NATURAL HISTORY

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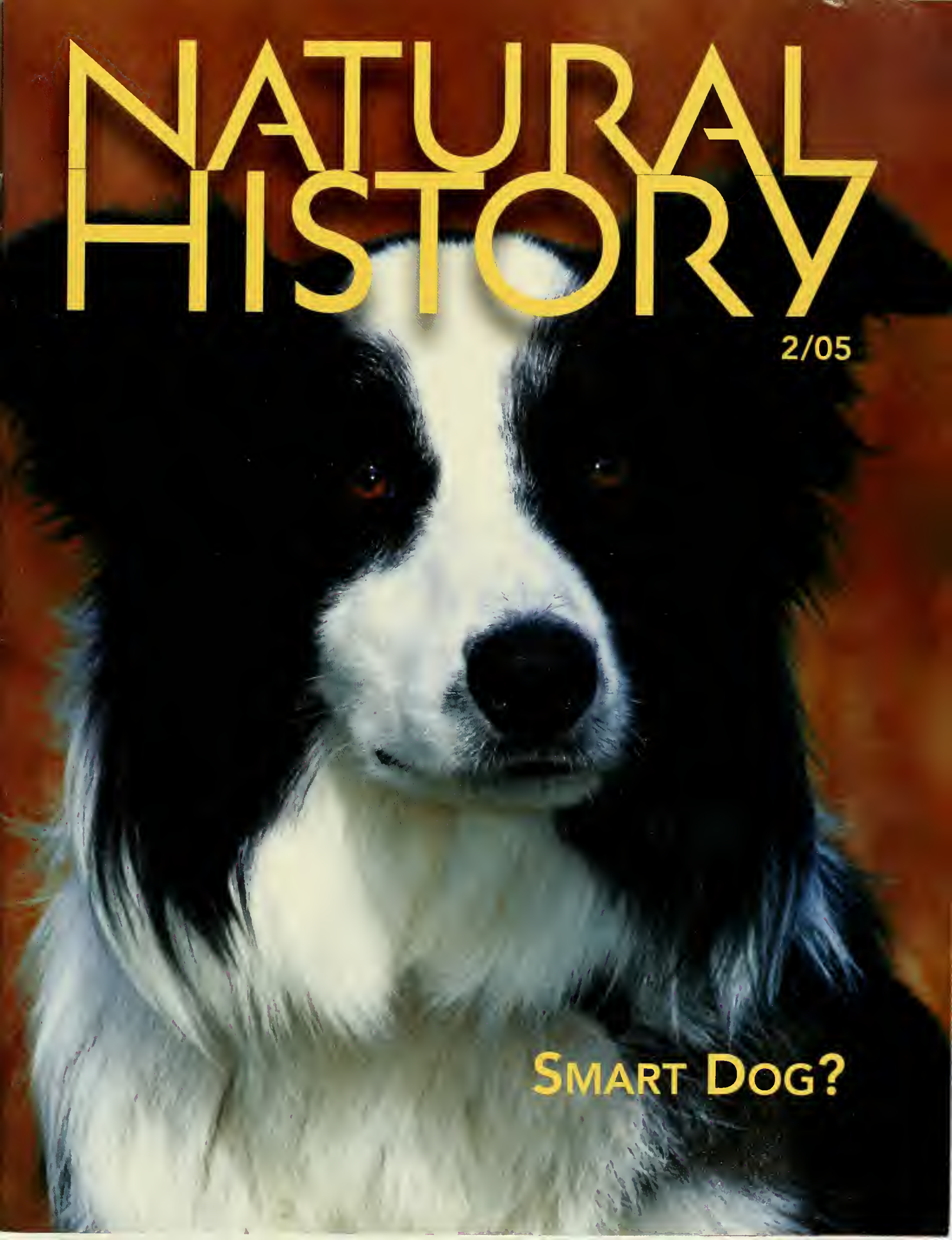

SMART DOG?


Future home of
TOYOTA
MOTOR MANUFACTURING, TEXAS

NATURAL HISTORY

FEBRUARY 2005 VOLUME 114 NUMBER 1

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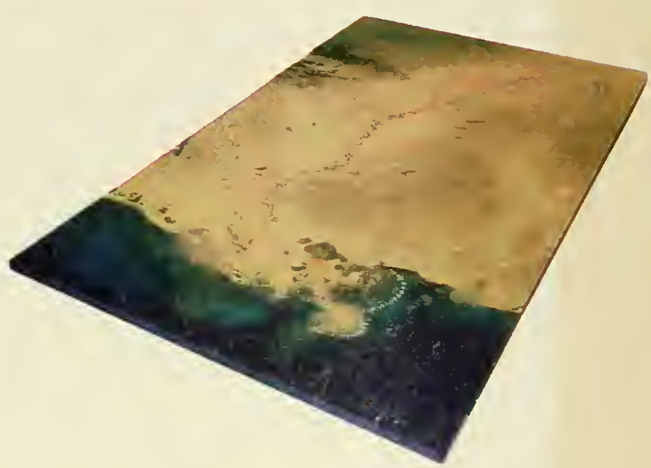

ON THE COVER:
Nine-month-old border collie

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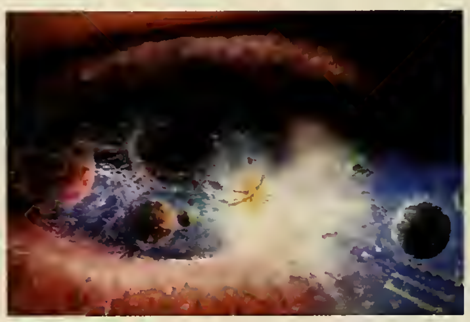

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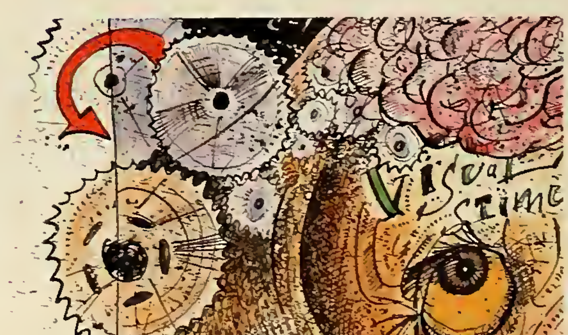

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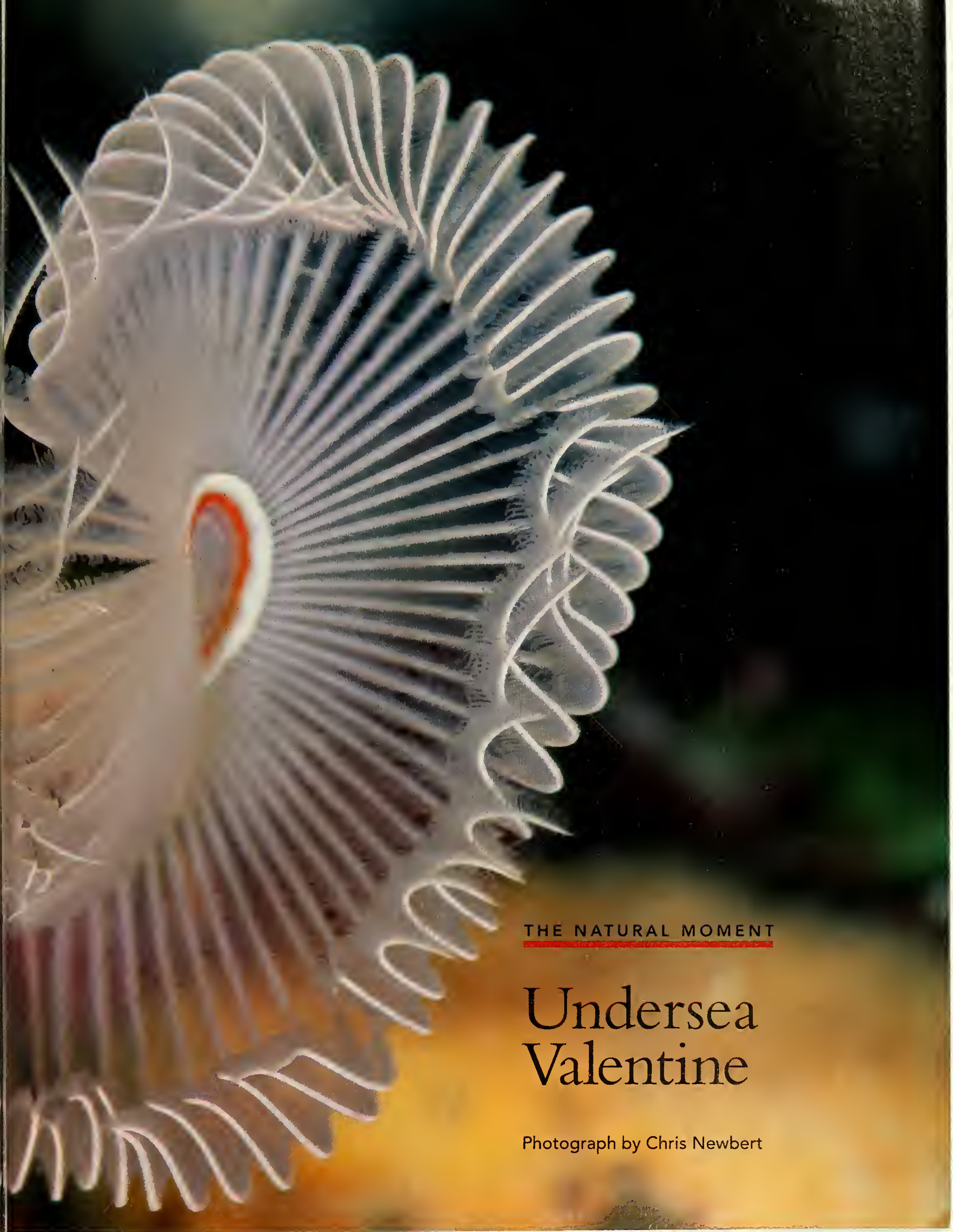

THE NATURAL MOMENT

Undersea Valentine

Photograph by Chris Newbert

THE NATURAL MOMENT

◄ *See preceding two pages*

Sometimes nature bears an uncanny resemblance to a cultural icon—the Roman alphabet displayed on an array of butterfly wings, for instance. Photographer Chris Newbert was leading a dive safari in the Solomon Islands of the South Pacific when a familiar shape stopped him cold: a heart. His seducer was a marine worm, or polychaete, measuring less than an inch across. Viewed from above, as in Newbert's photograph, the worm appears to be free-floating. In fact, only the crown of the worm's head is visible to the passing swimmer: the rest of its body is rooted in a tube.

Worms of the order Sabellida have evolved long appendages on their head, thereby earning them the name "feather dusters." Those ropy extensions, with their great swaths of surface area, serve two purposes: exchanging gases for respiration and netting food. Occasionally the worm will shed its crown or lose it to a hungry predator, and be forced to regenerate the headdress.

Newbert credits his find—which never changed shape while he was watching—to the Eden-like abundance of the Solomon Islands. Warm waters, rich marine life, and well-preserved coral reefs make the Solomons "one of the best diving sites in the world," he says. At least 485 species of coral live in the area—so surely, some worm head somewhere is the spitting image of Cupid himself.

—*Erin Espelie*

UP FRONT

Unintended Consequences

There are also unknown unknowns. —Donald Rumsfeld

The secretary of defense got that one right. He might have added that what you don't know you don't know can surely hurt you. Shea Penland's article, "Taming the River to Let In the Sea" (page 42), is an object lesson in the price of arrogance when dealing with nature. Rich Louisiana lowland along the Mississippi River and the Gulf Coast has been subject to recurrent flooding since the end of the last ice age. But another kind of flood, the surge of settlers and entrepreneurs who began arriving in the early nineteenth century, put irresistible pressures on every acre of lowland. The "obvious" way to claim the land for permanent use was to build levees against the vagaries of an unruly river.

Who would have thought that the very act of flood control would put the state, almost two centuries later, at risk of catastrophic inundation by a rising sea? Yet as the levees channeled the water, they also kept fresh soil carried by the muddy Mississippi from replenishing the sediments that made up the lowlands. Those lands settled and compacted, just as they always had, but without resupply, the surface sank. The subsidence, coupled with the projected rise of sea level caused by global warming, leaves much of coastal Louisiana, including New Orleans, just one perfect hurricane away from celebrating Mardi Gras with the catfish.

• • •

Susan Okie's "Fat Chance" (page 34) presents another example of a problem with an "obvious" solution. Since the mid-1980s, obesity, particularly in children, has ballooned into an epidemic. What's worse, "everyone knows" that the cure is simple: eat less, exercise more, choose your parents. But following those rules has about as much to do with losing pounds as getting rid of your germs has to do with recovering from a disease: while true, the rules are really more like truisms, and they can dangerously oversimplify the realities of confronting widespread obesity.

Weight control turns out to be as fraught with complexity as flood control. Lose weight, and not only does your appetite increase (as every dieter knows), but also your metabolism slows and your level of involuntary fidgeting declines. You even burn fewer calories per unit exercise. Gain weight, and the reverse holds. What's more, the genetic predisposition to obesity may involve dozens of genes, making the underlying metabolic interactions almost impossible to disentangle.

• • •

At least there's a simple answer to the question posed by Bruce Blumberg and Raymond Coppinger in our cover story (page 48): "Can Dogs Think?" Or is there? In spite of two books that present the evidence for language, thought, and general intelligence among those of the canine persuasion, the scientific jury is still out. The doggy brain remains the adorable mystery it always has been.

—Peter Brown

CONTRIBUTORS

Newbert

Since taking up underwater photography in 1972, **CHRIS NEWBERT** ("The Natural Moment," page 6) has won more than thirty international awards in the field. He published his first underwater-photography book, *Within a Rainbowed Sea,* two decades ago. The sequel, *In a Sea of Dreams,* a photographic collaboration with his wife, Birgitte Wilms, with text by Newbert, appeared in 1994. The couple has been featured on the Discovery Channel and on the Outdoor Channel's nature-photographer series, *Nature's Best.*

Henry

After living and working in Canada's boreal forest for much of the past thirty-five years, **J. DAVID HENRY** ("Northern Exposure," page 26) is keen to convey the richness of this little-known region and promote its sustainable economic use. A conservation ecologist in the Yukon Territory for the Canadian government's Parks Canada Agency, Henry has helped develop a program to monitor the regional effects of climate change in Kluane National Park and Reserve of Canada. He is also working with the Vuntut Gwitchin, a Native American group in the northern Yukon, on a study of wolverines and other predators. Henry's book *Canada's Boreal Forest* was published in 2002 by Smithsonian Institution Press. His article "Spirit of the Tundra" appeared in *Natural History* in the December 1998/January 1999 issue.

Okie

Penland

SUSAN OKIE ("Fat Chance," page 34) says her training as a family physician came in handy when she interviewed children and their parents, as well as physicians and scientists, for her forthcoming book, *Fed Up! Winning the War Against Childhood Obesity.* An award-winning science journalist, Okie began reporting for *The Washington Post* in the summer following her first year at Harvard Medical School. During her nineteen-year career with the paper, she covered a variety of national and international medical and science stories, including President Ronald Reagan's recovery from gunshot wounds and the AIDS epidemic in the United States and Africa. *Fed Up!* will be published this month by Joseph Henry Press. Okie is now a contributing editor for *The New England Journal of Medicine.*

Raised in northeastern Florida, **SHEA PENLAND** ("Taming the River to Let in the Sea," page 42) has been fascinated from an early age by the mysteries of coastal phenomena. While pursuing a Ph.D. in coastal geomorphology at Louisiana State University in the late 1980s, he investigated such environmental threats as coastal erosion, wetland loss, and oil spills throughout the world. Now the Director of the Pontchartrain Institute for Environmental Sciences at the University of New Orleans, and the University's Braunstein Professor of Petroleum Geology, Penland collaborates with fellow scientists and educators on practical solutions to coastal and environmental problems in Louisiana and elsewhere.

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Doctor Dolittle's Dilemma

Stephen R. Anderson's thesis ("A Telling Difference," 11/04) that syntax is unique to human communication is undermined by his lack of knowledge of critical distinctions between the grammars of spoken English and American Sign Language (ASL).

Koko uses several aspects of ASL syntax in the utterance, "You sip?" (see the photograph of Koko and me at a tea party, below). She indicates a question by maintaining eye contact, holding the sign for an extended period of time, and raising her eyebrows. She adjusts the subject of the phrase from "I sip" to "you sip" by moving the sign away from her lips and turning it toward me, thereby altering the direction of the sign. Her pursed lips and forward-leaning posture are additional grammatical inflections.

The sign "sip" is Koko's invention, a combination of the signs "eat" (fingers to mouth) and "drink" (thumb to mouth). "Sip" can be a noun or a verb; the distinction is marked in ASL by repetition of the contact motion if the sign acts as a noun, and by a single contact if it acts as a verb. Koko regularly uses this syntactic feature of sign.

Interested readers can see Koko's sign language in action in the 1999 PBS *Nature* documentary, "A Conversation with Koko."

Francine Penny Patterson
The Gorilla Foundation
Woodside, California

Given the premise that the "power and . . . centrality" of language exists in the production of novel sentences and in our use of recursive syntax, it comes as little surprise when Stephen R. Anderson concludes that language is uniquely human.

My own perspective suggests a different response, one that moves beyond asking whether apes "have" language or not. Indeed, humans don't "have" language. We create language when we interact: as linguists have shown, we dynamically transform each other's utterances as we talk and gesture in conversation. Seven years of research on the spontaneous communication patterns of captive bonobos and gorillas has taught me that these apes, too, create meaning with each other in nuanced ways, using vocalizations, facial expressions, gestures, and body postures.

A focus on whether apes can do what humans can do misses the real significance of ape communication—how beautifully it shows us the deep primate roots of the social, emotionally-based creativity inherent in human communication.

Barbara J. King
College of William and Mary
Williamsburg, Virginia

Stephen R. Anderson correctly concludes that animals do not have, and cannot learn, human language. But this negative conclusion overlooks the other half of Dr. Dolittle's dream: to understand animal communication systems on their own terms. Today, in experiments with a laptop and a microphone, bioacousticians can record, modify, and play back animals' vocalizations. They can then interactively explore how animals perceive and interpret the signals. Although such work is only beginning, it has already revealed surprising similarities between human and animal communication.

Complex animal vocalizations appear more akin to music, with its vaguely defined, affectively rich "meaning." For some people, this conclusion may be cause for relief—for others, disappointment. But for a latter-day Dr. Dolittle, it needn't be cause for despair. Animal communication systems are things of great interest and beauty, in and of themselves.

W. Tecumseh Fitch
University of St. Andrews
St. Andrews, Scotland

STEPHEN R. ANDERSON REPLIES: Francine Penny Patterson's comments unfortunately follow her standard practice of presenting only an isolated anecdote, heavily filtered by her own interpretation. The picture she supplies is certainly cute, but it is not worth a thousand words (or a thousand frames of video). When she provides a substantial unedited corpus of Koko's signing for independent evaluation by other investigators—as is standard in scientific inquiry—it will be possible to evaluate the significance of this work on our understanding of nonhuman primate cognitive abilities.

My conclusions about the research done on "signing" apes are not "undermined by . . . [a] lack of knowledge," as she would see if she read the chapter of my book, *Doctor Dolittle's Delusion*, that deals with signed language. Ms. Patterson herself confuses the morphological relation between a verb and a derived noun, with syntax.

I do not wish to deny that animals have rich mental lives, or that they communicate and "create meaning,"as Barbara J. King suggests. As W. Tecumseh Fitch points out, new techniques are being developed that enable us to investigate animal communication and cognition on their own terms. This research is much more constructive than the effort to show whether or not animals "have language" in the human sense.

Look Up!

I greatly enjoyed Neil deGrasse Tyson's delightful article, "Ringside Seat" (10/04), which mentions my work on the Supernova Early Warning System

(SNEWS) project. I have just two trivial corrections: first, I am now at Duke University, not at M.I.T., as mentioned in the article, and second, among the nine detectors mentioned, some are still in planning stages.

I would also like to add one important point: amateur astronomers (who are probably well represented among readers of *Natural History*) are an integral part of SNEWS. Because a neutrino burst can point only vaguely to a core collapse event, amateurs, with their worldwide viewing capabilities, may well be the first to pinpoint a supernova's location following a SNEWS alert. Information on how to sign up for a prompt neutrino-based alert can be found at the SNEWS Web site (snews.bnl.gov). I hope that some fortunate readers get the opportunity for ringside seats indeed!

Kate Scholberg
Duke University
Durham, North Carolina

The lessons in Neil deGrasse Tyson's article are best demonstrated in the exploration of the planets by robotic spacecrafts such as *Voyager* and *Cassini*.

Understanding the natural world often involves a detailed examination of a phenomenon, as well as the environment in which it resides—in other words, seeing the trees *and* the forest. Planetary explorers have done both for years. When photographing the moons in the outer solar system, *Voyager* carried both a narrow and a wide-angle camera, which enabled us to place high resolution images into wider geological contexts. *Cassini* carries two cameras for the same reason.

