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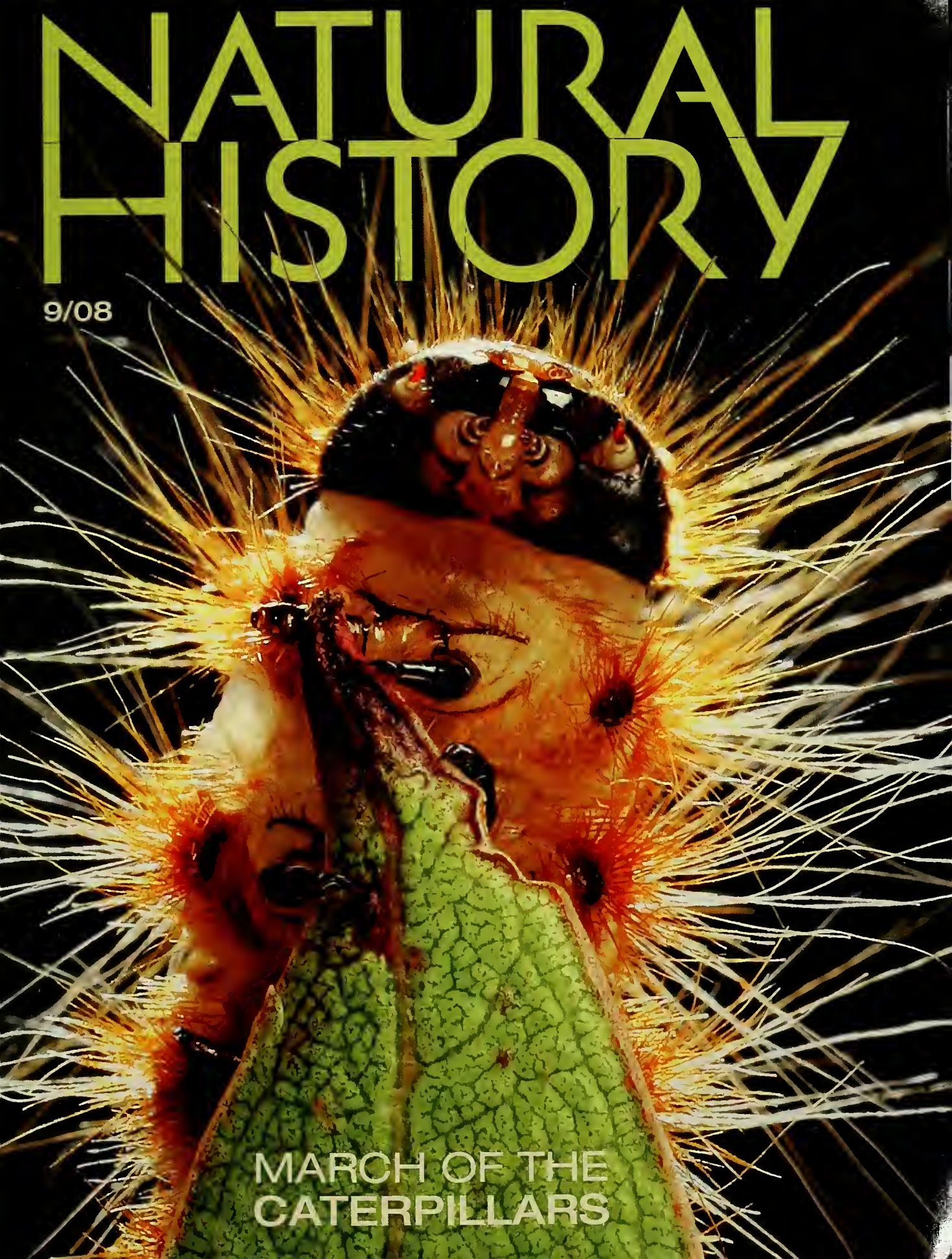

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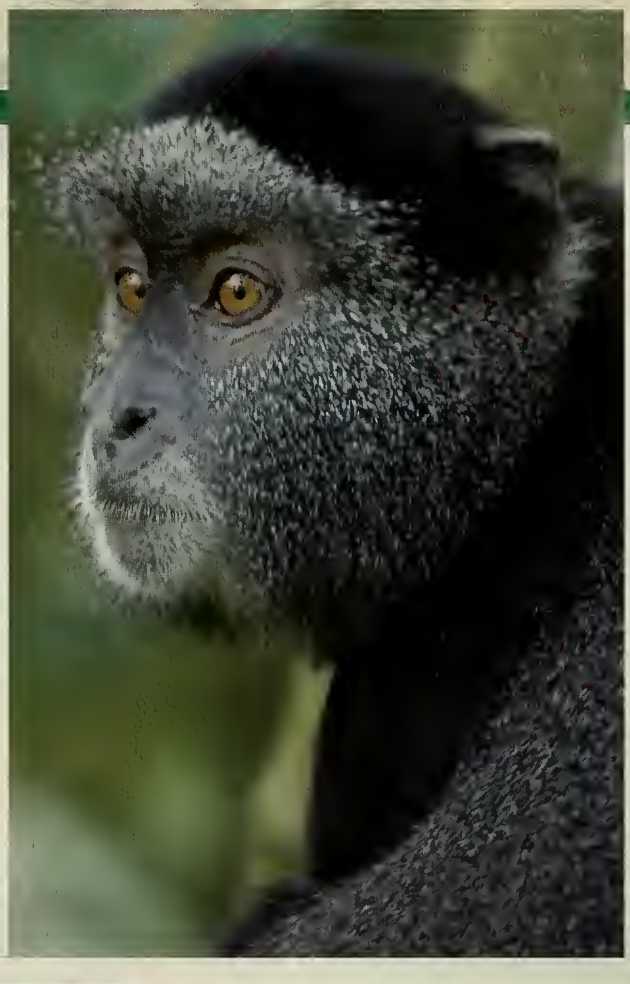
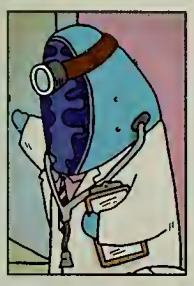


Blue monkey (Cercopithecus mitis) on watch in western Kenya

FEATURES



DEPARTMENTS

ON THE COVER: *Processionary caterpillar (Ochrogaster sp.) feeds on a eucalyptus leaf in Victoria, Australia.*
PHOTOGRAPH BY CRAIG BORROW/NEWSPIX

PTOOEY!

Photograph by Scott Linstead

See preceding two pages

THE NATURAL EXPLANATION BY ERIN ESPELIE



When the barn owl shown here opened its mouth, photographer Scott Linstead expected to hear an ear-piercing shriek. But no sound came out. Instead, after some dry heaving, the owl coughed up a roundish pellet.

Many bird species upchuck pellets, or castings: lumps of indigestible leftovers, trapped and trash-compacted in the gizzard. Even songbirds will spit up little wads of seed husks or insect exoskeletons, and a shorebird might hawk up a hunk of crab shell. But owls, being rapacious and apt to swallow their prey whole, are particularly well known for ejecting large, furry pellets chockablock with bones, beaks, and claws. Those pellets must be regurgitated before an owl's next big meal.

Dissecting owl pellets and identifying the birds' diet by the skeletal remains has become a popular classroom activity around the world. Biologists at Queen's University Belfast and University College Cork recently proved, however, that such dissections are no rote exercise: ten barn-owl pellets offered up a whopping fifty-three skulls of a mammal never before found in Ireland, the greater white-toothed shrew (*Crocidura russula*). Live trappings in Tipperary subsequently confirmed that the shrew is in fact a new Irish resident.

In April Linstead traveled from Canada down to the talon of southern Texas, just west of Corpus Christi, to capture some native-wildlife portraits. There, a local rancher tipped him off to a barn-owl nest inside an abandoned hunter's blind. The avian parents—probably mates for life, as are most barn owls—were tending three eggs, cushioned only slightly from the wooden floor by feathers, excrement, and shredded pellets.

At the sound of any approaching vehicle, the male would fly off, while the female alighted on what seemed to be her favorite perch, in a nearby tree. Linstead took advantage of this predictability. He set up his own blind—a camouflage pup tent—about thirty feet away from the perch, and instructed his assistant when to drive by. On the day he took this series of photos, the female preened and stretched on her perch for about forty-five minutes before disgorging the pellet and flying off, ready to hunt for the next meal.

Scott Linstead worked as an aerospace engineer and then as a highschool physics teacher before transitioning to professional wildlife photography. He lives with his wife, Stephanie, in Maple Grove, Quebec. More of his work can be viewed at www.scottyphotography.com.

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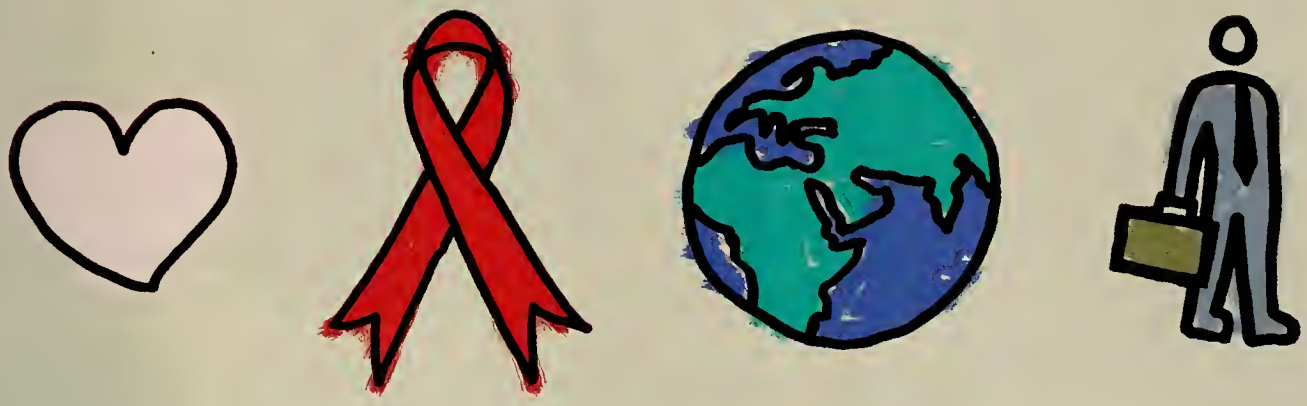

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[1] UNAIDS, *2007 AIDS Epidemic Update*
[2] *FORTUNE*, March 2008
[3] *Ethisphere® Magazine*, June 2008

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BODY ENGLISH

SOMETIMES GESTURES are critical. I can remember when I was in the dentist's chair having my wisdom teeth chiseled from my lower jaw. I was breathing laughing gas and had been shot full of anesthetic, but somehow I could still sense the intense pain. Unable to speak, I was saved by making the T-shaped "time-out" sign with my hands. Such a symbolic gesture is nonverbal, in the sense of unspoken. But we are constantly using more subtle forms of nonverbal communication, from unconscious gestures to pheromones.

On the Internet, the Nonverbal Library (www.linguaggiodelcorpo.it/biblio/), maintained by Marco Pacori, an Italian psychologist and psychotherapist, explores a fascinating array of signals we broadcast. For my guide to Web sites on nonverbal communication, please visit the magazine online (www.naturalhistorymag.com).

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

Slippery Specimen

Jamie James writes in "Burmese Motorcycle Diaries" [6/08] that Joe Slowinski was the first to describe a new species of cobra since 1922. I'm not disputing this claim, but I do want to point out that another cobra was described after 1922, though probably erroneously. In 1932 my father, Gerd H. Heinrich, was on a bird-collecting expedition in Indonesia. He had been hunting at night when a snake reared up in the beam of his flashlight. Thinking it might be a cobra, he fired off a shot that killed it. He brought the dead but still writhing snake back to his tent to play a practical joke on his wife and her sister. Although they were not amused by the prank, they were curious about the snake's identity, and the party brought it back to Germany with them. In 1933 the zoologist Ernst Ahl pronounced it to be a deadly cobra of a new species, which he named *Naja celebensis*. Recently, however, I have been in contact with Mark-Oliver Roedel, the herpetologist of the Museum of Natural History at Humboldt University in Berlin, who informed me that herpetologists now believe the specimen was the commonly found—and nonpoisonous—*Boiga dendrophila*. The end result? No cobra, no new species of snake—but quite a snake hunt.

Bernd Heinrich
University of Vermont
Burlington, Vermont

Canid Kudos

I just had to comment on the amazing talent of Mauricio Antón. He absolutely brought to life the article by Xiaoming Wang and Richard H. Tedford "How Dogs Came to Run the World" [7-8/08]. His illustrations made a good story into a great story.

William Kremer
Watsonville, California

Erratum

In "Birds of a Different Feather," by Eben Goodale, Amila Salgado, and Sarath W. Kotagama [7-8/08], the editors regret scrambling a few photo credits. Please note these corrections: page 25 (sunset): Amila Salgado; page 26 and 27 (ashy-headed laughingthrush): Chinthaka Kalutota; page 28 (Sri Lanka scimitar babbler): Vimukthi Weetathunghe.

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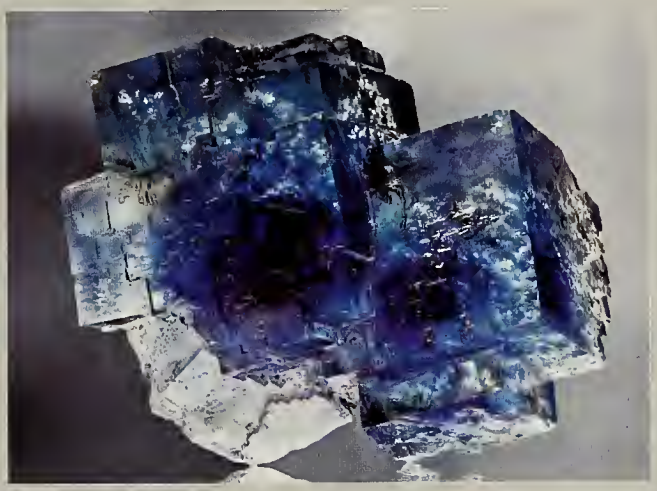
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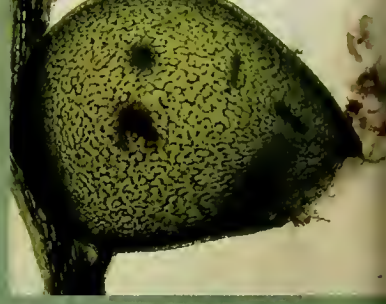
Greens Eat Their Greens

Bladderworts, carnivorous plants of the genus *Utricularia*, live in water or soggy soil. To snare their snacks, bladderworts set ingenious little traps, sometimes in the hundreds, among their waterborne leaves. The traps maintain an internal pressure lower than that outside; when passing prey triggers an exterior hair, a trapdoor snaps open, and inflowing water carries the prey inside to be digested.

