NATURAL HISTORY

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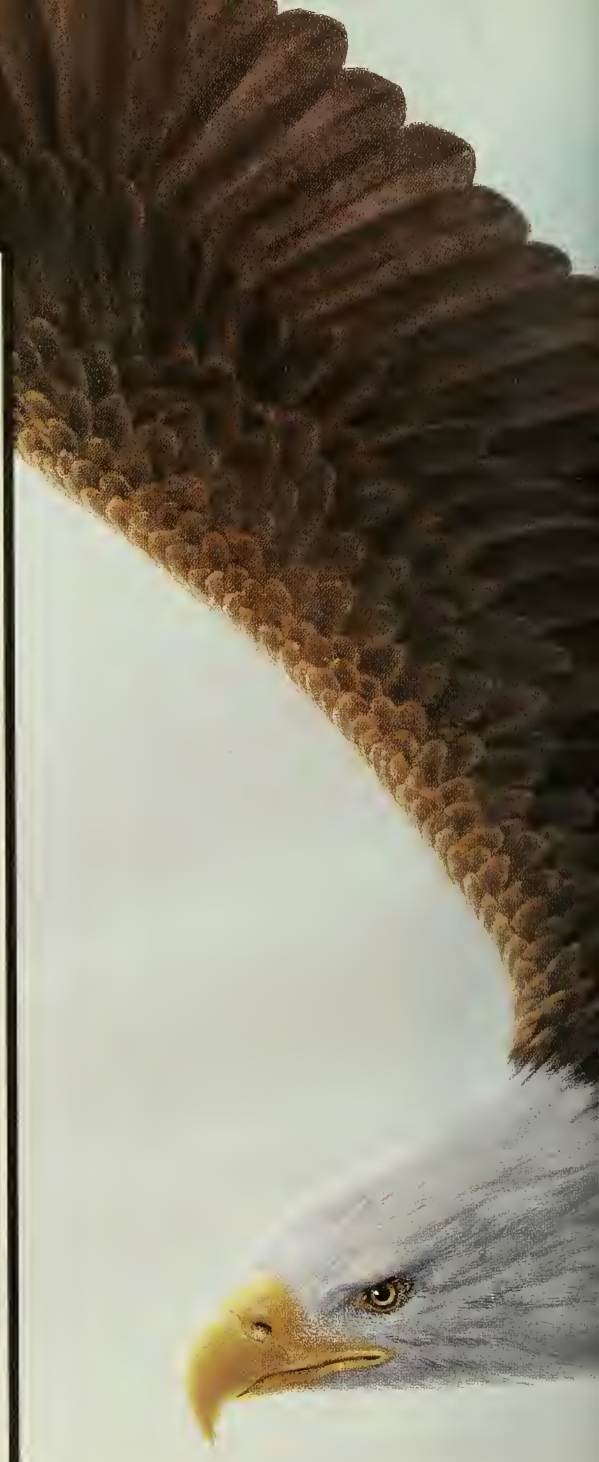


NATURAL HISTORY

FEBRUARY 2001 VOLUME 110 NUMBER 1

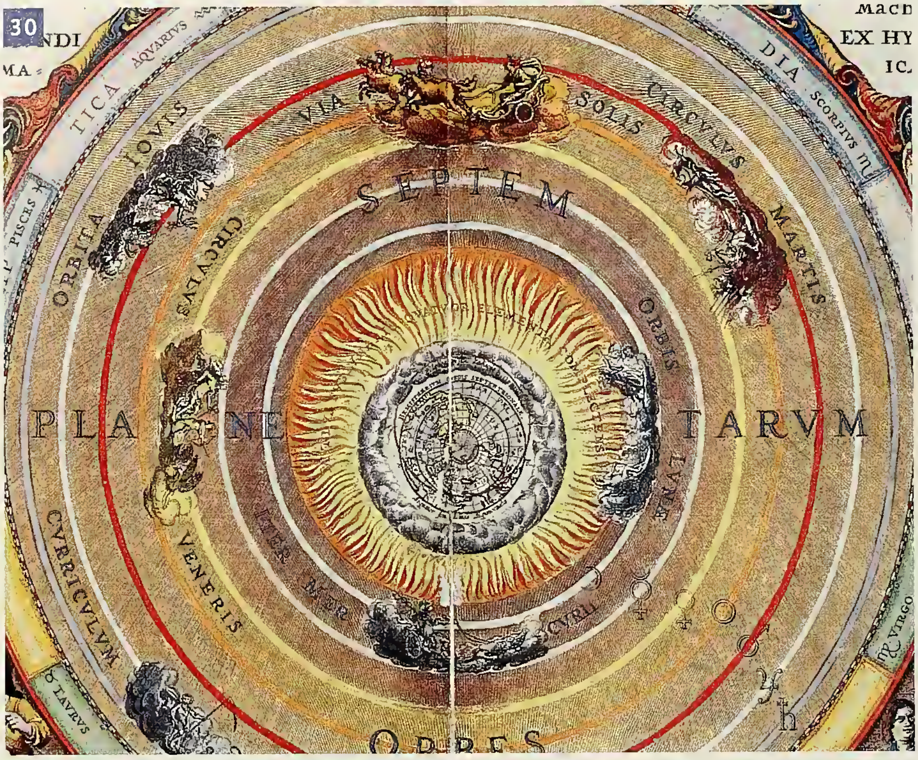
FEATURES

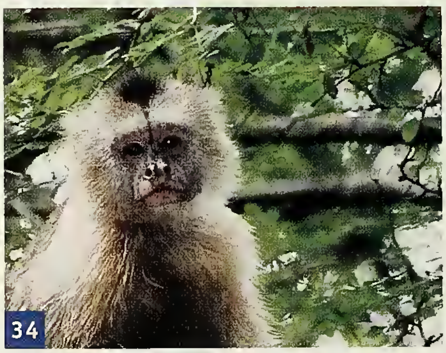
COVER Purple prickly pear is one of myriad cactus species in Agua Caliente Canyon, Arizona.

STORY BEGINS ON PAGE 26

PHOTOGRAPH BY JACK OYKINGA

DEPARTMENTS





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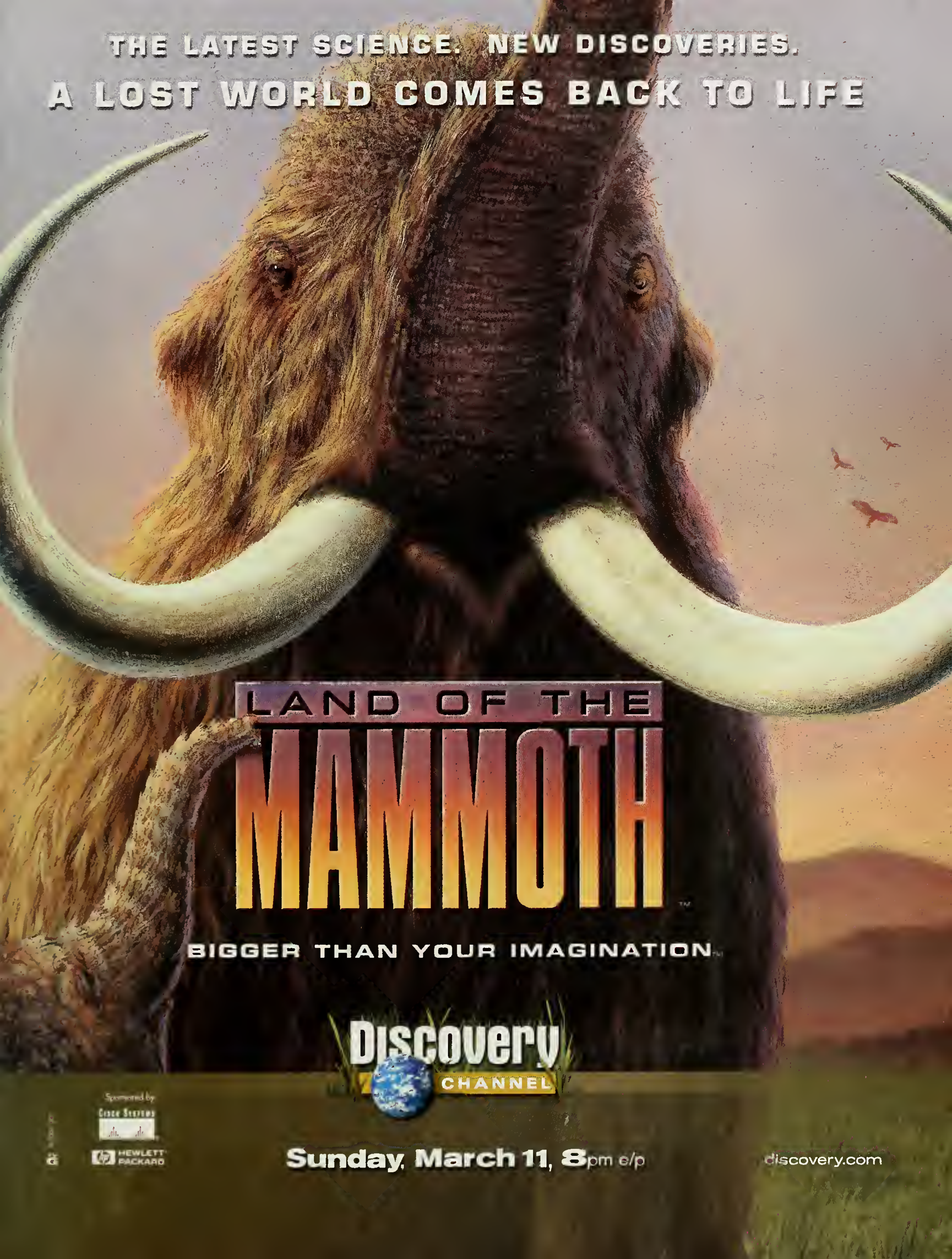

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UP FRONT

Collective Memory

We are all historians, archivists, curators. We paste family photographs into albums or cram them into boxes along with school yearbooks and letters from old friends. We hold on to material objects, however plain, that embody private memories. A few people I know are quite ambitious in their efforts to possess a past that is theirs alone. With some historical detective work, they manage to reconstruct a genealogy, tracing their line back to early colonists or distant shores. Others among us, however, can't peer very far into the family past without losing track of our ancestors, whether in the chaos of minor and major migrations or the tragic oblivion of slave ships, massacres, famines, plagues, and wars.