In 1989, when *Voyager* made close flybys of Neptune and Neptune's largest moon, Triton, the answers to our initial questions begot more questions. No longer were we asking how big Triton was, or how reflective its surface. Those questions were answered the minute we had the first resolved images of the moon. Instead, we could proceed to the next stage, and ask about the thermodynamic processes responsible for Triton's strange surface. Such is the nature of scientific progress. As long as the next level of detail brings patterns and not randomness, there will always be knowledge to gain by stepping in close for the magnified view and stepping back for the big picture.

Carolyn Porco
Cassini Imaging Team Leader
Boulder, Colorado

Natural History *welcomes correspondence from readers* (nhmag@naturalhistorymag.com). *All letters should include a daytime telephone number, and all letters may be edited for length and clarity.*

Curlews alter their eating habits just before migration.

Preflight Meals

As migration day approaches, birds build up their energy reserves. But fattening up means putting on weight—not an ideal state for animals that need to stay aloft for hours or days at a time. To compensate, internal organs such as the gizzard, gonads, and intestine may shrink. A mutable digestive tract is more common in birds than you might expect: in robins, for instance, it lengthens as the bird switches from a diet of earthworms in summer to less easily digested fruit salads in the fall.

This quirk of avian physiology turned out to be the key to explaining some odd behavior of the eastern curlew, a shorebird that vacations in Australia before taking off to breed in Siberia. According to the observations of two ornithologists, Yuri Zharikov and Gregory A. Skilleter, both of the University of Queensland in Brisbane, Australia, the curlew goes on a special diet as departure day approaches. Cutting down on hard-shelled crabs—its usual and still abundant prey—the bird turns to "yabbying," a time-consuming hunt for a certain shrimp that inhabits deep burrows. The shrimp is harder to find but more nourishing.

So what's going on? The curlew's gizzard—the organ that crushes the crab shells—apparently shrinks before migration, and so a diet heavy in crabs becomes a digestive challenge. Soft-shelled shrimps are suddenly the more appealing meal. ("Why do eastern curlews *Numenius madagascariensis* feed on prey that lowers intake rate before migration?" *Journal of Avian Biology* 35:533–42, 2004) —*Stéphan Reebs*

An Earthy Bouquet

Whether you call them *aaloo bhaja*, chips, french fries, *patat, patatas fritas, pommes frites*, or just plain fries, whether you douse them in cheese, gravy, ketchup, mayonnaise, vinegar, or just plain salt, most likely you find them hard to resist. One of the reasons could be their matchless aroma.

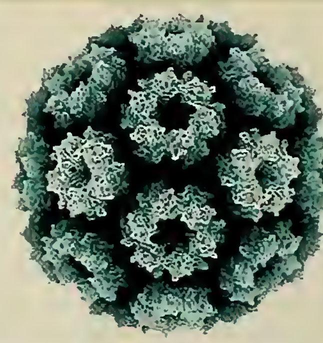
Wil A.M. van Loon and his chemist colleagues at Wageningen University in the Netherlands recently trapped and identified 122 compounds that waft through the air as one munches the greasy, golden strips of potato. Most of the compounds form in the browning process, and about fifty of them can be detected by an olfactorily alert diner. When asked to describe what they were smelling, the investigators' team of tasters detected not only the obvious aroma of fried potatoes, but also such notes as "buttery," "earthy," "green," "nutty," "spicy," and "sweaty." Move over, wine snobs: you've got some plebian competition. ("Identification and olfactometry of French fries flavour extracted at mouth conditions," *Food Chemistry* 90:417–25, 2005) —*Avis Lang*

Fearful Symmetry

To anyone in bed with a bad cold, the knowledge that the rhinovirus embodies a remarkable geometry is probably of little comfort. To physicists, however, it's of great interest.

Poised in the twilight zone between the living and the nonliving, a virus is just a short strand of DNA or RNA coiled tightly inside a shell made of protein molecules. As it happens, the shells (capsids) of more than half the known viruses are shaped much like an icosahedron—a three-dimensional structure with twenty identical faces, each an equilateral triangle. The icosahedron is one of only five regular convex polyhedrons, the symmetric "Platonic solids" that fascinated the ancient Greeks (the cube is another).

Roya Zandi, a physicist at the University of California, Los Angeles, and several of her colleagues have devised a model that explores the viral fondness for icosahedral architecture. Viruses form via "self-assembly": as they emerge spontaneously from a solution of RNA and protein molecules, they tend to take on shapes that minimize their total energy. A lot of energy is needed to break those shapes apart, and so they are highly stable.



What shape best serves a virus's needs?

Sure enough, the icosahedron emerged as the capsid's best bet for self-preservation. Add to that the fact that an icosahedral shell comes closest of all the Platonic solids to maximizing the volume that can be enclosed with a given amount of building material—thereby creating maximum wiggle room for the genome inside. All told, those features give icosahedral viruses a winning combination: maximum stability and ample living space. ("Origin of icosahedral symmetry in viruses," *Proceedings of the National Academy of Sciences* **101**:15556–60, 2004) —*Ashok Prasad*

Remains of a Roman granary at Hadrian's Wall in northern England

The Quartermaster's Challenge

Feeding the troops was just as important to the armies of ancient Rome as it is to the modern armies in Iraq. Grain, grain, and more grain was the basic diet, according to the second century B.C. historian Polybius. Each month, a Roman infantryman received four *modii* of wheat (the *modius,* an ancient Greek unit of dry measure, was about a third of a U.S. cubic foot). An auxiliary, or noncitizen, cavalryman received eight modii of wheat (presumably half for him and half for his horse) and thirty modii of barley (all for his horse). Of course, all that grain had to be stored somewhere.

Today the granaries of Roman forts have been leveled, but their foundations remain. Alan Richardson, an archaeologist based in the county of Cumbria in northern England, has calculated— on the basis of ground dimensions for two dozen granaries—how much floor space would have been allotted to each soldier's grain supply. His results show that each infantryman got five square feet, each cavalryman about seven and a half. Hence if Polybius was right, and cavalrymen were allotted nearly ten times the volume of food supplied to infantrymen, the cavalry forts probably needed resupply from a depot every two to four months, depending on such unknowns as whether the granaries had one story or two. Luckily for the troops, the Romans knew a thing or two about logistics. ("Granaries and garrisons in Roman forts," *Oxford Journal of Archaeology* **23**:429–42, 2004)

—*T.J. Kelleher*

Why We Count by Tens

Digging for fossils on Nova Scotia's Bay of Fundy can be unnerving. Twice a day the highest tides in the world sweep up the beach, threatening to pin unwary visitors at the foot of a bluff. But the rewards of digging there are worth the risk. One site, dated to between 345 million and 359 million years ago, has just yielded the oldest extensive collection of tracks ever found of four-legged terrestrial animals.

Spencer G. Lucas, a paleontologist at the New Mexico Museum of Natural History and Science in Albuquerque, and his colleagues report that six kinds of tracks, all left by different species and now carved into the rock, have been discovered by a local collector, Chris Mansky. The footprints range from three-quarters of an inch to four inches long, all of them made by feet with five digits. There's little evidence of dragging tails or bellies, suggesting that most of the animals were walking, not sliding or slithering.

Before the find, no one could be sure about the number of toes on the first terrestrial tetrapods. Five is a common number for fossil feet, but some with fewer digits had been found, and some with more. But the newfound tracks make it clear that pentadactyls were prominent among the earliest conquerors of land. (gsa.confex.com/gsa/2004AM/finalprogram/abstract_77934.htm)

—*S.R.*

Beach in Nova Scotia abounds in Paleozoic footprints with five toes.

May I Borrow Your Genome?

By any standard, the sex life of the edible frog, *Rana esculenta*, is a strange affair. Common in Europe, the frog is a hybrid of *R. lessonae* and *R. ridibunda*. Put a male and female *R. esculenta* together, though, and their offspring rarely survive. So how

Edible frog engages in genetic gymnastics.

does an edible frog avoid becoming the end of the genetic line? It broadens its horizons.

Before meiosis (the process of cell division that leads to the formation of sperm or eggs), *R. esculenta* dumps one parental half of its genome—usually the *R. lessonae* half—then goes in search of a mate from the species whose genome is now missing from its germ cells. So, in effect, *R. esculenta* is re-created from scratch with every new generation. Without enough *R. lessonae* to mate with, however, edible frogs couldn't reproduce. There's also the danger that *R. esculenta* numbers could explode, increasing the ratio of *R. esculenta* to *R. lessonae.* Shouldn't this system collapse? Heinz-Ulrich Reyer, a zoologist at the University of Zurich in Switzerland, and his colleagues have discovered why it doesn't.

The team compared *R. esculenta* and *R. lessonae* females throughout the year, noting the number of eggs in their ovaries, the concentration of sex hormones in their blood, their reproductive activities, and other relevant attributes. Their finding: the key to the stability of the system is that *R. lessonae* females can breed almost twice as often as their hybrid counterparts. ("Low proportions of reproducing hemiclonal females increase the stability of a sexual parasite-host system *(Rana esculenta, R. lessonae),*" *Journal of Animal Ecology* **73:** 1089–1101, 2004) —*Nick W. Atkinson*

Meltdown

From the Himalaya to Mount Kilimanjaro to Patagonia, the warming climate is assailing the world's 160,000 or so glaciers. Monitoring and measuring all the glaciers directly would be impossible, and so earth scientists have turned to satellite data for help. The Landsat satellites, managed jointly by NASA and the U.S. Geological Survey, have been tracking global land features at a 100-foot resolution since 1982. A first assessment for part of the European Alps, the world's most densely populated high-mountain region, has just been reported by geographer Frank Paul and his collaborators at the University of Zurich-Irchel in Switzerland. The picture is not encouraging.

Glaciers everywhere are in retreat.

Between 1985 and 1999 the Swiss glaciers lost at least 18 percent of their surface area—seven times the rate of loss calculated for the preceding century. At that rate, Paul and his colleagues expect, all Alpine regions below 6,500 feet will be iceless by the year 2050. And by 2100, your descendants vacationing in Switzerland will have to climb above 8,000 feet if they want to catch a glimpse of what remains of the icy behemoths. ("Rapid disintegration of Alpine glaciers observed with satellite data," *Geophysical Research Letters* 31: L21402, 2004) —*S.R.*

A Fine Romance

A juvenile goby prowls the corals of Australia's Great Barrier Reef. The solitary young fish is searching for a sexual partner, though the actual sex of the potential partner is not a factor: anygoby will do. The juvenile's gonads have no true gender, nor are they programmed to mature at some fixed age. Instead, an encounter with an available adult of the same species (most likely one whose mate has just died) will trigger sexual maturation into whichever gender is reproductively effective: male if the juvenile settles down with a female, female if the partner is a male.

This unusual sexual development shows up in the coral goby, *Gobiodon erythrospilus,* studied by Jean-Paul A. Hobbs and his co-workers at James Cook University in Townsville, Australia. In most vertebrates, gender is genetically determined, and sexual maturation follows a timetable. In some fishes, though, gender is not predetermined, and sex changes in adulthood are not at all unusual. The coral goby, however, is the first known vertebrate in which social conditions simultaneously determine both sexual maturation and gender identity.

For a coral goby, the first encounter makes the mate.

Being flexible is a fine way to maximize one's options: roomy expanses of real estate are rare, solitary adults occupying them are even rarer, and the coral reefs have so many predators that a juvenile in search of a mate can easily get eaten if it spends too much time cruising. So life is safer for a juvenile that can quickly adapt to the gender of any partner that fate sends its way—and baby fish are more likely to result. ("Social induction of maturation and sex determination in a coral reef fish," *Proceedings of the Royal Society of London B* 271:2109–14, 2004) —*S.R.*

Speed Limit

In Einstein's universe, time and distance may stretch like rubber, but the speed of light remains immutable.

By Neil deGrasse Tyson

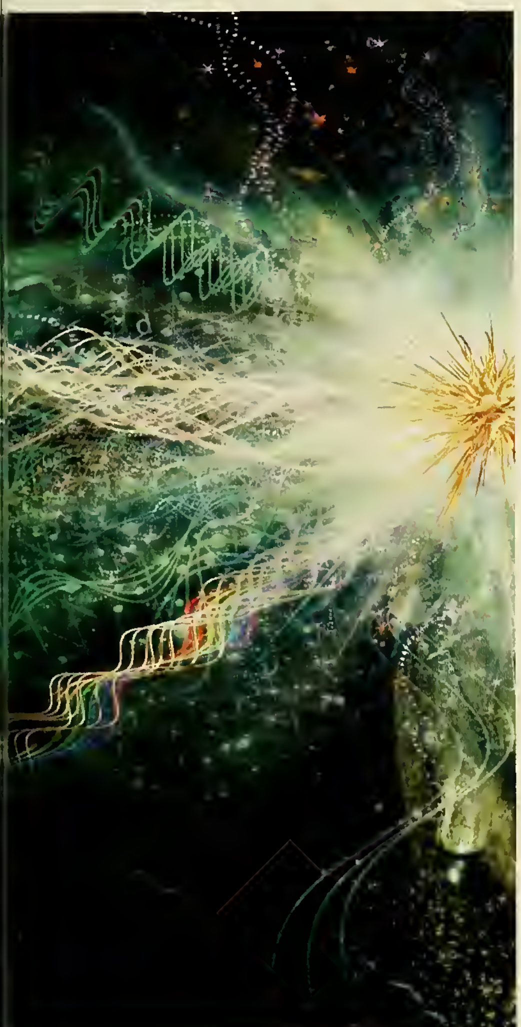
Other than the space shuttle and Superman, not much else in life travels faster than a speeding bullet. But nothing moves faster than the speed of light in a vacuum. Nothing.

But as fast as light moves, its speed is decidedly not infinite. Because light has a speed, astrophysicists know that looking out in space is the same as looking back in time. And with a good estimate for the speed of light, we can come close to a reasonable estimate for the age of the universe.

These concepts are not exclusively cosmic. True, when you flick on a wall switch, you don't have to wait around for the light to reach the floor. Some morning while you're eating breakfast and you need something new to think about, though, you might want to ponder the fact that you see your kids across the table not as they are but as they once were, about three nanoseconds ago. Doesn't sound like much, but stick the kids in the nearby Andromeda Galaxy, and by the time you see them spoon their Cheerios they will have aged more than 2 million years.

Minus its decimal places, the speed of light through the vacuum of space, in Americanized units, is 186,282 miles per second—a quantity that took centuries of hard work to measure with such high precision. Long before the methods and tools of science reached maturity, however, deep thinkers had thought about the nature of light: Is light a property of the perceiving eye or an emanation from an object? Is it a bundle of particles or a wave? Does it travel or simply appear? If it travels, how fast and how far?

In the mid-fifth century B.C. a forward-thinking Greek philosopher, poet, and scientist named Empedocles of Acragas wondered if light might travel at a measurable speed. But the world had to wait for Galileo, a champion of the empirical approach to the acquisition of knowledge, to illuminate the question through experiment. He describes the steps in his book *Dialogue Concerning Two New Sciences,* published in 1638: In the dark of night, two people, each holding a lantern whose light can be rapidly covered and uncovered, stand far apart from each other, but in full view. The first person briefly flashes his lantern. The instant the second person sees the light, he flashes his own lantern. Having done the experiment just once, at a distance of less than a mile, Galileo writes: "I have not been able to ascertain with certainty whether the appearance of the opposite light was instantaneous or not; but if not instantaneous it is extraordinarily rapid—I should call it momentary." Fact is, Galileo's reasoning was sound, but he stood much too close to his assistant to be able to time the passage of a light beam, particularly with the imprecise clocks of his day.



A few decades later the Danish astronomer Ole Romer diminished the speculation by observing the orbit of Io, the innermost moon of Jupiter. Ever since January 1610, when Galileo and his brand-new telescope first caught sight of Jupiter's four brightest and largest satellites, astronomers had been tracking the Jovian moons as they circled their huge host planet. Years of observations had shown that, for Io, the average duration of one orbit—an easily timed interval from the moon's disappearance behind Jupiter, through its re-emergence, to the beginning of its next disappearance—was just about forty-two and a half hours. What Romer discovered was that when Earth was closest to Jupiter, Io disappeared about eleven minutes earlier than expected, and when Earth was farthest from Jupiter, Io disappeared about eleven minutes later.

Romer reasoned that Io's orbital behavior was not likely to be influenced by the position of Earth relative to Jupiter, and so surely the speed of light was to blame for any unexpected variations. The twenty-two-minute range must correspond to the time needed for light to travel across the diameter of Earth's orbit. From that assumption, Romer derived a speed of light of about 130,000 miles a second. That's within 30 percent of the correct answer—not bad for a first-ever estimate, and a good deal more accurate than Galileo's "If not instantaneous. . . ."

James Bradley, the third Astronomer Royal of Great Britain, laid to rest nearly all remaining doubts that the speed of light was finite. In 1725 Bradley systematically observed the star Gamma Draconis and noticed a seasonal shift in the star's position on the sky. It took him three years to figure it out, but he eventually credited the shift to the combination of Earth's continuous orbital movement and the finite speed of light. Thus did Bradley discover what is known as the aberration of starlight.

Imagine an analogy: It's a rainy day, and you're sitting inside a car stuck in dense traffic. You're bored, and so (of course) you hold a big test tube out the window to collect raindrops. If there's no wind, the rain falls vertically; to collect as much water as possible, you hold the test tube in a vertical position. The raindrops enter at the top and fall straight to the bottom.

Finally the traffic clears, and your car hits the speed limit again. You know from experience that the vertically falling rain will now leave diagonal streaks on the car's side windows. To capture the raindrops efficiently, you must now tip the test tube to the angle that matches the rain streaks on the windows. The faster the car moves, the steeper the angle.

In this analogy, the moving Earth is the moving car, the telescope is the test tube, and incoming starlight, because it does not move instantaneously, can be likened to the falling rain. So to catch the light of a star, you'll have to adjust the angle of the telescope—aim it at a point that's slightly different from the actual position of the star on the sky. Bradley's observation may seem a bit esoteric, but he was the first to confirm—through direct measurement rather than by inference—two major astronomical ideas: that light has a finite speed, and that Earth is in orbit around the Sun. He also improved on the accuracy of light's measured speed, raising it to 187,000 miles per second.

By the late nineteenth century, physicists were keenly aware that light—just like sound—propagates in waves, and they presumed that if traveling sound waves need a medium (such as air) in which to vibrate, then light waves need a medium too. How else could a wave move through the vacuum of space? This mystical medium was named the "luminiferous ether." The physicist Albert A. Michelson, working with the chemist Edward W. Morley, took on the task of detecting it.

Earlier, Michelson had invented an

apparatus known as an interferometer. One version of this device splits a beam of light and sends the two parts off at right angles. Each part bounces off a mirror and returns to the beam splitter, which recombines the two beams for analysis. The precision of the interferometer enables the experimenter to make extremely fine measurements of any differences in the speeds of the two light beams: the perfect device for detecting the ether. Michelson and Morley thought that if they aligned one beam with the direction of Earth's motion and made the other transverse to it, the first beam's speed would combine with Earth's motion through the ether, while the second beam's speed would remain unaffected.

Turns out, M & M got a null result. Going in two different directions made no difference to the speed of either light beam; they returned to the beam splitter at exactly the same time. Earth's motion through the ether simply had no effect on the measured speed of light. Embarrassing. If the ether was supposed to enable the transmission of light, yet it couldn't be detected, maybe the ether didn't exist at all. Light turned out to be self-propagating: neither medium nor magic was needed to move a beam from one position to another in the vacuum. Thus, with a swiftness approaching the speed of light itself, the luminiferous ether entered the graveyard of discredited scientific ideas.

And thanks to his ingenuity, Michelson also further refined the value for the speed of light, to 186,400 miles per second.

Beginning in 1905, investigations into the behavior of light got positively spooky.

That year, Einstein published his special theory of relativity, in which he ratcheted up M & M's null result to an audacious level. The speed of light in empty space, he declared, is a universal constant, no matter the speed of the light-emitting source or the speed of the person doing the measuring.

What if Einstein is right? For one thing, if you're in a spacecraft traveling at half the speed of light and you shine a light beam straight ahead of the spacecraft, you and I and everybody else in the universe who measures the beam's speed will find it to be 186,282 miles per second. Not only that, even if you shine the light out the back, top, or sides of your spacecraft, we will all continue to measure the same speed.

Odd.

Common sense says that if you fire a bullet straight ahead from the front of a moving train, the bullet's ground speed is the speed of the bullet *plus* the speed of the train. And if you fire the bullet straight backward from the back of the train, the bullet's ground speed will be its own *minus* that of the train. All that is true for bullets, but not, according to Einstein, for light.

Einstein was right, of course, and the implications are staggering. If everyone, everywhere and at all times, is to measure the same speed for the beam from your imaginary spacecraft, a number of things have to happen. First of all, as the speed of your spacecraft increases, the length of everything—you, your measuring devices, your spacecraft—shortens in the direction of motion, as seen by everyone else. Furthermore, your own time slows down exactly enough so that when you haul out your newly shortened yardstick, you are guaranteed to be duped into measuring the same old constant value for the speed of light. What we have here is a cosmic conspiracy of the highest order.