Biologists have long noted algae among the insects, nematodes, and other minute animal prey in bladderwort traps. Are the algae symbionts? Are they swept in accidentally with animals? Or could bladderworts actually eat algae?



Bladderwort trap, magnified 25×, contains algae.

THOMAS LENDL, UNIVERSITY OF VIENNA

To advance the debate, Marianne Peroutka of the University of Vienna and several colleagues analyzed 1,450 traps from four species of *Utricularia*. More than half the traps contained algae, often unaccompanied by animal prey. In fact, algae constituted as much as 80 percent of trap contents under certain conditions. Intriguingly, the softer the water the plant inhabited, the more algae its bladders bore. Soft water, low in minerals, supports less animal life than hard water does, and Peroutka thinks bladderworts may compensate for the lack of meat by eating more greens. Indeed, some of the entrapped algae appeared semi-digested, as others have noted.

A few other carnivorous plants are known to eat plant matter, so perhaps we should start calling them omnivores. (*Plant Ecology*)

—*Ashok Prasad*

Chimpanzee fancies cooked cuisine.

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Raw Deal

When early humans mastered the use of fire, their immediate rewards were warmth, light, and protection from nocturnal predators. Investigators have assumed that our ancestors also quickly realized the advantages of flame-cooked food—easy chewing and digestion—though clear evidence has been hard to find. A new study bolsters that idea, showing that we share our fondness for cooked grub with our wild cousins, the great apes.

Victoria Wobber and her graduate advisor at Harvard University, Richard Wrangham, along with a third colleague, gave a choice between cooked and raw food to a number of captive apes. Chimpanzees clearly preferred cooked carrots, sweet potatoes, and beef over the raw alternatives. They did not express any preference in the case of white potatoes and apples—perhaps, the scientists say, because both remain relatively unchanged by cooking. A few bonobos, gorillas, and orangutans were also tested, and except for a penchant for cooked beef, not many expressed a preference, but those that did agreed with the chimps. The findings concur with research showing that cats favor cooked meat and rats opt for cooked starch.

If animals with no regular access to cooked food nevertheless prefer it, it is plausible that our ancestors would have readily roasted their own victuals once they got the chance—a fine story to tell your guests around the barbecue this evening. (*Journal of Human Evolution*)

—*Stéphan Reebs*

Junk Food Diet

In the Baltic Sea, birds called common guillemots raise their young on herringlike fish called sprat. In the 1990s, local sprat became unusually abundant after populations of their main predator, cod, plunged because of overfishing and climatic changes. Yet during that time, guillemot chicks grew poorly. Why?

The answer may lie in the "junk food hypothesis," which holds that poor-*quality* food can hamper the reproductive success of marine predators just as badly as low-*quantity* food. Henrik Österblom, the biologist from the Baltic Nest Institute at the University of Stockholm who studied the guillemots, noted that sprat were leaner when they were abundant and had to compete for limited supplies of zooplankton. The lean sprat made less-nutritious meals for the guillemot chicks. The chicks' parents tried to compensate by bringing home more sprats, but because they catch and carry just a single fish at a time, it was hard to keep up.

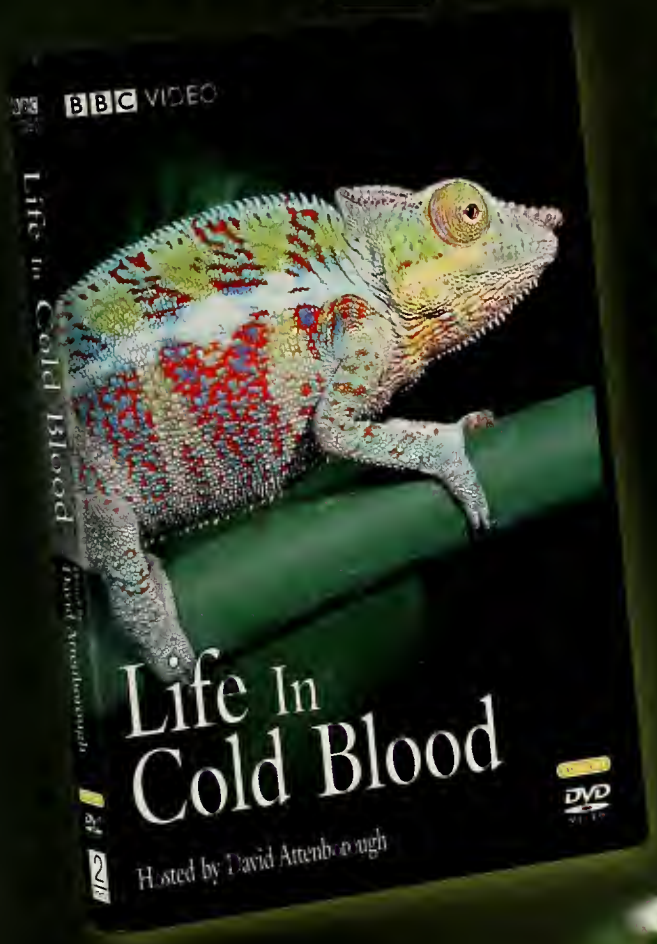
The guillemots aren't alone: recent experiments have shown that many marine fish-eaters, including Steller's sea lions and kittiwakes, either can't raise healthy young or can't maintain their own weight when fed low-energy food, however plentiful. With colleagues, Österblom reviewed all the papers he could find on the subject and concluded that the junk food hypothesis could explain, at least in part, recent cases of breeding failure among northern marine predators. (*Oikos*)

—*S.R.*

Common guillemots

DAVID TIPLING/ ALAMY

BBC Warms Hearts with Cold-Blooded Creatures



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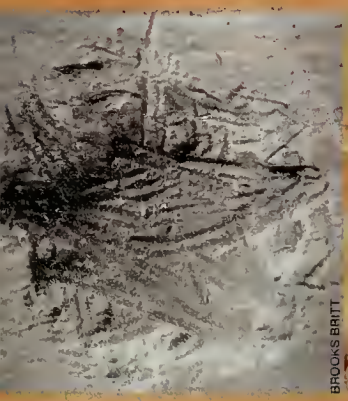
Jurassic Undertakers

Dermestid beetles are well known in forensic circles: they congregate on corpses to feed and breed, and their presence and life stage can help establish when the victim died. Some species haunt natural history museums, where they can be pests (munching the dead skin of stuffed animals) or helpers (enlisted by curators to clean bits of tendon and muscle off skeletons). Now, new evidence shows that dermestids were recycling carcasses as far back as the Jurassic.

Working with two collaborators, Brooks B. Britt of Brigham Young University in Provo, Utah, examined the 150-million-year-old fossil of a *Camptosaurus* dinosaur and observed that most of its bones bear minute pits, grooves, bores, and scratches. Those, the team established, are the telltale signs of dermestid larvae that tried to get at the bone marrow after the putrid dinosaur meat ran out. The marks matched those made by modern-day dermestids and not those of any other insect scavengers, such as termites (which can consume an entire human skeleton), mayfly nymphs, or moth larvae.

After examining 7,000 fossilized bones in addition to the *Camptosaurus*'s, Britt says insect marks are common but often go unnoticed. Insect activity could explain some fossil mysteries, such as "dinosaur dentures"—teeth that are found side by side in perfect order but without any supporting jaw. Chances are, scavenging insects ate the whole bone away before it could fossilize. (*Ichnos*) —*S.R.*

Dinosaur bone marked by scavenging dermestid-beetle larvae, below left, magnified 15x; adult dermestid beetle, below right, helps clean a museum specimen.



BROOKS BRITT

THE NATURAL HISTORY MUSEUM, LONDON

Brown-throated three-toed sloth catches some Zs.

Not So Slothful

Sloths have a reputation for sluggishness, so nobody was surprised when a 1983 study reported that they sleep sixteen hours a day—one of the highest values ever recorded for any species. But the sloths under scrutiny were living in captivity, a necessity given the complex and cumbersome equipment needed to pick up sleeping animals' brain waves. Now, the development of lightweight recorders has enabled the first field study, which may force a redefinition of the word "slothful."

Niels C. Rattenborg of the Max Planck Institute for Ornithology in Seewiesen, Germany, and seven colleagues captured three adult brown-throated three-toed sloths (*Bradypus variegatus*) in the jungles of Panama. The team fitted small brainwave and muscular-activity recorders onto the sloths' heads, then let them go. During the next five days, the scientists were surprised to find, the sloths indulged in just nine and a half hours of sleep daily.

To elucidate sleep's still-mysterious function, researchers often compare species, and they try to correlate sleep time with ecological conditions and physiological traits. Rattenborg warns that captivity, with its abundant food, lack of predators, and attendant boredom, may permit animals to be abnormally drowsy, and so may muddy scientists' understanding of their natural sleeping habits. (*Biology Letters*) —*S.R.*

Gut Reactors

Bacteria may be humble single-celled creatures, but they're sophisticated enough to anticipate regular events, such as the arrival of day, thanks to their internal circadian clocks. A new study shows that they can also anticipate and prepare for sporadic events, as long as the events are reliably preceded by a signal.

What kinds of events? Well, to colonize the gut of a mammal, *Escherichia coli* must first enter the warm-blooded diner's mouth, where the bacteria experience a temperature rise; a short time later, they end up in the intestines—a place with low oxygen levels, as well as fierce competition from other microscopic settlers. Bacteria would do well to anticipate low-oxygen conditions and begin to adjust metabolically from the moment they enter the mouth.

Indeed, when Ilias Tagkopoulos, his graduate advisor Saeed Tavazoie, and Yir-Chung Liu, all at Princeton University, cranked up the heat on *E. coli* in the laboratory from 77 to 98.6 degrees Fahrenheit, the bacteria immediately deactivated genes involved in aerobic respiration (which requires oxygen) and activated genes governing anaerobic respiration (which doesn't).

Then the team repeatedly exposed a population of *E. coli* to a rise in oxygen following a rise in temperature, a sequence unlikely to occur in nature. The bacteria's native low-oxygen response all but vanished within a hundred generations, confirming that their foresight is flexible and results from natural selection. (*Science*) —*S.R.*

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Bee Brains

Honeybees are clever little creatures. They can form abstract concepts, such as symmetry versus asymmetry, and they use symbolic language—the celebrated waggle dance—to direct their hivemates to flower patches. New reports suggest that they can also communicate across species, and can count—up to a point.

With colleagues, Songkun Su of Zhejiang University in Hangzhou, China, and Shaowu Zhang of the Australian National University in Canberra managed to overcome the apian impulse to kill intruders and cultivated the first mixed-species colonies, made up of European honeybees, *Apis mellifera*, and Asiatic honeybees, *A. cerana*. The researchers confirmed that the two species have their own dialects: foraging in identical environments, the bees signaled the distance to a food source with dances of different durations. Remarkably, despite the communication barrier, *A. cerana* decoded *A. mellifera*'s dance and found the food.

Also at the Australian National University, Marie Dacke and Mandyam V. Srinivasan trained European honeybees to pass a particular number of colored stripes in a tunnel to get a food reward, which was placed by a stripe. When they removed the food, the bees still returned to the same stripe. Next, they mixed things up on the bees: they varied the spacing of the stripes, and even replaced stripes with unfamiliar markers. The insects consistently passed the same number of markers to approach the former reward site, demonstrating that they could count, up to four.

SONGKUN SU AND SHENGLU CHEN, ZHEJIANG UNIVERSITY

In a mixed-species hive, a European honeybee (blue) gives directions to its Asiatic (green) and fellow European (red) hivemates.

The studies burnish the impressive list of honeybees' known cognitive abilities, all achieved with a brain the size of a sand grain. (*PLoS One*, *Animal Cognition*)

—*Graciela Flores*

Iced Punch

Wide rivers of ice, called ice streams, flow through relatively slow-moving polar ice sheets, en route to the sea. Glaciologists had assumed that ice streams just creep steadily along—until one was recently shown to pack a powerful one-two punch, generating seismic waves twice a day.

The seismic signals from Antarctica's sixty-mile-wide Whillans Ice Stream are as strong as those of a magnitude-seven earthquake, which could cause major damage in a developed area. But, whereas an earthquake of magnitude seven might last ten seconds, the Whillans signals continue for ten minutes or longer. They resemble earthquakes at glacial speed, says Douglas A. Wiens of Washington University in St. Louis.

Wiens, with three colleagues, discovered the signals after analyzing recordings from seismographs located 600 miles from the ice stream. To pinpoint the signals' cause, they embedded GPS antennae on and near Whillans. It's the ice stream advancing abruptly, by about eighteen inches, that causes the signals, the team discovered. In turn, the advances are caused by a combination of ocean tides—which lift and lower floating ice at the stream's outlet—and pressure from ice upstream. One of the daily slips is triggered by high tide, with a second following five to twelve hours later. (*Nature*)

—*Harvey Leifert*

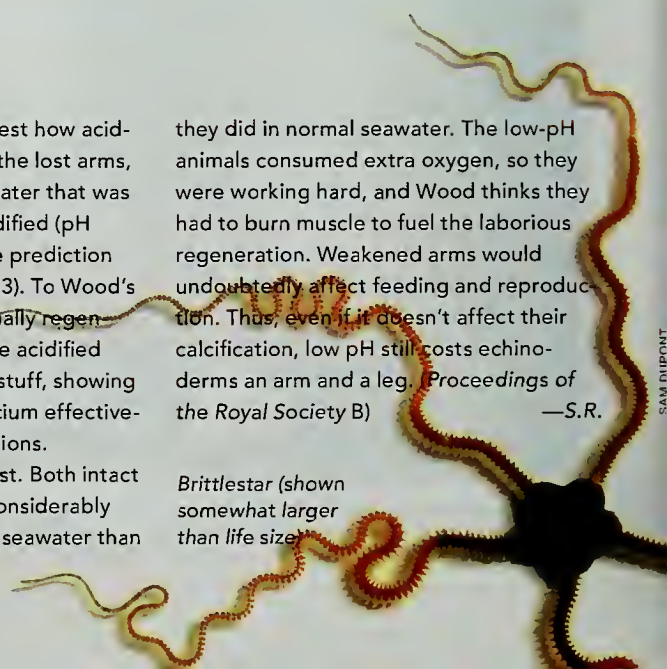
Arm Wrestling

The oceans absorb about half the carbon dioxide humankind releases into the atmosphere, and seawater is consequently acidifying. That's a big problem for shellfish, corals, and certain other calcareous creatures, because lowered pH dissolves their shells and skeletons. Echinoderms—starfish and their relatives—have calcium-based skeletons, too, and so researchers have assumed they are likewise subject to slow dissolution.

