands of animal and plant species flourished and perished over the last 3.5 billion years.

What the fossil record also clearly shows is that the life forms that existed millions of years ago were successful in their own right. They lived and reproduced in numbers large enough to maintain their species over incredibly long periods of time.

We should not fall into the trap of considering early hominids as a "half-baked" or "missing link" version of the final perfect human seen in our times. We would do better to consider these earlier species as successful adaptations to the conditions that were prevalent at that time, all members of an extensive "family bush" to which we also belong.

If you only have the bones, aren't you limited to information about a species' size and shape?

With some of the later hominid species, like the members of the genus Homo, artifacts like stone tools have been found that give us fascinating insights into what they were up to. The earliest stone tools date back to about 2.6 million years ago – but currently, the earliest fossil hominids are dated back to 6, perhaps even 7 million years ago. So what could we possibly know about the behavior of these much older species?

Our ability to reconstruct ancient hominid behavior predating the earliest known stone tools is more limited, but it is possible nonetheless. The bones themselves leave us clues.

For examples, fossilized teeth can help us reconstruct ancient diets. The teeth of *Paranthropus boisei* were very large, set in

The fossilized remains of Lucy, a 3.2 million year old *Australopithecus afarensis*. Found by Donald Johanson in Ethiopia in 1974, Lucy remains the oldest and most complete adult human ancestor ever found. Photo by Thomas R. DuBrock.

A life-size photo mosaic of the ceiling of Debre Birhan Selassie Church, created in Gondar, Ethiopia in the 17th century A.D., dominates a gallery featuring religious artifacts from Christianity, Judaism and Islam. Photo by Thomas R. DuBrock.

immense jaws, with the lower jaw connected by massive muscles to a bony ridge on top of the skull. This configuration suggests the ability to crack open or chew through some very tough foods.

Given that Paranthropus existed for 900,000 years or more, the retention of these dental traits must imply that they served a purpose. As the thinking goes, if they were eating primarily softer food items, like berries, then over time, the massive jaw architecture and the very large teeth would have diminished in size.

Another approach involves observing the behavior of living primates and identifying trends or patterns that have a possible counterpart in the fossil record. Among some living primates, like gorillas and orangutans, there is a marked difference in size between males and females, referred to as *sexual dimorphism.*

For example, male orangutans weigh twice as much as females. They are much stronger and are prone to violence, with other males during mating season as well as with females and their offspring. Long-term observations have established that female orangutans prefer to avoid males outside the mating season.

Similar sexual dimorphism is also seen in the fossil record, in the skeletons of male and female Australopithecines. Based on patterns observed today, and the evident size differences among fossil hominids, we can suggest that such behavior may have also existed in the past: male Australopithecines acting violently among each other during mating season as well as against females and their offspring whenever they met.

A large mural in the exhibit shows hominids in their changing environments – but how can you know what those environments were like?

In the mural, you'll see Lucy depicted in a forested environment – but photos from the site in which she was discovered in 1974 show a barren desert. It appears that 3 million years ago, this part of Africa was a lot more forested that it is today. That is interesting, but how do we know?

Reconstructing an ancient environment, like the work of a good detective, relies on looking for as many clues as possible.

One of these clues is pollen, the powder consisting of pollen grains, which carries the male sex cells of seed plants. They are virtually indestructible and easily identifiable under a microscope. Soil samples taken from the walls of excavation trenches are analyzed for their pollen content. This allows us to identify what plants lived in the area and how they fared over time. Plants are good indicators of environmental conditions; having a preponderance of tree pollen during a certain time period would allow one to suggest that the area was forested at that time.

Fossilized animal remains can also help reconstruct the environment. Encountering the remains of tree-dwelling animals is an indication of the presence of a forested environment. Fish bones, or the remains of hippos and crocodiles, would imply a lake or river environment.

Fluctuations in temperatures over long periods of time can be retraced using oxygen isotope analysis in ice samples. Tree ring data can also tell us about similar changes in temperatures and rainfall.

Reconstructing ancient environments will never be as accurate as what we expect to hear from the weatherman, yet these reconstructions provide us with a big picture that is sometimes quite different from what we see around us today.

How do you know Lucy is 3.12 million years old?

It is fairly easy for all of us to grasp events that happened a generation or two ago. Quite often, we have heard such stories from our parents and grandparents. Most people can also conceptualize events that occurred centuries before their time. We know Napoleon existed, and so did Julius Caesar. Babylon was a reality as well. But as we keep going further back in time, questions arise. How do we know that Lucy lived 3.12 million years ago?

Radiocarbon, or C14, dating is a very well-known technique, but it is limited to dating artifacts from only the past 50,000 years or so. Since Lucy lived well before that, radiocarbon is of no use to us in this case.

The approaches used in dating the fossil remains of early humans vary from region to region. In Africa, there are regions where we can use volcanic ash to help date the layers in which, or between which, early human fossils have been found. This technique, known as *paleomagnetic dating*, has been used in East Africa, including on the site where Lucy was found.