But all of us leave the chronicling of deep time and large-scale history (the stories of our nations, our ethnic or religious groups, our species itself) to the professionals—historians, archaeologists, paleontologists, and (these days) even geneticists, who trace the winding paths of our genes on strands of DNA. Yet these large-scale stories, together with the irreplaceable historical objects connected with them, belong to all people. In an important sense, a document such as the Magna Carta or the map of the human genome belongs to everyone, as do humanity's artistic and architectural masterworks. Machu Picchu, Luxor, the Parthenon, Angkor Wat, and all the other special places built by our forerunners, while the pride of particular nations, can also be said to be the property of the world.

ALEXANDRA AVAKIAN

Tourists at the site of Babylon's Hanging Gardens

As John Malcolm Russell explains in this month's issue, the land we now call Iraq (known in the past as Mesopotamia, Sumer, Assyria, and Babylonia) is the birthplace of writing, irrigation, cities, religion, monumental architecture, and other major human innovations. Iraq, writes Russell, is one big archaeological site. Certain of the country's ancient places, such as Nineveh and Babylon, are well known; others are obscure and have yet to be fully excavated. During the Gulf War, some sites were severely damaged, and in the years since, many have been critically endangered by looting.

However one views the politics and events that have led us to this point, Russell's article and Alexandra Avakian's photographs serve to remind us that if the special places of Iraq are destroyed or lost, all of us are diminished.—*Ellen Goldensohn*

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LETTERS

Daddy Longlegs

I was delighted by "Touchy Harvestmen" (10/00), by Rogelio Macías-Ordóñez. I will be able to use my newfound knowledge of how the daddy longlegs feels its way through life in my own work as a naturalist. It will help city kids relate to and be less afraid of these gentle creatures. I've been told that daddy longlegs are poisonous but have mouthparts too tiny to inflict wounds in humans. Is this true?

Carolyn Sanford
Clinton, Maryland

Harvestman

ROGELIO MACÍAS-ORDÓÑEZ REPLIES: Those of us working with daddy longlegs have all heard and been puzzled by that story, as there is no evidence to support it. I polled some fellow biologists, and one explanation was that at some point, an article on a group of somewhat poisonous Australian spiders that are also called daddy longlegs was picked up by the U.S. media, and the creature was interpreted to be our own harvestman daddy longlegs. The colleague who related this also commented that the poisonous harvestman story has become an urban legend and is one of the most commonly asked questions about arachnids. True members of the harvestman order, Opiliones, can produce secretions to which some people may be especially sensitive, but that's all.

Snakes' Breath

Carl Zimmer's article on snakes ("Biomechanics," 11/00) reminded me of a question I've never heard answered. Given that snakes regularly swallow prey thicker than their own bodies, how do they breathe during this process?

Joe Kesselman
via e-mail

BRAD MOON (whose work Zimmer discussed) REPLIES: Snakes can hold their breath for a long time but can also breathe while feeding. These reptiles have one very long lung and one short, vestigial lung. If a snake is using the front of its body to squeeze or swallow a mouse, for example, then it can use muscles in its midsection to help pump air to the long lung. Also, the epiglottis, or opening to the trachea (in the floor of the snake's mouth), can be pushed forward a little and opened to let in air. While a snake is ingesting prey, it will periodically stop its jaw movements to stick out the epiglottis and breathe.

Serpent Encounters

J. Alan Holman's article ("Endpaper," 11/00), in which he mentioned the smooth green snake, was of special interest to me because I had seen one of these little gems of the serpent world just a couple of weeks earlier. On an exceptionally warm fall day, my wife and I went for a walk at a nature preserve, a mixed area of open sphagnum bogs and glacially derived sand dunes, now overgrown with white pine and hardwoods. No less than five snakes—four garter and one smooth green—crossed our path that day.

I had last seen a smooth green snake fifty years ago. At the time, I was staying at a farm in northwestern Pennsylvania owned by the uncle of a friend. The uncle had yelled at my friend and me just the day before for releasing a large snake that we had found near the house. His exact words were "I don't care how big a snake it is, I want you to kill it." Even after his reprimand, I was so entranced by the smooth green snake that I captured it, placed it in a small box, and kept it secretly in the farmer's home until I was able to leave on the bus with the snake hidden in my luggage. I kept it in an aquarium for several weeks and fed it insects. Eventually I released it in my own neighborhood.

Roy H. Senn
Rome, New York

Celestial Names

In "Celestial Events" of 11/00, on the naming of recently discovered celestial bodies, author Richard Panek mentions only names from Western cultures and none from peoples elsewhere in the world. The International Astronomical Union should be pressed to name some percentage of newfound features using terms from the astronomies of peoples of Africa, the Middle East, Latin America, the Pacific, Australia, and Asia.

Allen F. Roberts
Los Angeles, California

RICHARD PANEK RESPONDS: The brevity and limited scope of my article made references to non-Western cultures impractical, but you will be glad to know that other cultures are indeed well represented in the names of new celestial bodies. Just a cursory look at the first page of the International Astronomical Union's list (wwwflag.wr.usgs.gov/nomen-bin/search.cgi) of


ADVENTURES

nomenclature approvals for 2000 turns up a Mayan name for morning Venus and features named for a gigantic Egyptian serpent, a Talysh (Caspian Sea) river deity, a Sumerian thunderbird, and a Quechua potato goddess. There are thirteen more downloadable pages that include names from Aztec, Australian Aboriginal, Indonesian, Sioux, Polynesian, Madagascan, Vietnamese, Tibetan, and other cultures.

Double Your Pleasure

Neil de Grasse Tyson's account of geometric progression ("Universe," 11/00) reminded me of two early legal cases in England that also teach this lesson well. In 1661 James sued Morgan for their agreed-upon price of a horse: one barleycorn for the first nail in its shoes, doubled successively for each of the other thirty-one. Morgan must have been dumbstruck upon learning that he owed nearly 4.3 billion barleycorns, but the judge directed the jury to decide upon a fair value for the horse, which it set at eight pounds. Several decades later, Thornborough gave Whitacre a half-crown in exchange for a grain of rye that was to be doubled in number each week for a year. The judge knew this would be "a vast quantity" and thought the jury would "consider the folly of the defendant" and award a reasonable amount, but the parties settled before trial when the grateful Whitacre offered to return the half-crown and to pay Thornborough's legal costs. The judge was right, of course. This vast quantity of 4.5 quadrillion grains, or 4.4 billion bushels, was about 540 times the total amount of rye harvested in the United States in 1997.

William (Tom) Thomas
Oak Ridge, Tennessee

Setting the Banding Record Straight

The article by Annette Heist on song learning in hummingbirds ("Singing in the Brain," 10/00) offered a fascinating glimpse into a little-known part of the lives of these familiar birds. However, as an ornithologist and bird bander whose specialty is hummingbirds, I was surprised to read the author's assertion that hummingbirds cannot be banded due to risk of injury and impaired flight.

I'm happy to report that the 3,000-plus hummingbirds that I've handled as part of studies here at the Southeastern Arizona Bird Observatory appear quite comfortable wearing their specially made bands and have absolutely no trouble flying with these minuscule aluminum rings around their legs. In fact, some of my avian acquaintances have worn their bands for as long as eight years with no apparent ill effects, racking up thousands of frequent-flyer miles on their annual migrations and nesting up to three times per year.

Admittedly, banding hummingbirds is a research specialty. Of approximately 4,000 licensed banders in the United States, less than 3 percent are permitted to band hummingbirds. As with our other native birds, hummingbirds are banded with the permission of, and using numbered bands issued by, the Bird Banding Laboratory, a division of the U.S. Department of the Interior.

Sheri Williamson
Bisbee, Arizona

ANN AND ROB SIMPSON

Banded hummingbird at feeder

THE EDITORS RESPOND: Every article in the magazine is a collaboration and reflects the effort and input not only of the author but also of scientists and editors. The error that you and other dedicated banders pointed out originated in a misinterpretation of information from an ornithology lab. But the failure to scrutinize the statement was ours. We thank you for your enlightening letter.

Drawing Water

Carl Zimmer's discussion of Barbara Bond and Michael Ryan's work on the natural limits to tree height ("Biomechanics," 10/00) left me wondering about one thing: After a tree drops its leaves in the fall, how does the process get started again in the spring? Without any active stomata to draw up water, how do the buds get enough water so they can open into leaves?

Van L. Knowles
Lexington, Kentucky

BARBARA BOND REPLIES: This is a great question. Cells in buds are alive through the winter. In spring, light and temperature patterns send signals to the buds to begin converting their stores of starches into sugars, creating high osmotic potential in the cells. Water then moves into the cells by osmosis. As the water arrives in the cells, it increases the "tension" of the water in the buds surrounding the cells, causing water to be pulled up from the roots.

Natural History's e-mail address is nhmag@amnh.org.

CONTRIBUTORS

Mention social insects and most people tend to envision a beehive or a termite mound, not a white globe housing a contingent of caterpillars. Entomologist **Terrence D. Fitzgerald** ("The Nightlife of Social Caterpillars," page 38) has spent much of his professional life documenting the ecology of butterfly larvae that live in colonies. A professor of biology at the State University of New York College at Cortland, Fitzgerald teamed up in 1996 with Dessie Underwood (now at the University of California, Davis) to study the colonial, cold-adapted madrone caterpillars of Mexico's Sierra Madre Occidental. For the 4/95 issue of *Natural History,* he wrote "Caterpillars Roll Their Own," on leaf-rolling caterpillars.

Art historian **John Malcolm Russell** ("Robbing the Archaeological Cradle," page 44) has witnessed some of the ways in which Iraq's heritage has been lost following the Gulf War. While excavating in 1989 and 1990 at Nineveh, he photographed sculptures from the palace of the Assyrian king Sennacherib, a monarch whose exploits are recorded in the Bible. In 1995 he was shown many of the same sculptures, but by then plunderers had cut them up to sell piece by piece on the antiquities market. An associate professor of art history and archaeology at the Massachusetts College of Art in Boston, Russell is the author of *The Final Sack of Nineveh* (Yale University Press, 1998). Photojournalist **Alexandra Avakian** has worked in the Middle East, eastern Europe, central Asia, and Africa for such publications as *National Geographic, Time, Life,* and the *New York Times Magazine.* She thought that a story on the state of Iraq's archaeology would be a fresh way to address the impact of sanctions on that country and its people. On a couple of occasions she had to work during sandstorms, which, she concluded, gave her photographs an appropriately moody feeling. In particular, she liked photographing villages near the sites, knowing that they had been there, in some form, for thousands of years.