Hannah L. Wood of the Plymouth Marine Laboratory in England and two co-workers decided to check. They took brittlestars (*Amphiura filiformis*), removed an arm or two, and then, to test how acidity affected regeneration of the lost arms, exposed the animals to seawater that was either normal (pH 8.0) or acidified (pH 7.7—the standard worst-case prediction for the year 2100—and pH 7.3). To Wood's surprise, the brittlestars actually regenerated their arms faster in the acidified seawater than in the normal stuff, showing that they could lay down calcium effectively even under adverse conditions.

But there was a hidden cost. Both intact and regenerated arms had considerably less muscle mass in acidified seawater than they did in normal seawater. The low-pH animals consumed extra oxygen, so they were working hard, and Wood thinks they had to burn muscle to fuel the laborious regeneration. Weakened arms would undoubtedly affect feeding and reproduction. Thus, even if it doesn't affect their calcification, low pH still costs echinoderms an arm and a leg. (*Proceedings of the Royal Society B*)

—*S.R.*



SAM DUPONT

Brittlestar (shown somewhat larger than life size)

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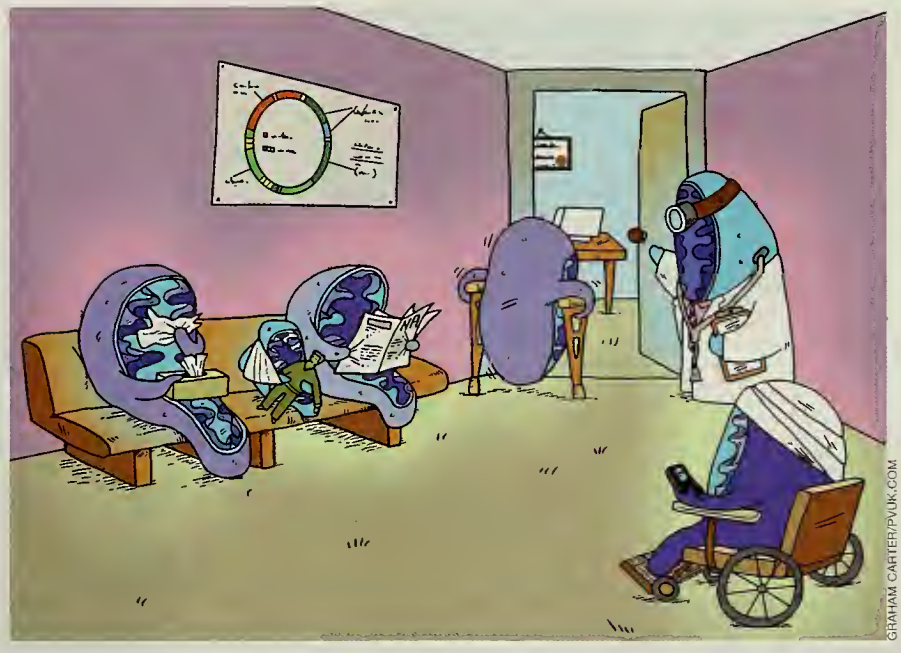
Power-Plant Meltdowns

Our mitochondrial DNA is implicated in maladies ranging from blindness and infertility to cancer and dementia.

As a small child, patient "MBM" used to sweat profusely during the night. By the age of seven, she sweated so constantly she needed to change her clothes several times a day. She ate prodigiously, yet could not put on weight. She was always exhausted. And her muscles were weak. MBM had a form of hypermetabolism, a syndrome usually associated with thyroid diseases. But the cause of her symptoms was different. When she was in her thirties, it was finally traced to her mitochondria—those small organelles that generate energy for the cell.

MBM's condition, the first recognized case of mitochondrial disease, was diagnosed in the late 1950s. Since then, mitochondrial malfunctions of one sort or another have been implicated in a disturbing array of human diseases, from blindness to cancer. Some estimates suggest that 1 out of 8,500 people is made sick by mitochondrial defects. For now, none of these diseases can be cured.

A single cell may contain hundreds, or sometimes thousands, of mitochondria. The involvement of those organelles in so many diseases is due to the many roles they play in the cell. For example, they are involved in apoptosis, or programmed cell death, a kind of suicide directive whose failure is implicated in some kinds of cancers. But of all the jobs mitochondria do, the most important is to provide power to the cell. Mitochondria are power stations in miniature, using oxygen to burn glucose and other food molecules, turning them into energy that is captured and stored in the bonds of a molecule known as adenosine triphosphate, or ATP. Just as power outages can have deadly effects on cities, so too they can have deadly effects on bodies.



GRAHAM CARTER/PVUK.COM

But to understand the health problems caused by mitochondria, one must also look to their unorthodox genetics, which are a direct legacy of their evolutionary history.

Humans, like other animals, possess not one genome, but two. The main one—the one usually referred to as "the human genome"—resides in the nucleus of the cell. You get one copy of it from your mother (via the egg) and one from your father (via the sperm). It is arranged as a set of linear chromosomes that altogether encode about 20,000 genes.

The other genome takes the form of a single circle and encodes only thirty-seven genes. Instead of inheriting it from both your parents, you inherit it only from your mother. And instead of being inside the nucleus, it is found inside the mitochondria.

Mitochondria were once free-living bacteria. But at some point 1.5 billion years ago or so, their ancestor took up residence inside another cell, providing it with energy in exchange for shelter. How that happened, and how the arrangement spread, is not yet understood. But the transition, the merging of two life-forms into one, was one of the great events in the history of life. All plants, animals, and fungi are the descendants of that ancient liaison. If it had not happened, perhaps Earth would still be home to nothing but bacteria.

The most significant legacy of the mitochondria's bacterial past is that they have retained their own DNA—well, some of it. Although their genome retains its ancestral form (circular DNA is characteristic of most bacterial genomes), over the millennia many of the original genes have been lost. A mitochondrial genome is a rump genome, a relic. When you're living full-time inside another being, genes

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essential for free-living become useless. If one of those genes is accidentally deleted, the loss does no harm, and may even bring a benefit. Smaller genomes can be copied faster, so a cell can make new mitochondria more quickly if it needs extra energy.

Interestingly, however, many of the original bacterial genes that have disappeared from the mitochondria have not vanished from the cell. Instead, they have been transferred into the cell nucleus. How such transfers happen isn't clear. One possibility is that they result when a mitochondrion that is no longer needed is being dismantled and its parts recycled. In that process the mitochondrial DNA is normally destroyed, but if it spills into the cell cytoplasm, bits may get spliced into the strands of nuclear DNA and become part of the main genome. Whatever the details, over the ages a substantial number of mitochondrial genes have been added to the main genome. And the process is ongoing: the odds that a human egg carries a new insertion are about 1 in 200,000.

Some of those transferred genes have evolved new functions in their new environment, and no longer have anything to do with the operations of the mitochondria. But others are involved in making proteins that the mitochondria need to do their job; such proteins are made in the main part of the cell and then delivered to the mitochondria. Indeed, most of the proteins that the mitochondria need to function are encoded by genes in the nucleus. The activity of genes in the nucleus is even required to copy the mitochondrial genome: mitochondria no longer have the equipment to copy their own DNA.

Fish, birds, reptiles, amphibians, and mammals have the same set of mitochondrial genes, in more or less the same order. That suggests that further losses are harmful, and the circular genome has evolved to be as small and streamlined as it can be while still doing its job. Even so, the genome is still susceptible to mutations, and if an organism inherits a mutated version, the result in some cases can be disease.

Sperm need a large and ready supply of energy in order to swim to meet an egg. To this end, a sperm cell has a belt of mitochondria—a sort of power pack—between its head and its tail. Faulty mitochondria are thus one cause of male infertility. However, when a sperm enters an egg, the mitochondria it carries are destroyed. Hence, in most animals, mitochondria are inherited only from the mother. (There are occasional exceptions. A few species—such as some mussels and clams—regularly deviate from a strict pattern of maternal inheritance. Also, accidents can happen: even in species such as humans that have this strict pattern, a few of the father's mitochondria may, once in a while, escape destruction.)

Being inherited only from the mother means that some human mitochondrial diseases are expected to be much more severe in men than in women. The reason is that, as far as the mitochondria are concerned, men are an evolutionary dead end. Mitochondria that interfere with a female's ability to survive and reproduce will not be passed on to the next generation. But mitochondria that interfere with a male's ability to survive and reproduce suffer no such penalty: they wouldn't have been passed on anyway. Male infertility, for example, is not a problem from the mitochondria's point of view.

Although many mitochondrial diseases do not, in fact, seem to impact males more than females, Leber's hereditary optic neuropathy—a sudden blindness owing to degeneration of the optic nerve—is an example of

one that does. More than 80 percent of those who get it are men, most of them between the ages of fifteen and thirty-five. The disease usually affects both eyes, and the ability to see is typically lost over a period of about four months.

This disease was first described in 1871, but because of its association with men, it was initially assumed to be a classical sex-linked disorder, like red–green color blindness or hemophilia, diseases tied to mutations on the X chromosome. (Women have two copies of the X, but men only have one, which means that harmful mutations on the X are more likely to affect men.) It was a century later, in 1972, that mitochondria were considered as a possible cause, and the first mitochondrial mutation associated with the disease wasn't discovered until 1988.

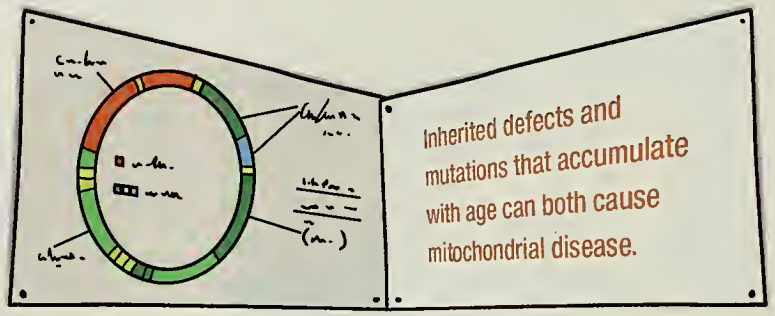
Three mitochondrial mutations are commonly implicated in Leber's hereditary optic neuropathy. Having any one of them predisposes you to the disease. However, those mutations are not the whole story: simply having one does not guarantee blindness in your future. And even if blindness strikes, though there is no cure, there is a chance of spontaneous recovery. With one of the mutations, only 4 percent of patients get lucky. But with either of the other mutations, the odds of a reprieve are better: around 22 percent for one of the mutations and between 37 and 50 percent for the other.

The direct inheritance of defective mitochondria is just one of the ways that mitochondria can cause disease. Several diseases, for instance, result from chunks of the mitochondrial genome being newly inserted into the main genome. Such insertions can be damaging if they interrupt the function of another gene—say, if the new piece of DNA lands smack in the middle of a working gene's code for a vital protein. One example is an unusual case of Pallister-Hall syndrome—a rare disease with symptoms that include extra fingers and toes, unusual growth of the brain, and a malformation of the airway. Usually, the disease is caused by ordinary mutations in a gene in the main genome called *GLI3*. This is a "transcription factor"—a type of gene that regulates the switching on and off of certain other genes. But one documented patient owes his symptoms to a snippet of mitochondrial DNA that has arrived in one of his copies of *GLI3*.

Because many genes in the nucleus are essential to the proper workings of the mitochondria, defects in those genes also can—and do—cause mitochondrial diseases. For instance, a mutation in one gene causes a kind of paraplegia; mutations in several others cause Leigh syndrome, a severe brain disease. In such cases, however, the inheritance of disease follows a clas-

sical genetic pattern rather than the from-the-mother-only inheritance of defects in the mitochondrial genome itself. (Complicating matters even further, however, some instances of Leigh syndrome appear to be caused by defects in the mitochondrial DNA.)

Perhaps the most significant cause of mitochondrial disease, however, lies not in the genetic faults some people inherit from their parents, but in the mutations most people accumulate in growing numbers of their mitochondria as they age.



Mutations of any sort are particularly likely to happen when DNA is being copied. And in the course of a lifetime, mitochondrial DNA gets copied a lot—far more than the DNA in the nucleus. Nuclear DNA is duplicated only during cell division. Mitochondrial DNA is copied whenever the cell makes new mitochondria—which can be often. Add to that the mitochondrial genome's proximity to the metabolic furnace, which spews damaging free radicals, and its lack of some of the protective mechanisms for DNA proofreading and repair that have evolved in the nucleus, and it's no surprise that this beleaguered little wreath of genes has a far higher intrinsic rate of mutation than the nuclear genome. Worse still, any mitochondrial genome that suffers a large deletion will be smaller—and thus easier to copy quickly. Copies of the faulty genome can then start to become more common.

Initially, none of this matters much. There are so many mitochondria in each cell that a faulty genome here or there won't have much impact. But as time goes by, the proportion of faulty mitochondria rises. Eventually, some cells will contain a large number of faulty mitochondria, and will thus lack the power to carry out their jobs. Among people under forty, most muscle cells contain intact mitochondrial DNA; ten years later, muscle cells start to show a wide variety of mutations in the mitochondrial genome. Certain types of neurons also build up mitochondrial mutations with age. The older you are, the more such mutations you are likely to have.

It has long been known that mitochondrial mutations are associated with a variety of progressive diseases, from Parkinson's (a degenerative disease of nerve cells) to heart disease. But until recently, direct evidence that mitochondrial defects were actually causing the diseases was lacking. This is beginning to change. Recent experiments show that mice bred to have mutations in a gene called *PolG* (which is in the nucleus) accumulate extensive deletions in their mitochondrial DNA. Apparently as a result of those mitochondrial deletions, they age much faster than normal mice. Another line of evidence comes from injecting human fibroblast cells with mitochondria from old rat-liver cells: the human cells quickly degenerate. (Young rat-liver mitochondria have no such effect.) And evidence is growing that your brain works less well the more deletions you have in the mitochondria in your neurons.