Improved methods of measuring soon added decimal place upon decimal place to the speed of light. Indeed, physicists got so good at the game that they eventually dealt themselves out of it.

Think about it this way: Units of speed always combine units of length and time—fifty miles per hour, for instance, or 800 meters per second. When Einstein began his work on special relativity, the definition of the second was coming along nicely, but definitions of the meter were completely clunky. As of 1791, the meter was defined as one ten-millionth the distance from the North Pole to the equator along the line of longitude that passes through Paris. In 1889 the meter was redefined as the length of a

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A Simple Heart

Its shape, in zebra fish, goes with the (blood) flow.

By Adam Summers ~ Illustrations by Tom Moore

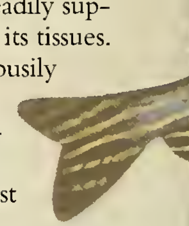
Blood is amazingly delicate and unstable. Essentially a suspension of cells and proteins in water, blood forms clots or clumps in response to any harsh mechanical treatment. That property keeps blood from pouring out uncontrollably after a break in a blood vessel, but it has also made it impossible so far to devise an artificial device that can pump blood without degrading its components and thereby increasing the risk of stroke.

The human heart is so miraculously gentle that it avoids that pitfall. Even as it contracts a hundred thousand times a day, pushing blood through a network of piping that is astonishingly complex, it keeps clotting to a minimum—in part because of its shape. What has been a mystery is how the heart achieves its shape, because its form doesn't seem to be entirely the responsibility of the genes that are active as the organ develops. Biomechanists studying the hearts of embryonic zebra fish have discovered that what shapes the heart, in part, are the forces of blood flow—the very same forces that, in other circumstances, turn blood into clotted goo.

Fish are half-hearted when it comes to blood flow, at least compared with mammals. The mammalian heart is actually two conjoined pumps: one sends blood to the lungs, to be oxygenated; the other supplies blood to the tissues of the body. A fish's heart, however, has a single pump that pushes blood into a bed of capillaries in the gills, before circulating it at low pressures throughout the rest of the body. In spite of such a major organizational difference, the early development of fish and human hearts is similar, and both kinds of heart have a similarly gentle effect on the fluid they pump.

Cutaway ventral ("front") views (not to scale) of three vertebrate hearts—human (left), bird (center), and amphibian—demonstrate the variety of shapes that the organ can assume. In the human and the bird hearts, the right side (the nomenclature reflects the heart owner's point of view) sends blood (blue) to the lungs to be oxygenated; on returning to the heart, the oxygenated blood (red) is then pumped to the rest of the body. Amphibian hearts have a three-chambered structure; although deoxygenated blood enters on the right of the heart and oxygenated blood enters on its left, the two flows are united (purple) in a Y-shaped structure called the conus arteriosus before they branch toward the lungs (and skin) or the rest of the body.

The zebra fish, a common denizen of home aquariums, has become a favorite subject of study by developmental biologists because its embryonic stage is transparent and a good size for microscopy, two attributes that make its organ systems easy to observe as they form. If you watch closely, you can see the heart of a zebra fish embryo beating rhythmically within a day of fertilization. That heartbeat has been a long-standing puzzle: Why does it begin so early, far sooner than seems necessary? At that stage, the embryo is still so small that diffusion alone could readily supply oxygen and nutrients to its tissues. Yet, there is the tiny heart, busily working away, pushing blood through a rudimentary circulatory system.



Jay R. Hove, a physiologist now at the University of Cincinnati, and Reinhard W. Köster, now a biologist at the the Institute of Developmental Genetics in Munich, and colleagues at Caltech have presented convincing evidence that the paradoxically early appearance of the fish's heart enables fluid forces to shape the young pump into a gentle giant. Earlier investigations had already demonstrated that cardiac endothelial cells, primordial cells that control the development of the heart, change shape when subjected to shear forces—just the kind of forces a fluid exerts when it flows past a fixed object. Hove and Köster have shown experimentally that the shear forces of flowing blood in the developing heart are strong enough to reshape the heart as it matures.

Measuring fluid forces in the heart of an embryonic zebra fish a day and a half after fertilization is no mean feat. After all, the entire embryo could fit on the head of a pin, and the heart is far thinner than a human hair. No probe available is small enough to measure flow directly in something that size. The investigators had to rely instead on clever but indirect techniques.

The heart of the embryonic zebra fish first appears as a clear, straight tube, except for two regions of swelling along its length [*see diagrams at right*]. The two swellings contract in sequence, just as they do once they fully differentiate into the atrium, which receives blood from the body, and the ventricle, which pushes the fluid pumped into it from the atrium back out. Hove, Köster, and their colleagues estimated the amount of blood pumped with each stroke by measuring the initial and final volume of the ventricle, the larger of the two chambers of the heart. To make the measurement, they highlighted the blood of a number of zebra fish with a glowing green dye, then filmed the heart as it fully contracted and expanded.

From the volume of blood pumped and the duration of a single heartbeat, the team calculated the speed of the blood as it flowed through the heart. And once they had the fluid speed, they could determine the shear stress in the heart wall. The forces they calculated might seem small, but in a fish just thirty-seven hours old, the forces are strong enough to change which genes are turned on or off in endothelial cells, thereby reshaping the cells. Perhaps the shear forces trigger the cell membrane to release proteins that affect gene expression.

Zebra fish heart thirty-seven hours into development (a) is essentially a tube with two bulges, the atrium and the ventricle, that pump blood through the circulatory system. After four and a half days (b) the heart bends so that the atrium lies next to the ventricle, another contractile chamber called the bulbus arteriosis forms, and valves develop between chambers to prevent reverse movement of blood. Surgically inserted glass beads, either at the entrance to the atrium (c) or the exit from the ventricle (e), prevent normal development of the heart: the heart does not bend, neither the bulbus arteriosis nor the valves form, and the ventricle fuses shut (d, f).

A different technique showed that even greater shear forces can develop in older embryos. By four and a half days after fertilization, a zebra fish has grown to about an eighth of an inch long, and its heart has become as wide as a human hair. The heart is bent in such a way that the atrium and the ventricle lie next to each other, and valves to prevent blood from flowing backwards are already recognizable. Again the investigators filmed dark blood cells as they swirled in bright green-dyed plasma through the heart, then tracked the filmed positions of the cells frame-by-frame with the help of a computer. On the basis of that analysis they built a computer-based model of the blood flow, which showed that a high-speed jet of blood passes from atrium to ventricle with each beat, creating vortexes in the blood. The shear forces exerted by the vortexes are strong enough to rearrange the cytoskeleton of an endothelial cell, and thus to change the cell's shape.

The biomechanists hadn't proved that blood flow, rather than blood pressure, is the most important factor in heart development. To make sure, the workers implanted a microscopic spherical bead, either at the entrance or the exit of each heart: a bead that blocks the entrance reduces both blood flow and pressure in the heart, whereas one that blocks the exit reduces just the flow, not the pressure. After only twenty hours the results were clear. With either blockage the heart failed to develop normally: the valves did not form, the atrium and ventricle did not lie next to each other, and a contractile third chamber that appears in the normal heart never developed. Shear force is the major player in shaping the developing heart.

The heart works, in fact, largely because it is flexible. The genome does not code for a pump of specific shape, but rather for a cell type that can respond to shear, the force that damages blood cells. Those cells ensure that as the heart develops, it grows in ways that minimize shear. The end result is a pump gentle enough to circulate blood without causing dangerous clots.

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prototype bar made of platinum-iridium alloy, stored at the International Bureau of Weights and Measures in Sèvres, France, and measured at the temperature at which ice melts. In 1960, the basis for defining the meter shifted again, and the exactitude increased further: 1,650,763.73 wavelengths, in a vacuum, of light emitted by the unperturbed atomic energy-level transition 2*p*10 to 5*d*5 of the krypton-86 isotope. Obvious, when you think about it.

Eventually it became clear to all concerned that the speed of light could be measured far more precisely than could the length of the meter. So in 1983 the General Conference on Weights and Measures decided to define—not measure, but define—the speed of light at the latest, best value: 299,792,458 meters per second. In other words, the definition of the meter was now forced into units of the speed of light, turning the meter into exactly 1/299,792,458 of the distance light travels in one second in a vacuum. And so tomorrow, anyone who measures the speed of light even more precisely than the 1983 value will be adjusting the length of the meter, not the speed of light itself.

In 1983 the speed of light was defined—not measured—as 299,792,458 meters per second.

Don't worry, though. Any refinements in the speed of light will be too small to show up in your school ruler. If you're an average European guy, you'll still be slightly less than 1.8 meters tall. And if you're an American, you'll still be getting the same bad gas mileage in your SUV.

The speed of light may be astrophysically sacred, but it's not immutable. In all transparent substances—air, water, glass, and especially diamonds—light travels more slowly than it does in a vacuum.

But the speed of light in a vacuum is a constant, and for a quantity to be truly constant it must remain unchanged, regardless of how, when, where, or why it is measured [*see "The Importance of Being Constant," by Neil deGrasse Tyson, November 2004*]. The light-speed police take nothing for granted, though, and in the past several years they have sought evidence of change in the 14 billion years since the big bang. In particular, they've been measuring the so-called fine-structure constant, which is a combination of the speed of light in a vacuum and several other physical constants, including Planck's constant, π, and the charge of an electron.

This "derived constant" is a measure of the small shifts in the energy levels of atoms, which affect the spectra of stars and galaxies. Since the universe is a giant time machine, in which one can see the distant past by looking at distant objects, any change in the value of the fine-structure constant with time would reveal itself in observations of the cosmos. For cogent reasons, physicists don't expect Planck's constant or the charge of an electron to vary, and pi will certainly keep its value—which leaves only the speed of light to blame if discrepancies arise.

One of the ways astrophysicists calculate the age of the universe assumes that the speed of light has always been the same, so a variation in the speed of light anywhere in the cosmos is not just of passing interest. But as of October 2004, physicists' measurements show no evidence for a change in the fine-structure constant across time or across space.

No question about it. Einstein in 1905 and the weights and measures mavens in 1983 were on to something: The speed of light is not just a good idea. It's the law.

Astrophysicist Neil deGrasse Tyson *is the Frederick P. Rose Director of the Hayden Planetarium in New York City. His latest book, with Donald Goldsmith, is* Origins: Fourteen Billion Years of Cosmic Evolution *(W.W. Norton, 2004).*

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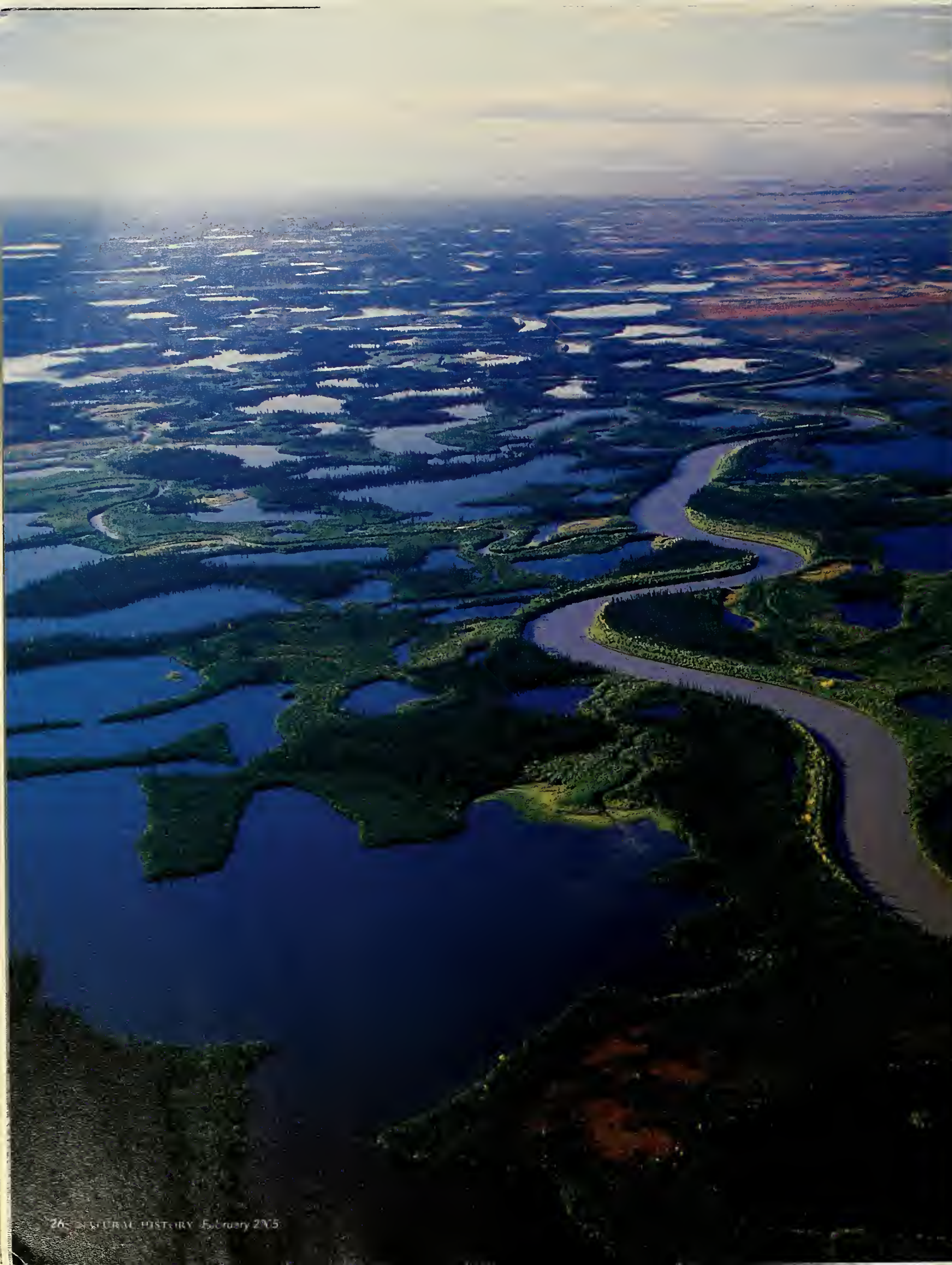

Northern Exposure

Can the planet-encircling boreal forest survive global warming and resource exploitation?

By J. David Henry

It's a clear autumn morning in northern Saskatchewan, and I am knee-deep in a peat bog. An invigorating breeze sets lemon-gold aspen leaves quivering in the surrounding hills, while above me, steeple-topped spruce trees sway in unison like a Baptist church choir. I bend forward, stretch out my fingers, and bury them deeply in the purple cushion of sphagnum moss. As my fingers sense the icy cold, I feel rooted in all the wetlands of the taiga—the boreal, or northern, forest that encircles the globe from Siberia to Scandinavia, from Newfoundland to the interior of Alaska.

Viewed from outer space, the taiga appears as a dark green mantle draped across the shoulders of the Earth. At

Boreal, or northern, forest, also known as the taiga (green areas in map above), makes up more than a quarter of the world's forests. The aerial photograph shows the view upriver in August, near the western edge of the broad delta of the Mackenzie River, which flows north through Canada's Northwest Territories and then into the Arctic Ocean. The low-lying land is forested mostly with conifers. The brownish areas bordering the Richardson Mountains, upper right, are covered with treeless tundra vegetation.

Fireweed and deciduous shrubs sprout in a freshly burned area of the boreal forest near Kluane National Park and Reserve in southwestern Yukon. Recurrent fires are a natural part of the ecology of the forest, releasing nutrients through the breakdown of woody debris and clearing the way for a new cycle of plant succession. Global warming, however, is likely to increase the frequency and destructiveness of the fires, which would allow grassland vegetation to overtake wooded areas.

ground level it comprises tracts of both dense and open-canopy forest dominated by conifers such as fir, larch, pine, and spruce, interleaved with boggy terrains. In Eurasia as well as in North America, the habitat extends some 4,000 miles east to west, and anywhere between 600 and 2,000 miles north to south, for a global total of some 1.5 million square miles [*see map on preceding page*]. The coniferous forests of the taiga make up 27 percent of the world's forests. Nothing like this vast, circumpolar ecosystem occurs in the Southern Hemisphere. At comparable southern latitudes—between fifty and seventy degrees—there is little land and much open ocean; moreover, conifers in the Southern Hemisphere are usually confined to higher elevations.

In North America at least, the northern and southern limits of the boreal forest are determined by the boundary between the frigid Arctic air overlying the Far North and the warmer air overlying the continental interior. The boundary between these air masses shifts with the seasons: its average winter position determines the southern limits of the boreal forest; its average summer position determines the northern limits. Trees and shrubs that fall within the winter range of the Arctic air mass must be able to survive minus-40-degree (or colder) weather for a month or longer. Only such hardy species as aspen, black and white spruce, Labrador tea, and tamarack can withstand such conditions—which they do by actively transporting water out of their living cells at the start of winter. As summer approaches, the air-mass boundary shifts northward, but north of it conditions remain too cold for the forest vegetation to prosper. The habitat gives way to the Arctic tundra, a treeless zone dominated by grasses, lichens, and sedges.

What alarms those of us who study the ecology of this vast northern habitat is that it is under siege from two great threats. One is global warming. The average annual temperature of the Earth's surface has risen by 9 degrees Fahrenheit since the end of the last ice age. Most climatologists agree that one degree of that increase—more than 10 percent of the total—has taken place in the past hundred years alone. And the Arctic is warming nearly twice as fast as the rest of the planet.

Studies of past variations in climate show that the boreal forest is sensitive to even small trends in temperature change, though how the forest will respond to global warming is hard to predict. For example, one might assume that the warming will drive the tree line northward and into higher elevations. But Isabelle Gamache and Serge Payette, both biologists at the University of Laval in Quebec, found that though black spruce forests near the tree line in northern Quebec have undergone accelerated growth in the past decade, they have seldom produced a good crop of cones. Hence the tree line in this region has not yet moved beyond its historical northern boundary.

The second great threat to the taiga is exploitation by people. In many areas around the globe, timber from the taiga is being harvested at unsustainable rates, and clear-cuts and logging roads have made the forest into a patchwork quilt. Cut lines pierce the habitat so that the underlying rock strata can be probed seismically for oil and gas, and pipelines are built to carry the fossil fuel. Massive hydropower developments are flooding large areas, disrupting caribou migration routes and allowing silt to accumulate in gravel spawning beds, making them unsuitable for the fish.

There is also a third, nonphysical threat to the habitat. It may be the biggest threat of all: many people just don't care. In North America the taiga is often devalued as "the land of little sticks," "just the bush," or "the land that God gave Cain." To many the habitat is nearly worthless, with poor soils that are difficult to farm and stunted trees good only for making grocery bags, newsprint, and toilet paper. Whatever resources there may be—or so goes the prevailing attitude—should be freely exploited. Many people from Siberia and western Russia, and, to a lesser extent, from Finland and Scandinavia, hold similar views.

Global warming and resource exploitation pose a one-two punch to an ecosystem that has flourished since the continental ice sheets melted away: the taiga has occupied its more southerly regions for between 10,000 and 12,000 years, and more northerly reaches for between 5,000 and 10,000 years. But just what do we stand to lose in this "land of little sticks"? And what, within human means, can be done to preserve it?

Are the trees of the boreal forest good only for making grocery bags, newsprint, and toilet paper?

Summer is short and intense in the taiga, winter cold and harsh. In the summer, hordes of insects rise in great clouds from the endless maze of bogs and surface water, supporting billions of birds that migrate to the boreal forest to raise their young. The scope of this phenomenon is just beginning to be appreciated. In North America, for instance, 290 species of birds breed in the boreal forest. As much as 40 percent of the continent's waterfowl population breeds there, including all of the whooping cranes that survive in the wild.

During the long winter, the boreal forest is covered in a warm blanket of soft, fluffy snow that provides insulation for many of the plants and animals. William O. Pruitt Jr., a zoologist at the University of Manitoba, has documented that at least six inches of taiga snow is essential to protect mice, voles, and shrews, as well as certain boreal birds that burrow into it at night. The snow also protects plant roots and, in the case of herbs, buds as well.

Permafrost, or permanently frozen ground, which underlies most of the Arctic tundra, also underlies nearly two-thirds of the boreal forest. "Permanent," of course, is a relative term: soil scientists define permafrost as any soil layer that remains continuously frozen for two or more years. Where permafrost is present, plant roots can grow only as deep as the annual thaw, and the active, upper layer of soil must supply all of the minerals and nutrients the plant needs. One of the most important factors affecting permafrost is vegetation cover: the thicker the cover, the more the permafrost is insulated against change.

In addition to its seasons, the taiga is subject to longer ecological cycles as well as to ongoing noncyclic processes. In many parts of the Arctic the lemming population in any particular locale tends to build up, then crash, in a four-year cycle—giving rise to the folk legend, now proved false, that lemmings are programmed to commit mass suicide when they become overabundant. Similarly, populations of moun-

Trans-Alaska Pipeline, pictured here near Atigun Pass, carries oil 800 miles, from Alaska's North Slope south to the ice-free port of Valdez. Such pipelines, along with roads, timber cutting, hydroelectric projects, and other forms of resource exploitation, contribute to the fragmenting of what were once continuous tracts of forest.