A professor of evolutionary biology at Australia's University of Sydney, **Richard Shine** ("Serpentine Cross-Dressers," page 56) has studied pythons in Australia and pit vipers in China. Shine (at right) earned a doctorate at the Australian National University with a dissertation on venomous snakes and a second doctorate in reptile ecology at the University of Sydney. Coauthor **Robert Mason,** an associate professor of zoology at the University of Oregon, discovered the "she-male" phenomenon in garter snakes while in graduate school. He met his future wife, Sarah, when she came to Manitoba as a volunteer at the province's snake dens. "Not too many people," he writes, "can say they met their spouse in a snake pit with 25,000 mating garter snakes swarming around their feet." For more on garter snakes, Mason and Shine recommend *The Snake Scientist,* by Sy Montgomery (Houghton Mifflin, 1999), with photographs by Nic Bishop.

Richard W. Burkhardt Jr. ("A Man and His Menagerie," page 62) has spent many happy hours at the National Museum of Natural History in Paris—years ago, while studying French biologist Jean-Baptiste Lamarck, and more recently, while researching the history of animal behavior studies. The key figure in his later research proved to be Frédéric Cuvier, the younger brother of Lamarck's rival on evolutionary matters, Georges Cuvier. A professor of history at the University of Illinois at Urbana-Champaign, Burkhardt is the author of *The Spirit of System: Lamarck and Evolutionary Biology* (Harvard University Press, 1977) and is now finishing up a book on the establishment of ethology as a scientific discipline in the twentieth century.

Paul Nicklen ("The Natural Moment," page 84) was raised in a tiny Inuit village on Baffin Island and has spent most of his life in Canada's far north. Trained in marine biology at the University of Victoria, he spent several years as a government wildlife biologist in the Arctic. Nicklen, who says he tries "to photograph stories rather than just take pleasing pictures," has snowmobiled 4,000 miles through the Arctic archipelago in search of polar bears and swum among seventy-ton bowhead whales in the Arctic Ocean. His work has appeared in *Natural History, Terre Sauvage,* and *Life.* Nicklen's latest book of photographs is *Seasons of the Arctic,* in collaboration with Hugh Brody (Greystone/Sierra Club). He lives in Whitehorse, Yukon.

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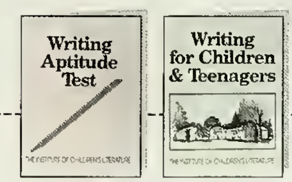

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BIOMECHANICS

Story by Carl Zimmer ~ Illustration by Sally J. Bensusen

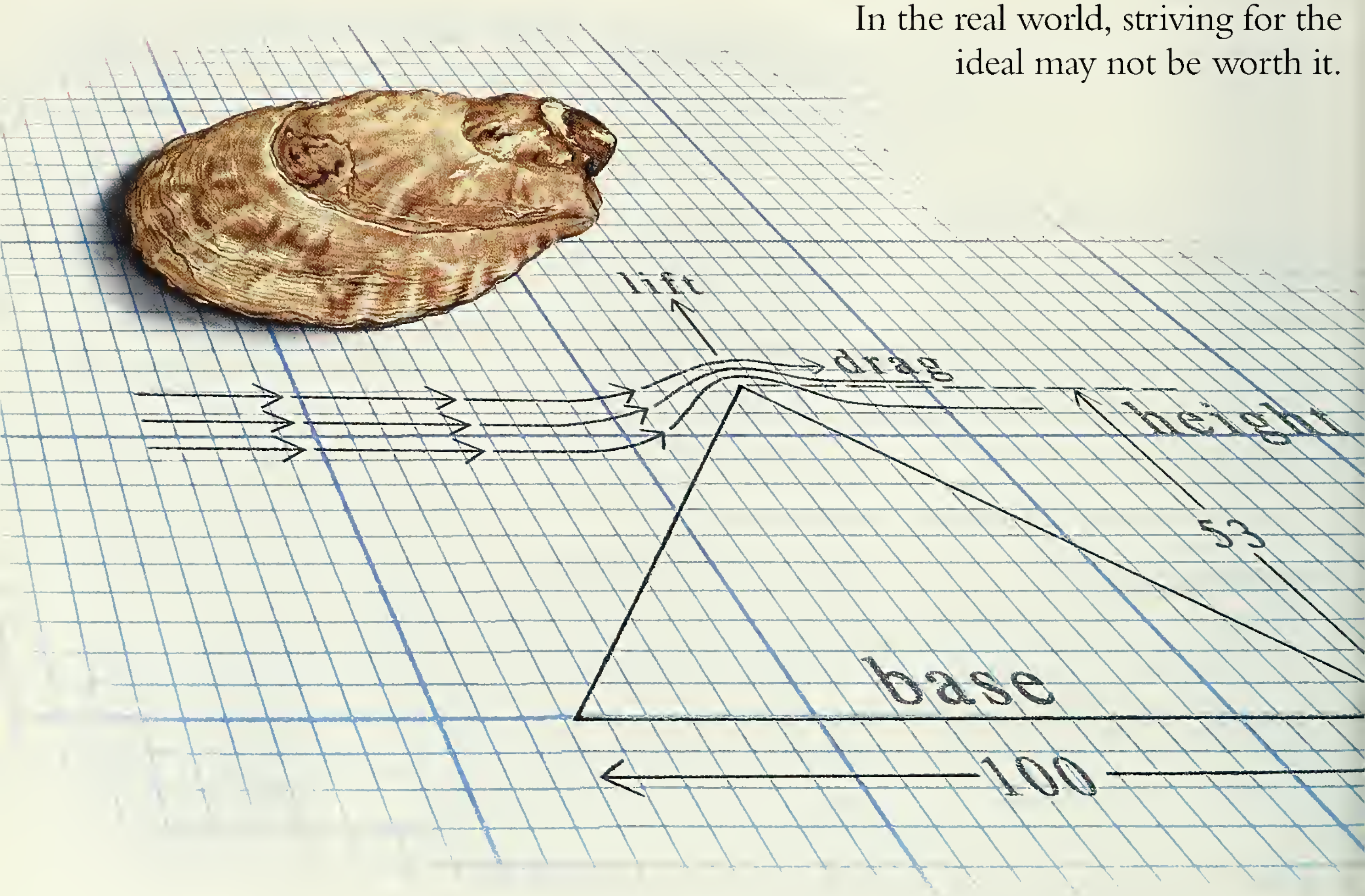
The Perfect Limpet

In the real world, striving for the ideal may not be worth it.

It would seem axiomatic that well-designed animals outperform badly designed ones and pass on to their offspring the genes that helped create that design. As good genes arise and spread, animal designs should theoretically shift from the flawed toward the better. So when a design is significantly inferior to what might seem best for a given situation, something interesting is probably going on. Stanford University's Mark Denny recently investigated one such apparently poor design—that of the limpet.

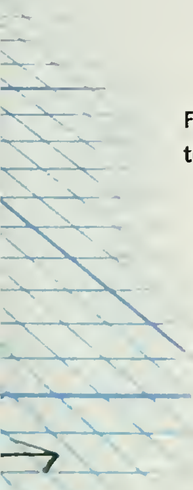
Limpets are marine gastropods that live on rocky coasts and in tide pools. They excrete a gluelike substance to anchor themselves to rocks but can loosen their grip enough to slide around on their single "foot" and graze on algae. The limpet's shell, a low cone that looks like a gently sloping hill, provides protection from crabs, birds, and other predators. It also helps the animals survive the waves that regularly slam against them at speeds greater than eighty feet per second.

The shape of a limpet's shell has a great deal to do with whether the animal remains securely attached to its rock or is ripped off and thrown onto dry land or into the waiting tentacles of a hungry sea anemone. There are two ways a wave can dislodge a limpet. If the limpet's shell is steep-sided, the



drag of the water against the sides of the shell will force it in the direction of the wave. But if the limpet has a rounded hump, the water may pull it off its rock in the following way: The presence of the limpet creates an interruption in the onrush of the wave, "squeezing" the water over the rounded top of the shell and forcing it to move faster, which lowers its pressure. Water flowing around the base of the shell moves more slowly, raising the pressure. This water pushes against the limpet under its shell, producing high pressure in its body as well. The difference in pressure—high beneath the shell, low above it—can create enough lift to suck the limpet right off its rock.

To measure the drag and lift experienced by limpets, Denny put acrylic models of their shells in a wind tunnel. (Technically, air and water are both fluids, and as such, they both flow. Air may be 800 times less dense than water, but it is easier to work with experimentally.) Some of the models had small holes to which Denny attached sensors that measured how pressure was distributed over the shell. Other models were rigged up with springs at their base to measure how much drag the wind imposed on them. And Denny tried out a range of different shell shapes—some with high peaks, some with low ones, some with central peaks, and others with peaks set off to one side.



For a limpet, the best way to avoid being swept from a rock by powerful waves is to have a shell with a height 53 percent of its length and a peak directly over its center. In reality, however, most of these mollusks, like the owl limpet at left, make do with a squat shell and an off-center peak.


PATTI MURRAY; ANIMALS ANIMALS

Mask limpets *(Tectura persona)*

Studying his results, Denny figured out the specifications for the perfect limpet shell: to get the best protection against the combined dangers of lift and drag, a shell's height should be 53 percent of its length and its peak should be directly over the center of its shell. Yet real limpets are a long way from perfection. Most of them are fairly squat, with an average height-to-length ratio of only 34 percent. Seemingly making matters worse, their peaks are generally well off center.

To understand why limpets have such an imperfect design, Denny switched from the ideal to the real, making a close study of the owl limpet, *Lottia gigantea*. Found along the California coast, the owl limpet can reach up to four inches in diameter. Its height-to-length ratio is an embarrassing 25 percent, and the peak of its shell is perched at its front end. Pugnacious, it pushes away other limpets that trespass on its little patch of rock. However, faced with certain predators, such as starfish, it lifts up its shell and slides away as fast as it can—at a speed of one inch per second. On the rocky coastline near his lab, Denny measured how much force it took to pry a limpet off a rock. He also lassoed limpets with a loop of string and tugged on them to gauge how well the shells withstood drag.