People from different parts of the world have different mitochondrial genomes: there is non-pathogenic variation here, just as there is in any other set of genes. (Paleoanthropologists have famously calculated that all those variants are descended from a single type that existed about 140,000 years ago in an East African woman, whom they have dubbed "mitochondrial Eve.") Some of those variants, however, may predispose their bearers to particular diseases, because they are prone to accumulating deletions at a faster rate. In other words, some mitochondria that function perfectly well early in life may be more likely than others to develop problems later.

On the flip side, other variants may be more robust or have favorable effects. Some Europeans have mitochondrial genomes that appear to protect them from Parkinson's disease, and others enjoy greater protection from severe dementia, such as Alzheimer's. Japanese centenarians tend to have a specific mitochondrial genotype, which is not found at particularly high frequencies in the younger population; that suggests it is a factor in their long lives.

Although there are nutritional and other treatments that can ameliorate the symptoms of some mitochondrial diseases, it doesn't look as though we'll have a cure for many of them anytime soon. But one day, perhaps, the techniques of gene therapy will address, at least, heritable mitochondrial defects—the ones inherited via the egg. Experiments in mice suggest that such an approach is possible. The procedure involves taking the nucleus from an egg that has abnormal mitochondria and placing it in an egg with normal mitochondria, from which the nucleus has been removed. A mouse with such genetic inheritance grows up free of mitochondrial disease. But the day when such a technique could be used in humans is probably still a long way off.

Olivia Judson, a research fellow in the Division of Biology at Imperial College London, is the author of Dr. Tatiana's Sex Advice to All Creation: The Definitive Guide to the Evolutionary Biology of Sex *(Owl Books, 2003).*

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Face-offs of the Female Kind

Turf battles between gangs of female blue monkeys reveal a complex social organization.

BY MARINA CORDS

Urgent, low-pitched growls emanate from dense foliage in the Kakamega Forest in western Kenya. The growls are punctuated by birdlike chirps and, every so often, a deep, resonant boom. The sounds get louder as two groups of blue monkeys, which are gray and black rather than blue, face off across an invisible line in the tangle of branches. Each group is about forty strong. In the front lines are adult females, the size of house cats, literally shoulder to shoulder, glaring and threatening. The opposing phalanxes move in parallel, sometimes pushing forward, sometimes retreating. Individual "soldiers" join and leave the front ranks; behind them, others—adult females, the juveniles, and the group's one resident male—chirp and growl in support, or simply sit and watch. Still others, usually at a distance from the commotion, seem completely unconcerned and uninvolved in the battle.

In my fieldwork on blue monkeys (*Cercopithecus mitis*), my colleagues and I have witnessed fierce encounters of that kind every month or so, while less dramatic confrontations, such as a couple of animals growling at their neighbors, occur every day or two. What's in dispute is territory, territory that contains the fruits, insects, flowers, and leaves that make up most of the diet of these monkeys. The battles are remarkable both for the ganglike cohesiveness they bring to what can otherwise seem a scattered, unconnected group, and for the intensity of the aggression that can erupt among females with normally peaceful demeanors. For it is the females that participate in these turf wars, grabbing and biting their opponents when aggressive threats are not enough.

A male juvenile blue monkey, the size of a chihuahua, looks into the distance in his Kakamega Forest home in western Kenya. Juveniles sometimes watch but seldom join in intergroup territorial aggression. Juveniles participate less often in fights than do adults, and male juveniles less frequently than female juveniles.

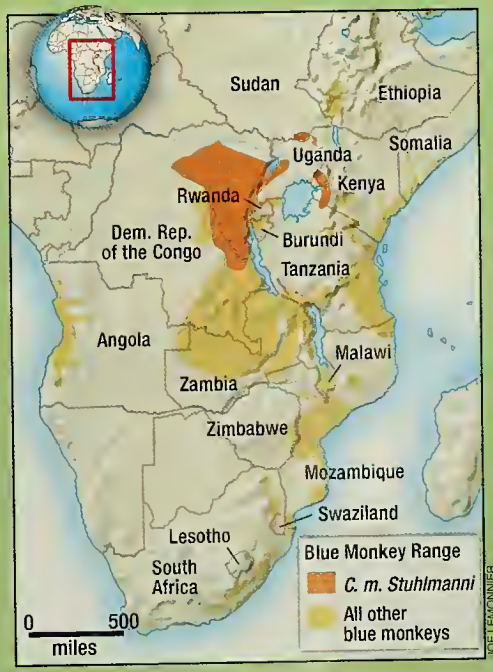
MARINA CORDS

Chimpanzees, our close relatives, are sometimes compared to politicians: they engage in power plays; they use diplomacy; they assign perks to various positions in a complicated social hierarchy. Blue monkeys, which seem calmer and less prone to form coalitions, appear to be more egalitarian. And yet my study of the group dynamics of territorial battles, and how these may figure into the way a group later splits into smaller new groups, has revealed unexpected complexity in blue monkey social structure. As in some human political organizations, those on top may depend more on those at the bottom than first meets the eye.

THE FEEDING TERRITORIES OVER which blue monkeys battle are often so specific that a person could draw lines to demarcate them: this tree belongs to this group, the next tree over doesn't. Groups can coexist peacefully very near one another as long as each stays on its side of these imaginary lines.

Territorial behavior occurs in many animals that defend feeding grounds, breeding areas, and in a few cases, courtship arenas. Among primates, territorial defense is just one way a group cooperates to compete with the neighbors. Not all primates are territorial in the way blue monkeys are, defending a specific piece of land. However, many primate groups react aggressively toward neighboring groups wherever they meet. Biologists would not call such populations territorial, but there is nevertheless cooperative defense of resources.

Quite a few researchers have investigated what certain primate species fight over; less often have they looked at how group members differ in their participation. Of those studies, almost all involve species in which the males



JOE LEMONNIER

do most of the fighting. My study focused on the question of why certain individual females did the fighting.

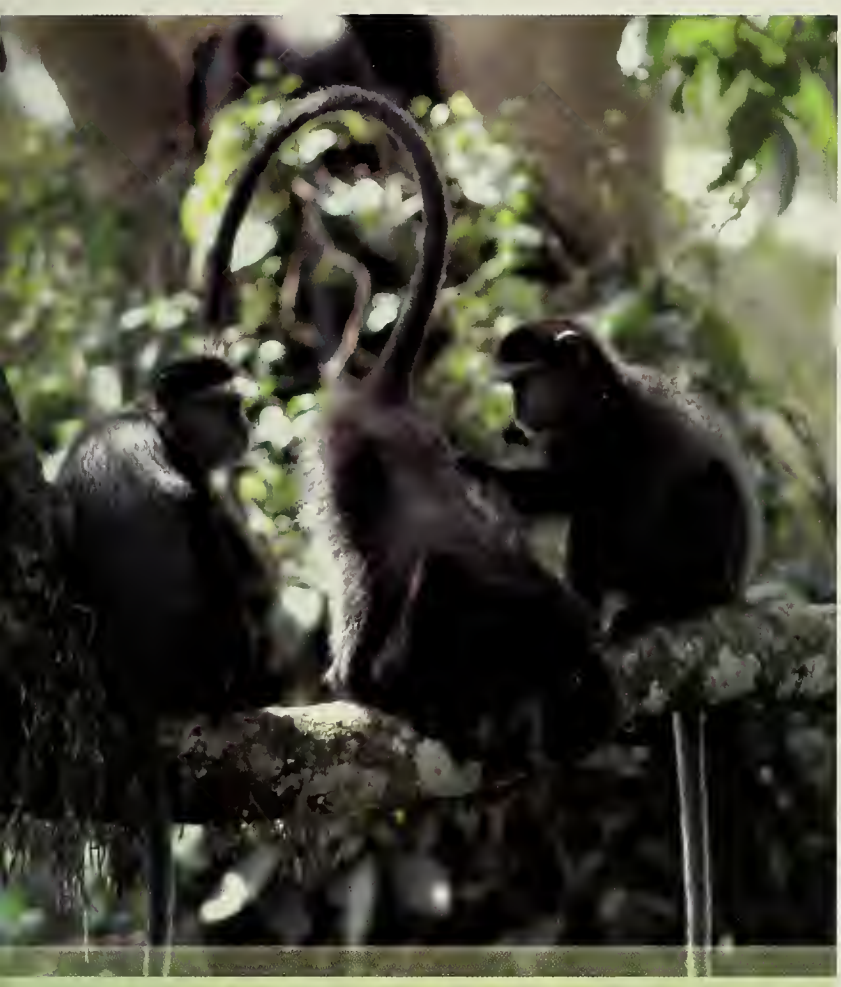
At first glance, it seems unfair that only some members of a blue monkey group would fight to defend a food supply that benefits all the group members—an effort that economists call "collective action for a public good." Indeed, those monkeys that sit out the battles are getting a free ride. As a matter of fact, any individual monkey would seem well advised to avoid joining an intergroup battle: it's a way to get the benefit (more food) without paying any cost (potential injury or even death).

The most severe wounds I've seen a female sustain in my twenty-nine years of study occurred during a group battle. For more than an hour, members of the front lines had taken each other on, sometimes grappling fiercely in a tangle as a roar of growls, chirps, and loud screams erupted. When the losing group finally retreated, I moved forward to get a closer look. Normally monkeys are wary of people, so I was amazed that I could come within six feet of an adult female. She was breathing heavily as she lay prostrate on some low branches, just level with my eyes. Her body was covered with flecks of blood—she must have been bitten all over, severely and repeatedly. Only after lying perfectly still for a half hour did she pull herself together and slowly move off to a safer distance.

More recently, in another prolonged, loud, and vicious group fight, another female had the skin ripped off the back of her calf, starting from the knee. The skin bunched down at her ankle like a frilly bobby sock, leaving the red calf muscle fully exposed; eventually she limped away, though carefully and in obvious pain. Both of those animals survived their injuries, but that was a matter of chance: open wounds in a tropical environment can become infected and lead to death.

Kamba, an adult female, nurses one of her daughters—a one-and-a-half-year-old. Females with young infants take part in fights rarely, if at all.

And yet, if every monkey chose to take a free ride to avoid such risks, no cooperative territorial defense would occur, and all would lose out. This dilemma is what economists refer to as a "collective action problem." Evolutionary biologists think in a parallel manner, because natural selection should act on animal decision making in a way that maximizes individual fitness. In other words, natural selection should favor selfish and self-protective decision making, which maximizes an individual's chances to survive and reproduce. If taking a free ride offers the best deal to the individual, collective action should always fall apart.



MAHINA CORDS, PP. 24-25

Above left: Spike, an adult female blue monkey, makes what the author calls a "hate face," a threatening facial expression that is usually accompanied by aggressive growls in a confrontation. Above: a mother, Lolita, whose tail is up in the air, is groomed by her daughter, Lobster. Another daughter, London, sits to mom's left. Mothers are sometimes prevented by lower-ranking females from joining splinter groups that include their offspring.

To understand from an evolutionary perspective why some members of a group of blue monkeys fight even though others ride free, it seems that there must be additional important factors that a simple model of cooperation does not take into account. For one thing, individual group members are not identical: one might expect some difference in participation if the costs and benefits of territorial defense are not the same for all potential participants.

OVER A FIVE-YEAR PERIOD, my colleagues and I monitored individuals' participation in territorial encounters in five study groups of the blue monkey subspecies *C. m. stuhlmanni* in the Kakamega Forest to see if such disparities in individuals' costs and benefits offered a compelling explanation for divergences in participation. As noted before, adult females regularly joined the fray, while adult males engaged infrequently—and when they did, it was mostly to vocalize from the back lines. (Although each blue monkey group usually contains only one resident adult male, an influx of male adults sometimes swells the group during the three- to five-month breeding season.) Juveniles were less likely than adults to get involved in the intergroup aggression; generally, however, the older the juveniles were, the more likely they were to join in. At every age, juvenile females participated more than juvenile males—foreshadowing the adult pattern.

We can in fact begin to explain these results in terms of the relative costs and benefits of participating in intergroup battles. From an evolutionary perspective, the relative reproductive success of female mammals is limited mainly by access to food: enduring a pregnancy, and in particular, lactating to support a growing infant, are energy-intensive life stages limited to adult females. Thus females have especially much to gain from defending a source of food, and it makes sense that they are more involved than males in defending feeding territories.

In contrast to females, the relative reproductive success of male mammals depends mainly on their access to female mates, at least in cases where paternal care is minimal (as is the case in blue monkeys). When male primates participate in intergroup aggression, they are usually defending mates, not food. Some exceptions to this generalization have recently been discovered: Eastern black-and-white colobus monkey males seem to defend feeding areas directly, for example. But researchers believe this may actually be a way to attract potential mates, rather than a defense of feeding grounds for their own sake. In blue monkeys, however, males are obviously less involved in battles between groups than females are, and it seems clear that defending food sources is not one of their strategies for attracting mates.

The age-related difference in participation, by contrast, may reflect the differing risk to individuals. Given the potential for extreme violence, smaller and more vulnerable individuals may be less inclined to take a risk. Not only juvenile monkeys, but also females with infants, are less likely to take part in intergroup aggression. This observation is also consistent with the idea that individuals make decisions based on their personal risks: a female carrying an infant is probably less agile in the branches, and agility is at a premium in the fast-moving action of escalated encounters.

Why, then, do females of higher rank in the dominance hierarchy participate more in territorial battles than do those of lower rank? Rank structure in blue monkeys is linear: if A is dominant to B and B is dominant to C, then A is dominant to C as well. In that respect blue monkey

hierarchies resemble those of many other Old World monkeys, such as the rhesus macaque and the baboon. What's different is that blue monkey rank structure is less "in your face": dominance interactions are rare, especially those more aggressive ones in which there is a clear loser. Instead, dominance is revealed over the long term by how a lower-ranking individual will tend to avoid a higher-ranking one or withdraw in her favor. It's a muted dance of approach and retreat in which the dancers perform occasionally. In fact, only after piecing together years of observations to detect repeated patterns did we perceive a hierarchy in blue monkeys at all.

RANK IS GENERALLY A POOR PREDICTOR of female blue monkey behavior, so we had not expected dominance rank to play a role during territorial battles. For example, females of lower rank do not travel more or farther to get food, do not spend more time feeding, and do not have a lower-quality diet than those of higher rank. Nor do they occupy spatial positions in trees (at the edges of a tree's crown) or in the group as a whole (on the edge of the group) that would expose them more to predators. Most important, there is no evidence that they breed less successfully: neither the rate at which they produce offspring nor the survival of their infants suffers compared with that of higher-ranking females.