Another technique used in this area is *biostratigraphy*, or the dating of layers of rocks and dirt based on the presence of animal fossils, which relies on the known and dated presence of specific animal species.

For example, if animal remains are found in association with hominid remains, then one can compare these animal remains against those found elsewhere, specifically those found in areas where other dating techniques are available, to figure out how old the hominid remains are. Scientists prefer working with animal species that had a great geographic range and with short-lived history. (The latter is important so that the period of time during which they could be incorporated in the sediment is relatively narrow and therefore easier to date.)

These approaches reflect flexibility on the part of scientists. You may be aware of a technique that would help you date a fossil, but if you do not have the right material (like volcanic ash) to work with, then you have to resort to other approaches.

Lucy's Legacy: The Hidden Treasures of Ethiopia is on display at the Houston Museum of Natural Science through April 27, 2008. If you have a question for Dirk about Lucy, the exhibition or anthropology in general, visit his blog at www.lucyexhibition.com

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Visitors to *Lucy's Legacy: The Hidden Treasures of Ethiopia* at the Houston Museum of Natural Science are invited to leave their impressions in a book at the end of the exhibit. Here is a selection:

"Lucy was great. I hope I can discover something like that when I grow up!" – Asha

"Lucy's worth more than diamonds. Thank you!" – Az

"We have come from Santiago, Chile to see the exhibit. Very well done and an inspiration to go to Ethiopia." – Tracy

"All the way up from Argentina to meet Lucy, this is Alex thanking you for this wonderful experience." – Alex

"Please thank the government of Ethiopia for this once-in-a-lifetime experience!" – Catherine

"I learned so much. This is a treasure." - AMA

"We enjoyed the Lucy exhibit! Truly amazing! We loved the buildup to Lucy's final life-size model. The human evolution panoramic was absolutely incredible and very life-like." – Dawn and Kim

"Hey Lucy! What a joy it was to get to see you in person!" –Sarah, Meghan and Ryan

"This is a tremendous teaching opportunity for the youth of Houston." – Jackie

"Absolutely phenomenal! What a pleasure! What an education!" – Mary

"Absolutely phenomenal! I had no idea how much Ethiopia added to our civilization!" – Cindy

"I am glad that my family and I had the extraordinary opportunity to see Lucy and to be able to expand our knowledge about how we are here."

"This answers a lot of questions." – Michael

"I remember when Lucy was discovered. It's so exciting to be able to see her in person." – Christine

"I have been truly blessed to have stood and looked at Lucy." – Hazel

"Lucy speaks after 3.2 million years. Our story must be heard." – Faye

A replica of an *Australopithecus afarensis* skull, on display at the entrance to the exhibit. The darker portions indicate the parts of Lucy's skull that were preserved. Photo by Thomas R. DuBrock.

Hold your next event at a place where great ideas can really take flight.

In the right environment, things can really take off. Looking for someplace different for a corporate meeting, event or employee incentive program? Think about the Houston Museum of Natural Science. For meetings beyond compare, consult with a Social Butterfly.

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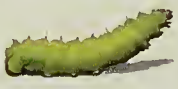


the Houston Museum *of natural science*

Chewing the Rat's Tail

By Bruce Anderson, with Cameron Ewart-Smith

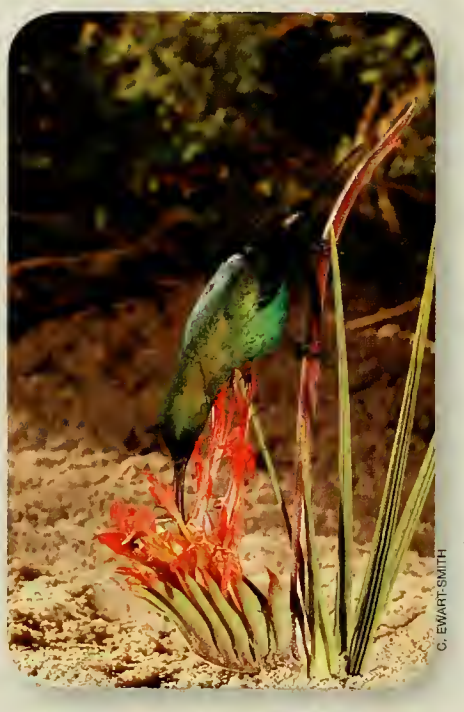
"We call it a rat's tail," the woodcutter said, sticking the plant stalk in his mouth. He chewed a soft, succulent end, letting the rest—which did look disconcertingly like a rat's tail—hang from his mouth. Soon he spat it out and grunted, "They're good on a hot day like this."