Denny found that the most important factor determining whether a limpet gets washed away or not is how tightly glued to the rock it is. If an owl limpet is hunkered down when hit by a wave moving at eighty feet per second, it has a 91 percent chance of holding fast, but if it has the bad luck to be running away from a starfish, it has only a 0.5 percent chance of not being washed away. An optimal shell design doesn't change the odds very much: a perfect owl limpet would have a 95 percent chance of holding fast if it was anchored, a 2.4 percent chance if it was on the go.

The minor risk posed by the owl limpet's shape is probably offset by the advantages. The off-center peak of this creature's shell allows the limpet to use it like a bulldozer to clear its territory of other animals. Fewer competitors mean more food, which may ultimately translate into more baby limpets. And together with the strength of its glue, the limpet's habit of hunkering down when big waves start pounding its rock may help compensate for its "poor" design.

Like engineering, biomechanics is all about trade-offs. But nature has a special set of trade-offs that human engineers don't have to worry about—when designing skyscrapers, they can be reasonably sure that other skyscrapers aren't going to move in and try to push theirs off the block.

Science writer Carl Zimmer is the author of At the Water's Edge *and* Parasite Rex.

NATURE'S INFINITE BOOK

A Tale of Two Reputations

Why we revere Darwin and give Freud a hard time

By Jared Diamond

We scientists have fantasies of being uniquely qualified to make great discoveries. Alas, reality is cruel: most of us are replaceable. For the vast majority of scientific contributions, if scientist X hadn't achieved it that year, scientist Y would have achieved the same result or something very similar soon thereafter. In modern molecular biology, most famous discoveries emerged as multiple teams raced toward the finish line, with the "loser" only a few months behind the "winner." For instance, if James Watson and Francis Crick hadn't published the correct structure of DNA on April 25, 1953, Linus Pauling, who was working on the same problem and had just published an incorrect structure, would surely have arrived at the correct answer within a short time.

Have any individuals really made a major, lasting difference to the course of science? More specifically, would their discoveries or conceptualizations have eluded other scientists until decades later if these individuals had not been born, and did their contributions have a unique impact that persisted long afterward? By those two criteria, I think that only two scientists within the last two centuries clearly qualify as irreplaceable: Charles Darwin and Sigmund Freud. (I feel unsure whether Albert Einstein's impact was as far-reaching.) A comparison of Darwin and Freud proves interesting. What made them irreplaceable, what exactly did they get right, what did they get wrong, how similar were their personalities and their peer relations, and how do their reputations compare today?

To begin with, Darwin and Freud were both multifaceted geniuses with many talents in common. Both were great observers, attuned to perceiving in familiar phenomena a significance that had escaped almost everyone else. Searching with insatiable curiosity for underlying explanations, both did far more than discover new facts or solve circumscribed problems, such as the structure of DNA: they synthesized knowledge from a wide range of fields and created new conceptual frameworks, large parts of which are still accepted today. Both were prolific writers and forceful communicators who eventually converted many or most of their contemporaries to their positions. (In this, they were unlike Gregor Mendel, the founder of genetics, who within his lifetime convinced nobody of the significance of his discoveries.)

Both made their contributions as a result of new insights, not as a result of inventing a new instrument or technology. In fact, both used little more than their eyes and ears. One must therefore pause to wonder why Darwin's views on evolution, and Freud's on the human mind, had not already been formulated by Aristotle and the ancient Greeks. The answer is that the views of both depended on the enormous amount of knowledge that had accumulated over the two millennia since Aristotle's time—not only discoveries about natural history and the human mind but also a developing framework of concepts and questions (what historians describe by the German word *Fragestellung*).

DRAWINGS BY DAVID LEVINE

Charles Darwin

Darwin's contributions came at a time when almost everyone (including scientists) believed in the divine and independent creation of species, and when scientists were recognizing patterns in the burgeoning discoveries about fossils, taxonomy, and biogeography but still lacked explanations for those patterns. Today Darwin is best known for establishing the fact of evolution and for recognizing the major role of natural selection in driving it. Actually, he achieved far more than those two most famous of his contributions. He also recognized sexual selection as an additional evolutionary driving force, laid the foundation for today's understanding of animal behavior, published a major work on the behavior and physiology of insectivorous plants, and provided the correct explanation for hierarchically branched taxonomies as well as for the origins of biogeographic regions, coral reefs, volcanic rocks, and soils. Underlying Darwin's contributions were his very broad technical competencies in anatomy, botany, embryology, geology, paleontology, taxonomy, and zoology, as well as his threefold methodological brilliance as an observer, experimentalist, and theoretician.

In his mastery and synthesis of many types of information and his ability to utilize diverse approaches, Darwin was unique. No biologist then or since has come even close to matching him, and that's why no one else made his contributions. While it is true that Alfred Russel Wallace and Darwin independently came up with the idea of natural selection and evolution, the reasons that Darwin, not Wallace, is regarded as the irreplaceable genius are instructive. Wallace's reasoning about natural selection, and the initial evidence he based it on, were essentially the same as Darwin's. But the papers about natural selection by Wallace and Darwin that the Linnean Society published side by side in its journal in 1858 were ignored. The world did not begin to be convinced of natural selection until Darwin published the *Origin of Species* a year later, making an overwhelming case by amassing evidence from many fields. Because Wallace lacked depth in many of the disciplines and approaches mastered by Darwin, Wallace could never have made the overwhelming case that Darwin did, and he frequently acknowledged Darwin's greatness thereafter.

Multifaceted geniuses, Darwin and Freud were keen observers, perceiving in familiar phenomena a significance that escaped everyone else.

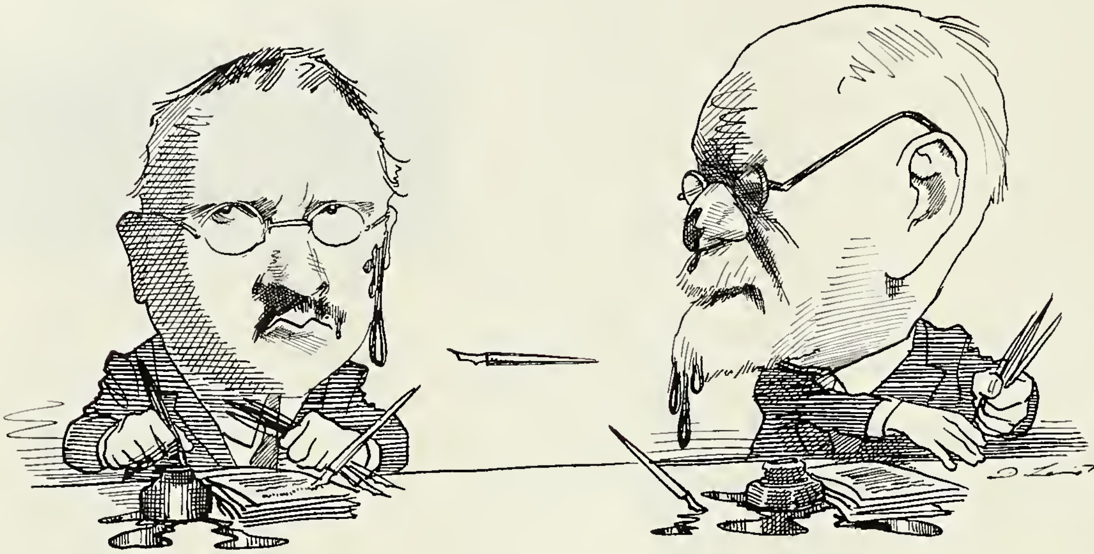
Freud's contributions came at a time when interest in mental illness and its classification was growing but its etiology was virtually unknown and treatments were mostly ineffective—in part because clinicians and researchers were still focused on conscious, cognitive processes. Freud's status is unique because he recognized an entirely different mental realm, and many of his concepts—pioneering and radical in their time—are so familiar today that they have entered the daily vocabulary of the general public. These include the idea of the unconscious, the significance of dreams, the lingering importance of early childhood experience, the Oedipus complex, motivational conflict, and defenses such as denial, rationalization, and repression. For some mental conditions, Freud also devised therapies based on the "talking cure" rather than just on the then-prevalent treatments of electric shock, hypnosis, or institutionalization. He also developed a unifying theory of the normal personality, recognized transference and countertransference in the patient/therapist relationship, and explored the broader social consequences of individual psychopathology.

Freud searched constantly for the underlying causes of mental disorders, and he developed techniques such as free association and the study of dreams to probe the unconscious. As with Darwin, Freud's immense contributions arose from the breadth of his competence—in anatomy, neurology, pharmacology, philosophy, physiology, and psychology. More than just a psychologist who wanted to understand what makes people tick, Freud also had the therapeutic goals of a physician who wanted to help people. Like Darwin, he had no contemporaries whose contributions approached his in scope and originality; there was not even the equivalent of a Wallace to be mentioned and explained away.

Those are some of Darwin's and Freud's successes. What about their omissions and failures? Given their achievements, it may seem absurd even to bring up the issue. This question reminds me of a cartoon of some cavemen pointing to another caveman and asking, "What's that guy done since he invented fire?" Of course they were limited by the technology of their time: one can hardly fault Darwin for not anticipating by a century the recognition of DNA as the genetic material, or Freud for not determining chemical structures and the role of neurotransmitters.

Nevertheless, we still can't help wondering about some things that Darwin and Freud might have recognized or might have gotten right but didn't. Darwin's foremost omission was his failure to progress in elucidating the principles of genetics. Such progress potentially lay within his grasp, because he designed and executed brilliant experiments with plants and published a whole book on cross-pollination and self-pollination. Similarly, the results of his many experiments in pigeon breeding might readily have suggested to him the concept of recessive and dominant traits. Yet Darwin failed to extract the fundamental genetic insights that Gregor Mendel extracted by planting peas during the years just before and after Darwin was writing the *Origin of Species*.