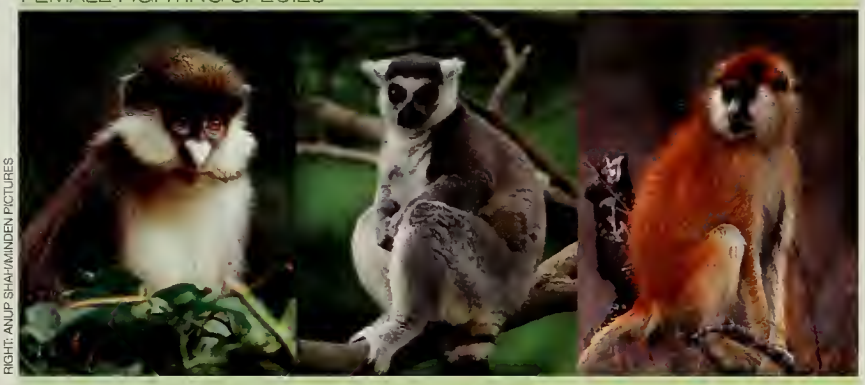
If high-ranking females possessed an advantage in any of those ways, one might understand their greater participation in group battles: they are the animals with the most to gain. But for blue monkeys there must be a more subtle explanation.

I can suggest two possibilities. The first is that participation in cooperative territorial defense is traded for other social services. Here behavioral biologists use another economics analogy: the idea that cooperative exchange can involve multiple "currencies." At the simplest level, one animal takes on the risks of an intergroup battle, while another pays back with a different social good. In some primate species, teaming up in aggressive alliances to sort out squabbles within a group is a significant service provided by friends, but in blue monkeys this seems too rare to be important. Other obvious contenders are social grooming, or perhaps tolerance while feeding: a monkey is allowed to feed undisturbed, rather than be chased away by a higher-ranking group member. And, for reasons that are as yet unclear, high- and low-ranking animals "play" with different currencies. At present we don't know whether such exchanges occur, but our team is monitoring exchange in all three currencies (territorial fighting, grooming, and feeding tolerance) to find out.

When two animals exchange services with each other, reciprocity is direct: I give something to you, and you pay me back in some way. But reciprocity can also be indirect, when an individual provides services to another and is paid back (whether in the same currency or not) by a third party or parties. In theoretical models, indirect reciprocity can persist when individuals have reputations, and when their fate in a marketplace of social partners depends on their reputations. Both theoretical models and experiments with human players suggest that investment in reputation occurs. For example, human subjects will donate to a public good if doing so enhances their reputation, and if others can use information about their reputation to make decisions about cooperating with them in the future. So, contribution to the public good can eventually bring benefits to the contributor, lessening the temptation to ride free. Whether nonhuman primates attend to reputations or practice indirect reciprocity is, however, currently unknown.

The second potential explanation for why high-ranking females fight invokes the theory of "reproductive skew."

FEMALE FIGHTING SPECIES



LEFT/MIDDLE: GERRY ELLIS; RIGHT: ANUP SHAH/MINDEN PICTURES

The six primate species pictured here engage in intergroup aggression, usually over territory. Those in the top row—(left to right) redtail monkey, ringtailed lemur, patas—mainly rely on the females to do the fighting. Males do most of the fighting in the species in the bottom row (left to right): black howler monkey, brown capuchin, and bonnet macaque.

MALE FIGHTING SPECIES

LEFT: LEE DALTON/NHPA; MIDDLE: ADRIAN HEPWORTH/NHPA; RIGHT: IAN GREEN/NHPA

MARINA CORDS

An adult female stashes some Solanum mauritianum, a plant in the potato and deadly nightshade family, in her cheek pouches. Such fruits, along with insects, and flowers, are at stake in intergroup blue monkey battles over territory.

This theory was originally devised to explain how reproduction is distributed among the members of a society. One might ask, for example, why high-ranking individuals do not always prevent lower-ranking ones from reproducing. A possible answer to this question is that lower-ranking individuals have something the members of higher rank need. For example, perhaps the social unit needs all of its members alive and well for any of them to reproduce successfully. If so, a higher-ranking individual might need to give up some control over reproduction to keep lower-ranking individuals around. Without such an incentive, the latter might go elsewhere.

That general idea may indeed apply to blue monkeys. Specifically, high-ranking females may need to keep low-ranking ones around to cope effectively with the aftermath of group fissions. Blue monkey groups tend to split when they reach fifty to seventy members. The reasons for such divisions are not well known in this species, but the consequences seem clear. The two new daughter groups, which are seldom the same size, engage in a series of intense intergroup battles to divvy up the original territory.

In fact, that is when territorial boundaries—normally stable over generations—change the most. Invariably, the smaller daughter group ends up with the smaller parcel of land, which may not be big enough for its needs. That new home range seldom includes the most visited portions of the original group's range, and it often includes areas that were relatively infrequently used.

The fact that there are different consequences for large and small daughter groups is one piece of the puzzle. Another is that lower-ranking females appear to have some control over how the group divides. They may choose not to join higher-ranking females in a new group, for example; in addition, they may actively and collectively exclude higher-ranking females. In one fission, we witnessed lower-ranking females harassing a higher-ranking matriarch that tried to join their subgroup. She was highly motivated to join it, as it included almost all of her many offspring. In the face of repeated, targeted threats and chases by lower-ranking females, however, she ended up with the smaller subgroup of females, all higher ranking than she was. She was thus at the bottom of the hierarchy in her new group, and separated from all of her family except her young daughter—and this position seemed to be imposed on her from below.

Presumably it is in the best interest of high-ranking females to join the larger subgroup during a group fission, but they risk being abandoned by lower-ranking individuals looking for a better situation elsewhere. If high-ranking individuals take on a greater share of territorial defense, they may create the staying incentive needed to retain a loyal following, thus ensuring the most advantageous outcome.

Our field research continues to investigate such questions of social structure by focusing on the behavior of individuals and their exchanges with one another, both one-on-one and in the context of group territoriality. This may prove to be a long undertaking, as some of the relevant social events occur rarely. Escalated attacks happen only once a month or so, and group fissions take place on average only once in ten years. With females living as long as thirty years or more, perhaps one should expect social lives that play out over a protracted period, but that presents scientists with a challenge. It's a good thing that human researchers live longer than their subjects!

Marina Cords is a professor of ecology, evolution, and environmental biology at Columbia University. Her research focuses on the social behavior, ecology, and reproduction of non-human primates, especially Old World monkeys. She has led a field study of blue monkeys in the Kakamega Forest since 1979, in which she combines behavioral observations with laboratory-based investigations of DNA and hormones.

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Lethal Fuzz

Bag-shelter moth caterpillars (Ochrogaster lunifer) from Australia feast on a eucalyptus leaf. Opposite page (top to bottom): oak processionary caterpillars (Thaumetopoea processionea) on a host tree in Europe; buck moth caterpillars (Hemileuca maia), found in eastern North America; moon moth caterpillars (Lonomia cyniva), found in Venezuela; processionary caterpillars (Euselasia chrysippe) congregating on a leaf of the Miconia tree in Costa Rica.

Toxic hairs enable some caterpillars to venture forth in conspicuous processions.

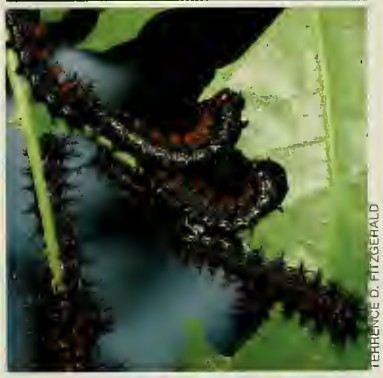
BY TERRENCE D. FITZGERALD

An epidemic of itchy, burning rashes, irritated eyes, and sore throats struck Belgium in the spring of 2007. Victims' reactions were severe enough to rally firefighters and dozens of troops—armed with gas-flame torches—to scour the northern countryside in search of the culprits. That summer a similar outbreak in west London set people to coughing and scratching, and the U.K. forestry commission launched its own extreme counterattack to blunt a recurrence this year.

What's responsible? Fuzzy caterpillars. Oak processionary caterpillars (*Thaumetopoea processionea*), to be exact: they wreak havoc on anybody unlucky enough to cross their path. Considered tree pests as well, because they defoliate oaks, oak processionaries sport an armament of poisonous hairs. The fine, stiff, sharp-pointed bristles readily penetrate skin, releasing a toxin on contact from their hollow cores. In response to the toxin, thaumetopoein, a victim's body releases histamine, which raises itching, red welts. Particularly sensitive people can suffer a much more serious, life-threatening reaction termed anaphylaxis.

Surprisingly, few of the victims in the outbreaks actually touched or saw the caterpillars. The hairs can be unavoidable on a windy day, floating invisibly in the air for more than a mile. High concentrations of the airborne hairs are common because the caterpillars live in large sibling groups—often of a hundred or more—and can achieve high population densities. The caterpillars move about in head-to-tail bodily contact, forming snakelike lines as long as twenty feet, a peculiar form of collective locomotion termed processioning. While this is an effective means of staying together, brazen marches render the insects conspicuous to predators, requiring strong defense against attack. Hence, the hairs—lots of them.

KHEDTZER/IMAGEBROKER/FLPA



TERRENCE D. FITZGERALD

INGO ARNDT/NATURE PL

KENJI NISHIDA

People all over the world have come into contact with the dozens of species of processionaries that have evolved around the world. In West Africa, for instance, inhabitants have eaten the *Anaphe* caterpillar for many generations. They deal with the hairs by singeing them as the caterpillars are roasted over a fire. Eating one or two of the tasty caterpillars is of no concern. But making regular meals of them, it turns out, often leads to serious symptoms: difficulty in speaking, impaired consciousness, rolling eyes, staggering, and tremors. Only recently has it been established that thiaminase, an enzyme in the caterpillar's body, destroys the victim's vitamin B1. The resultant vitamin deficiency, now known as seasonal ataxia, was responsible for about 70 percent of hospital admissions in Ikare, Nigeria, in August 1993. Fortunately, the symptoms disappear quickly with vitamin supplements.

The most dangerous of the processionaries is the South American *Lonomia*. In Brazil, a seventy-year-old woman suddenly fell into a coma after she placed a slipper on her foot. Hidden within was a *Lonomia* caterpillar. Doctors found lesions on her left foot where hairs had penetrated her skin. The toxin had triggered intracerebral hemorrhages, from which she died seven days later. More and more people are being exposed to the hazard because of deforestation and a decline in the caterpillar's natural enemies. An anti-lonomic serum, if injected in a timely manner, can save victims' lives.

Central America has suffered in recent years from female moths in the processionary genus *Hylesia*. The moth, like that of some other species of processionaries, has poisonous spicules on its abdomen, allowing it to carry on the nasty business of its

childhood. In 2005, Trinidad shut down offshore oil rigs when the moths fluttered about lights that burned through the night; the spicules broke from their abdomens, drifted invisibly through the air, and fell onto the exposed skin of the victims.

Animals as well as humans fall victim to processionaries. Veterinarians are accustomed to treating curious pets that molest caterpillar processions or nests; the unfortunate animals often suffer necrosis of their tongues, requiring that affected parts be cut out to save their lives. In Australia, the processionary *Ochrogaster* is the prime suspect in a recent rash of aborted foals: there is growing evidence that if pregnant mares ingest fragments of hairs left behind as the caterpillars march over the ground, their fetuses may die. Although the exact mechanism remains uncertain, the hairs may irritate the mare's gut, which allows pathogenic bacteria to invade the bloodstream.

While it is mostly because of their impact on human health that processionaries have attracted the attention of scientists, I was drawn to them for a wholly different reason. My interest was piqued after reading a series of essays on the pine processionary caterpillar (*Thaumetopoea pityocampa*) written more than a hundred years ago by the renowned French naturalist Jean-Henri Fabre. Fabre conducted remarkably detailed studies of the larva and the moth, which he recorded in his encyclopedic ten-volume *Souvenirs Entomologiques*.

In January 1896, Fabre wondered what would happen if the first caterpillar in a procession could be made to follow the last, creating a complete circle. He soon had his answer, for by chance a procession crawled onto a palm pot in his greenhouse and formed a circular procession around its rim. To his amazement the caterpillars circled for seven days before breaking free. Factoring in rest breaks during the cold nights, Fabre calculated, conservatively, that the caterpillars marched for eighty-four hours, circling the rim 335 times. He attributed the circling behavior to blind instinct, stating that the caterpillars lacked "the rudimentary glimmers of reason that would advise them to abandon it." His account of the circling procession is one of the best known of all insect stories, because it is viewed as a metaphor for mindless living. The story has been endlessly retold by inspirational speakers who see in it the folly of blindly following the crowd, striking off with neither a goal nor a leader, or confusing activity with progress.

I pondered Fabre's account, not from the point of view of one searching for inspiration, but from that of a scientist who had spent nearly all of his working years investigating the behavioral and chemical ecology

of social caterpillars. In truth, I doubted that caterpillars could be endlessly trapped in a circular procession merely because they adhered to an instinct to follow each other; something else was at work here. I also wondered, as had Fabre, how the caterpillars managed to form and maintain processions in the first place. Fabre observed that each caterpillar lays down a fine thread of silk as it marches along. Although he never formally tested his hypothesis, he felt that the caterpillars sensed those strands, leading them to trail one behind the other. Fabre was an acute observer, but he died long before the discovery of the role of pheromones in orchestrating the collective behavior of social insects. My research with other species of social caterpillars suggested that a previously undetected pheromone might be essential to the formation of processions. Thus, I set off on a study of the behavioral ecology of the pine processionary, which lives in southern Europe and northern Africa.

When I initiated my investigation, I was fully aware of the caterpillar's toxic nature. Insatiable experimenter that he was, Fabre reported that he suffered severe rashes when he poured extracts of the caterpillar onto his skin. One of his contemporaries, attempting a similar experiment, experienced a much more dangerous anaphylactic response and reported that "not only my hands, my arms, my legs, but my whole body became the seat of insupportable itching; soon my face swelled, my eyes puffed up and I had to give up writing my remarks." After suffering a severe conjunctivitis when a tiny fragment of a caterpillar's hair fell onto my eye, I found it necessary to move with caution in the field and to confine the caterpillars in my laboratory to a room fitted with air filters. Nonetheless, there were few days during my studies when I didn't have to deal with an itching dermatitis.