The woodcutter and I were working on a patch of sandy soil in the Western Cape Province of South Africa, several months after a wildfire. He was there to clear the charred skeletons of tall plants, and I was there for the stubby new growth sprouting at his feet. In particular, I was interested in *Babiana ringens*, the plant with the rat-tail stalk. (I had been studying it with colleagues at the University of KwaZulu-Natal and the University of Toronto.)

The fire had triggered the *B. ringens* plants to sprout bright splashes of red flowers. Those blooms attract pollinators, namely sunbirds. Most other bird-pollinated plants, including *B. ringens'* closest relative, *B. thunbergii*, have tall floral displays. But for some reason, the flowers of *B. ringens* cluster near the ground, and only a vestigial bud that almost never opens remains on top of its long stalk—the "rat's tail."

Why would the uppermost flowers disappear? Perhaps they were too attractive to grazing animals. But then why not also lose the seemingly useless stalk? Apparently the rat-tail structure remained functional enough to escape the evolutionary trash bin. My colleagues and I had wanted to find out whether the stalks aided visiting pollinators, and if so, how. So we did our own chopping.

As an experiment, we cut the stalks off a number of the plants and then watched sunbirds feed. We saw a male sunbird—bright, metallic green, with a long tail—land on a plant with a rat's tail and call out boldly from his perch. He then hopped down the stalk and, hanging head down, probed the tubular flowers for nectar. As the bird pushed his head deep inside the flowers to get the last few sips, the reproductive parts of the flowers painted pollen on his chest.



C. EWART-SMITH

Male sunbird, above, probes Babiana ringens *for nectar, picking up pollen in the process. Below right:* B. ringens *blooms only after a fire.*

Males, we observed, had a strong preference for plants with perches. They might be protecting their long tails from damage by avoiding the ground. Or perhaps they can better defend their territory or watch for predators from a lofty vantage point.

Females, in contrast, are drab and gray, much less conspicuous. And they seemed happy enough to rest on the ground near the experimental flowers to drink up, though they used the perches if any were available. Perhaps they have less to fear on the ground than the males?

We found that perchless plants "fathered" far fewer offspring than plants with perches—and for a couple of reasons. For one, the birds feeding from the ground picked up little pollen on their bodies. Plants without perches also had far fewer visits from birds, making self-pollination more common. That's a form of inbreeding, and inbreeding brings perils in plants just as it does in humans. (Think of the "Habsburg chin," an overgrown jaw so grotesque that it impaired eating: it arose in Spanish royalty who married close relatives around the time of the Renaissance.) One of those perils is producing few seeds. The rat's tail, we think, helps maximize seed production and minimize self-pollination by attracting sunbirds.

I tried to tell the woodcutter that he might have hurt the plant by nabbing its perch. He gazed at me suspiciously. Later, as I headed back to my car, I saw him pause, lean on his axe, and stare at the red flowers at his feet. He wiped his brow and shook his head, then resumed work.

Bruce Anderson is a biologist at the University of Stellenbosch in South Africa. He has a strong interest in the evolution and persistence of plant-animal interactions. Cameron Ewart-Smith is a freelance writer and photographer based in Cape Town. He is the editor of Wild, *a wildlife magazine published in Africa.*

B. ANDERSON

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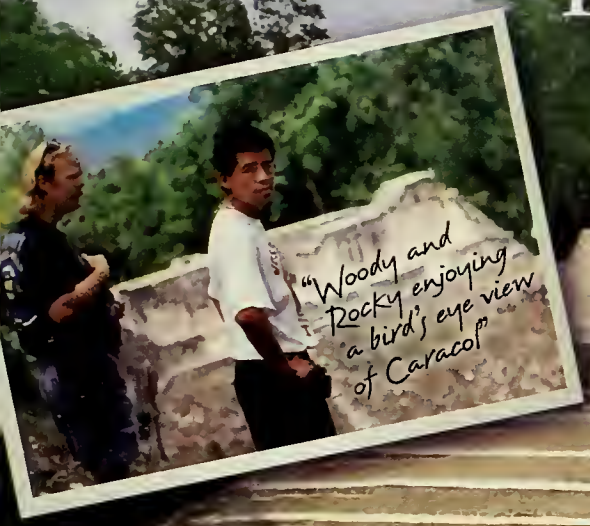

"My husband Woody and I stepped out of the Chiquibul Rainforest and felt like we had just discovered a lost civilization; there in front of us stood Caracol, the largest of Belize's Maya ceremonial centers.

The temple and surrounding scenery are magnificent, with lush palm trees and orchids growing beautifully in the wild. We took a break for a moment in the cool shade of the temple and watched a green iguana bobbing its head up and down as if nodding hello. We hiked the whole area with our wonderful guide, Rocky Mai, who gave us a running commentary on the Maya in perfect English.

Belizeans are the friendliest people we've come across in our travels, and the country itself is amazing. One minute you're hiking through an untamed ecosystem, the next you're walking through the door of a plush resort with all the amenities. This is my idea of roughing it."

-- Ann Bridges --

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