Darwin also got some big things wrong. He shared the then-widespread belief in "soft inheritance," the assumption that the environment could cause adaptive changes in the hereditary material, but his younger contemporary August Weismann showed that this could not be so. Darwin accepted the postulate of "blending inheritance" (the fusion of a mother's and father's characteristics in their offspring), even though his own experiments on pigeons refuted it. Much more surprising are two other errors: he eventually failed to acknowledge the reality of species as non-interbreeding sets of populations, and hence he also eventually failed to accept that new species originate predominantly through geographic isolation, although that precise issue underlies the title of his most famous book. What makes the latter two errors so striking is that Darwin had previously formulated both ideas correctly but then abandoned his formulations in later editions of the *Origin*. These mistakes had long-lasting consequences, because they were not rectified by other biologists until about eighty years later and because a significant minority of biologists persist in those errors today.



Carl Jung Sigmund Freud

Freud also made some disconcerting omissions and errors. He was a man of his time in some of his views of women; he believed, for example, that a woman's main and appropriate role was that of wife and mother. Rooted in an era that tabooed discussions of sex, he rebounded to the opposite extreme and exaggerated the roles of sex and sexual conflict in the development of the psyche. He gave insufficient credence to some patients' reports of being sexually abused as children. His emphasis on a death wish is now viewed as wrong or greatly exaggerated. At least in part because his driving motivation was to help and to cure people, not just to understand them intellectually, he was not scientifically rigorous. And as a therapist, Freud could be faulted for not departing from his focus on individuals to develop therapy for couples, families, or groups.

Today we seem much more inclined to castigate Freud for his omissions and errors than Darwin for his. I suspect that there are two reasons for our differing attitudes toward these two pioneers. One is that Freud's failures, unlike Darwin's, have had a direct impact on the lives of individual human beings. Most of us don't suffer as a result of Darwin's having eventually attributed too much scope to the process termed sympatric speciation than it actually deserves. But a powerful man's mistaken ideas about women have certainly caused suffering, just as victims of child abuse have been made to suffer when the reality of their trauma has been denied.

The other reason we are inclined to judge Freud more harshly than Darwin is that these two scientists were near opposites in their relations with peers. In this regard, we find much to admire in Darwin and much to deplore in Freud. Darwin was outstandingly generous in crediting others—including, most notably, Wallace—for their work. While Darwin came in for severe criticism from other scientists and in turn often expressed his disagreement with their views, he responded courteously, used scientific arguments, and completely avoided personalizing disputes. I can think of no one about whom he expressed hatred or said nasty things, and no one whom he tried to impede professionally. Freud, on the other hand, was outstandingly ungenerous: he denied credit to others, was intolerant of rivals, hated many people, and surrounded himself with unquestioningly loyal admirers. Freud's fallings-out with his famous psychoanalytic contemporaries Alfred Adler, Josef Breuer, Carl Jung, and Otto Rank are merely the most notorious examples. A legacy of this aspect of Freud's personality has been the ugly tendency among psychotherapists, especially those closest to the Freudian tradition, to personalize disputes and to break into factions.

Darwin was generous in crediting other scientists. Freud was intolerant of rivals and surrounded himself with unquestioning admirers.

Both Darwin and Freud have had their detractors, and the ideas of both men initially faced fierce opposition. Today very few scientists hold low opinions of Darwin, either as a person or as a scientist. The overwhelming majority of those who fundamentally disagree with Darwin's findings today are not scientists at all, but creationists, who do not engage seriously with the facts of biology. Virtually no contemporary scientists believe that Darwin was basically wrong. Since Darwin's time, we have of course discovered masses of new facts, formulated new concepts, and advanced beyond many of his specific interpretations, but modern biologists still consider themselves to be Darwin's intellectual descendants, working within his tradition.

By contrast, Freud's detractors remain numerous, even though they take for granted many of his concepts and contributions. Just consider how the Library of Congress's 1998–99 exhibition on Freud in Washington, D.C. (which has since traveled to major museums worldwide) triggered demands by serious thinkers that negative views of Freud be represented. There were protests that Freud was unworthy of even being honored by an exhibition. A corresponding exhibition on Darwin would have been protested only by creationists. I acknowledge a legitimate moral base underlying such Freud-bashing: the human consequences of his scientific errors, and his often ugly interpersonal relations.

Freud's errors, unlike Darwin's, have the potential for direct, damaging impact on the lives of individual human beings.

But there are two other types of Freud-bashing that are not defensible. One consists of pointing out all the new things learned and all the new therapies devised since Freud, as if these represent his failures or demonstrate the uselessness of his work. Yes, we now know much more about how people think and how to help them than we did in Freud's day. But just as with Darwin, that subsequent progress began with Freud's insights and would have been unthinkable without them.

The other type of Freud-bashing—much more damaging because it hurts patients—comes from a too-narrow focus on biological psychiatry. I fully accept the importance of biological psychiatry, having devoted some of my own research to problems in that area (neurotransmitters and manic-depressive illness). It has now become clear, as it could not have been in Freud's day, that some major thought and mood disorders have a biological basis, even though the details of that basis in the most widespread syndromes (depression, manic-depressive illness, schizophrenia, autism) remain elusive.

Many medical-school psychiatry departments were once bastions of Freudian psychoanalysis, whose practitioners resisted biological studies. But now the pendulum has swung to the opposite extreme: psychiatry departments have become bastions of molecular biology, at which much more time is devoted to studying and teaching psychopharmacology than to what are called talk therapies. Outside academia, however—among clinical psychologists, social workers, and lay analysts—those therapies are a growth industry. Among the many reasons for academe's imbalance are its reductionist bias and its professional reward system: many Nobel Prizes and National Institutes of Health grants are available for biochemical research, but many fewer NIH grants and nary a Nobel Prize for talk therapies. Other considerations are that contemporary Western societies tend to seek technological fixes, and health insurance companies are more willing to reimburse claims for drugs than for talk therapy. Certainly, it would be less painful for both therapists and patients if our problems could be solved by taking pills rather than accepting responsibility for our suffering and then learning new ways of interacting with others. Not only that, but the stigma of "mental illness" and the challenges of moral responsibility would be diminished if one's problems arose from chemical processes beyond one's control (as is true in some cases) rather than from voluntary actions.

To my mind, academe's swing away from talk therapies is tragic. Major advances are still being made in this field—for instance, in crisis counseling and in child and family therapy. Almost all of us face stress in our jobs, our health, our personal relationships, and our own aspirations. Almost all of us carry emotional and cognitive baggage from our early lives that leaves us with some inappropriate responses in our lives as adults. Some of those problems can be dealt with by talking with friends. But some problems require professional distance, experience, and skills—the skills in which a talk therapist is trained and that are far beyond the capacity of a friend to deliver.

Even specialists in biological psychiatry need thorough training in talk therapies, because it can be difficult to figure out whether a patient's problems have a primarily biological or a primarily nonbiological basis. Even clients whose problems are probably fundamentally biological (such as in manic-depressive illness) tend to have associated psychological issues that need attention. Physicians who rely heavily on prescribing drugs often don't take time to establish a relationship with a patient, regularly forget that the patient and physician are locked in an emotionally charged relationship, and then are surprised at how often patients fail to take the drugs prescribed for them. Understanding that unique two-way relationship was one of the many deep and far-reaching insights that put Freud right up there with Darwin.

Jared Diamond is a professor of physiology at the UCLA School of Medicine and a research associate in ornithology at the American Museum of Natural History.

THIS LAND

Cactus Country

An Arizona canyon provides a taste of desert and a glimpse of uplands.

By Robert H. Mohlenbrock ~ Photographs by Randy Prentice

Rising above the Sonoran Desert, the Santa Rita Mountains extend north to south, falling roughly midway between Tucson, Arizona, and Nogales, Mexico. The highest peaks, including 9,453-foot Mount Wrightson, are topped off with verdant forests of Engelmann spruce and ponderosa pine, while cacti and other desert plants grow at the base of the mountains, at about 3,000 feet, and penetrate dry canyons up to 4,000 feet. The range is a favorite among naturalists because of its varied plant and animal life and the scattering of natural springs, but only a few routes provide easy access into the rugged terrain. The most popular destination, reached by a highway that pierces the north side of the region, is a camping and recreational facility at the head of Madera Canyon; my favorite locale, however, is Agua Caliente Canyon, best reached from the west. Both canyons are under the jurisdiction of the Nogales Ranger District of the Coronado National Forest.

Lying at 3,600 to 4,200 feet, Agua Caliente Canyon harbors mostly desert

Jumping cholla

grassland and isolated stands of oak, while pinyon pine and alligator juniper are scattered on the surrounding dry, rocky slopes. Natural springs help feed some streams that flow intermittently


Purple prickly pear

in response to rainfall; other streambeds are washes, entirely dry except after heavy rains. One reason I am attracted to this canyon is that it is one of the few places in the United States where one can find two species of *Amoreuxia*, which are essentially tropical wildflowers. The birdlife, too, is alluring. Several species of hummingbirds flit about the blooms of the Arizona trumpet and the desert honeysuckle, while the rat-tat-tat of five different kinds of woodpeckers may be heard. Occasionally the elegant trogon, more common in Mexico, will fly overhead. Mammals are also plentiful. Although rarely seen, mountain lions and bobcats periodically cross the canyon. Likelier to be encountered are javelinas (collared peccaries) and coatimundis (large, ring-tailed cousins of the raccoon).

To get to Agua Caliente Canyon, exit Interstate 19 at Canoa Road and follow the east frontage road south before turning eastward into the canyon on Elephant Head Road. Eventually you will connect with a road that climbs along the south side of the canyon, heading toward the Smithsonian Institution's Fred Lawrence Whipple Observatory. Tours of that facility, located on the 8,585-foot summit of Mount Hopkins, depart from a visitors center and are available by reservation. Before you reach the visitors center, located at the base of Mount Hopkins, you will find a rough, unpaved road that leads off to the left for a quarter mile, down into the canyon, to Agua Caliente Spring. As its name indicates, the water from this spring is hot. Heated underground through geothermal processes, the water feeds an intermittent stream.

From the spring, you can pick up any of several hiking trails. One that heads toward Mount Hopkins passes two rocky knolls that top off at 4,962 feet and 6,012 feet. Together they are known as the Devils Cash Box, named for a 1909 gold strike. Intrepid hikers can also trek onward to the Madera Canyon campground or the summit of Mount Wrightson.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of U.S. national forests and other parklands.