I conducted my field studies in Catalonia, Spain, where the life cycle of the pine processionary begins in early August, when the moth lays up to 300 or so eggs on pine needles. Soon after they hatch, the tiny caterpillars construct a flimsy silk nest around a few pine needles. That nest is abandoned after a short while, and over the next month the caterpillars collectively build a succession of nests at new sites in the branches of the tree. Their nomadic nesting habits end after their second molt, when they initiate the construction of a

Pine processionary moths lay eggs on the needles of pine trees every August. When the young larvae hatch, they construct and abandon a succession of small nests at different spots on their home pine tree. After two molts they build a large, permanent nest (center) that is formidable to intruders, thanks to toxic hairs strewn throughout, and that provides good shelter through the winter. In March the caterpillars leave their nest in search of a site where they can bury themselves underground, spin cocoons, and metamorphose. Adult moths emerge in August.

dense and virtually impenetrable silk nest they will inhabit for the rest of their larval lives. The permanent nest stands apart from the caterpillar's food supply, and they march from it to feeding sites on the host tree, returning home hours later with full guts. It is with the initiation of the permanent nest and the long marches that the caterpillars' hairs, until now soft and harmless, grow into stiff, toxic bristles. Their nest becomes littered with those bristles, fortifying it against attack by would-be predators.

A striking feature of the pine processionary's life cycle is that the insect spends the winter in the caterpillar stage. Since insects are ectothermic, producing no body heat, one would expect that they would lie immobilized in their nests on cold winter days. To determine how the caterpillars fared during winter, I set up activity monitors near nests in mid-February. The monitors projected invisible infrared beams across pathways the caterpillars used when they foraged. When the beam was interrupted by a passing caterpillar, the signal was sent to a data logger, time-stamped, and later uploaded to a computer for analysis.

During the week of my study, temperatures in the afternoon reached average highs of 63 degrees Fahrenheit, but plummeted rapidly to below freezing after sunset. Yet the monitors revealed that the caterpillars only left their nests after dark and returned before dawn. One morning I observed that water had turned to ice in a pot left outside overnight, and I was sure I would find that the caterpillars had spent the previous night snug in their nests. But the data loggers revealed that they had been active outside their nests until the temperature dropped below 28 degrees, at which point they became immobilized. As soon as the first rays of the morning sun struck them, their bodies warmed, allowing them to make their way back to the nest, and by 9 A.M. all were home.

The study revealed that the caterpillar has one of the lowest "chill-coma" temperatures (the temperature when all activity ceases) ever documented for an insect. It is likely that selection pressure from daytime predators accounts for that seemingly strange behavior. For not all predators are put off by the pine processionary's toxicity. Remarkably, the hoopoe, the great tit, and the great spotted cuckoo are all able to feed on the caterpillars without ill effect.

Although the nest serves as a secure retreat, it has another equally essential function. During sunny days, it traps solar radiation. Thermo-sensitive probes I placed in nests in February registered as high as 100 degrees during the day. Heat trapping warms the caterpillars enough during even the coldest days to enable them to efficiently metabolize the food they've collected during their nightly forays.

In early March the caterpillars take their last meal, an event followed by a grand procession. Up to now they have confined their forays to the host tree, but on this occasion they march down to the base of the tree and set off over the ground in a snaking procession. The leader advances, goaded on by the mass of caterpillars that push from behind. The caterpillars are in search of a place to spin their cocoons. Along the way they test the ground, seeking loose soil, and eventually they bury themselves side by side several inches underground to undergo metamorphosis. The timing is right because the nests would be much too hot to occupy in the torrid summers that characterize much of their range. The pupating processionaries stay underground until August, when, as moths, they burrow up through the soil [*see illustration on preceding two pages*]. Children who uncover one of the communal crypts while digging in sand in the summer become inadvertent victims of the caterpillars' hairs. The abandoned nests, too, continue to spew toxic particles into the air well into the summer.

My goal was to determine how the pine larvae are able to maintain their orderly processions. First off, I found that the caterpillars left behind a persistent trail. I did this by marking the precise course of a procession with pins and then releasing single, uninitiated caterpillars along the pathway. That simple test revealed that individual caterpillars followed the procession when released as long as a full day after the procession had passed.

Next I tested Fabre's hypothesis that the strands of silk the caterpillars lay down as they march are the basis for the trail: I temporarily plugged the tips of the silk-spinning apparatus, the spinneret, of each member of a group of caterpillars. That had no effect on their ability to line up and follow one another, or on the ability of a caterpillar introduced to the trail hours later to follow its path. The trail was an invisible one.

Further investigation revealed, as I had suspected, that processionaries mark their pathway with a pheromone secreted from the underside of their abdomens. When I sealed the suspected site of pheromone secretion, as well as the spinnerets, the caterpillars did not leave a persistent trail that a lone latecomer could follow. Nevertheless, they still formed and maintained processions. That suggested tactile stimulation—caterpillars brushing each other from behind—was the ultimate basis for the formation and maintenance of processions. To test that, I had to sacrifice a caterpillar and pull its eviscerated skin over the end of small stick, making a model of a caterpillar. With the model, I found I could lead a procession in any direction by moving it slowly in front of the leader.

LEFT: ATELIER DE FABRICATION DES TIMBRES POSTE PARIS; RIGHT: THE NEW YORK TIMES

New York Times article, right, published July 6, 1913, chronicles the power in numbers of migrating caterpillars. Opposite page: French stamp commemorating the entomological work of Jean-Henri Fabre, issued in 1956.

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Moreover, I was able to do the same with a model made from a completely unrelated species of caterpillar.

If tactile stimuli alone are adequate to allow the caterpillars to march in line, what then are the functions of the silk pathway and the trail pheromone? I concluded that the sticky silk, bonding to the smooth branches of the host tree, gives the caterpillars' feet extra traction. And the persistent pheromone serves to guide the caterpillars back to the nest after their nighttime feeding foray (and also enables laggards to catch up). The caterpillars discriminate between old and new pheromone trails and between trails made by different numbers of individuals. That facilitates efficient and coordinated movement between the nest and distant feeding sites.

During their final over-the-ground procession, however, the caterpillars rely solely on tactile stimuli to stay together. (The leader has no foreknowledge of where to go, but may use the Sun for direction.) I learned this by rapidly removing single, centrally located caterpillars from their places in line, dividing processions in two. The new leader of a rear contingent would swing its body in a frenetic search for the caterpillar that had been snatched away, then end up striking off independently in a new direction. None succeeded in bridging the gap I had created. Either the caterpillars do not lay down a pheromone trail during these terminal marches or the rough terrain renders it too spotty to be a useful guide.

And what of Fabre's caterpillars that circled endlessly around the rim of a pot? My suspicion was that the caterpillars were not adhering blindly to their instinct to follow each other, but were in effect physically trapped on the rim. I tested this by arranging for caterpillars to make a circular trail on a flat surface rather than on the rim of a pot. I placed seventeen inside a circular arena on a tabletop. The caterpillars soon arranged themselves against the wall of the arena and commenced marching in an unbroken, head-to-tail circular procession. After half an hour I removed the arena, freeing the caterpillars from any physical constraint. If Fabre's interpretation had been correct, the caterpillars should have continued to circle for days, or until they grew exhausted. But in fact, they continued in a circle for a short time (on average in my experiments, only two minutes), then marched off in a straight line. When I tried the same experiment with caterpillars younger than those used by Fabre, I learned that the young ones are more dependent on the trails. Their circular processions lasted an average of two and a half hours. One group circled continuously for twelve hours—a remarkable performance, but far short of the seven days.

But what does keep caterpillars marching around a rim? I once climbed the ninety-one steps of the Temple of Kukulkán at Chichén Itzá and found, as have many others, that going up the steep staircase is much easier than coming down, which is quite scary. Fabre's circling caterpillars likely found themselves in a similar predicament, weighing their secure footing on the rim of the pot against a plunge down its steep and smooth sides. In one famous case of similar entrapment, the *New York Times* reported that in June of 1913, teeming hordes of another social species, the forest tent caterpillar, climbed onto the tracks of the Long Island Rail Road. Rather than go up and over, the caterpillars showed the same reluctance to descend as had Fabre's. The rails were soon covered with the slippery remains of tens of millions of caterpillars, until eventually the wheels of locomotives spun in place!

Terrence D. Fitzgerald studies the behavioral and chemical ecology of social caterpillars. Most recently, his interest has turned to processionary caterpillars, which have taken him to Mexico, Costa Rica, and Spain. Fitzgerald teaches at the State University of New York at Cortland, where he is a distinguished professor of biology.

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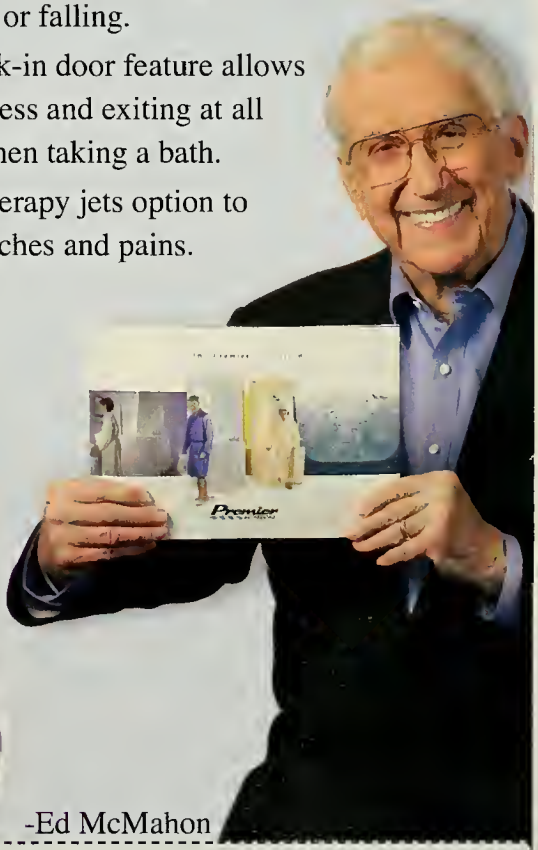

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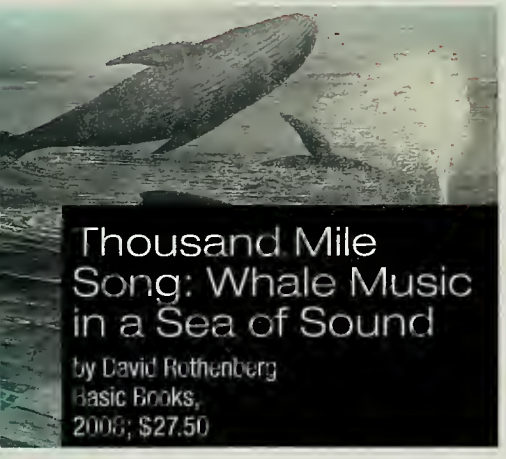


Thousand Mile Song: Whale Music in a Sea of Sound

by David Rothenberg
Basic Books, 2008; $27.50

Philosopher David Rothenberg, the author of *Why Birds Sing,* has now turned his ear to the sea. Enchanted by the siren call of the humpback when it first reached human ears in the late 1960s, he has interviewed a selection of artists and scientists who share his fascination with the vocalizations of whales and dolphins. That's not all: because he is also a jazz musician of some note, he has tried to communicate with cetaceans directly, joining the undersea chorus on his clarinet via an amplifier and submerged speakers, and listening for a response.

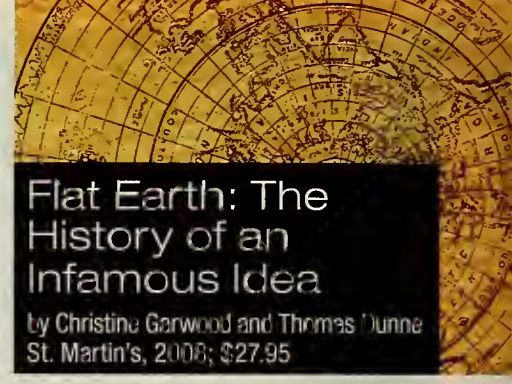
Although cetaceans are fellow mammals, they inhabit a world as alien to us as another planet. Not surprisingly, some of that strangeness rubs off on the humans Rothenberg interviewed. Why else would an otherwise ordinary individual like Paul Knapp spend twenty winters on a raft in the Caribbean listening to whale songs through a hydrophone and inviting strangers to listen? Yet for those of us who are content to admire a snippet of whale music on a CD, aficionados like Knapp serve as interlocutors between species.

Many whales can click, grunt, or squeal, but only two species, bowheads and humpbacks, actually sing structured songs. The humpback song is by far the most complex, lasting up to twenty-three hours, a vocalization longer than that of any animal in the world except perhaps a U.S. senator in full filibuster. Scientists who have analyzed the spectra of these songs describe them as a series of extended, repeated phrases that end with similar syllables or patterns of rising and falling tones—rhyming, at least to cetacean ears.

To human ears, the song of the humpback whale sounds otherworldly, yet strangely appealing. Judy Collins recorded "Farewell to Tarwathie" in 1970 accompanied by a chorus of humpback background singers, and her album *Whales & Nightingales* quickly rose high on the charts. When, that same year, Alan Hovhaness incorporated recorded whale songs into a classical piece, "And God Created Great Whales," the *New York Times* critic commented, "His whales spoke profoundly."

Profoundly, yes, but what are they saying, exactly? Do the songs aid in attracting females? If so, then why do female humpbacks, which do not sing, show so little evident interest in the songs of the males? Do the songs aid in navigation? In fostering group cohesion? In warning of dangers? No one that Rothenberg interviewed seems to know the answer.

As to the whales themselves, they seem to have cooperated with Rothenberg only grudgingly, if at all. The author barged in, uninvited, on several cetacean jam sessions, most notably among belugas along the coast of the White Sea, in the remote Russian Arctic, and among male humpbacks near the shore of Maui, Hawaii. You can listen to interspecies riffing on the CD that accompanies the book, and you can even watch Rothenberg playing with beluga whales on YouTube (just Google *Rothenberg beluga*). I'm not sure there's any call-and-response going on, though Rothenberg seems to think so. But musically? Judge for yourself: as Duke Ellington said, "If it sounds good, it *is* good."



Flat Earth: The History of an Infamous Idea

by Christine Garwood and Thomas Dunne
St. Martin's, 2008; $27.95

Everybody knows that the Earth is a sphere. In fact, despite popular myths about Columbus's defiance of a supposed flat-Earth establishment, the roundness of the Earth has been conventional wisdom for almost 2,500 years. In ancient Athens, Aristotle cited the always-circular shadow of the Earth on the Moon during a lunar eclipse as just one of several proofs that we live on a globe, and around 200 B.C. the scholar Eratosthenes, using the lengths of shadows at different locations in Egypt, calculated the Earth's circumference with remarkable accuracy.