Bull moose in Alaska issues a call during the rut. The species' dispersal instincts are well adapted to the forest's fire ecology. If a female with a yearling gives birth, she drives the yearling away, thereby reserving the local habitat for herself and her new calf. Meanwhile, the yearling may locate newly burned, browse-rich areas, which are widely scattered.

tain hares in the Siberian taiga fluctuate according to a ten-year cycle. In North America, the boreal forest is the land of the snowshoe hare and its predators—coyote, red fox, lynx, and great horned owl. Populations of snowshoe hares also fluctuate dramatically over approximately ten-year periods, increasing a thousandfold, then crashing. The hare's predators, particularly the Canadian lynx, closely follow suit, albeit a year or two behind the cycle of the hares. Furthermore, the cycle is more or less in sync across the entire North American taiga: hare densities usually peak within a year or two at every location.

One of the most important processes shaping the boreal forest is fire: indeed, the taiga can be considered a forest forged in fire. Research done in North America shows that a typical tract is apt to be consumed by a forest fire every century or two, a pattern that has persisted for thousands of years. Forest fires are often the principal agent of forest regeneration, releasing nutrients through the breakdown of woody debris and clearing the way for a new cycle of plant succession. The mosaic of habitats left by fires of various vintages enhances the region's overall biodiversity.

Because fire is a continual factor in their lives, many boreal species have evolved adaptations to it. The seeds of bristly sarsaparilla, currant, and soapberry lie dormant in the soil and germinate only after being burned: ecologists call the process "seed banking." Most of the cones produced by jack pine and lodgepole pine look like miniature hand grenades—and are just about as tough. They, too, normally open only after being exposed to the heat of a forest fire; in fact, once ignited, they ooze resin, feeding the fire and so helping ensure that they will open completely and disperse their seeds. Even the timing is adaptive. Just after a fire the ground is relatively clear of competing species and the soil is rich in minerals: that's when the seeds have their best chance to germinate and thrive.

The boreal forest is also a land of bogs, which we in Canada commonly call muskegs, a word derived from the Cree for "grassy bog." A bog can develop in any depression where water collects. Its prime vegetation is sphagnum (any of fifteen different species), a three-inch-tall moss that tends to dominate other plant life by blocking drainage and limiting nutrients. As the years pass and new moss grows, the remains of dead moss slowly accumulate beneath the living layer. In the cold, waterlogged, acidic, and increasingly compacted layers of peat thus created, organic decay virtually halts.

Because the material in them decays so poorly, peat bogs are among the Earth's most important carbon sinks—storehouses of carbon. Ever since the last ice age, they have helped offset global climate warming by taking carbon out of the atmosphere (where it circulates as carbon dioxide and acts like a heat-trapping blanket) and incorporating it into organic molecules—where, because of the insufficient decomposition, it remains locked up.

The capacity of bogs to offset global climate change is now being put to the test. As many people are well aware, climate change is, in part, a natural trend. But the trend appears to be accelerating because of the carbon dioxide and other so-called greenhouse gases that burning fossil fuels release into the atmosphere [*see "Glaciers That Speak in Tongues," by Wallace S. Broecker, October 2001*].

Peat bogs in the boreal forest are among the Earth's most important carbon sinks, acting as brakes on global warming.

The ongoing global climate change is thought to be drying out large areas of taiga, lowering the water table, accelerating the rate of decomposition (thereby releasing greenhouse gases more rapidly into the air), and greatly increasing the frequency of forest fires. The area burned every year in western North America has doubled in the past thirty years, and fire ecologists expect it to increase by as much as 80 percent in the twenty-first century.

The warmer, drier climate has also helped cause massive outbreaks of spruce bark beetle and mountain pine beetle in the northern conifer forests. The insects have left millions of dead mature trees in their wake, thereby further increasing the risk of conflagrations. And as the region warms up, the peat bogs will be subject to more forest fires and more rapid decomposition, turning their sequestered organic carbon into atmospheric carbon dioxide and methane. Those effects could transform the circumpolar boreal forest from a carbon sink into a carbon source.

Across the North, the higher average temperatures are also thawing long-stable layers of permafrost, causing some trees to tilt or topple. Slopes are already failing, causing large landslides in forested areas. And when thawing causes the ground to shift, pipelines, too, can be damaged, threatening surrounding habitats with polluting spills. On the Alaska-Yukon border, glaciers are melting at three times their long-term average rate. Even though Alaska and the Yukon have suffered severe droughts and record numbers of forest fires during the past two summers, glacier-fed rivers and lakes have been in flood throughout most of those seasons, drowning vegetation and causing damaging erosion.

More clearly within humanity's power to control than global warming is, are the effects of resource exploitation within the taiga itself. On the basis of satellite images, the organization Global Forest Watch, based in Washington, D.C., has mapped what it calls the "intact forest landscapes" of the circumpolar taiga. Those tracts are defined as forested areas of at least 200 square miles that show no signs of recent logging, mining, hydroelectric development, or clearing for agriculture.

Only in the more northerly reaches of the forest, where the canopy is relatively open, are such tracts common; in the southern boreal forest, unfragmented forests are becoming increasingly rare. Thirty years ago, when I worked as a boreal ecologist in Alberta, the northern half of the province was almost intact. Now there are half a million miles of roads, pipelines, and seismic cut lines. The same pattern holds elsewhere in North America and in Eurasia.

Such forest fragmentation is a consequence of decisions made both by outside developers and by local inhabitants. The taiga is no vacant wilderness. In Canada, for instance, almost 4 million people—a third of them Native Americans—live in the boreal forest. Those northern residents have to support themselves and their families. How should they make a living?

Women in Övertorneå, a rural municipality in Sweden's boreal forest region, do their family baking in a communal hut that makes efficient use of fuel and other resources. Such facilities grew out of an effort, following a recession in the 1980s, to create an ecologically friendly, self-sustaining local economy. The idea of what is now known as an "ecomunicipality" proved workable in Scandinavia and Finland and is now generating adherents in Canada, New Zealand, and the United States.

One option is to embrace plans for resource extraction and hydroelectric megaprojects, in the expectation that development will create jobs and, in the long run, lead to more modern local economies. The counterargument, however, is that any such gains will only be short-lived. After the resources have been extracted, the region could be left without a sustainable economic base, stripped even of the natural habitats that could draw ecotourists or support traditional forms of subsistence.

One innovative response to the dilemma is the "ecomunicipality" movement, born in the taiga regions of Sweden and Finland during the economic recession of the early 1980s. One of the hardest-hit northern areas was Övertorneå, a Swedish *kommun*, or rural municipality, on the Swedish-Finnish border. Övertorneå embraced about 6,000 inhabitants, distributed over a 900-square-mile area that included the main town and several villages. In the early 1980s unemployment skyrocketed to 20 percent, and many people, particularly young families, migrated to urban centers to seek jobs.

Amid the general sense of despair and pessimism, some citizens and government leaders suggested reviving the local economy along more ecologically sustainable lines. More than 600 residents took part in study circles to discuss regional development, and village associations took charge of exploring various initiatives and putting them into practice. Out of those grass-roots citizens' groups emerged Sweden's first ecomunicipality.

Blanket of snow covering the Finnish taiga, including the spruce trees pictured here, provides protective insulation for small animals as well as for the roots of trees and other vegetation.

During the next six years, more than 200 small businesses that promoted ecological sustainability were launched in Övertorneå. The new enterprises included beekeeping operations, ecotourism, fish farms, and a regional association of organic farms. To support the vision of sustainability, the Övertorneå government invested in a heating plant powered by so-called biofuels (ethanol, methane, and other fuels produced from the biological waste products of farms, sawmills, and other enterprises). The local government also purchased organic foods in greater quantities, established a health spa based on organic foods and Finnish herbal remedies, and built an "ecovillage" (a subdivision designed for a high level of self-sufficiency and communal cooperation) to attract new families into the area. The initiatives not only helped dispel the widespread pessimism about the region's future, but also revived interest in local culture, including language, music, and theater.

More recently, Övertorneå has encouraged greater use of public transportation by expanding its system of buses and vans and by making them free of charge. Many citizens and the government have bought ethanol-burning vehicles, and ethanol fuel pumps are now available in the region.

As additional ecomunicipalities began to arise elsewhere in Sweden and in Finland, Norway, and Denmark, the planning process they followed became more systematized, and it is now promoted by an advisory and research organization called The Natural Step (www.naturalstep.org). The movement has reached communities as diverse and far-flung as Christchurch, New Zealand; Santa Monica, California; and Whistler, British Columbia. Corporations such as Electrolux, IKEA, Mitsubishi Electronics, and Scandic Hotels have adopted the same framework to move their own operations toward sustainability. Last year Sarah James, a community planner from Boston, and Torbjörn Lahti, the town planner for Övertorneå during the 1980s, published *The Natural Step for Communities,* a how-to manual as well as an update on the experiences of many ecomunicipalities and ecologically concerned corporations.

Implementing The Natural Step process demands years of dedicated work and cooperation. How wide its appeal may be has yet to be seen. One of the sparks that ignited this movement is that, at the outset, most Swedes and Finns regarded their boreal forest in a positive light. Whether or not they live within it, they frequently refer to the taiga as their national forest, viewing it as the fountainhead of their traditions and legends and as a continual inspiration for their contemporary culture. Among the native peoples in other northern regions—the Dene of North America; the Yakuts of Siberia; the Sami of Scandinavia, Finland, and western Russia; and many others—similar sentiments are held. They are one of the hopeful signs that the boreal forest will survive. But such values are just one human element in a tug-of-war over the ultimate fate of the taiga resources. □

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Fat Chance

Doesn't "everyone know" that serving supersize meals to a young couch potato is a sure recipe for an obese child? Then why is the current epidemic of childhood obesity such a mystery to science?

By Susan Okie

Rudolph L. Leibel's genes may have predisposed him to become a scientist, but his decision to spend his life trying to discover the causes of obesity was environmental happenstance, the result of a chance encounter. In the spring of 1977, Randall, a severely overweight child, and Randall's mother showed up at the pediatric clinic of Cambridge Hospital in Massachusetts, where Leibel was a specialist in hormone disorders. Leibel could find no evidence that hormone deficiency or, indeed, any other known medical condition, was the cause of Randall's obesity. But what struck the young doctor was the response of Randall's mother when Leibel told her there was little he or anyone else could do for her son: "Let's get out of here, Randall," she snapped. "This doctor doesn't know s--t."

Chastened by her words, Leibel soon traded his hospital post for the low-paying toil of a rookie laboratory scientist. At the Rockefeller University laboratory of Jules Hirsch, a leading figure in research on obesity, Leibel and Hirsch conducted extensive studies of weight homeostasis: how the body responds both to weight gain and weight loss by fighting to restore the status quo ante.

In one of the studies, volunteers were induced to overeat to gain weight—a task that proved remarkably difficult. Whether they were fat or lean at the outset, the volunteers' bodies responded by turning up the metabolic rate, boosting the levels of certain hormones, reducing hunger, and burning up more calories as heat—all in a coordinated effort by the autonomic nervous system to restore the body's original weight. By contrast, when volunteers' food intake was restricted in order to promote weight loss, their bodies fought back even more fiercely: metabolisms slowed; the volunteers moved around less often and, even when they were exercising, their muscles burned fewer calories; and everyone felt constantly and uncomfortably hungry. A host of physiological defense mechanisms had swung into play, all aimed at regaining the lost pounds.

Such tight physiological regulation of body weight persuaded Leibel that a chemical signal from the body's stores of fat was being sent to the brain. Leibel's hypothesis led to the discovery of a gene that coded for the hormone leptin, which is produced by fat cells. Animal studies soon proved that leptin does indeed pass through the circulatory system to the brain. Could leptin be the key player in the signaling system Leibel had envisioned? If the brain detected enough leptin, would it decide that enough fat cells were storing energy, and so conclude that it was safe to stop eating? Sure enough, mice that could not produce leptin ate nonstop and grew enormously obese. Treating such mice with leptin normalized their body weight.

The gene for leptin was identified and sequenced as the result of an intensive collaborative effort between Leibel and his Rockefeller colleague Jeffrey M. Friedman. When the announcement was made in 1994, it was greeted with much fanfare. Many people (along with some drug companies) predicted that the newly identified gene would enable the hormone to become a miracle cure for obesity. It has not turned out that way.

Today, instead, the United States and many other countries are faced with an epidemic. Most people tend to think of an epidemic as an outbreak of a contagious illness. But to public health officials, obesity rates since the mid 1980s have exploded dramatically and unexpectedly, just as if they reflected the outbreak of a new infectious disease. Noting that obesity and physical inactivity, along with tobacco smoking, are the major causes of "noncommunicable diseases," the World Health Organization estimated that 60 percent of the 56 million deaths worldwide in 2001 were caused by such obesity-related illnesses as heart disease and type 2 diabetes.

Among children, obesity can have adverse effects that persist for life, just as surely as a virus can. For example, there is evidence suggesting that a person's general body weight reaches a "set point" sometime during puberty, and so extreme obesity in childhood, left untreated, carries with it all the health risks of obesity for the rest of one's life: substantial increases in the risks of diabetes, heart disease, and other adverse medical consequences. Some officials have even begun to respond with the kind of alarm that might greet the global resurgence of polio. As David L. Katz of the Yale School of Public Health puts it:

> Children growing up in the United States today will suffer more chronic disease and premature death because of the way they eat and [because of] their lack of physical activity than [they will] from exposure to tobacco, drugs, and alcohol combined.

Even though the discovery of leptin has not led to a cure for childhood obesity, it has helped to show that the condition is largely biological, and not simply the result of faulty parenting or lack of willpower. And the years since the discovery have been hailed as a golden age for obesity research. In little more than a decade, investigators have sketched, in broad outlines, the biological system that regulates body weight. They have also learned a great deal about genetic vulnerability to obesity.

The control centers for tracking energy balance and regulating body weight are situated primarily in the hypothalamus, a small part of the brain that specializes in integrating messages from many parts of the body and orchestrating the organism's response to its environment [*see illustration on opposite page*]. The hypothalamus communicates via nerve pathways and chemical signals with many other areas of the brain, as well as with the organs of the cardiovascular, digestive, reproductive, and endocrine systems (the latter encompasses the glands that secrete the hormones circulating in the blood).

Some evidence suggests body weight reaches a "set point" during puberty. So untreated childhood obesity can lead to the medical risks of adult obesity.

The output of the hypothalamus can fine-tune a number of unconscious processes that affect a person's weight, such as the rate at which the body burns calories in carrying out certain cellular processes or through spontaneous muscle activity, such as fidgeting. Conceptually, at least, understanding how the body controls such unconscious processes is fairly straightforward. What is surprising for some people is that signals from the hypothalamus also affect the cerebral cortex, the "thinking" part of the brain. The hypothalamus can modify such conscious, purposeful behaviors as food-seeking, simply by increasing or decreasing the appetite. As Leibel puts it, those unconscious signals contribute to such conscious actions as ordering a pizza or having a second piece of pie. Just because a behavior is conscious, he adds, doesn't mean that all aspects of it are voluntary.

To exert its control, the hypothalamus needs reliable, relevant information about the body's current need for food. But where does that information come from? Leptin and, to a lesser extent, insulin carry information about long-term energy depots. The level of leptin in the blood reflects how much fat is stored in the body. Its chief function seems to be to protect energy stores and prevent starvation. When a human or other mammal's food intake is severely restricted, leptin levels drop within twenty-four hours—well before fat stores have been materially depleted by being burned for energy. The fall in leptin immediately prompts the hypothalamus to lower the metabolic rate, increase the appetite, and, to some extent, suppress the reproductive and immune systems so as to focus the body's resources on gaining food.

Insulin, the hormone produced by the beta cells of the pancreas, is released into the bloodstream in response to glucose from food. It helps the body maintain a balance between storing glucose and fat and burning them. Insulin also serves as another signal to certain nerve cells in the brain, informing them about the body's overall nutritional status. The brain also receives messages from the digestive tract. Constant updates about food availability and the timing of meals are relayed to the hypothalamus by various messenger molecules released by cells in the stomach and intestinal tract.

What about the genetics? If Randall were Leibel's young patient today, the boy might undergo testing for a genetic cause of his obesity. A few unlucky people are born with a single genetic mutation that stacks the deck against them so overwhelmingly that they become severely overweight almost no matter what the environment. At least five distinct "obesity genes" have been identified so far. Each of them is so critical to the regulation of appetite and food intake that certain mutations in any of them can lead to extreme obesity.

The mutations that cause such "monogenic," or single-gene, obesity are quite rare. Moreover, even if a physician can diagnose such a condition, there is still no guarantee that it can be treated successfully. Nevertheless, monogenic cases of severe obesity have helped investigators understand how the body regulates food intake and fat stores in people without such debilitating mutations. And even though monogenic obesity is rare, Leibel notes, it does reinforce the idea that specific molecules are highly potent in determining energy balance and body weight in humans.

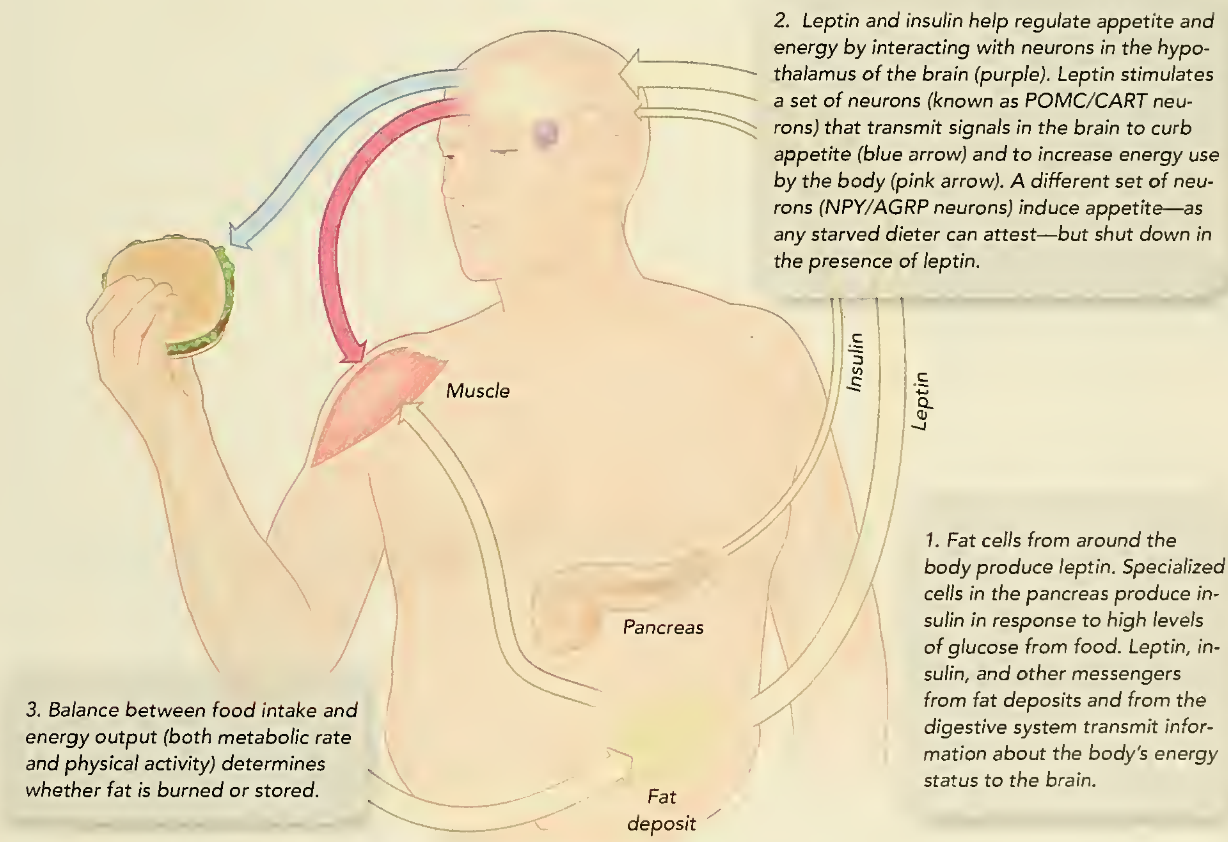
What about the vast majority of overweight children and adults, whose obesity is not the result of a single defective gene? The scientific consensus is that such people may have multiple genes whose net effect predisposes them to eat a few extra calories, burn up a bit less energy than they take in, or store the excess as fat. Like the members of a band, the genes in each person's personal collection play together, along with various factors in the environment, to determine the person's specific vulnerability to becoming overweight.

How many genes might be at play? Investigators don't yet know. At first, just after leptin was discovered, many people thought there must be a single obesity gene, and some believed it had been found. Now at least sixty genes are being investigated, and some workers fear that as many as a hundred genes could be contributing to the obesity risk.

Leibel's own suspicion, after examining patterns of obesity inheritance in families drawn from various populations and ethnic groups, is that the number of important players is much smaller. He suggests that each person may have as many as a dozen genes that combine to determine the individual risk of obesity. Some genes—perhaps six or seven of them—are probably major players that help determine the likelihood of obesity in people all over the planet. The rest of the dozen or so genes may have arisen from gene variants more common in one ethnic population than in another. That, says Leibel, is what makes the genetics so complicated. No one knows which genes are major players, and which genes are minor ones. And so the geneticists have no way of knowing how to apportion their efforts.