For visitor information, contact:
Forest Supervisor
Coronado National Forest
300 W. Congress Street
Tucson, Arizona 85701
(520) 670-4552
www.fs.fed.us/r3/coronado

HABITATS

Desert grassland plants include many cacti, the most spectacular of which are the saguaro, with its thick, armlike branches, and a number of large chollas, such as the tree cholla, the jumping cholla, and the cane cholla. Also prominent are various prickly pears, with their flat, padlike stems, and the fiercely spined Arizona barrel cactus, which may grow to a


Arizona barrel cactus

foot in diameter and more than three feet tall. Smaller species include the Arizona rainbow cactus, sporting multicolored spines; claret cup, named for its flower; pancake cactus, which grows up to four inches in

JOE LEMONNIER


Ocotillo

diameter and lies flat on the ground; pincushion cactus, which stands about two inches tall; and the two- to five-inch-tall nipple cactus, whose stems end in small rounded tips.

A plant with cactuslike spines that is actually related to Mexico's boojum tree is ocotillo. After a rain, its barren, gray-black stems change overnight to green as small leaves emerge from buds covering the plant. After a few days of dry weather, the leaves fall off and the plant resumes its dormant appearance. While cactus flowers have many petals, the ocotillo's red flowers have only five, united at their base to form a tube.

Stands of oak may appear in shallow depressions and other places that have slightly more moisture. The dominant (and often only) species is Gambel's oak.

Dry, rocky slopes support a few kinds of stunted trees, among them Gambel's oak, silverleaf oak, pinyon pine, and alligator juniper. Most do not grow more than twenty feet tall under the arid conditions. Typical shrubs include squawbush (a type of sumac); coral bean and fairy duster (both members of the pea family); two types of hibiscus, or rose mallow; and cliff Fendler bush. Snapdragon vine, a plant with arrowhead-shaped leaves and dark red or bluish purple flowers with a yellow center, scrambles over some of the shrubs. Prickly pear cacti found here are the clock-face prickly pear, Engelmann's prickly pear, cliff prickly pear, and purple prickly pear. Wildflowers that grow scattered in rocky soil include pine-needle milkweed, Arizona trumpet, long-leaved phlox, and a true wild cotton. Two uncommon species with three-inch-wide orange flowers are *Amoreuxia palmatifida* (yellow show) and *A. gonzalezii*, the only two members of the tropical Cochlospermaceae family that are found in the United States.

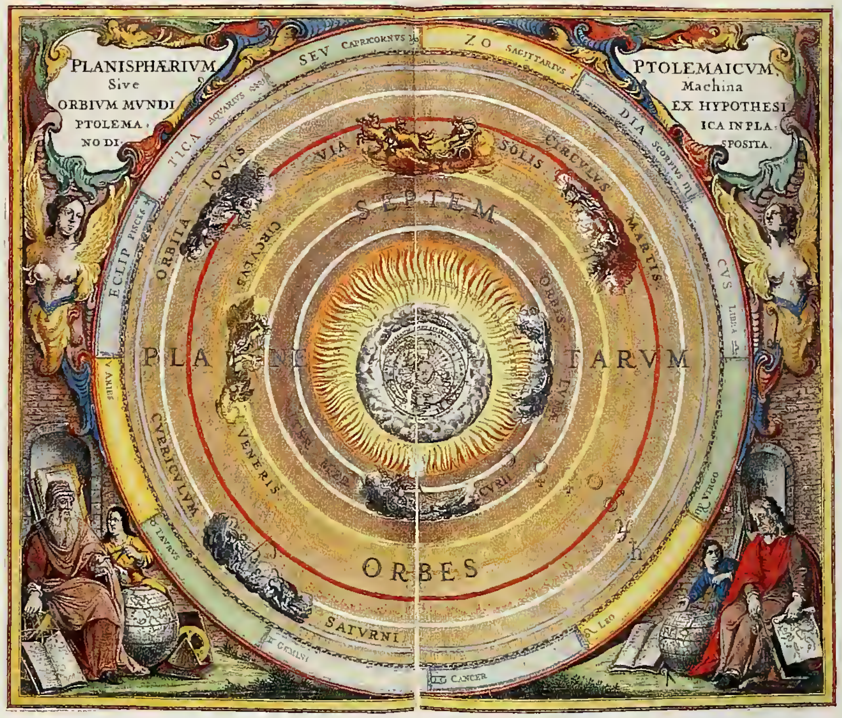
On some dry slopes—perhaps because they are not quite so rocky—shrubby species include quinine bush, silk tassel bush, desert sumac, mescat acacia (white thorn), and wait-a-minute bush (a type of mimosa). Wildflowers that grow here are dogweed, springleaf zinnia, wedgeleaf scurfpea, and trailing windmills (a creeping plant whose flowers are grouped by threes into what appear to be single blossoms).

Streams, although they may flow only intermittently, help support the growth of several trees, among them blue palo verde, mesquite, velvet ash, small-leaved mulberry, netleaf hackberry, and soapberry. A common shrub is seep willow, a member of the aster family whose narrow leaves resemble those of willows. Wildflowers near streams include the bright-yellow-flowered monkey flower; a *Mecardonia* with tiny purple snapdragon-like blossoms; a thoroughwort with lavender flower heads; and Albert's dome, a plant with yellow flower heads that each have a central raised dome.

Washes support only plants that can survive long stretches of extremely arid conditions. Two shrubs here are desert broom and burro bush, while wildflowers include desert honeysuckle, with long, tubular, brick-red flowers, and woolly feverfew, with white or greenish flowers.


Elephant Head

CELESTIAL EVENTS



"Ptolemaic System," from *Harmania Macrocasmica* by Andrea Cellarius, 1661

Center Stage

Repositioning the Sun at the hub of our celestial neighborhood was only the first step.

By Richard Panek

It almost goes without saying that today we wouldn't think of the solar system as "solar" if there had been no Copernicus to put the Sun at its center. But more than 450 years after the beginning of the Copernican revolution, it can be difficult to remember that "solar" is only half the story.

When we look at the night sky now, we take for granted that the little lights that wander—the planets—bear a greater resemblance to Earth than they do to all the little lights that don't wander—the fixed stars. For thousands of years, however, the reverse seemed true. Earth was Earth, and the little lights were little lights, whether they were on the move or not. The conceptual divide was between Earth and just about everywhere else—between "here" and "there." If a further distinction existed out "there," dividing planets from stars, it fell, vaguely, between "far" and "farther."

The Copernican system alone didn't necessarily change that. To be sure, it rearranged the heavens, dispatching the Sun to the center of the universe and sending Earth, the planets, and the stars spinning in orbit around it. But for an earthly observer, the basic distinction between here and there continued to hold.

Only with the advent of the telescope in the early seventeenth century did astronomers begin to identify similarities between Earth and the other planets, such as their shared global shape and the presence of moons. And only with the invention of dedicated precision instruments throughout the rest of the century did astronomers begin to appreciate the relative distances to celestial objects. As Rice University historian of science Albert Van Helden once wrote of this era's technology, "Every new discovery brought the planets closer to the earth, and every improvement of the telescope showed the stars to be even farther away."

Early in the seventeenth century—at the end of the reign of the geocentric universe—most astronomers estimated the distance to the fixed stars to be 20,000 Earth radii. By the turn of the eighteenth century, that estimate stood at 20,000,000,000 Earth radii—a millionfold increase. On such a scale, the planets suddenly didn't seem so far after all. However improbably, those wandering lights in the night sky were relatively near, leaving the stars alone to occupy the impossibly vast stretches of far and farther.

Nothing captured this new celestial hierarchy better than the coining of the term "solar system," which apparently dates from the early 1700s. In the three centuries since then, our ears, sensitized by the Copernican revolution, have come to hear an emphasis on the word "solar." But the understanding that Earth belongs to a system was no less profound.

By the end of the eighteenth century, philosopher Immanuel Kant and mathematician Pierre-Simon de Laplace had independently proposed that the Sun and planets shared a common birth, condensing out of a mass of gas. Despite some untenable details of their hypothesis, the German astrophysicist Carl Friedrich von Weizsäcker retained much of their basic thinking in the more sophisticated model of the nebular

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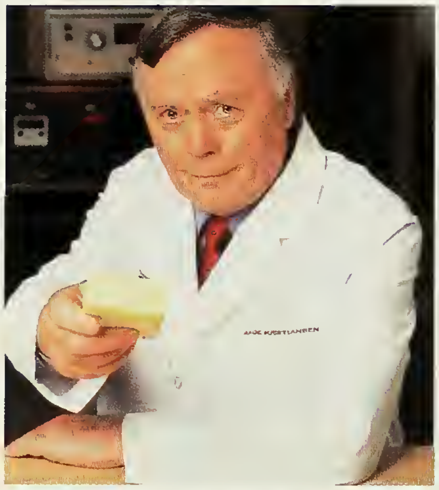

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Tempur-Pedic, Inc., 1713 Jaggie Fox Way, Lexington, KY 40511 evolutionary process that he worked out in the 1940s.

Indeed, our conception of the solar system continues to evolve to this day. Just within the past decade, astronomers have discovered Kuiper Belt objects—small, icy bodies at the outer reaches of the solar system that may number in the billions. As University of Arizona researcher Jeffrey Larsen reported at an astronomy meeting this past August, "Our solar system seems to be populated with many objects that even a few years ago were not seen because they are extremely faint. We still do not know yet how far out they go."

Or do we? In late October, just two months after Larsen spoke, three researchers announced that although they had conducted six extensive surveys, they hadn't detected any Kuiper Belt objects at a distance of more than fifty-five astronomical units (AU) from the Sun, approximately at the outer range of Pluto's orbit. (One AU equals the distance between Earth and the Sun, or about 93 million miles.) Does the solar system really peter out at Pluto? Or will better technology and instrumentation reveal fainter objects? And how would either scenario alter current theories of solar system formation?

While astronomers ponder these questions, the rest of us can enjoy an especially spectacular planetary display in February by our solar system

THE SKY IN FEBRUARY

Mercury reaches inferior conjunction on February 13. The planet comes back into view during the last week of the month, appearing low in the east-southeast before dawn.