One would think that Christine Garwood would find mighty slim pickings for a history of flat-Earth dissent. On the contrary, she's assembled an entertaining rogues' gallery of Victorian eccentrics and modern-day fundamentalists who resist evidence virtually anyone else would find conclusive. Even in an era of daily satellite photos from space, you can still find a few serious anti-globe partisans by Googling *flat Earth.*

Garwood's flat-Earthers employ a peculiar brand of inverted logic to bulwark their odd beliefs. Samuel Rowbotham, who lectured and wrote widely about the flat Earth in the mid-1800s under the pseudonym "Parallax," described the Earth as a flat, stationary disk centered on the North Pole, ringed at its outer edges by an impenetrable barrier of ice. The Sun circled overhead, only a few hundred miles up, and the Moon and stars were luminous bodies not much farther away. If challenged during a speech, Rowbotham would

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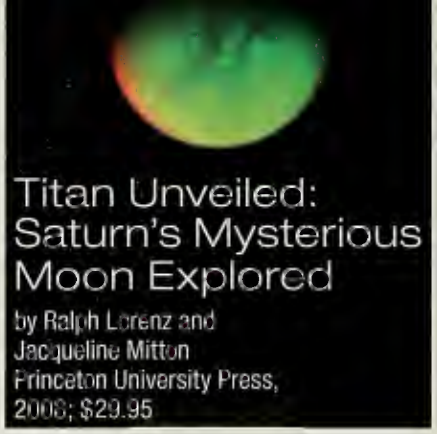
confidently cite abstruse technicalities or invent spurious data. What caused day and night if the Earth did not turn? The "expansion and contraction of the solar path" and a "special law of perspective." Since we can't see the North Star from south of the equator, isn't the Earth round? Not so: on 23 January, 1862, the North Star was seen from a spot 23 degrees south of the equator. The speaker's resolve in the face of tough counterclaims was enough to persuade at least a few members of his audience.

In one of the more poignant episodes of her book, Garwood recounts the story of Alfred Russel Wallace, the great naturalist and contemporary of Darwin, who accepted a wager of £500 to prove that the Earth curved. The test, with two presumably independent judges, was to see if two markers at the same exact height above a straight canal in England, six and three miles from a telescope, would appear to line up when viewed through the telescope. Wallace knew that the far marker would appear lower than the middle one, owing to the Earth's curve down and away. And so it did; but in a stunning exercise of doublethink, one of the judges—who turned out to be a partisan of Parallax—interpreted what he saw as confirming just the opposite. The ensuing brouhaha was embarrassing to Wallace, and, if anything, strengthened the hand of the contrarians.

Some of Garwood's characters were charlatans, to be sure. But a good fraction seem to have been genuine believers, most often biblical literalists who found satisfaction in holding fast to a view not shared by what they regarded as an intellectual elite. If that sounds a bit like contemporary creation science, I'm sure there's something to be learned from Garwood's book: that while good ideas eventually prevail, bad ideas never die.



When the *Huygens* probe entered the atmosphere of Saturn's largest moon, Titan, on January 14, 2005, there was no one at the controls, and it was nail-biting time at the European Space Operations Center in Darmstadt, Germany, where data from the probe was to be received. Since radio signals take more than an hour to travel between Saturn and Earth, detailed landing instructions had been loaded into the probe's computer prior to its 1997 launch aboard NASA's *Cassini* spacecraft. Mindful of recent space failures, most notably the 1999 disappearance of *Mars Polar Lander* during the final stages of its descent, the mission scientists were understandably apprehensive.

Hurtling downward, *Huygens* slammed through Mach 1 about 100 miles above Titan's surface and marked its arrival with the firing of a small "drogue" chute out of its backside. Catching air, the drogue pulled out a larger parachute, slowing the probe to a leisurely 164 feet per second and allowing the craft to jettison its heat shield, still glowing from the friction of its encounter with Titan's atmosphere. A while later, after a series of last-minute maneuvers and deployments, *Huygens* touched down, the first human artifact to land on the satellite of another planet. Operating remarkably close to plan, it began transmitting a variety of measurements to *Cassini* for relay back to Earth, including pictures of a hazy, rock-strewn plain. A few hours later, just as jubilant astronomers in Darmstadt were receiving the first radio transmissions, the lander sent out its last packet of data, its batteries exhausted and its mission accomplished.

Ralph Lorenz, one of the scientists who waited nervously in Darmstadt on that day, has teamed with veteran science journalist Jacqueline Mitton to convey both the human and scientific drama of remote robotic space exploration. His firsthand experience, expressed in a series of bloglike entries, makes one appreciate the compromises that have to be made to design instruments that are durable, lightweight, and effective; the program glitches and course corrections that force well-laid plans to go astray; and the ingenious ways in which Earth-bound engineers turn technical problems into research opportunities. Above all, Lorenz and Mitton reveal a world, perpetually covered with thick ocher clouds, about which practically nothing was known prior to the *Cassini* mission.

Thanks to the *Huygens* landing, and to repeated approaches by the *Cassini* orbiter, we now understand Titan is a unique place, shaped by geological and meteorological forces that are, in some ways, frigid analogues of terrestrial ones. Up close, we see features that resemble dune fields, river channels, lake beds, and mountains, albeit barren, desolate, and cold ones in comparison with Earth's. At temperatures near –289 degrees Fahrenheit, ice plays the role of rock, methane drizzles from the clouds, and liquid hydrocarbons carve winding channels across the surface. The all-too-brief *Huygens* mission is now over, but *Cassini*, still in orbit around Saturn, swings by every now and then. Although Lorenz and Mitton had to end their account at press time, the unveiling of Titan continues to this day.

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

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SKYLOG BY JOE RAO

Jupiter shines high above the southern horizon at dusk, making it September's most prominent planet. It is enthroned in the constellation Sagittarius, the Archer, just to the upper left of the eight stars that form a pattern known as the Teapot. What, you might ask, does a teapot have to do with a mythological centaur drawing a bow?

Forty-seven constellations, including Sagittarius, bear the names of mythological figures that the ancients saw in certain bright patterns of stars. Other constellations were defined in the seventeenth and eighteenth centuries, with names such as "microscopium" and "telescopium." Modern star atlases, following the precedent set by the International Astronomical Union in 1930, recognize eighty-eight constellations in total, and draw boundaries between them so that every bit of sky is unambiguously assigned to one of them. The Teapot falls within Sagittarius, but it has no official status as a constellation. It is one of the many striking patterns of stars called asterisms. (In fact, some of the Teapot's stars are shared with another asterism called the Milk Dipper, a ladle that appears to be dipping into the Milky Way.)

BRIAN ABBOTT/DIGITAL UNIVERSE/AMNH; ENGRAVING, U.S. NAVAL

The Teapot (red lines) and the Milk Dipper (yellow lines) are two simple patterns that connect stars in the constellation Sagittarius, the Archer, whose traditional figure is suggested by an illustration from a seventeenth-century star atlas. The blue lines define the portion of the sky that modern astronomers assign to the constellation.

Asterisms are often more familiar than their host constellations. They also can include stars from more than one constellation. For instance, the Summer Triangle comprises the brightest stars in three different constellations: Vega (in Lyra, the Lyre), Deneb (in Cygnus, the Swan), and Altair (in Aquila, the Eagle). That asterism lies nearly overhead soon after darkness falls on September evenings.

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

SEPTEMBER NIGHTS OUT

1 Mercury, Venus, and Mars spend much of September clustered close together—unfortunately they are hard to see against the bright evening twilight. Scanning the western horizon through binoculars, about fifteen to thirty minutes after sunset this evening, you might pick out the three planets forming a right triangle, with Mercury at the bottom, Venus to Mercury's upper right, and Mars off to Mercury's upper left. Below and left of the triangle is the narrow crescent Moon, approaching three days past new.

7 The Moon waxes to first quarter at 10:04 A.M. eastern daylight time (EDT).

11 Venus and Mars are separated by only 0.3 degree.

12 Venus is within 3.6 degrees of Mercury.

15 The Moon becomes full at 5:13 A.M. EDT. As the full Moon closest to the autumnal equinox (for the Northern Hemisphere), it is called the Harvest Moon.

22 The Moon wanes to last quarter at 1:04 A.M. EDT. At 11:44 A.M., the equinox takes place, as the Sun crosses the celestial equator (Earth's equator projected against the sky) from north to south. Autumn begins in the Northern Hemisphere and spring begins in the Southern Hemisphere.

29 The Moon is new at 4:12 A.M. EDT.

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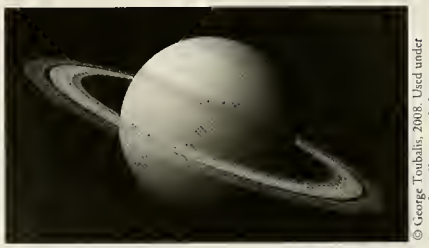
About Your Professor

Dr. Frank Summers is an astrophysicist in the Office of Public Outreach at the Space Telescope Science Institute (STScI) in Baltimore, Maryland, where he presents



the findings of the Hubble Space Telescope and developments in general astronomy to the public through various media and educational outlets. He received his M.S. and Ph.D. in astronomy from the University of California at Berkeley.

Dr. Summers was a key member of the scientific advisory committee for the Academy-Award nominated IMAX film *Cosmic Voyage*. He also directed, co-wrote, and created the 3-D visualizations for the IMAX short film *Hubble: Galaxies Across Space and Time*, which won the Large Format Cinema Association's Best Short Film Award in 2004.

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Into The Field

The Young Naturalist Awards essay contest promotes student participation in scientific research.

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The 2008 Young Naturalist Awards winners with Meg McDonald, President of Alcoo Foundation, the contest sponsor; Rosomond Kinzler, Senior Director, National Center for Science Literacy, Education and Technology; and Rob DeSalle, AMNH, Curator, Institute for Comparative Genomics.

Irrigation or Evaporation?
by Jacob Polfer (Grade 7)
Jacob compared the rate of evaporation in the lake near his Florida home to the amount of lake water used by homeowners for irrigation. Although his findings were inconclusive, Jacob now discounts irrigation as the main cause of dramatic drops in lake water levels.

"My family lives in a nice house on Lake Catherine . . . Every so often—like after a hurricane—it goes up a great deal, but then quickly drops again! Now the lake is very low and every dock is three or more feet out of the water."

COURTESY OF JACOB POLFER

River Crossings: Effects on Wildlife in and around the Fort River,
by Annie Vernick (Grade 7)
Annie wondered whether the many water crossings in her town posed barriers to local wildlife. Using the Massachusetts River and Stream Crossing Standards, Annie proved that most of her town's crossings inhibit wildlife and fail to meet the state's standards.

"The most challenging part of my fieldwork was measuring the dimensions of the crossings, which were often long and difficult to reach. The most enjoyable part was going into the river, feeling its energy and seeing the life forms in and around it."

Nesting Preferences of the Alfalfa Leafcutting Bee, *by Russell Babb (Grade 8)*
A beekeeper, Russell came upon information about solitary bees that led him to wonder about their nesting habits. After doing background research and talking to bee experts, he decided to conduct an experiment to determine where solitary bees prefer to nest.

"I can't believe it! Solitary bees have already started nesting in the wooden blocks. Fifty-one holes have been filled. I can tell because there are tiny

COURTESY OF ANNIE VERNICK

COURTESY OF RUSSELL BABB

cut-up pieces of leaves in the holes. I think the bees are making a place to put their larvae."

Investigating the Effect of Silver Nanoparticles on Aquatic Organisms,
by Eric Keen (Grade 8)
Eric tested concentrations of silver nanoparticles, used in commercial products, on four aquatic organisms. He saw that, while some died from the exposure, silver nanoparticles promoted growth in others, but, at higher concentrations, prevented reproduction.

"An ever greater quantity of silver nanoparticles is finding its way into wastewater and eventually our rivers and streams, where little is known about the possible adverse effects on aquatic organisms."

A Study of the Filtration Capabilities of the Eastern Oyster (*Crassotrea virginica*) and Soft-shell Clam (*Mya arenaria*),
by Alexandra Day (Grade 9)
Eastern oysters (*Crassotrea virginica*) were once so plentiful they could filter the entire Chesapeake Bay in three to four days. Alexandra wondered if other species, like the soft-shell clam (*Mya arenaria*), could filter water as well or better. She found both species equally improved the water.

"My research indicated that *M. arenaria* is a plentiful species, so I expected that locating twelve specimens would be a simple task. Sadly I was mistaken . . . My exposure to the profound decline of this species strengthened my resolve to improve bay water quality."

Colors Within: A Study of the Pigmentations in Deciduous and Broadleaf Evergreens,
by Megan Guerrero (Grade 9)
Surprised by the many trees in her new home state of Texas that did not change color, Megan discovered, through experimentation, that broadleaf evergreens showed a higher intensity of the same pigments found in deciduous trees, even though the pigments were not outwardly visible.

"The trees are preparing for a whole new season of life to begin. The change of colors during this magical season is more than a beautiful landscape, for it's the colors within that provide the food for life itself."

Birds of a Feather Feed Together,
by Sarah Barlow (Grade 10)
Intrigued by the birds of western Albemarle County, Virginia, Sarah experimented to find a seed mixture that would induce multiple visits, and provide maximum variety with minimal waste.

"The housing development that I live in is close to a wooded area, but other houses surround my home and my yard does not have any mature trees. . . Although a diverse number of species visited the feeders, I wonder if my data would have been altered or affected if other species had come."

Grasshoppers in the Rockies: Surmounting Alpine Challenges,
by Michelle Bayefsky-Anand (Grade 10)
Before a field trip to the Canadian Rockies as part of a summer course, Michelle learned that grasshoppers were abundant in the chilly alpine meadows. She wondered what adaptations would allow them to live in this severe environment.

"Even in August, at 1,980 meters, it snowed as I bushwhacked up the mountain through a dense fog to a subalpine site. But as soon as the sleet stopped, the grasshoppers began hopping."

Gestural Communication by a Group of Western Lowland Gorillas,
by Jennifer Draiss (Grade 11)
At the Congo Gorilla Forest exhibit at the Bronx Zoo in New York, Jennifer studied the auditory, tactile, visual, and olfactory signals of 11 gorillas. She documented a repertoire of 44 distinct gestures, two of which have not been seen in any other group.