Most people, of course, do not become severely obese, even in today's calorie-rich environment. The average person consumes between 7.5 million and 10 million calories per decade, yet Americans and people in other developed countries typically gain only half a pound to a pound a year throughout their adult lives. To gain any weight at all, they must eat more calories than they burn—but the amount needed to account for the typical weight gain is only about ten to twenty calories a day. That's about the equivalent of one Ritz cracker, or less than 1 percent of the average adult's daily intake.

A calorie imbalance that small can't be reliably measured by studying people in their normal habitat. To study how weight gain and loss quantitatively affect people's appetite and metabolism, Leibel and his associates had to confine volunteers to hospital research wards and measure every mouthful. They found, surprisingly, that obese people do not eat more than lean people in proportion to their body size. Nor do obese people have slower metabolisms than lean ones, as long as they remain at what is their own "normal" weight. They still balance their calo-



Simplified schematic diagram portrays some of the signaling pathways and feedback systems that control appetite, energy expenditure, and ultimately weight loss or gain. Mood, stress, smell, taste, and social routine also play important roles in food intake.

rie intake and output very precisely to maintain a constant weight, just as lean people do. It's just that the weight they maintain is higher.

Yet the laws of thermodynamics dictate that people who are overweight must, at some point, have taken in more energy than they spent in order to gain the extra pounds. "There's no way around it," Leibel says. "You cannot eat like a canary and become the size of a pterodactyl." But in most cases, once obese people have reached a personal set point determined by their own physiology, their weight stabilizes. Their food intake and their metabolic rates, when adjusted for their body size, are similar to those of lean people.

To gain half a pound to a pound a year, an adult needs to eat just ten to twenty calories a day more than she burns. That's about the equivalent of one Ritz cracker.

When a person loses weight, however, the circumstances shift dramatically. Whether people start out lean or obese, when they lose 10 to 20 percent of their body weight, their bodies respond by becoming more efficient and using less energy, in an effort to conserve calories and replenish lost reserves of fat. The reduction in energy expenditure is about 15 percent larger than would be expected for the amount of weight lost. That almost certainly accounts for some of the tremendous recidivism among dieters, Leibel says. Studies suggest that some 95 percent of people who lose weight by dieting gain it back within five years.

So though genes determine individual vulnerability to weight gain, environmental factors help dictate the outcome—the weight that a person reaches during childhood or adulthood. Imagine, Leibel says, that you can rank a hundred people, on the basis of their genetic endowment, from 1 to 100 according to their tendency to store excess calories as body fat. Then that same genetic ranking will tell you how they'll line up relative to one another in most environments. What it won't tell you, though, is what those hundred people will look like in any particular environment. For example, if a hundred people were exposed to famine and had to subsist on a starvation diet, they would all become thin—but some would lose less weight than others, according to their genetic endowments.

In spite of the scientific progress made in disentangling the body's complex systems for regulating food intake, energy use, and energy storage, no one really knows how to treat most cases of obesity. Meanwhile, most of the developed world is facing an expanding public health crisis that clearly has not arisen because of newly mutated genes. Obesity is increasing at an unprecedented rate in the United States, and in many other countries as well. For example: in a study conducted in Europe between 1983 and 1986, more than half of the adults between the ages of thirty-five and sixty-five were either overweight or obese; and even in Japan and China, and throughout Southeast Asia, obesity rates have risen sharply during the past two decades. Recent shifts in the modern environment are undoubtedly at the root of the epidemic. People eat more and move around less. Most of us in the developed world enjoy an abundance of cheap, tasty, high-calorie foods, rely on cars, elevators, and other forms of motorized transportation, and lead sedentary lifestyles, in part because of the difficulty of incorporating walking and other kinds of activity into our daily routines.

Such a "toxic environment," in the words of Kelly D. Brownell, a health psychologist at Yale University, is playing on individual genetic vulnerability, thereby causing unhealthy weight gain in increasing numbers of people. And if environmental factors are at fault, then by changing the environment—or by learning ways whereby we can consciously change our responses to it—it may be possible to slow down or even reverse the trend. Nevertheless, one must sound a cautionary note on what may be too sanguine an assessment: obesity experts who are studying the epidemic think that a comprehensive solution to the rise in obesity will require broad environmental and social changes—a daunting task.

Leibel is proud that his genetic research has helped put a stop to "blaming the victim," shifting the blame for fatness away from the people who suffer from it. The continuing discovery of obesity genes is proof that biological variation in vulnerability to weight gain is the main reason some people are fat and others are lean. That's why Leibel views much of the current national debate about measures to prevent obesity with some concern. He points out that no one yet knows precisely what actions will be most effective. "On some level this is a disease that everybody thinks they understand, and yet in fact nobody understands," he says. "We really don't know what has happened, other than on a very macro, thermodynamic level. Food intake is greater than energy expenditure. Period." □

This article was adapted from Susan Okie's forthcoming book, Fed Up! Winning the War against Childhood Obesity, *which is being published by Joseph Henry Press* (http://www.jhpress.org) *in February.*

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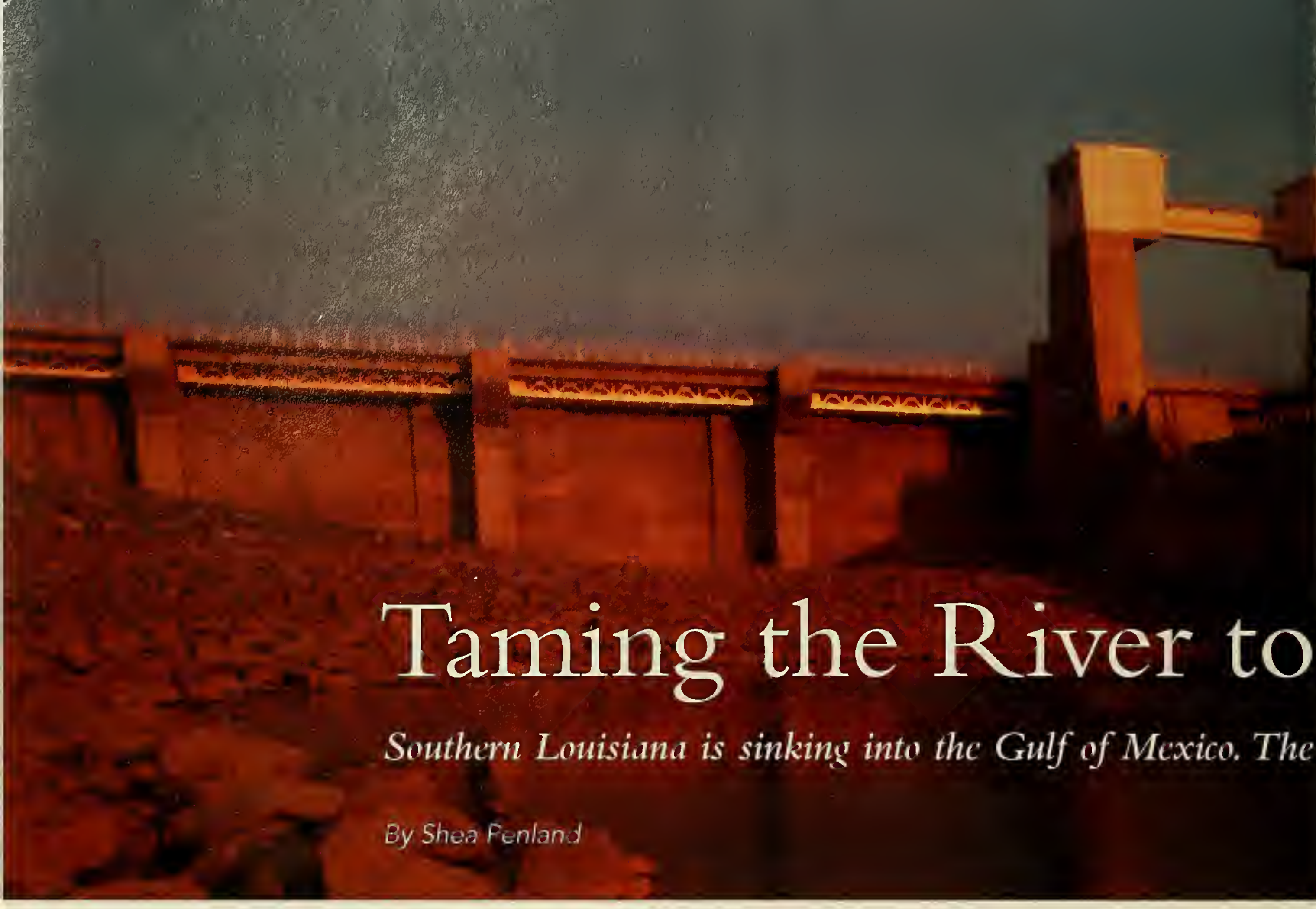


Taming the River to

Southern Louisiana is sinking into the Gulf of Mexico. The

By Shea Fenland

If you live in Louisiana and don't know how to swim, now might be a good time to learn. The state is rapidly disappearing into the Gulf of Mexico. As a result of hundreds of years of natural-resource exploitation and modifications to the flow of the Mississippi River, whose silty waters created the delta region of southern Louisiana, the state's coast lost more than 1,900 square miles of land in the twentieth century alone. At the current rate of loss in Louisiana, an area of wetlands the size of the Baltimore-Washington, D.C., metropolitan area will disappear by 2050. Without putting a massive program of ecological restoration into effect immediately, the fertile crescent of the Mississippi River is doomed to wash away sometime in this century.

Habitable land has always been a critical issue in coastal Louisiana. Much of the state lies only a few feet above sea level; the highest elevation in Louisiana is only 535 feet. Much of the city of New Orleans is actually below the level of the Gulf of Mexico. No wonder, then, that the earliest European explorers, colonists, and entrepreneurs became preoccupied with "taming" the Mississippi. Wherever people settled, they built levees, channels, and canals to control the floods; they reclaimed land from the bottoms of swamps and running rivers; and they did whatever else they could to harvest the bounty of Louisiana's deltaic Eden.

The Mississippi and other rivers, of course, are not the only threat to Louisiana's lowlands. Every year hurricanes pose a threat from the Gulf of Mexico. The accompanying storm surges cause local, short-term flooding, but they also lead to permanent erosion of the coastal marshes and barrier islands in the Gulf, which provide the only protection for the inhabited lowlands farther inland. Louisianans have focused on river flooding for hundreds of years, yet only in the mid-1970s did the state begin to take the coastal erosion problem seriously.

The breakdown of the marshes and beaches coupled with the drainage of reclaimed lowlands remains a disaster in the making. New Orleans's defenses would simply crumble if a truly enormous storm lingered over the city for long: a storm the size of, say, Hurricane Ivan, which made landfall along the Gulf coast of Alabama last fall, roughly 150 miles to the east. Even many residents do not realize that New Orleans is on the brink of becoming the next Atlantis, the fabled island that, according to Greek legend, sank into the sea.

Let In the Sea

surprising culprit is overambitious flood control.

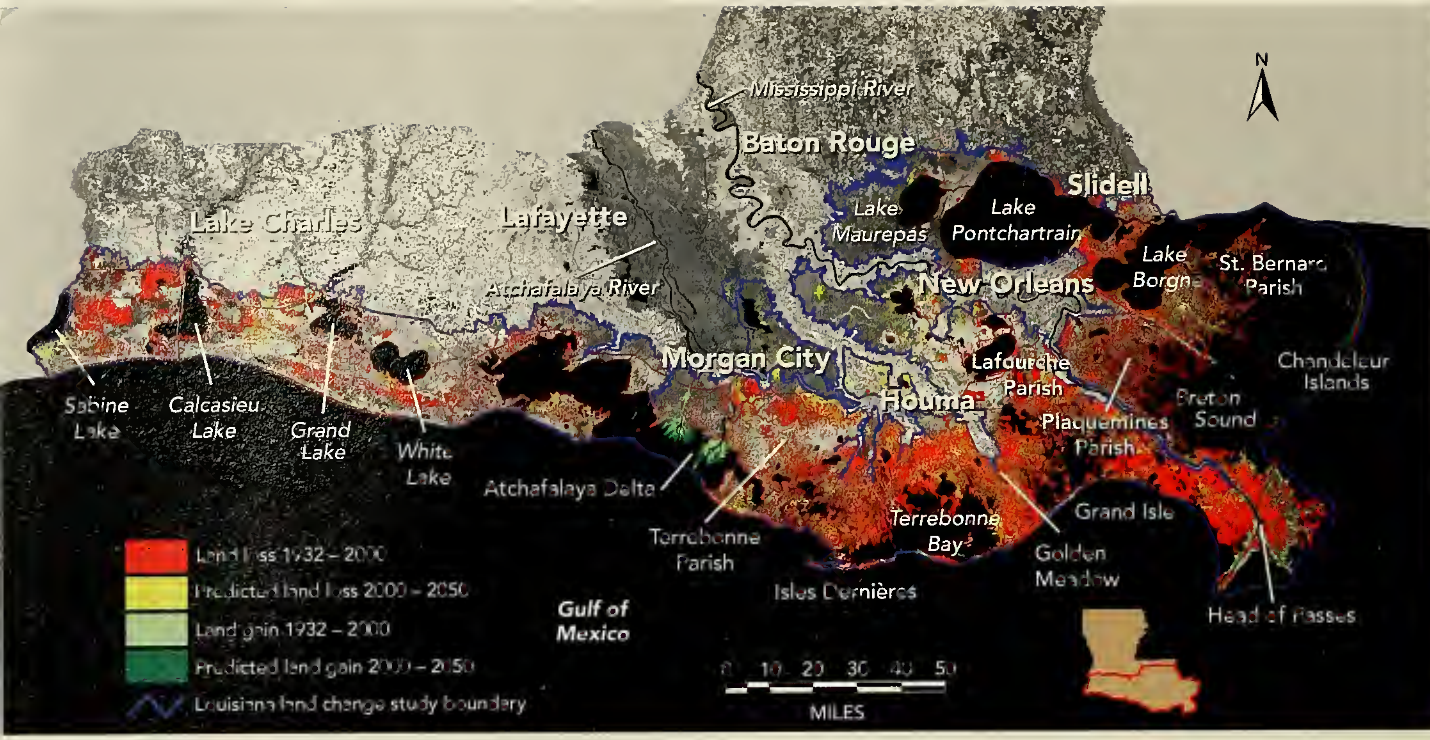
Old River Control Structure, the keystone of modern attempts to control the Mississippi River, allows no more than 30 percent of the water in the Mississippi to leave its main channel and flow down the Atchafalaya River to the Gulf of Mexico. Without the control structure, the Atchafalaya, which has a steeper grade to the Gulf, would most likely "capture" the Mississippi and become the main drainage channel of central North America, leaving cities such as Baton Rouge and New Orleans high and dry.

Important as they are, though, beach erosion and flooding are still not the heart of the problem facing Louisiana: subsidence of the delta plain is. Before the levees were built to channel and "control" the Mississippi and other nearby rivers, floodwaters would spread out and slow down as they flowed over the delta. When the flow slowed, the river would deposit its burden of silt, forming a new layer of earth. But the levees, which now constrict floods along a 1,200-mile corridor of the Mississippi, keep the floodwaters from spreading across the delta. Instead, the river-borne silt is lost off the edge of the continental shelf.

The delta, primarily mud that already filled the Mississippi River valley before the levees were built, is continuously being compacted under its own weight. As it compacts, it loses elevation, and without floods, no new sediments can arrive to build the land back up. In the past several hundred years, subsidence rates have ranged from a foot to four and a half feet per century.

Compounding the risk of catastrophic flooding is global climate change. Many climatologists expect such change to cause hurricanes even more frequent and more violent than the ones of the past several years. Sea levels are expected to rise by ten to twenty inches. As Louisiana's marshes and barrier islands sink farther into the sea, the people of Louisiana could find themselves exposed to the elements. But the present trends and ominous signs of coastal land loss in Louisiana threaten much more than just the environment, economy, and people of the state. The importance of the Mississippi and, in particular, New Orleans to the commerce of the nation makes the crisis a threat to the entire United States.

The threatened collapse of coastal Louisiana has been centuries, even millennia, in the making. Eighteen thousand years ago, with the end of the last ice age, sea levels began to rise dramatically. For thousands of years the great glaciers that had formed in the preceding era melted into the ocean, until, four thousand years ago, the sea level stabilized. But



Actual and projected areas of land loss and gain in coastal Louisiana are detailed on the map above, based on a map by the Louisiana Land Change Study. Land builds up when the Mississippi, its flow slowed as it meets the still waters of the Gulf, deposits its burden of silt. Some land loss results from erosion, but the most important effect is subsidence. Silt left by flooding subsides with time, and without regular flooding to renew the layers of silt, the ground can sink low enough to become immersed in the Gulf. The areas running from just east of Morgan City, eastward to Head of Passes and the Chandeleur Islands are the ones affected by the absence of regular flooding; two centuries' worth of levee building and flood control on the Mississippi have led to that unintended consequence. The most active areas of land buildup are the Atchafalaya Delta, south of Morgan City, and limited areas around Head of Passes, at the present mouth of the Mississippi.

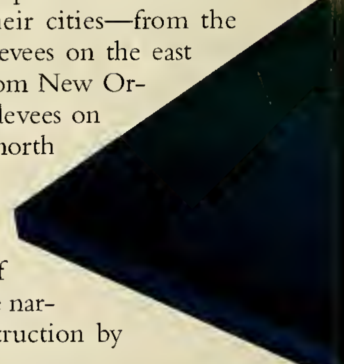
the Mississippi now met the sea in what had been its old valley. The river water, halted in its course by the Gulf of Mexico, no longer had the energy to carry its sediment. The sediment, falling out of the flow, began filling in the ancient river valley. The result was a subsidence-prone delta that could maintain its elevation only so long as sediment from upstream reached the delta plain each year.

Meanwhile, for thousands of years, the Mississippi Delta has undergone a process known as "delta-lobe switching." The path the river takes to the Gulf is constantly changing, because the river is continuously drawn along the most efficient path to the Gulf [*see map on opposite page*]. Thus time and again the delta forms and reforms. By roughly four thousand years ago, the St. Bernard delta lobe was building up to the east of New Orleans and cut off three bays from the sea; those became lakes Maurepas, Pontchartrain, and Borgne [*see map above*]. The lobe terminated at the Chandeleur Islands, to the east. Geologically, though, that drainage did not last long. By roughly three thousand years ago, the Mississippi was probably also entering the Gulf via the Lafourche lobe, which lies southwest of present-day New Orleans. That delta lobe formed the region around the present-day communities of Houma, Golden Meadow, and Grand Isle.

In the past thousand years the volume of flow through the St. Bernard and Lafourche delta lobes has waned significantly. Their distributaries shifted to a more efficient course through what is now the main stem of the Mississippi, downstream from New Orleans. But that course is doubtless no more permanent than the others.

As I noted earlier, ever since European settlers began living in the Mississippi River valley, they have been building levees to protect themselves—both their farmland and their cities—from the river's floods. By 1812 the levees on the east bank extended 135 miles, from New Orleans to Baton Rouge. The levees on the west extended 210 miles, north to the Red River.