Venus hangs in the western sky this month as darkness falls. Climbing as high as 42° above the horizon at sundown in midnorthern latitudes, it sets about three and a half hours after the Sun. It is so bright during February that observers should have little trouble finding it, even before sunset. The 20th is the date of its greatest brilliancy. Viewed through a telescope, the planet's crescent appears to grow both larger, as it approaches Earth, and thinner, as it shows us more of its night side. By month's end, Venus's disk is large enough for viewers to recognize its crescent phase (using binoculars with at least 7x magnification).

Mars can be found in the constellation Libra at the beginning of February but crosses over into Scorpius on the 19th, remaining there for the rest of the month. Throughout February it appears to rise out of the southeast between 1:00 and 1:30 A.M. Local Standard Time (LST). As the planet draws nearer to Earth—its distance shrinking from 137 million to 112 million miles—it brightens by half a magnitude, reaching +0.5 by month's end. Mars appears to pass less than 2° below the Moon on the morning of the 15th.

Jupiter, at magnitude -2.4, ranks next to Venus in brightness this month. The giant planet is visible all evening; look for it near the meridian at sunset as it disappears below the western horizon at about 2:00 A.M. LST at the beginning of February and about midnight by month's end. The ruddy first-magnitude star Aldebaran can be found southeast of the planet. Jupiter seems more than twice as bright as the star Sirius, which at early evening sparkles in the southeastern sky, below and to the left of the bright planet. On the evening of the 2nd, when the Moon is just past first-quarter phase, it slips below Jupiter.

neighbors. On the first day of the month, Jupiter and Saturn will line up strikingly with the first-quarter Moon in the southern sky. And on February 20 and 21, Venus will reach a magnificent -5.4 magnitude, the brightest it will be until the end of 2002. Without magnification the planets can never be anything more to earthly observers than lights that wander. Even so, they can also serve as nightly reminders of how much our understanding of the universe has changed, near and far.

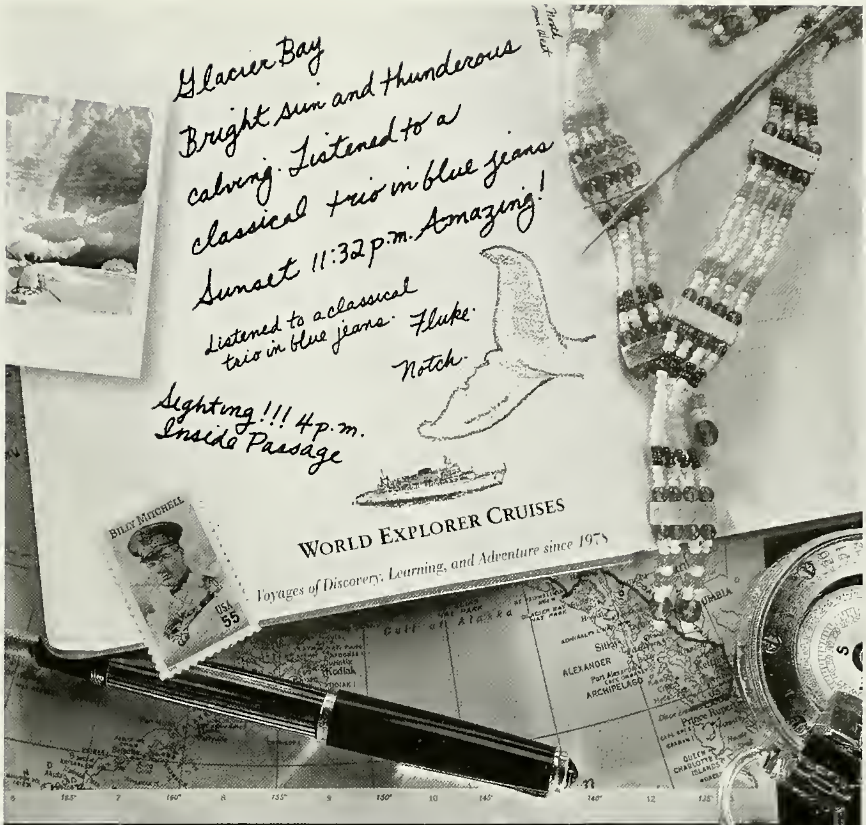
Richard Panek is the author of Seeing and Believing: How the Telescope Opened Our Eyes and Minds to the Heavens *(Penguin, 1999).*

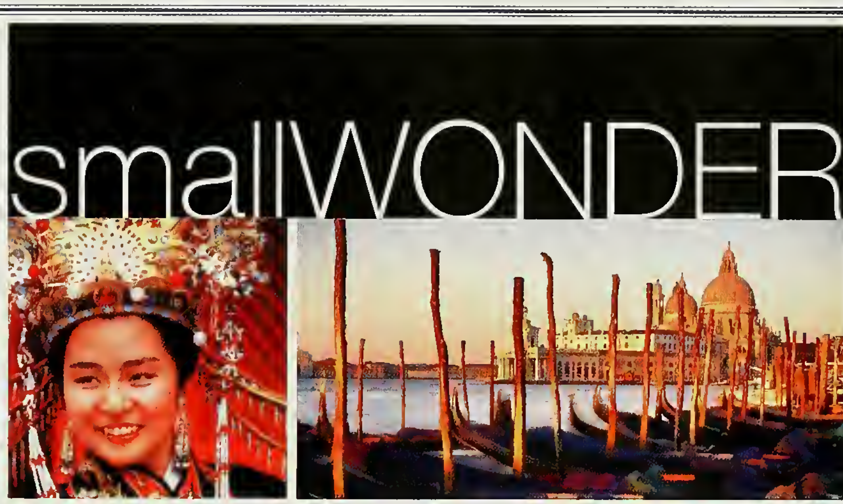
By Joe Rao

Saturn, found near the meridian this month during evening twilight, sets after midnight LST. It appears as a yellowish white, zero-magnitude "star" in the constellation Taurus, about 8° southwest of the Pleiades and about the same distance west of the much brighter Jupiter. Tipped at about 24.5° to our line of sight, Saturn's famous ring system can be easily viewed, through even a small telescope. At dusk on February 1 and again on the 28th, the Moon, Saturn, and Jupiter will appear stretched out in a line.

The Moon is at first quarter on February 1 at 9:02 A.M.; full Moon is on February 8 at 2:11 A.M. Since the full Moon occurs only nine hours after reaching perigee (its nearest point to Earth), ocean tides will be much higher than normal for a few days around this date. Last-quarter Moon is on February 14 at 10:23 P.M., and the new Moon falls on February 23 at 3:21 A.M.

Unless otherwise noted, all times are given in Eastern Standard Time.





IN SUM

MONKEYING WITH MILLIPEDES

Twenty years ago, ecologist John Robinson, of the Wildlife Conservation Society, observed puzzling behavior in a group of wedge-capped capuchin monkeys *(Cebus olivaceus)* in central Venezuela. Upon finding a millipede, the monkeys rubbed it all over their bodies, their eyes appeared to glaze over, and they frequently placed the arthropod in their mouth while


XIMENA VALDERRAMA

Wedge-capped capuchin

THOMAS EISNER

drooling. Three or four often shared a single millipede, passing it from one to the other. Afterward the monkeys rubbed up against one another, apparently to spread the millipede's secretions. Up to ten bouts of this frenetic, ecstatic anointing could take place within a single day.

In 1988 Robinson invited his student Ximena Valderrama, now in Columbia University's anthropology department, to conduct a two-year follow-up study at his field site. Valderrama collected some of the millipedes *(Orthoporus dorsovittatus)* used by the monkeys and sent them to chemical ecologists Thomas Eisner and Athula Attygalle, of Cornell University. After "milking" the millipedes for their secretions, which are produced by glands along their sides, the chemists determined that they contained benzoquinones, which are powerful insecticides and disinfectants.

Because the monkeys anoint themselves exclusively during the rainy season, when they are vulnerable to infection by mosquito-borne botfly larvae, Valderrama and her colleagues hypothesize that the animals intentionally apply the benzoquinones as protection against biting insects and parasites. Although millipede secretions contain other toxins and even carcinogens, they appear to cause the monkeys no harm. ("Seasonal Anointment With Millipedes in a Wild Primate: A Chemical Defense Against Insects?" *Journal of Chemical Ecology* 26:12, 2000)

A VEGETARIAN CROCODILE

Until now, the fossil record of the last 200 years has presented a remarkably stable array of crocodiles. Several gigantic varieties appeared during the age of the dinosaurs, but these long-snouted, aquatic carnivores seem not to have undergone any radical changes over the eons. Recently, however, paleontologist Gregory Buckley, of Roosevelt University in Chicago, and his colleagues unearthed the fossil skull of a previously unknown crocodile—and it appears to have been a short-snouted vegetarian.

Simosuchus clarki, extracted from approximately 70-million-year-old rocks in Madagascar, has a short pug nose, a tall head, and nostrils that point out from the front of the face, not upward, as in typical living crocodilians. Some features of the thick skull suggest that it may have been an adept head-burrower. An adult *Simosuchus* would have been only about three feet long.

The most unusual feature of the new species is its multicusped teeth, which resemble those of presumed herbivorous dinosaurs such as ankylosaurs and stegosaurs. *Simosuchus* seems to have undergone a convergent evolution with


CAROLYN MCKEE-FREESE

Reconstruction of *Simosuchus*

these armored, tanklike dinosaurs. In addition to the similarities in tooth form, this species had a broad, compact body and a heavy-boned skull like those of the dinosaurs. However, its skull also shows the characteristic osteoderms, or bony plates in the skin, that distinguish crocodiles from their dinosaur relatives.

The new fossil also presents a puzzle for geologists because of its resemblance to *Uruguaysuchus*, an extinct crocodile from South America. Buckley and his colleagues think this suggests that Madagascar and South America may have been linked 80 million years ago, long after the young Atlantic Ocean is believed to have separated the two landmasses. ("A Pug-Nosed Crocodyliform From the Late Cretaceous of Madagascar," *Nature* 405, 2000)

IDENTICAL EMU TWINS

A group of researchers in New Zealand has documented the first case of identical twinning in birds. S. M.