"As I walk past the window, I hear a loud bang coming from my right. I turn, and see a small gorilla pressed against the window looking at me. I hear a few more bangs, and see that three more gorillas have come to the window, eagerly looking to see who has come to visit them."

Juvenile Blue Crab Cannibalism,
by Lauren Hickey (Grade 11)
Focused on helping rejuvenate the blue crab population, a species vital to the Chesapeake Bay ecosystem, Lauren tested whether cannibalism in juvenile blue crabs increases with population density. Her results proved her hypothesis.

"No longer on field trips do we focus on the great aspects of the largest estuary in the world. Instead, we convey a message to our children that this bay is sick and dirty and nearly beyond help."

COURTESY OF ERIC KEEN

COURTESY OF ALEXANDRA DAY

Providing Habitat for Threatened *Drymarchon corais couperi* Utilizing Simulated *Gopherus polyphemus* Burrows,
by David Futch (Grade 12)
Eastern indigo snakes inhabit gopher tortoise burrows, an option on the decline. David's experiment showed that, over time, simulated burrows closely aligned to natural burrows were able to provide an alternative habitat for multiple species.

"After hearing of the decline of the indigo snake, I visited Bok Tower, a local nature conservatory in Lake Wales, Florida, that has about twelve indigo snakes on the property. The director of horticulture, David Price, suggested the idea of a 'snake box.' I was hooked."

Resilience of a Red Sea Fringing Coral Reef under Extreme Environmental Conditions: A Four-Year Study,
by Zaki Moustafa (Grade 12)
While diving in the Red Sea, Zaki made an amazing discovery: a fringing coral reef just offshore. He worked to identify the species living there, determine the reef's health, catalog natural and human influences, determine water-quality characteristics, and share his results with the scientific community.

"I sat gazing out at the Red Sea's distinct and beautiful waters, majestic mountains jutting upwards from the desert landscape behind me. Little did I know that very day would give a higher sense of meaning and accomplishment to the next four years of my life."

Anthropogenic Radionuclides in the Estuarine Environment near a Boiling Water Nuclear Reactor,
by Anastasia Roda (Grade 12)
Anastasia checked for anthropogenic radionuclides (radioactivity) in water, sediment, and marsh samples at 42 sites near a boiling water nuclear reactor near New Jersey's Barnegat Bay and her results showed higher levels of radioactivity near the reactor.

"Many beautiful streams and creeks drain into the bay from the mainland, each with its own special character. The bay is home to an incredibly diverse wildlife population, and until recently, it had supported a thriving fishing industry."

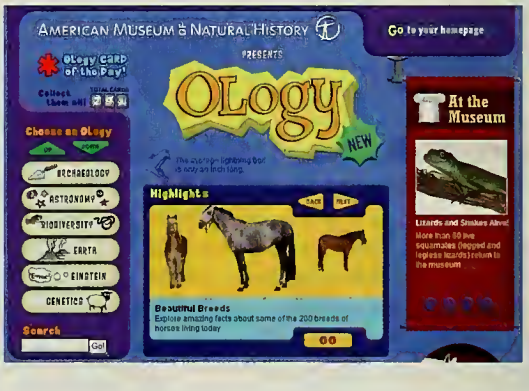
The full-length essays and information on how to enter the contest can be found on the Museum's Web site at www.amnh.org/youngnaturalistawards. **The Young Naturalist Awards program is sponsored by Alcoa Foundation.**

OLogy: New and Improved

Take a good thing and make it better. That was the goal of the designers of OLogy, the Museum's award-winning Web site for children. And they have done just that—with a new look, exciting new features, and searchable connections to a wealth of scientific information and current happenings at AMNH.

First created in 2000 by the National Center for Science Literacy, Education, and Technology, part of the Museum's Education Department, OLogy provides a fun-filled introduction to science for children 7 through 11, a critical period, say the experts, during which most children develop a keen interest in science or not. The main intention of the recent redo was to bring more of the great OLogy content up front to help kids quickly see and find what they're interested in.

To that end, a newly-added search capacity allows visitors to jump directly to specific content. Also, the OLogies—paleontology, archaeology, and biodiversity, etc.—which were once reached through a simple homepage menu are now organized into topical channels, akin to television channels, through which visitors can choose a variety of feature stories and activities. A conscious effort was made to bring more of the Museum experience to the forefront, too, with specific OLogies for temporary exhibitions, a feature called "At the Museum," and links to the same



compelling Science Bulletins videos one might see on a visit to the Museum or on the Science Bulletins Web site.

Of course, the site still offers such popular original features as interactive games, quizzes, puzzles, "stuff to do" away from the computer, and links to other science sites, for example, NASA for Kids or Scholastic Science Explorations. Children can also still sign into their own privacy-protected homepages to collect interactive digital OLogy cards and create projects for the OLogy Hall of Fame.

OLogy can be reached through a link at the bottom of the Museum's homepage at www.amnh.org, directly at www.amnh.org/ology, and from within temporary exhibition Web sites by clicking, naturally enough, "For Kids."

At the Museum

AMERICAN MUSEUM OF NATURAL HISTORY

www.amnh.org

EXHIBITIONS

The Horse
Through January 4, 2009
This exhibition reveals the powerful and enduring bond between horses and humans, and explores the origins of the horse family, which extends back more than 50 million years.

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

Lizards & Snakes: Alive!
Through January 5, 2009
Meet over 60 live lizards and snakes, and discover some of their remarkable adaptations.

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

Saturn: Images from the Cassini-Huygens Mission
Through March 29, 2009
Stunning images reveal details of Saturn's rings, moons, and atmosphere.

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

On Feathered Wings
Through May 25, 2009
This striking photography exhibition showcases the majesty of birds in flight.

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

Unknown Audubons: Mammals of North America
Through January 18, 2009
Gorgeously detailed depictions of North American mammals by John James Audubon, best known for his bird paintings.

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

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

HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME

Virtual Universe
Our Nearest Neighbors
Tuesday, 9/2, 6:30 p.m.

Celestial Highlights
Planets in the Autumn Sky
Tuesday, 9/30, 6:30 p.m.

These programs are supported, in part, by Val and Min-Myn Schaffner.

LECTURES

At Saturn: Tripping the Light Fantastic
Monday, 9/15, 7:30 p.m.
With Carolyn Porco, Director of Cassini Imaging Central Laboratory for Operations (CICLOPS).

HAYDEN PLANETARIUM SHOWS

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

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

IMAX MOVIES

Sea Monsters: A Prehistoric Adventure

Funded in part by the National Science Foundation, *Sea Monsters: A Prehistoric Adventure* was produced by National Geographic Cinema Ventures.

LATE NIGHT DANCE PARTY

One Step Beyond
For featured performers and dates, visit
www.amnh.org/onestepbeyond.
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INFORMATION

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

TICKETS AND REGISTRATION

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

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Field Mouser

By Shomita Mukherjee

A piercing shriek shattered the silence of the hot summer night in Sariska Tiger Reserve, a protected area of northwestern India. In the headlights of my vehicle I saw a small cat and a pair of golden jackals circling around a dead peafowl. In a flash, with another loud scream, the cat leapt onto the back of one of the jackals and jumped off, spurring both jackals to flee, tails between their legs. The triumphant cat picked up its bounty and went into the bushes to feast.

That was no house cat, I knew, but a wild cousin: the jungle cat, *Felis chaus,* a species that ranges globally from Turkey to Vietnam. With long legs, a short tail, a broad nose, and enormous ears ending in little tufts of hair, the jungle cat looks somewhat like its larger cousin, the caracal. As it happens, the jungle cat and the caracal overlap in parts of India, including Sariska, occasionally leading even seasoned wildlife enthusiasts to mistake one for the other. The competition with caracals and other cat species in India keeps jungle cats in Sariska small, weighing on average ten pounds; jungle cats in Israel, in contrast, average twenty-two pounds.

That brief "face to muzzle" encounter occurred more than a decade ago, when I was investigating Sariska cat life for my doctoral dissertation. It was one of the few jungle cat sightings I made. Most of the time I contented myself with tracks in the dirt, bird kills, scratch marks on trees—or scats. I found that rodents provided up to 70 percent of the cats' daily energy intake. Inside Sariska they often dined on the spiny-tailed mouse and the Indian gerbil. But the highly adaptive animals also hunted in the agricultural fields adjoining the reserves, where house mice and black and brown rats outnumber the native species.

Irrigated agriculture, especially in the western regions of India, has surely benefited the jungle cat: the water supply and boost in rodent populations are both advantageous. Yet, in northern India, jungle cats litter mainly during winter, which coincides with harvest. No doubt many kittens are lost during that period, as machinery and people move through the fields.

It was in a sugarcane field that I found two five-day-old jungle kittens, abandoned by their mother during harvest time. I raised them, and in the process realized how little I had known about the species' behavior. Their affinity to water was striking: when summer came, they would sit in a tub of water, taking their toys in to play. What I found particularly impressive was their repertoire of calls—they meowed, chirped, purred, gurgled, growled, hissed, and barked. Indeed, both were females, and when in estrus, they barked *a lot.*

Much has changed since I finished my study in Sariska Tiger Reserve. Poachers have extirpated the tigers, and leopards have taken over as the "big cats" for now. Confronted with increasing human density, conservation even of an animal as small and seemingly common as the jungle cat is not assured. Although the species is protected under Indian law, the Wildlife Protection Society of India has reported the seizure of more than 3,000 jungle cat skins from poachers during the last decade.

As for the kittens I kept, I'm unsure of their fate. One escaped when she was in estrus and the other I released into the wild when she was about nine months old. I had hoped to track them with radio collars, but a lack of funding prevented it.

Shomita Mukherjee completed her master's degree and Ph.D. through the Wildlife Institute of India, with a focus on the ecology and conservation of small cats. She is currently doing post-doctoral research at the National Center for Biological Sciences, Bangalore.

FRANCOIS SAVIGNY

Jungle cat near Sariska Res


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ALAIN HUBERT

EXPLORATION HAS A NEW PURPOSE

Arctic Ocean Traverse – North Greenland, 2007: Three hundred miles from the nearest land, the Arctic Ocean lies at the edge of the sea ice, only yards from Alain Hubert's feet. While previous explorers encountered ice many meters thick, Hubert finds only water where the Ocean should normally be frozen into a thick multi-year ice pack. Dogged by anomalous sea ice conditions, Hubert is repeatedly forced to find an alternative route across the now open water. Still 120 kilometers from his goal, each new discovery of fractured ice leads him to fear for the worst. June 14th, 2007: Alain Hubert and Dixie Dansercoer's 106-day crossing ends, but the journey is far from over. Hubert continues his quest to find the cause of this change in the ice.

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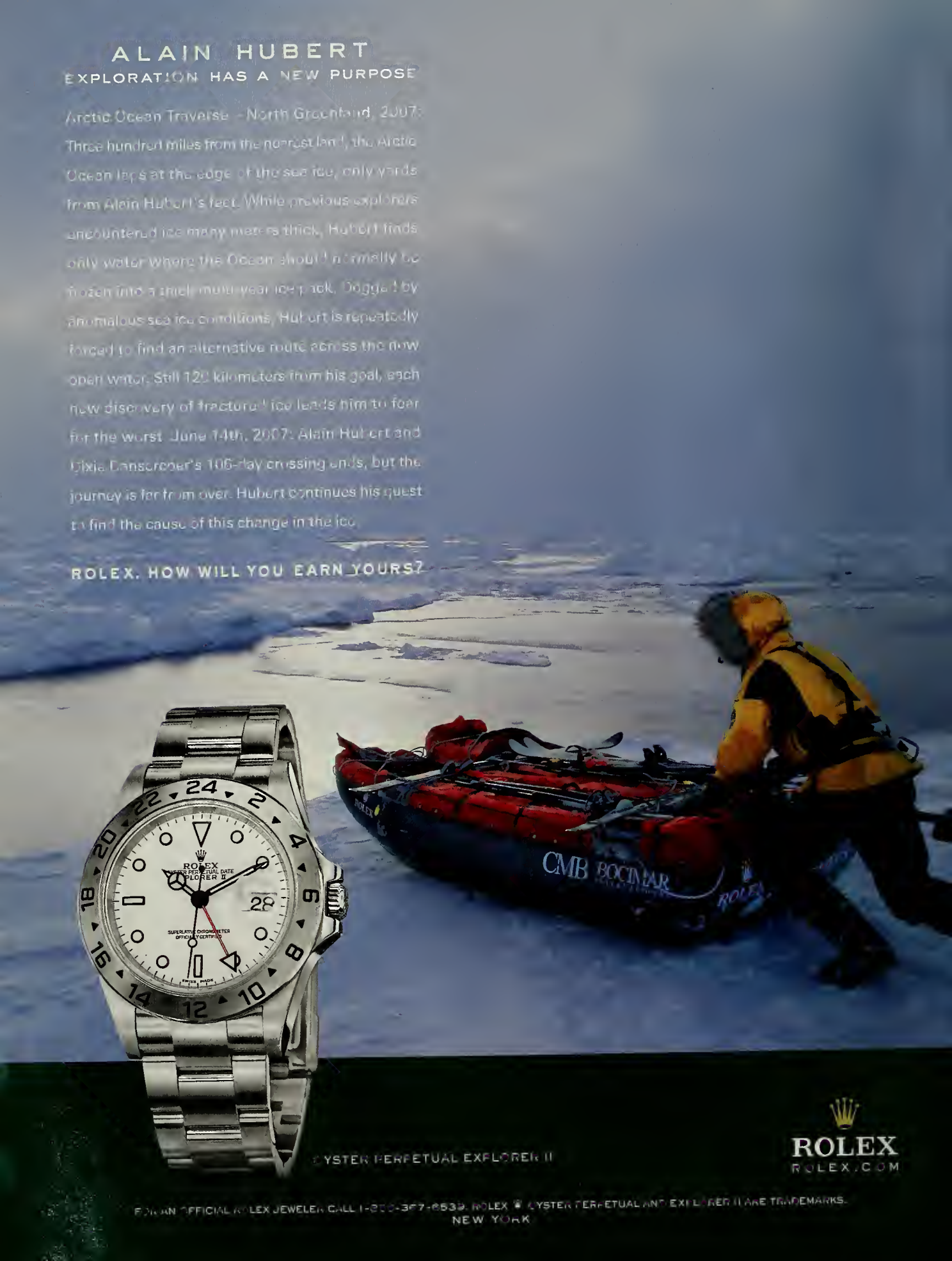

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