Unfortunately, levee construction during that early period of flood control was of poor quality. The levees were narrow, low, vulnerable to destruction by

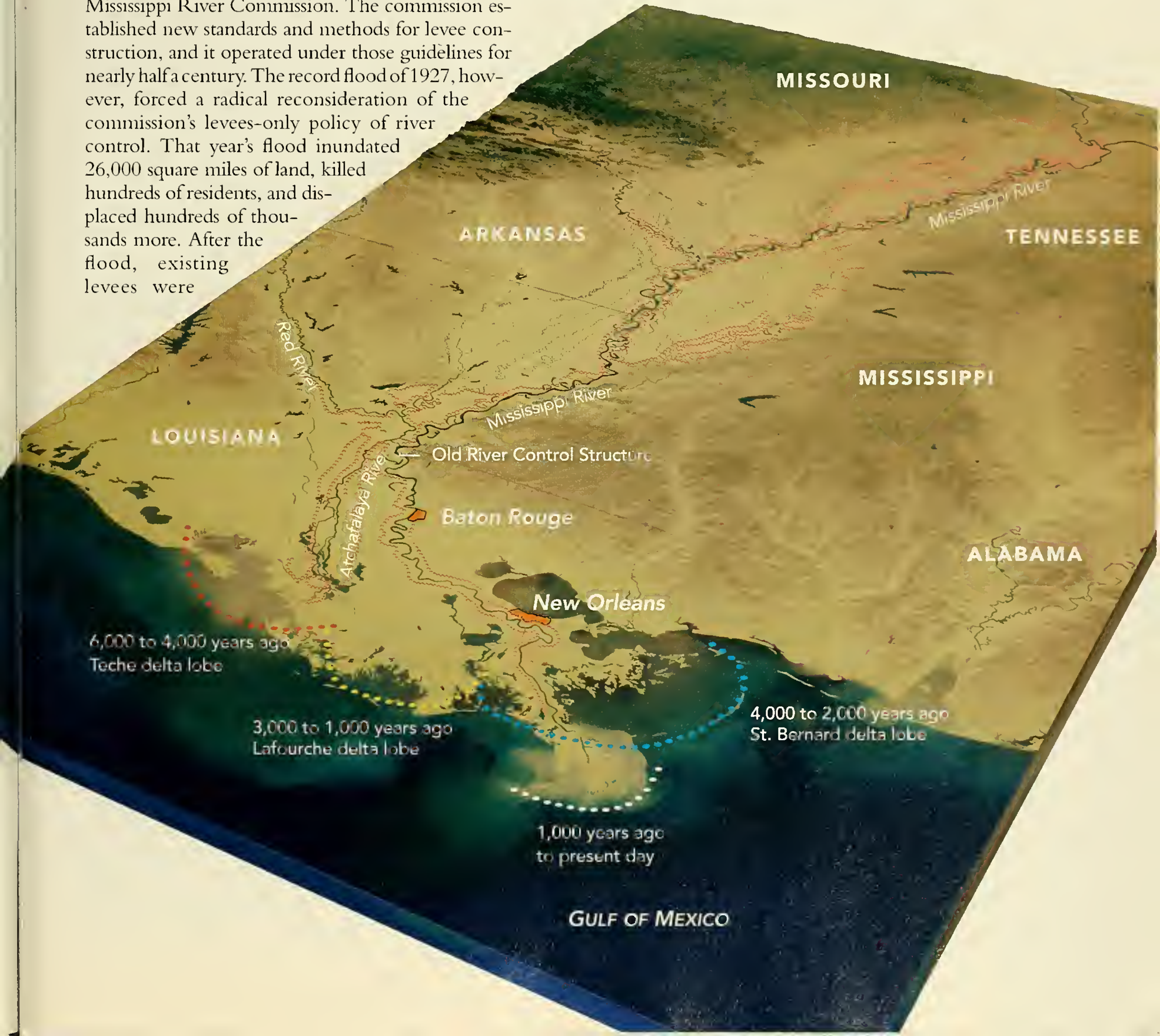


Mouth of the meandering Mississippi has relocated several times in the past 6,000 years. The map shows the extent of some of the delta lobes, or land built up by river-borne sediments, together with the estimated period of the main sediment deposition. The dates for the deposition of the lobes sometimes overlap. The delta lobes are marked by a series of colored dots. The present delta is marked in white. The lines of red carets upstream mark the extent of today's system of levees for flood control.

large floods, and generally ineffective at controlling the river. The shoddy workmanship, combined with severe flooding in the first half of the nineteenth century and the growth of New Orleans and surrounding communities, compelled the U.S. Congress to act. The Swamp Land Act of 1849 authorized Louisiana to create a system of levee districts. Each district received donated federal land that it could sell; the proceeds were to finance levee construction and land reclamation.

The American Civil War, and severe floods in 1862, 1865, and 1867, undid much of the work done under the Swamp Land Act. In 1879 Congress made the U.S. Army Corps of Engineers the leader of a new agency charged with controlling the river, the Mississippi River Commission. The commission established new standards and methods for levee construction, and it operated under those guidelines for nearly half a century. The record flood of 1927, however, forced a radical reconsideration of the commission's levees-only policy of river control. That year's flood inundated 26,000 square miles of land, killed hundreds of residents, and displaced hundreds of thousands more. After the flood, existing levees were rebuilt, extended, and reinforced with revetments. But the commission also tried new approaches, building floodways to divert water from the river and digging cutoffs to speed the passage of floodwaters.

A further problem became apparent in the early 1940s. At that time the Mississippi River Commission engaged Harold N. Fisk, a geologist at Louisiana State University, and a team of geographers and geologists to investigate delta-lobe switching by the Mississippi. Fisk and his colleagues realized that the Mississippi River would soon shift down the shorter course of the Atchafalaya River to the Gulf of Mexico. In response, the Corps of Engineers built a massive concrete structure known as the Old River Control Structure, at the confluence of the Red and



Mississippi rivers, where the Atchafalaya begins. This structure controls the volume of water that flows down the Mississippi, allowing no more than 30 percent of the flow to enter the Atchafalaya. The remaining 70 percent continues past Baton Rouge and New Orleans to the Mississippi's present delta in the Gulf. With the completion of the Old River Control Structure, the Mississippi River appeared tamed.

It was obvious, even in the 1950s, that the sediments of the historic spring floods no longer reached their natural resting grounds in levees, swamps, and marshes. At the time, that seemed a blessing. The primary effect, however, was to restrict sedimentary land buildup to two isolated locations on the coast: at Head of Passes, seventy miles southeast of New Orleans, where the Mississippi River reaches the Gulf, and at the Atchafalaya River outlets, south of Morgan City. Elsewhere across Louisiana, coastal land loss continued to worsen. Flood control had set the stage for disaster.

Without floods, New Orleans, like the rest of the Mississippi Delta, is subsiding as its sediments compact.

Initially, no one viewed coastal land loss as a problem as severe as flooding. Hurricanes, though causes of flooding and locally catastrophic erosion, did not immediately affect state or national coastal policy. The first official recognition that beach erosion in Louisiana needed higher-level attention came with a Corps of Engineers report on Grand Isle, the state's only developed barrier island.

The state did not sit up and take notice, however, until shoreline erosion began to threaten state coffers in the 1950s. Controversy arose over the ownership of mineral rights under the Gulf of Mexico, between the offshore boundary of Louisiana and the water bottom claimed by the federal government. The office of the Louisiana attorney general, seeking to garner support for offshore claims, conducted the first comprehensive analysis of shoreline erosion for the period from 1932 until 1954. The survey showed that Louisiana's Gulf shoreline had receded by an average rate of six and a half feet per year. By 1969 the rate of erosion had risen to seventeen feet per year.

Louisiana soon had more bad news. In 1970 a report noted that the state had lost interior coastal lands at a rate of almost six square miles a year between the 1890s and 1930s. Furthermore, the rate had accelerated to more than sixteen square miles a year by the 1950s. The U.S. Fish and Wildlife Service found that between 1955 and 1978, Louisiana lost more than thirty-five square miles a year.

Such conditions put human settlements at great risk from encroaching water. To combat it, New Orleans and other communities are protected by two kinds of levee. One defends against the Mississippi's annual floods; the other protects against deadly hurricane storm surges. Meanwhile, without the floods, New Orleans, like the rest of the delta, is subsiding as its sediments compact—and there is no question, of course, of intentionally letting muddy waters into the city to add new sediments there.

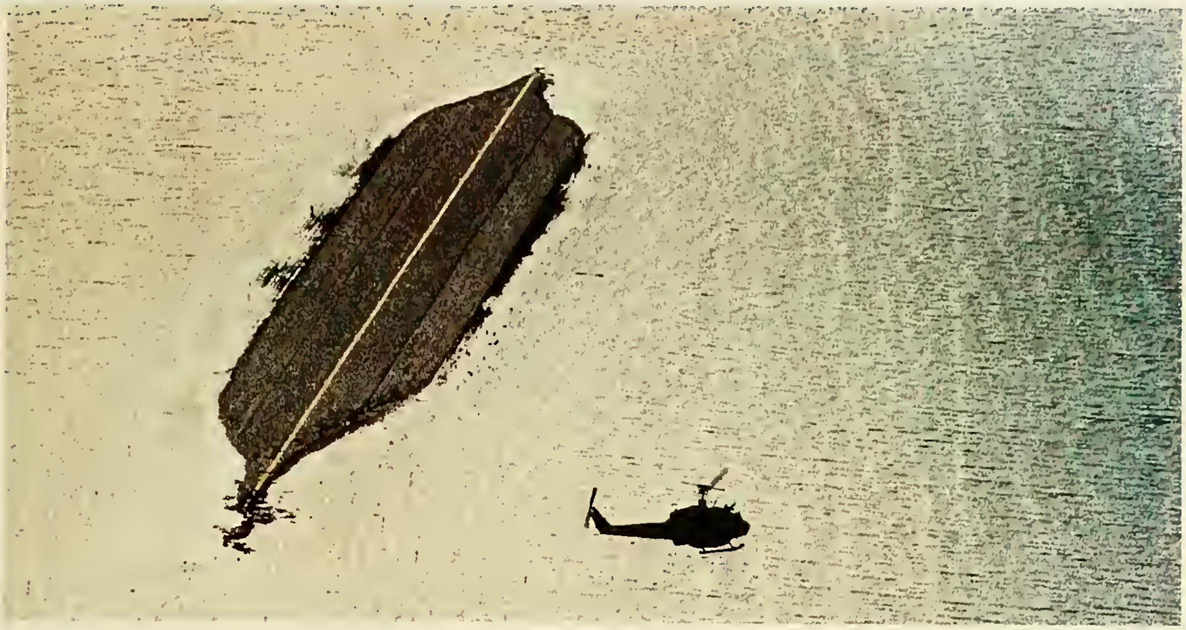
The downside of flood control is not limited to the natural dispersal of sediments. It also interferes with the dispersal of nutrients across the delta. Even before the twentieth century, early conservationists noted that the river alterations were causing entire ecosystems in areas away from the main stem of the river to decline. Years after the levees and spillways were completed, investigators from the Louisiana Universities Marine Consortium discovered a "dead zone" of water—at times as large as Massachusetts—spreading over the Gulf of Mexico from the shoreline at the mouth of the Mississippi. Devoid of dissolved oxygen, the dead zone owed its existence to massive flows of fertilizers collected by the Mississippi and its tributaries.

By the early 1980s, despite the signs of impending disaster (many of which had originated out of the decisions made by the federal government), federal and state agencies were still reluctant to attempt any kind of restoration. So locals acted first. In 1984, the frustrated government of coastal Terrebonne Parish, some forty miles southwest of New Orleans, appropriated $1 million for the first barrier-island restoration project in Louisiana, at Isles Dernières, under the direction of Robert S. Jones, the parish engineer and a leader in barrier-island restoration.

In 1989, finally prodded into action, the Louisiana legislature established the Louisiana Wetlands Conservation Authority, and Congress subsequently passed the Coastal Wetlands Planning, Protection, and Restoration Act of 1990 (CWPPRA). By that time the combined funding of various state and federal coastal restoration programs in Louisiana had reached more than $50 million a year.

Throwing money at a problem is one thing; spending it wisely is another. But the restoration projects envisioned seemed to incorporate the best thinking about how to address the present problems. The projects included the diversion of freshwater and its sediment from the Mississippi into marshes, the creation and protection of marshes, shoreline erosion control, and the restoration of barrier islands.

One of the first restorations was the Caernarvon



Floodwaters inundate an airfield in Saint Paul, Minnesota, in spring 2001. Saint Paul is some 1,500 miles upstream from New Orleans, and protected by earthworks, but even there the power of rain and snowmelt coursing down the river is not to be underestimated. Levees protect New Orleans too, both from the river's waters as well as from hurricane storm surges from the Gulf of Mexico, but without a better balance between flood control and sediment buildup in coastal Louisiana, a big spring flood or an autumn hurricane threaten to put Bourbon Street into Davy Jones's locker.

Freshwater Diversion Project, which began operation in 1991. Planned prior to CWPPRA, the project called for discharging as many as 80,000 gallons of freshwater per second into the swamps, marshes, and shallow bays east of the Mississippi River and downstream from New Orleans, in Saint Bernard and Plaquemines parishes. That lowland area had been losing as much as a thousand acres a year. The Caernarvon project consisted of a set of diversion gates built through the existing flood-control levees; the flow through the gates was intended to mimic the natural over-bank flooding that built the delta.

Since 1991 the Caernarvon project has become a model that has afforded valuable practical experience with restoration techniques. But it has also had unwanted effects. For example, the freshwater diversion project disrupted seafood harvesting by coastal communities, and as a result of lawsuits brought against the project, local oystermen have been awarded more than $1 billion in damages.

From 1991 until 1998, more than forty-five projects began under the auspices of the CWPPRA. But it soon became obvious to both state and federal governments that the coastal land loss in Louisiana far exceeded the capabilities of the original CWPPRA legislation to address it. A new effort, known as Coast 2050, was set up to evaluate and plan for a larger-scale restoration of coastal Louisiana. That work resulted in a plan with an anticipated price of $14 billion.

The Coast 2050 effort subsequently evolved into the Louisiana Coastal Area Ecosystem Restoration Project, or LCA, in which I participate as a geologist. In an effort to draft the legislation needed to carry out restoration, multiple LCA teams write, meet, review, and rewrite feverishly. Congressmen, government leaders, and other power brokers have also descended on Louisiana to determine how big the crisis is.

The magnitude of the crisis, though, should be obvious: the largest river ecosystem in the United States is collapsing right in front of us. And if leaders are wondering whether we can succeed, the answer is yes—our experience with CWPPRA has taught us we can. No handbook for coastal restoration exists, but willing spirits can and will move ahead to restore America's wetlands.

My colleagues and I proceed according to the best principles of practical science: we apply what we know, we test and adjust in the field, and we are not afraid to seize on unexpected success. But what we learn through hard empirical work will someday create a body of disciplined knowledge that can be applied throughout the world. Our work in Louisiana will someday form part of the foundation of a new field—environmental restoration science—that will prove as important to university education in this century as geology and engineering have been to date.

In 1925, one visionary, Percy Viosca Jr. of the Louisiana Department of Conservation, foresaw the impending ecological collapse of coastal Louisiana and the necessity of restoration. He wrote:

> Man-made modifications in Louisiana wet lands [are] a failure, destroying valuable natural resources without producing the permanent compensating benefits originally desired.... Our future conservation policy should be a restoration of those natural conditions best suited to an abundant marsh, swamp, and aquatic fauna.... [With them] the state and nation may enjoy... a more enduring prosperity. □

REVIEW

Can Dogs Think?

Maybe yes, and maybe no. What dogs do quite well, though, is make people think that dogs can think.

By Bruce Blumberg and Raymond Coppinger

Where is the dog owner who hasn't wondered just what might be going on in that canine head? Those who train dogs professionally are certainly moved at times, in moments of frustration, to doubt that anything is going on in there at all. If dogs are so smart, why can't more than a small percentage make it through training as agility dogs, customs dogs, guide dogs, or obedience dogs, to perform reliably at tasks that seem quite straightforward?

Yet when it comes to presuming that there are such things as canine minds or canine thinking—as the books under review do in their titles—ordinary skepticism seems to take the night off. If only one could just sit down with a dog over a glass of sherry and ask, What's on your mind? Maybe that's the key to the matter: dogs seem to possess some special talent that makes people think about them as drinking buddies. It is the rare dog lover who doesn't have a story about some astonishingly humanlike behavior in a dog. Dog owners all seem to want to prove their dogs are special—veritable geniuses in the world of animal cognition, or at least, like the children in Garrison Keillor's Lake Wobegon, all above average.

Even animal experts, who are supposed to know better, can find it hard to resist the temptation to explain canine behavior with fanciful "just so stories." Dog stories almost invariably imply that the dogs in question can think—and think like people.

But stories are one thing, science another. In science, the best one can do is observe the behavior of dogs in natural and controlled settings, and then, on that basis, make testable inferences about canine cognition. Yet despite the popularity of dogs—or maybe, in large part, because of it—the scientific investigation of canine behavior and cognition has lagged far behind that of many other animals. The reasons are not hard to fathom. Ethology, for instance, is the study of the behavior of animals in their natural habitats, but for domesticated canines, the "natural habitat" is the somewhat artificial one people have created. Another reason for the dearth of scientific studies is the deep emotional bond between dogs and people, which poses a constant challenge to the objectivity of the investigator. Particularly when people's tendency to anthropomorphize their dogs is coupled with such thorny concepts as "mind" and "thought," the need to be aware of unconscious bias and unfounded interpretation is paramount.

How Dogs Think: Understanding the Canine Mind
by Stanley Coren
Free Press, 2004; $26.00

If Dogs Could Talk: Exploring the Canine Mind
by Vilmos Csányi
North Point Press, 2005; $25.00

Two recent books tackle the problem head on. In *How Dogs Think: Understanding the Canine Mind,* Stanley Coren, a psychologist at the University of British Columbia and a noted author on dog-human interactions, concludes that the scientific evidence just doesn't support ascribing humanlike mental activity to dogs. In *If Dogs Could Talk: Exploring the Canine Mind,* Vilmos Csányi, an ethologist at Eötvös Loránd University in Budapest and a noted dog expert, seems equally convinced of the opposite conclusion.

Most dog books fall roughly into two types: the ones that focus on training, and the ones that tell dog stories. And though Coren and Csányi serve up healthy portions of both, they also strive mightily to go beyond those formulas and report what rigorous research has to say about whether dogs have minds and can think—and, if so, to what degree they think like people.

Coren begins his book by tracing the history of the concept of mind as applied to canine cognition—what he calls "the battle between 'dog as thinker' and 'dog as machine.'" In Coren's account, philosophers such as Plato and Diogenes exemplify the former, whereas strict behaviorists such as B.F. Skinner insist on the latter. Expert opinion then just swings back and forth between these two poles like a pendulum.

Is the field of canine cognition doomed forever to repeat this seemingly endless dispute? In his book *Wild Minds: What Animals Really Think,* Marc D. Hauser, a psychologist and neuroscientist at Harvard University, suggests a different approach. Hauser sees an animal's ability to solve problems—to act intelligently—as indicat-

ing that it possesses a set of "mental tools." Those tools arise out of a complex interplay of genes, development, and learning. Hauser further suggests that, to the extent a species faces specific problems, its tool kit may include unique or specialized tools, of greater or lesser quality, that do not occur in the tool kits of other species. Species specialization does not make one species "smarter" than another, according to Hauser, just "wonderfully different."

Applied to dogs, Hauser's approach cuts through the vague but passionate disputes about whether dogs think, or just act like robots. Instead, he suggests that research focus on relatively straightforward comparisons between the mental tools deployed by various species. For example, how well do dogs compare with other species in remembering objects that are out of their sensory range? This mental tool, known as "object permanence," presumably must be brought to bear if a dog is to answer that age-old question, "Where is your ball?" Mental tools that deal with object permanence, as well as counting, mapmaking, knowledge about the nature of objects, and on and on, help an animal solve problems such as where to find hidden caches of food.

How does this talk of toolboxes apply to people? Humans have special mental tools—a "theory of mind," for instance—that help them solve "psychological problems" such as "What is that person thinking?" Other tools open up cognitive possibilities such as consciousness, self-referential behavior, and language. One key point to emphasize is that possessing a given mental tool says nothing about how the tool works. It implies only that an animal possessing it can perform the information-processing necessary to solve a particular problem.

For Hauser, the concept of "mind" is shorthand for the mental tool kit an animal possesses. Hauser generally avoids the terms "thinking" and "consciousness" as unnecessarily vague and unhelpfully reliant on human-centered actions. His point is that, though people usually insist they know what such terms mean, the terms have not even been defined as they apply to *Homo sapiens*. How, then, can investigators possibly ask whether other animals think or are conscious? Focus objectively on the problems animals can or cannot solve, Hauser cautions, and leave the underlying brain mechanisms to the neuroscientists, and the speculative theories to the philosophers.

One wishes Coren and Csányi had been as circumspect. Coren has written a thorough and fascinating description of sensory information processing in dogs; the trouble is, he wants to call it thought, which just trivializes the meaning of thinking. When, late in his book, Coren does speak directly of "thinking" and "mind," he falls into the very trap Hauser warns against. In Coren's analysis, "mind" is not a species-specific collection of tools, but rather shorthand for the set of psychological tools possessed by people, including self-awareness and the ability to reflect on one's own actions.

Coren is at his lively best when discussing the sensory capabilities of dogs, offering a clear overview of the latest research. With Coren's guidance, the reader can imagine if not the mind, then at least some approximation of the eye—and ear, skin, tongue, and, most importantly, nose—of the dog. Coren even offers suggestions for improving the design of dog toys. (For example, dogs may see red and green as various shades of yellow, and so toymakers would do best to avoid producing red toys intended for playing on a green lawn.) He explains why dogs are so interested in sniffing the nether regions

of other dogs (and, embarrassingly enough, of people). He discusses the acoustics of dog commands and how they, in turn, reflect characteristics of the dog's auditory perception. He even describes the best way to pet a dog. Both the novice and the experienced dog lover will find this part of his book fascinating and entertaining.

After such a detailed description of canine sensory capabilities, it is ironic that when Coren turns to the subject of dog training, the very approach he advocates is the practical application of the ideas of Skinner, who minimized the importance of understanding a specific animal's perceptual and cognitive machinery. In using this approach, Coren runs the danger of treating individual dogs as if they can all be trained alike, ignoring the exceptionally wide individual variation among dogs' abilities to learn tasks, though he does deal briefly with variations in learning from breed to breed.

Although Coren the dog lover is convinced that dogs engage in some kind of mental activity, Coren the scientist is not fooled into reading more into their abilities than the evidence seems to warrant. Toward the end of his book he fesses up: "I recognize that for the entire book I have been dodging . . . the question [of mind]." Several pages later he throws in the towel: "Although dogs *may* [our emphasis] have fine mental abilities," he acknowledges, that does not mean they think "the same way that a human does." But those admissions come only after Coren has spent a large part of his book coyly skirting the issue, hinting at what readers may want to hear rather than educating them about how to think about dog cognition in informed ways.

For all this agonizing, it may seem ironic that Coren has already anticipated the conclusion of his book by making its strongest argument early on, almost in passing. Language, he remarks, is a dividing line between the cognitive abilities of people and dogs. It's a crucial concession. After all, many dogs seem to have some capacity for understanding language, and some dogs have quite a lot. Is language the key to the mind of the dog, or is it an example of how dogs solve "just enough" of the problem of acting sentient that they convince people they are solving the complete problem?

Last summer—too late for either of these books to have taken account of the findings—Juliane Kaminski and Josep Call, both cognitive psychologists at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, reported in the journal *Science* on their work with a remarkable border collie named Rico. Rico, they asserted, "knew the names" for 200 objects. Perhaps even more impressively, Rico could learn the name for a novel object after the object was presented and the name was repeated just two or three times. In children, this ability to rapidly associate a word with an object is called "fast mapping," and it is widely seen as one of the key building blocks for language acquisition.

Children learn in three weeks what Rico has taken nine years to learn.

In the same issue of *Science* the cognitive and linguistic psychologist Paul Bloom of Yale University provided a commentary on the work. Clearly impressed with Rico's abilities, Bloom nonetheless pointed out that, in contrast to the remarkably open-ended variety of children's vocabularies, Rico's word list was limited to the domain of the fetchable and to the specific training situation. Those restrictions make Rico's use of words quite different from that of children. Children recognize that words can be used in a variety of contexts. When they are young, they learn ten words a day, on average, and so children learn in three weeks what Rico has taken nine years to learn.

The study also presented no evidence that Rico knew anything about syntax or semantics beyond "fetch [the specific object] and give it to [x]." But therein might lie one secret of canine intelligence. Fast word mapping, even if limited to particular domains, might be all dogs need to fool the dog lover in us. It makes people believe that dogs know what people are saying, and that belief may be at the center of the social bonding that ensures their comfy lives as our pets.

In discussing the mental activities of dogs, Coren, compared with Csányi, is a model of careful and cautious analysis. In spite of Csányi's disclaimers that he is merely presenting an untested hypothesis, he repeatedly writes as if dogs not only "think," but also have minds—in fact, a version of the same mental tool kit that people putatively possess. "My theory," he writes, "is that humans and dogs were able to establish such tight links because . . . dogs acquired mental traits that resembled those of humans in many respects." Csányi even goes so far as to say that the mental resemblance between dogs and people offers "a peek into the early period of our own evolution."

That is quite a statement, and one for which Csányi offers precious little evidence. And there is more:

> Through the process of domestication, we have continued to breed the descendants of animals that were attracted to us, understood our forms of communication best, and were most easily adapted to our social circumstances.

But making use of our forms of communication does not necessarily imply "understanding." And even if one takes the quoted statement at face value, Csányi draws the conclusion that to understand human communication, the dog must have developed "mental traits that resembled those of humans in many respects." That simply doesn't follow—dogs may be solving problems in ways completely different from the ways people do. To assume that dogs solve problems completely, and do so in completely human ways, is to close one's eyes to the special ways dogs either solve these problems or perhaps, at least, fool us, as a species, into thinking they do.

Csányi is at his anthropomorphic worst when he resorts to dog stories to reach conclusions. One section of his book is a diary of the cognitive accomplishments of his two dogs. A typical entry describes one of them as listening "with rapt attention," looking "questioningly," and whining "in a pleading manner." Csányi is to be applauded for such focus on the everyday lives of dogs. And his descriptions of the many experiments done by his research group on the cognitive underpinnings of dog-human interactions are strong points of his book. But passages such as the diary entry are overloaded with anthropomorphic presuppositions about the very mental states he has set out to investigate.

Hauser's concept of mental tools may be a particularly useful way to describe the minds of animals whose world we can partly infer but never fully enter. It is obvious that, at times, both Coren and Csányi want to believe the canine mind resembles the mind of a person. Perhaps their dogs even reached into their canine mental tool kits and behaved in such a way as to convince both authors that dogs in general share many human psychological tools.

If so, that would be an amazing specialization. If dogs could write books, a good topic would be the following brain-twister: "How should dogs behave in order to get people to think that dogs are thinking like people do, so that people will behave as dogs want them to?" But even to imagine this possibility is to fall, however briefly, into the anthropomorphic trap that lies in wait for all who study dogs.

BRUCE BLUMBERG, *a research scientist at the Massachusetts Institute of Technology, is currently developing computational models of dog learning and training.* RAYMOND COPPINGER *is a professor of biology specializing in canine behavior at Hampshire College in Amherst, Massachusetts. He is the co-author, with Lorna Coppinger, of* Dogs: A New Understanding of Canine Origin, Behavior, and Evolution *(University of Chicago Press, 2002).*

By Laurence A. Marschall

A Cow's Life: The Surprising History of Cattle and How the Black Angus Came to Be Home on the Range
by M.R. Montgomery
Walker & Company, 2004; $25.00

Only a vanishingly small fraction of the U.S. population lives within earshot of a moo anymore, so it's easy to forget that modern civilization and modern breeds of cattle evolved symbiotically. Cattle were domesticated perhaps as early as 10,000 years ago, and have long been a principal source of meat, milk, and power for hauling loads and tilling land. The "bovine ilk" (in Ogden Nash's inimitable phrase) was the first large creature to be genetically engineered, in the sense that it was selectively and intensively bred. In the millennia since early Mesopotamians first converted the fierce, ancestral aurochs into the contented cow, a wide variety of specialized breeds have been developed. And of all those breeds, according to M.R. Montgomery, the epitome of bovinity is the Aberdeen Angus, or Black Angus, cow.

So who is he to say? Montgomery is a writer living in Lincoln, Massachusetts, a bosky and exclusive suburb of Boston, whose only working bovine residents, to my knowledge, are confined to an Audubon Society farm (though numerous cuts of deceased specimens probably grace the Sub-Zero freezers of the town). But he has worked on a ranch in Montana, and he's a skillful and charming wordsmith; moreover, he's done his research so well that even readers without a whit of interest in cattle husbandry—vegetarians included—will find much to ruminate on in his book.

Oklahoma boy with Black Angus calf

The Aberdeen Angus, as the name suggests, is a product of Scotland. At least since the Roman occupation of Britain, highland farmers have grazed cattle on their lands in the summer to sell to English markets in the south. The long, cold northern winters and a lack of plentiful forage, however, forced the Scots to sell their cattle "lean" to buyers who would fatten them up later in the more temperate English climate.

Then in the early 1800s, the Highlanders discovered a readily grown and easily stored variety of yellow turnip that their cattle simply loved. Fattened cattle yielded bigger profits than lean ones, so the Scottish cattle economy and cattle-grazing industry took off. Ambitious Scottish landowners began to develop stock animals that were hardy, easy to breed and raise, and, pound-for-pound, provided the tenderest, best-tasting meat. The result was the Aberdeen Angus.

Montgomery acknowledges three of the great Scottish stockbreeders—George Macpherson-Grant, William McCombie, and Hugh Watson—as the founding fathers of the so-called Black Angus line. Those men, however, not only established a purebred line; they also managed to preserve the line by paying close attention to ancestry, establishing a formal system of cattle registry that, to this day, enables ranchers anywhere in the world to trace individual Angus cows back to members of the original herds.

Thankfully, Montgomery's book does not dwell for long on the history of the landed gentry. But he does serve up plenty of anecdotes about ranching life in the western United States, as well as welcome digressions on the economics of modern-day beef raising and the basics of bovine psychology. And there's more in this book than any non-cowboy would ever want to know about artificial insemination. In the end, though, it's impossible not to share the author's enthusiasm. "Cows are also wonderful just to look upon," he concludes. Thanks to Montgomery, they're also wonderful to read about.

Professional Savages: Captive Lives and Western Spectacle
by Roslyn Poignant
Yale University Press, 2004; $30.00

In 1883 P.T. Barnum's traveling circus advertised an Ethnological Congress of Strange Savages, so that white urbanites in the U.S. could gawk at such oddities as "wild" Nubians and "ferocious" Zulus. Although advertised as educational, Barnum's shows were at best a kitschy take on ethnic diversity, showcasing the skill and ingenuity of unfamiliar people, without ever letting go of the assumption that white European culture reigns supreme.

Roslyn Poignant probes the deeper subtext of these spectacles in an ambitious attempt to recreate the inner lives of two groups of Australian Aborigines. Recruited in remote villages in north-east Queensland by one of Barnum's agents, these "cannibals" looked every bit the savage to Barnum's American and European audiences. In the book's cover photograph, for instance (one of many publicity stills that Poignant has unearthed), the neatly trimmed beard, black suit, and gold watch chain of the agent, one Robert A. Cunningham, contrast starkly with the shaggy hair, loincloths, and nose ornaments of the Australians. Staring fiercely—or perhaps uncomfortably—at the camera, they brandish boomerangs and spears.

Poignant has managed to dig up a surprisingly large number of contemporary documents about these performers in newspaper files, government archives, and the business records of Barnum and his contemporaries. Several continental anthropologists, it turns out, interviewed the Aborigines during a European tour, and Cunningham himself kept a scrapbook of letters, playbills, and press clippings. The account that Poignant has assembled from all that material, as one might expect, is rather more complicated than the simple stereotype the publicity photograph seems to portray.

Three Aborigines pose with a stuffed dog for a publicity photograph, made in Paris in 1885.

For one thing, Cunningham hadn't plucked his Aborigine troupe from a pristine state of nature. Some had already worked for white settlers; others for the Australian police. Their original motive for signing on to the tour is unclear, but if they were duped into thinking it was a lark, they soon made the best of the situation. Once they understood how long it might be before they returned home, they learned to speak English. They deliberately adopted the persona of stage savages—even to the point of inventing show-stopping stunts with the boomerang and elaborate yarns about life in the bush.

Offstage, it was different. In one photograph, the "savages" appear bundled up in Western-style hats and wool coats, indistinguishable, except for the color of their skins, from the white man posing with them. "We are not savages," one of them told a reporter, "although we are natives of a wild country."

Ultimately, though, the fate of many of the performers was a sad one. One by one, they died of infections their immune systems had never been exposed to. While the rest of the troupe moved on to the next city and the next show, the dead were buried in unmarked graves. One notable exception was Tambo, who died in 1884 and, unknown to his comrades, was embalmed and displayed as a sideshow curiosity for many years afterward. His remains were kept in the basement of a Cleveland funeral home until 1993, when they were discovered and returned to Australia for burial.

People in northern Queensland still talk about their relatives who traveled abroad as performers in the late 1800s. But though they welcomed the return of Tambo's remains, it would be premature to read Poignant's account as a sign of justice served at last. Such stage shows may have no place in our age of global consciousness, but who can say the same about the racism and xenophobia that made Barnum's spectacles so popular?

The Remarkable Life of William Beebe: Explorer and Naturalist
by Carol Grant Gould
Island Press, 2004; $30.00

Who has not heard of William Beebe (1877–1962), one of the greatest natural historians of the twentieth century? In a recent informal survey by an independent investigator (myself), every person in the physics department of a small liberal arts college recognized Beebe by name—even though none of the respondents were biologists and some of them were mere tots when he died.

Author, scientist, adventurer, radio personality (he was a frequent guest on the popular radio show *Information Please* in the 1940s), Beebe was equally at home in the salons of high society, the tropical jungle, or the uncharted ocean. He was a confidant of Teddy Roosevelt, a friend of A.A. Milne and Rudyard Kipling, and a dinner partner to Katharine Hepburn and Walt Disney. As a director of the Department of Tropical Research of the New York Zoological Society, he established a landmark research station in South America, where he and his colleagues conducted pioneering studies of species diversity and animal behavior. He explored the Galápagos before they became a boutique vacation site, tracked rare birds in the Himalaya, and wrote the definitive monograph on pheasants, a monumental four-volume set.

In the 1930s, at an age when most scientists are thinking of a pleasant sinecure in academic administration, Beebe entered an entirely new field of research: the study of the bottom of the sea. With little thought for comfort or safety, he and Otis Barton, the inventor of the bathysphere, sardined themselves into a five-foot-diameter steel ball, and had themselves lowered on a cable deep into the Atlantic Ocean. On one dive in 1932, radio listeners heard Beebe's voice live over NBC as he descended almost half a mile beneath the waves.

Beebe never stopped working, continuing his research at sea and in the rainforest until he was well into his eighties. He was a man of many talents, but if there was one great theme to his life, it was to carry on the scientific work of Darwin and the public advocacy of Darwinism. In two dozen books, most of them instant best sellers, he popularized the wondrous diversity of life and the interconnectedness of nature, striking themes that would be taken up in succeeding generations by scholars such as the ethologist Konrad Z. Lorenz and the biologist George B. Schaller (who currently occupies Beebe's office at the Bronx Zoo).

In spite of his high profile, however, Beebe was, according to science writer Carol Grant Gould, an intensely private person. Colleagues and students bustled around his research camps in droves, but much of the master's time was spent in solitude, lying motionless on the jungle floor as he observed the behavior of a moth or a bird, or writing a magazine article in his study. He specifically discouraged biographers, leaving his scientific papers and his voluminous daily journals to the protection of his colleague and confidant Jocelyn Crane, much to the dismay of his wife, the romance writer Elswyth Thane.

Drawing on Crane's records, made available in 1989, and a host of other sources, Gould has written an engrossing account of Beebe's professional and personal life, effectively compressing his decades of hyperactivity into a mere 400 pages. Gould is an unabashed admirer of the great naturalist, and though she tries to show some of his dark side—the occasional blue funks and some unhappy experiences in marriage—the Beebe that comes through in this book was a happy man, one of those lucky people who lived life well, inspired others to do the same, and left the world a better place.

William Beebe in British Guiana, 1917

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

Howls and Growls

By Robert Anderson

In the first chapter of his *Origin of Species,* Charles Darwin argued that if you wanted tangible evidence for evolution, you need look no further than the family pet. "Artificial selection" among domesticated animals, he noted, had resulted in extraordinary variations in a relatively short time, and "natural selection," Darwin explained, would work in much the same way.

To get some sense of how much variation exists among those of the canine persuasion today, visit the Web site of the American Kennel Club (www.akc.org). The site lists entries for the 150 pure breeds recognized by the club (there are hundreds more). The Web site of the Westminster Kennel Club (www.westminsterkennelclub.org) is, of course, the best place to find information about the clubs' dog show—the premier event of its kind—which takes place in New York City on February 14–15.

If you want to explore the natural history of the domestic dog, a good place to start is the Web site of the Natural History Museum of Los Angeles County, at the online version of a recent exhibition titled "Dogs: Wolf, Myth, Hero & Friend" (www.nhm.org/exhibitions/dogs). Click first on "Evolution and Diversity," which outlines the history and effects of both natural and artificial selection. Next click on "Form and Function," from the vertical menu at the left, where you'll find brief accounts of the three senses that make dogs so exceptionally useful to people: vision, hearing, and smell.

For details about the impressive canine sense of smell, check out the site of the Canine Olfactory Detection Laboratory (www.vetmed.auburn.edu/ibds/doglab.htm). Trainers at the lab specialize in teaching the animals to locate explosives and illegal drugs.

Dogs are also contributing to the study of genetically transmitted disease in humans. This past summer the National Institutes of Health announced the first sequencing of a canine genome (a news summary is available at www.nhgri.nih.gov/12511476). The summary notes that, because of the long history of selective breeding, many dog genomes carry information about diseases that afflict both dogs and people. Hence canine genetic sequences will prove useful for research on, among other things, cancer and autoimmune disorders.

Genetic studies have also helped emphasize that the apparent variety among dog breeds is mainly skin deep: every domestic dog is "cousin" to the wolf. At the "Canid Genetics" page of "The Wolfdog" site (w3.fiu.edu/milesk/genetics.htm), Kim Miles, a member of the Florida Lupine Association, has summarized some of the studies, and presents them with links to the related scientific papers. Miles notes that in 1993 the American Society of Mammalogists and the Smithsonian Institution reclassified all domestic dogs as *Canis lupus familiaris*, a subspecies of the gray wolf.

So what about wolf evolution? On the home page of the "Natural Worlds" Web site (www.naturalworlds.org/), click first on "World of the Wolf," which will take you to the topic page. Click on "Wolf History—The Fossil Record" to find a page of images linked to information about both extinct and extant wolf species.

More on the genus *Canis* is available at "The Searching Wolf" (www.searchingwolf.com/ws.htm). Scroll down the home page to see an impressive list of links to sites on all things "wolf" (near the bottom, you'll even find a list of wolf sites specifically for kids). I particularly enjoyed the audio files of wolf vocalizing, which you can access by clicking on "Sounds," in the blue menu box at the left. Launch the sound clips hyperlink, and try playing "Wolf Chorus Howling" to find out how your own domesticated wolf may react to the call of the wild.

ROBERT ANDERSON is a freelance science writer living in Los Angeles.

Clock or Chaos?

Planets orbiting distant stars suggest that the stability of our own solar system may be tenuous.

By Charles Liu

For many years people thought it was impossible to run a mile in less than four minutes. Then on May 6, 1954, on a windy track in Oxford, England, Roger Bannister ran the mile in 3 minutes, 59.4 seconds. Within a few years, runners were routinely breaking that artificial barrier—and folks could hardly remember why anyone had ever thought the four-minute mile was an impossible dream.

Half a century later, astronomers have collectively undergone a similar change of mind, concerning the difficulty of finding planets in solar systems other than our own. Until a decade ago, planets were thought to be so hard to detect that, even if they were plentiful outside our solar system, they might never be found. Now astronomers are detecting more than a dozen new "exoplanets" a year. To date they have discovered close to a dozen exoplanetary systems, and the count of planets known to be orbiting stars other than the Sun is more than 130. It's a wonder how anyone could ever have believed that exoplanets would be impossible to find.

Gregory Gioiosa, *Ancient Grace*, 1999

At first, limited by technical challenges, the planet hunters found only giants: planets thousands of times the mass of Earth—more massive, in fact, than all the planets in our solar system put together. Since those first discoveries, though, the lower limit to the newfound planets has declined rapidly; late this past summer, for instance, research groups based in Europe and the United States announced that several planets, each the mass of "just" twenty Earths, had been independently discovered. (The mass of the planet Jupiter is equal to about 320 Earth masses.) It seems inevitable that, eventually, Earth-size planets will be found in planetary systems much like our own, brimming with planets, asteroids, and comets.

When astronomers study all those exoplanets and the systems they inhabit, it is natural to look to our own solar system as a template for other planetary systems. The objects in our solar system move in such clocklike and orderly ways that you might think their motions would have been completely understood long ago. As it turns out, though, the phenomena associated with just about any orbital system are remarkably complex. A case in point is an odd "scalloping" effect photographed in detail among the rings of Saturn just a few months ago by the *Cassini* spacecraft. The scalloping, it turns out, is a surprising result of gravitational interactions between Saturn's moons and the billions upon billions of particles that make up Saturn's rings. Predicting these complicated dynamics usually requires successive numerical approximations—no single formula will do the job.

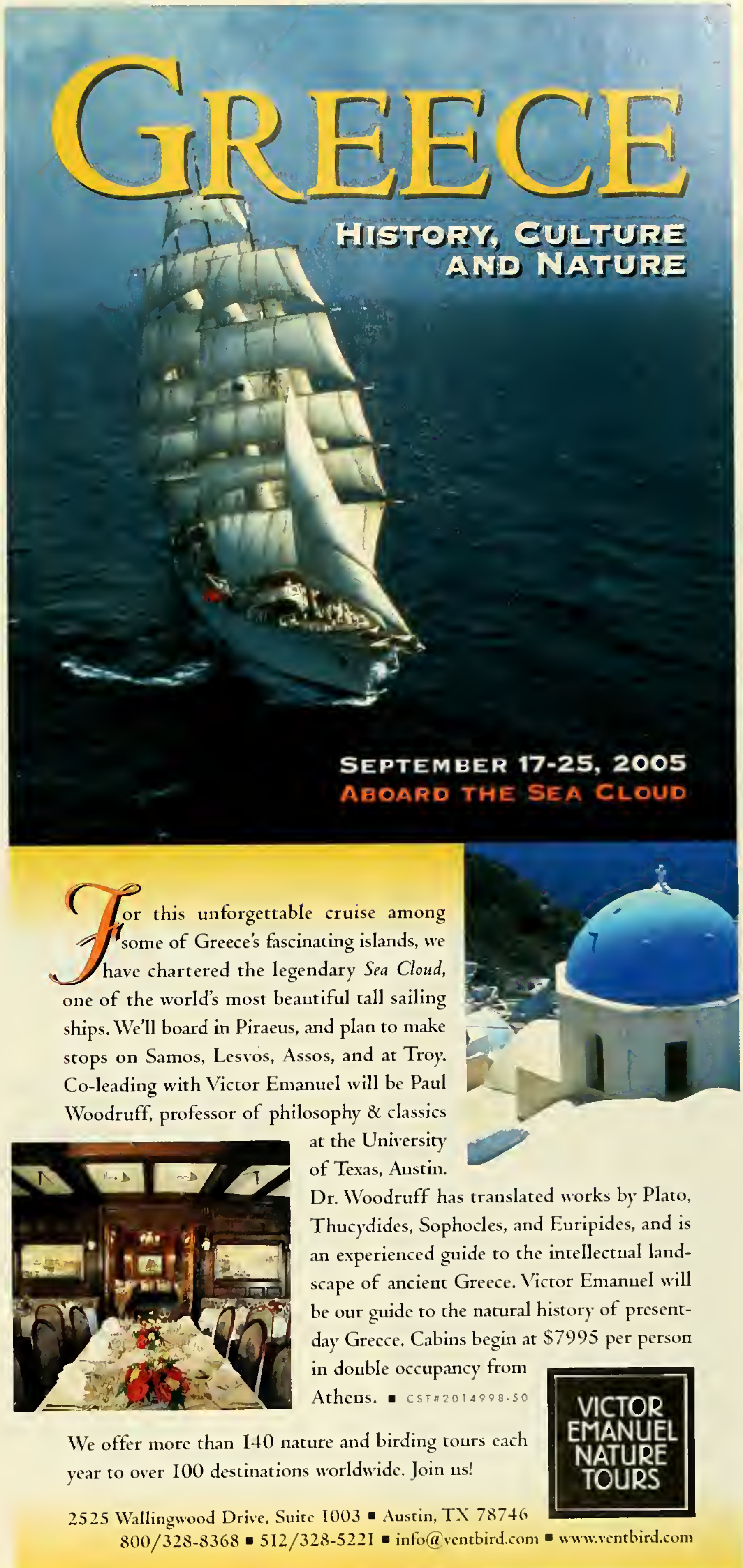
In a similar way, for exoplanetary astronomers, the computer is almost as important a tool as the telescope. With highly accurate models of complex orbital motions, computers can simulate a large number of planetary scenarios, and calculate how virtual solar systems evolve over time with a vastly sped-up clock. Such simulations can go a long way toward explaining how planets and planetary systems form, why they look the way they do, and what will happen to them as time passes—without having to wait thousands or millions of years for the actual physical events to unfold.

One of the most pressing questions

in the study of planetary systems is: how stable are they? Put another way, how likely is it for a planetary system to last undisturbed for the lifetime of its central star, and how likely is it for the planets to be gobbled up by the star or flung out into interstellar space? A new study by Rory Barnes and Thomas Quinn at the University of Washington in Seattle suggests that the long-term stability of most planetary systems—our own solar system included—may be a bit precarious.

If a star has only one planet orbiting around it, predicting its stability in the future is pretty straightforward. With more than one planet, though, only a few special configurations result in stable orbits [*see "Going Ballistic," by Neil deGrasse Tyson, November 2002*]. Otherwise, such a multiplanetary system can become "chaotic"—the motions of the planets can suddenly, dramatically, and almost unpredictably change. We on Earth have been lucky so far: the many planets in our system have maintained highly stable orbits around the Sun for more than 4 billion years. The result has been a multiplanetary environment calm enough for an ecosystem to develop and for life to evolve here on Earth. But astronomers have long wondered: is our solar system the exception or the rule?

Exoplanetary systems provide a natural set of test cases to help answer that question. Barnes and Quinn began with the characteristics of five observed exoplanetary systems, each with two or more planets in orbit about a central star. They then simulated the motions of those systems for what would be, in the physical world, as long as a billion years into the future, watching for signs of instability. For all five systems, they discovered that the planets' orbits seemed to hold steady as long as nothing perturbed the system. Even relatively small changes in the orbits, however, were usually enough to eject at least one planet from the system in less than 1 million years. Put another way, exoplanetary systems are generally stable on fairly long timescales—



but the margin for error is not high.

The most intriguing part of Barnes and Quinn's work is the analysis they performed on our own solar system. And guess what? By their calculations, it wouldn't take much to perturb our own system, either. Just as the flap of a butterfly's wings in China might set off a hurricane on the other side of the globe, as chaos theorists propose, a small gravitational nudge, perhaps from a rogue planet, might well be enough to eject one of our sister planets—maybe even Earth itself—into deep space.

I wouldn't lose any sleep over this scenario, though. Four billion years of stability is a pretty good track record, at least as good as a four-minute mile. And there are no runaway stars or planets nearby to knock us for a loop—none that we know of, anyway.

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

THE SKY IN FEBRUARY

By Joe Rao

Mercury cannot be seen during most of February because it is on the other side of the Sun relative to Earth: the innermost planet reaches superior conjunction on the 14th. By late in the month Mercury becomes visible low above the western horizon at twilight, a preview of its showing in March, when the planet will make its best evening apparition of the year. Mercury sets an hour after sunset on the 28th and shines at magnitude −1.3.

Venus becomes coy, as Cupid has his day; the planet is moving behind the Sun. Early in the month, however, during late dawn (around 6:30 A.M. local time), Venus can be seen through binoculars low in the east-southeast, so long as nothing obstructs the horizon.

Mars, brightening from magnitude 1.4 to 1.2 during February, rises about two-and-a-half hours before the Sun all month. The Red Planet moves eastward twenty-one degrees this month, relative to the stars behind it, passing from the constellations Ophiuchus, the serpent-bearer, into Sagittarius, the archer, at the beginning of the month. A slender sliver of the Moon is well below and to the right of Mars on the morning of the 5th.

Brilliant Jupiter, shining at magnitude −2.2, drifts slowly westward against the stars of the constellation Virgo, the virgin, this month. The planet rises in the east just after 10:30 P.M. local time as February begins, and around 8:45 P.M. by month's end. The best time to look at Jupiter through a telescope without atmospheric interference is between midnight and dawn, when the planet appears highest in the sky, toward the south.

Saturn, in the east at dusk, is visible for most of the night during February. The planet's motion is retrograde this month, shifting nearly two degrees to the west with respect to the stars of the constellation Gemini, the twins. At midmonth the ring system is tilted twenty-two degrees to our line of sight. A waxing gibbous Moon keeps company with Saturn and the nearby twin stars of Gemini (the mythical brothers Castor and Pollux) on the night of February 19–20.

The Moon wanes to last quarter on the 2nd at 2:27 A.M. and to new on the 8th at 5:28 P.M. Our satellite waxes to first quarter on the 15th at 7:16 P.M. and to full on the 23rd at 11:54 P.M.

All precise times are given in eastern standard time.

EXPLORER GUIDE

The Museum's Deep Freeze

Freezing-cold white gas burps from the caps of space-age cryogenic storage vats in the basement of the American Museum of Natural History every time a technician inserts another carefully contained snip of DNA.

D. FINNIN/AMNH

Cryogenic storage vats in the Ambrose Monell Collection for Molecular and Microbial Research

The vats are part of the Ambrose Monell Collection for Molecular and Microbial Research, a treasure trove of frozen biological samples and part of the Museum's Institute for Comparative Genomics. The collection's mission is to provide an accessible, centralized repository of frozen tissue specimens and broadly, to archive and catalog molecular genetic biodiversity for scientists who study living and extinct wildlife.

The 2,000-square-foot facility is outfitted with nine liquid nitrogen–cooled containers that safeguard tissue sample cells by maintaining the specimens at temperatures below -150°C. The facility has the capacity to store more than half a million specimens ranging from frozen whole tissues, such as whole insects and leeches, to samples of purified DNA from such animals as humpback whales.

Before this frozen tissue lab opened in 2001, many scientists had no choice but to keep samples in conventional freezers at temperatures ranging from -20°C to -80°C, which could have subjected the samples to changes in the structures of proteins and fats, damage from the growth of microorganisms, and extensive desiccation after only six months of storage. The Monell Collection takes a "colder is better" position on long-term storage.

As part of the Museum's natural history collection, the frozen tissue collection is a dynamic library that makes unique and important research materials available to the scientific community and helps document the extinct and living biota on Earth. It will allow scientists, today and in the future, to take advantage of advances in molecular genetic and genomic technology to answer questions about how forms of life have spread across Earth, evolved, and become extinct over time. In a time of massive species loss, this relatively compact repository is helping scientists to preserve a comprehensive record of Earth's biodiversity and to refine the family relationships among different creatures, information that can help prevent further losses of threatened populations.

The genome of an organism contains a vast amount of information that addresses these patterns of life, but this information is meaningless unless it is related to the organism as a whole. For this reason, data from the bar-coded glass vials of the collection are entered into a modern bioinformatics database that documents, among other things, how, where, and by whom the tissues were collected. The database will ultimately link to taxonomic information, bibliographic citations, geospatial referencing information, genetic data, digital images, and more.

The Ambrose Monell Collection for Molecular and Microbial Research was established with leadership support from The Ambrose Monell Foundation. Significant support has also been provided by the National Aeronautics and Space Administration (NASA) and the City of New York.

D. FINNIN/AMNH

Museum President Ellen V. Futter with Constantine and Trustee Anne Sidamon-Eristoff at the annual Museum Ball on Wednesday, November 17, 2004. A cocktail hour in the Theodore Roosevelt Rotunda was followed by an elegant dinner and dancing in the gorgeously decorated Milstein Hall of Ocean Life. An auction featured such highly sought-after items as a private, behind-the-scenes tour of NASA and a trip to Mongolia's Gobi Desert with a renowned Museum paleontologist. All proceeds from the evening support the Museum's educational and scientific programming.

Welcome to the Genome:

A User's Guide to the Genetic Past, Present, and Future

By Rob DeSalle and Michael Yudell

Welcome to the Genome, published by Wiley in association with the American Museum of Natural History, is a reader-friendly introduction to one of today's most complex, cutting-edge, and controversial fields of science and its far-reaching implications.

Authors Rob DeSalle, Curator in the Museum's Division of Invertebrate Zoology, Co-Director of the Molecular Laboratories, and curator of the acclaimed *Genomic Revolution* exhibition, and Michael Yudell, now Assistant Professor of Public Health at Drexel University, describe the ongoing story of our attempts to decipher the code of biology's Rosetta Stone and to use it to better our lives. From the promise of personalized medicine and gene therapy to disputes over the safety of genetically modified foods, there is little doubt we are in the midst of a "genomic revolution."

Engagingly written and illustrated in full-color, the book delves into the history of the study of genetics and genomics; presents the challenges facing today's life scientists, legislators, and ethicists as well as the general public; and considers the ground-breaking possibilities and difficult decisions that lie ahead of us. The authors' straightforward explanation of genomic science and technologies is complemented by a thorough discussion of the related social and political issues.

Despite the incredible advances of the recent past, we have only just begun to unravel the famed double helix and can only imagine what will be revealed. *Welcome to the Genome* is an essential guide for those who want to understand—and participate in—the accelerating promise of the genomic revolution.

C. CHESEK/AMNH

The Museum's 11th annual Family Party, held on Wednesday, October 20, 2004, drew more than 1,600 children and parents. Families dined under the famous blue whale and engaged in entertaining and educational activities. With the guidance of Museum scientists and educators, kids of all ages could dig for dinosaurs, explore space, learn about ocean life, conduct science experiments, and even feed live animals (shown). Proceeds from this event support the Museum's educational public programming.

R. MICKENS/AMNH

In celebration of the opening of the Museum's landmark exhibition *Totems to Turquoise: Native North American Jewelry Arts of the Northwest and Southwest*, on view through July 10, 2005, representatives of Native American communities offered blessings and performed ceremonial songs and dances. *Left*, a dancer from the Haida Nation from the Queen Charlotte Islands in Canada; *right*, the White Buffalo Dance performed by the Cellicion Traditional Zuni Dancers of New Mexico.

Museum Events

AMERICAN MUSEUM ō NATURAL HISTORY

www.amnh.org

HERMES JUSTINIANO

Catarata el Encanto ("Enchanted Waterfall") in eastern lowland Bolivia's Noel Kempff Mercado National Park

EXHIBITIONS

Totems to Turquoise: Native North American Jewelry Arts of the Northwest and Southwest
Through July 10, 2005
This groundbreaking exhibition celebrates the beauty, power, and symbolism of the magnificent tradition of Native American arts, examining techniques, materials, and styles that have evolved over the past century as Native American jewelers have transformed their traditional craft into vital forms of cultural and artistic expression.

The Butterfly Conservatory: Tropical Butterflies Alive in Winter
Through May 30, 2005
A return engagement of this popular exhibition includes more than 500 live, free-flying tropical butterflies in an enclosed habitat that approximates their natural environment.

Vital Variety: A Visual Celebration of Invertebrate Biodiversity
Through Spring 2005
Invertebrates, which play a critical role in the survival of humankind, are the subject of these extraordinarily beautiful close-up photographs.

Fall Colors across North America
Through March 13, 2005
The fiery colors of autumn come to life in these images by Anthony E. Cook, taken as he journeyed from deep southern bayous to northern tundras.

Exploring Bolivia's Biodiversity
Through August 8, 2005
These lush photographs of Bolivia take viewers on a journey through the mountain landscapes of the Andes to the dense lowland tropical forests of the Amazon and the dry forests of the Chaco. Informative captions are in English and Spanish.

This exhibition is made possible by the generosity of the Arthur Ross Foundation.

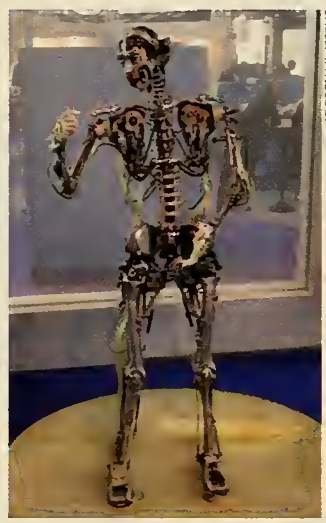
GLOBAL WEEKENDS

BLACK HISTORY MONTH
Lift Ev'ry Voice: Black Music in America
Three Saturdays, 2/12–2/26
1:00–5:00 p.m.
Films, performances, and discussions with award-winning artists, industry experts, and scholars in celebration of the African-American influence on America's musical landscape.

Global Weekends are made possible, in part, by The Coca-Cola Company. The American Museum of Natural History wishes to thank the May and Samuel Rudin Family Foundation, Inc., the Tolan Family, and the family of Frederick H. Leonhardt for their support of these programs.

LECTURES

Farming the Seas
Thursday, 2/10, 7:00 p.m.
This film explores what's at stake as the aquaculture industry spreads across the globe. Discussion follows.



SHELLY WYNKOOP

Chico MacMurtrie/Amorphic Robotic Works *Skeletal Reflection* (servo controlled pneumatics, with vision interactive system)

The Sky Is Not the Limit
Thursday, 2/17, 7:00–8:30 p.m.
Neil deGrasse Tyson, Frederick P. Rose Director of the Hayden Planetarium, shares memories of his infatuation with the universe, which began on the roof of his Bronx apartment building.

Art/Science Collision: Robotics in New York
Thursday, 2/17, 7:00 p.m.
Demonstrations and discussion of robotics in performance and visual art.

FAMILY AND CHILDREN'S PROGRAMS

Astrofavorites for 4- to 6-Year-Olds: Earth and Space
Three Thursdays, 2/3–2/17
4:00–5:30 p.m. (Ages 4–6, each child with one adult)
Our most popular children's workshops are now available as a discounted series: Earthly Adventures; Solar System Adventures; and The Sun and Its Energy.

Space Explorers: Telescope Star Party
Tuesday, 2/8, 4:30–5:45 p.m.
(Ages 8 and up)
On the second Tuesday of each month, kids (and their parents) can learn under the stars of the Hayden Planetarium.

Dr. Nebula's Laboratory: Planetary Vacation
Sunday, 2/20, 2:00–3:00 p.m.
(For families with children ages 4 and up)
Dr. Nebula is taking a cosmic vacation! Join Scooter to track this voyage to explore the planets and moons of our solar system.

The Earth Moved
Sunday, 2/27, 1:00 p.m.
In her witty and offbeat style, and with the assistance of live worms, Amy Stewart shows just how much we depend on the humble earthworm.

NEW!
AMNH WINTER ADVENTURES

Monday–Friday, 2/21–2/25, 9:00 a.m.–4:00 p.m.

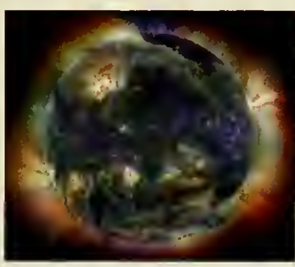
Destination Space: Astrophysics
(For 2nd and 3rd graders)
Learn about the universe through hands-on activities and Museum explorations.

Significant educational and programming support for this program has been provided by the National Aeronautics and Space Administration (NASA).

Robotics
(For 4th and 5th graders)
Create robots for an imaginary exploratory voyage while learning principles of robotics, computer programming, and mechanical engineering.

Puppets on Parade
(For 2nd and 3rd graders)
Make puppets, perform skits, learn about puppetry across cultures, and go on a puppet "treasure hunt" in the Museum's halls.

HAYDEN PLANETARIUM PROGRAMS



COURTESY OF SOHO/EXTREME ULTRAVIOLET IMAGING TELESCOPE (EIT) CONSORTIUM.

Composite image of the Sun that combines images from three wavelengths

TUESDAYS IN THE DOME
Virtual Universe
Motion and Time
Tuesday, 2/1, 6:30–7:30 p.m.

This Just In. . .
February's Hot Topics
Tuesday, 2/15, 6:30–7:30 p.m.

Celestial Highlights
The Zodiac and the Vernal Equinox
Tuesday, 2/22, 6:30–7:30 p.m.

LECTURES
The Outer Solar System
Monday, 2/28, 7:30 p.m
With Mike Brown, Department of Geology and Planetary Science, California Institute of Technology.

Astro Turf
Monday, 2/14, 7:30 p.m.
With M. G. Lord, author and critic.

COURSE
Astronomy, Art, and Physics
Saturday, 2/26
11:00 a.m.–4:00 p.m.

PLANETARIUM SHOWS

SonicVision
Fridays and Saturdays, 7:30, 8:30, and 9:30 p.m.
Hypnotic visuals and rhythms take viewers on a ride through fantastical dreamspace.

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

The Search for Life: Are We Alone?
Narrated by Harrison Ford
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What Shadows Can Foretell

By David Brendan Hopes

The artist's studio I share with several like-minded amateur painters boasts a contingent of smaller occupants as well. Dozens of groundhogs—odd little creatures, featureless, curious, like reddish, fuzzy, scurrying pillows—live up and down the river road, at least two under the foundations of every busy warehouse. My studio mates and I were going to do a series of sentimental woodchuck paintings—like the famous blue dogs—but realized there was no way to communicate that the shape was a woodchuck and not some furry, amorphous Shmoo. The creature is already too droll to be joked about successfully.

We watched as our resident groundhogs dug a series of tunnels around the utility pole at the end of the studio property. We spent hours chattering, hours keeping away from our work, with groundhogs as our excuse. Among ourselves we created groundhog limericks, groundhog haiku, groundhog jokes, groundhog substitutions for the characters of our favorite stories. The animal's mien is so contentedly humorous that we always imagined the groundhogs were taking part in the fun.

The groundhog is the only animal with an American holiday named after it. It is an enormous rodent, sometimes hitting fourteen pounds. My guess is, our holiday can probably trace its roots to the cult of the Celtic goddess Brigid, whose Christian feast day is February 1—the day before Groundhog Day—and whose association with the coming of spring was far more direct than the little groundhog's. Brigid's pagan feast day, Imbolc, falls midway between the northern winter solstice and the spring equinox. Being half-way to spring was important enough to the ancient Celts that one of the covered passages they built on the Hill of Tara, in Ireland, aligns with the rising Sun on the midway day. Brigid's association with a dark passage does not, I suppose, have to undergo too many contortions to become a woodchuck tentatively showing its paws at the mouth of a burrow. We get to keep the story of the goddess while pretending not to believe in goddesses anymore.

Most European nations identify with some predator or creature of the air, ascendant and belligerent: the bear, the eagle, the lion. I would like to visit the country that adopts the groundhog as its emblem—someplace that curls up against the secrets of the earth, a little Belgium of the imagination, tables piled with cakes, the Sunday bells ringing (not too loud), the light falling on rolling hillocks studded with salad greens.

Years ago I was hiking beside the French Broad River in western North Carolina, when I came to the roadside in time to see a mother woodchuck crossing what was then state road 191 with her three pups. I watched as a truck, veering deliberately to hit them, wiped out the babies. At the time, I was passing that spot regularly, so I was witness to what unfolded that day and the days that followed.

Two of the babies disappeared after the first night, perhaps taken by scavengers or dragged off the pavement by their mother. The third baby lay on the roadside for four more days. Every day the mother was there, too, watching over her last baby as though there were some hope for its life. She must have known it was dead. After the fourth day, the sad little body was gone, but the mother was not. For two more days she was at the roadside, lying where her baby had lain. I had thought it was grief, and surely it was, but there was something more. The mother woodchuck was bearing witness. To every driver, every boy in a pickup as old as himself, everyone who knew even a little of the story—and there must have been dozens who noticed her vigil at the roadside—her drooping sad posture broadcast, *Look what you have done.*

This essay was adapted from David Brendan Hopes's forthcoming book Bird Songs of the Mesozoic: A Day Hiker's Guide to the Nearby Wild, *which is being published by Milkweed Editions in March.*