THE EVENING STANDARD, PALMERSTON NORTH, NZ

Twin emus with shell

Bassett, of the Ratite Research Centre at Massey University in New Zealand, and several colleagues describe two emu chicks *(Dromaius novaehollandiae)* hatched from the same extraordinarily large egg at an emu farm in Colyton, New Zealand. The egg was artificially incubated, and humans assisted the two female chicks to emerge from the shell. Although their combined weight on hatching was about the same as that of a single normal chick, by eighteen months of age they were near average size.

Fraternal twinning—two fertilized ova becoming trapped inside a single shell—is a rare but well-documented occurrence in some birds. As with human fraternals, the two birds are no more closely related than are ordinary siblings. A DNA analysis of the New Zealand emu hatchlings' blood showed a complete genetic match, however, indicating their formation from a single ovum that split after fertilization. ("Genetically Identical Avian Twins," *Journal of Zoology* 247, 1999)—*Richard Milner*

IN THE FIELD

MARK STOUFFER; ANIMALS ANIMALS

A biologist recounts how a peaceful retreat became a cold-weather zoo.

Winter Guests

By Bernd Heinrich

Even before I finished building the cabin, I could see that it had potential. Bubo, my tame great horned owl, perched on one of the rafters rather than staying out in the woods, where the blue jays harassed it. Similarly, as soon as I crossed the doorstep, the June hordes of bloodsucking blackflies and horseflies left off their hot pursuit. Aside from harboring a few stray houseflies in late summer, the inside of the cabin was a sanctuary. When winter came to the Maine woods, however, my cabin became more appealing to the wild local fauna, and many adopted my haven as their own. As a first-time log cabin builder, I had made many construction mistakes, and the biggest was not anticipating the entrance of winter guests—thousands of them.

Among mammals, my annual visitors now include a few common smoky shrews, short-tailed shrews, red-backed voles, and, last but certainly not least in numbers, deer mice. As far as I'm concerned, all are welcome except the cutest of the lot, the deer mice. Normally, deer mice spend winter high in tree holes, where they build cozy nests and stay warm by huddling in groups. Since I built the cabin, I've done my best to plug every conceivable opening with oakum, a sisal fiber more often used to stop holes in wooden boats, but deer mice seem to penetrate the cabin more easily than water does a boat. The mice apparently get inside through tiny apertures and then create more openings by pulling out the oakum plugs between the logs. In this they are aided by the larger and stronger flying squirrels that use the oakum for lining their winter nests in natural tree holes or in birdhouses that I provide, primarily for other occupants.

On any winter night I can hear swarms of deer mice scampering overhead in the space between the metal roofing and a sheet of insulating Styrofoam. At intervals the footsteps stop and I hear crunching as the mice chew the Styrofoam as well as the tar paper beneath it. White Styrofoam flakes stream down like snow all over the bed and floor. Once inside, the mice shred clothing for their nests, leave peanuts in my bed, and burrow into the dry goods. The possibility that they might carry disease tweaks at the back of my mind, too. If I set traps, I commonly catch up to four mice in a night, but many more have the run of the place. The joint efforts of the deer mice and the flying squirrels also appear to provide the main means of entrance for "the crowd."

The crowd is always snug inside, come winter. It consists mostly of cluster flies. According to Harold Oldroyd, who wrote the fly bible, the 1964 *Natural History of Flies,* there are several species of these robust flies of the genus *Pollenia.* Most of them are several times the size of houseflies. *Pollenia* are calliphorid, or "flesh," flies. The larvae of our native species eat the flesh of dead animals, but the species in the cabin, *Pollenia rudis,* was introduced from Europe, and the larvae parasitize earthworms. Big and bristly, these flies are not handsome, in contrast to the metallic green or gun-barrel blue of our native *Pollenia* (which never enter the cabin at all).

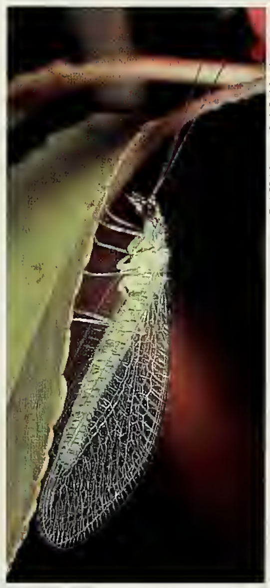
In the fall *P. rudis* perch in crowds on the logs outside the cabin and sun themselves. When it starts to get cool, they slip through the cabin cracks. By November most of them seem to have made their way inside, but they remain totally unobtrusive unless I build a roaring fire in the woodstove. Then, within minutes, they come poking out of all the crevices and, in an hour or so, if it is still daylight, gather by the thousands in buzzing masses at each of the eight windows, making a collective hiss. They apparently perceive the warmth as the return of spring and take it as their signal to try to leave by flying directly to the light at the windows. If offered an exit, at least they do not try to stay on. Even on the coldest days, if I open the windows, they rush out and fly a short distance before the cold grips them and they fall to the snow. The flies are not dead, only immobilized. When subjected to the cold of a Maine winter, these flies quickly become cold-hardy, being physiologically equipped to endure low temperatures. Under lab conditions, I have found that some succumb to freezing at -20° C if cooled rapidly, while others can rebound from -10° C and crawl about within seconds of being warmed up, like those in the cabin.

The larvae of numerous species of ants and beetles spend the winter inside tree trunks, where they endure temperatures close to that of the ambient air. Unlike the quickly revived flies, the larvae I have brought into the cabin seem stone dead even after hours of relative warmth. Only after a few days do they begin to show signs of life. The substances that fortify these larvae against the cold may also account for their lengthy stupor. Ant and beetle grubs contain glycerol or other sweet-tasting "antifreeze" (I have not tasted the flies), which prevents ice-crystal formation in the body, renders them inactive, and also takes a long time to leave the blood.

The other winter cabin guests—primarily of three species—are beautiful and more benign in habit. When the cabin is heated, for example, they don't have the annoying *P. rudis* tendency to hover around the bed light and then, when it's turned off, to dash under the covers and buzz there rudely.

JAMES H. CARMICHAEL; PHOTO RESEARCHERS, INC.

JAMES H. ROBINSON; PHOTO RESEARCHERS, INC.



N. E. BECK JR.; PHOTO RESEARCHERS, INC.

Opposite: Deer mouse, wanted for breaking and entering. Above: Welcome visitors include the mourning cloak butterfly (top left), multicolored Asian ladybug (bottom left), and green lacewing.

The first of these, mourning cloak butterflies, usually remain in crevices outside and only rarely make it into the cabin. In the fall I commonly see one or two fluttering under the roof. The second species has arrived here in numbers only in the past few years. These occupy the cabin by the thousands some years and by the dozens in others; this winter, none have appeared. They are multicolored Asian ladybugs or ladybird beetles, first introduced to the southern United States to control aphids. Like many of our endemic species of ladybirds, these beetles have handsome red-and-black coloration. Asian ladybugs, however, are more varied. Their "background" hue can be deep red or orange or yellow. They may have no spots or have tiny black dots or spots that coalesce into black bands.

Not everyone has fond feelings for these beetles. In some parts of the country, they themselves have become pests by their sheer numbers as they adapt to life in vertical dwellings rather than their traditional Asian crevices and caves. And like many other insects whose bright colors serve as a warning to stay clear, multicolored Asian ladybugs taste bad to predators and give off a noxious smell when crushed. My tolerance for the beetles stems from their own predatory habits. Multicolored ladybugs and their larvae feed on aphids and other plant-sucking insects, such as the woolly adelgid, which is decimating hemlock stands from Virginia to New England. It is claimed that as it develops, a single multicolored Asian ladybug can devour 600 to 1,200 aphids. The adelgid was introduced from Asia and became a serious problem in the mid-1980s, close to the time the Asian ladybird beetles first started showing up in my cabin. Once attacked by adelgids, a hemlock tree dies. So far, I have not had a problem with adelgids on my hemlocks, and I welcome the beetles into their overwintering home.

The third insect that is a regular but never abundant visitor is the green lacewing. The light, bright green of this insect extends to its four wings, delicate membranes stretched between a network of veins. To me, lacewings have a certain aura. But this is lost on aphids. Lacewing adults as well as their larvae, commonly called aphidlions, are ferocious predators. In the woods I often find the adults hibernating under loose dead bark in the winter. They are rare enough in the cabin to be a treat.

The diversity and abundance of winter wildlife is not unique to my cabin. Anyone can be similarly blessed. By allowing a few openings, I now play host to the good, the bad, and the beautiful.

Bernd Heinrich is a professor of biology at the University of Vermont, Burlington.

Nightlife of Social Caterpillars

For cold-adapted larvae on the peaks of the Sierra Madre, the action begins after dark.

By Terrence D. Fitzgerald

Illustrations by Utako Kikutani

ROBERT AND LINDA MITCHELL

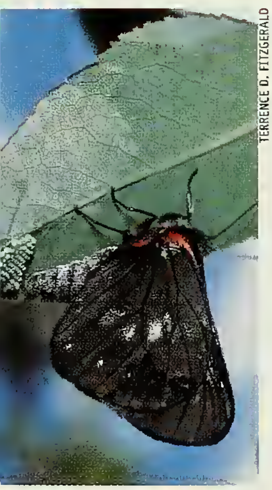
Above: Madrone trees festooned with caterpillar nests. Scenes of a life cycle, opposite, clockwise from upper right: Tiny yellow-green hatchlings; mature caterpillars tending the nest; pupation; mating; and egg laying.

I began to suspect there might be trouble ahead when we had driven for many miles without seeing any cars in the oncoming lane. We had gotten a late start and were traveling at night along twisting and precipitous Highway 41, which leads from the Mexican coastal town of Mazatlán east to the city of Durango, some 180 miles from the Pacific in the Sierra Madre Occidental range. My colleague Dessie Underwood and I had come to this rugged region to study the madrone caterpillar, the larval stage of the pierid butterfly *Eucheira socialis,* a distant relative of the cabbage white butterfly familiar to North American gardeners. Living in colonies at elevations of approximately 8,000 feet, madrone caterpillars nest on the branches and feed on the leaves of the madrone tree, which grows on the fringes of pine forests on the mountain peaks and keeps its leaves all winter. Although snow is rare here, nights are cold and frost is common. But throughout the winter, the madrone caterpillars continue to feed and grow, foraging under frigid conditions that few other insects could tolerate. Dessie and I had teamed up to study their ability to survive deep winter in the mountains.

As our car approached a tortuous part of the highway aptly called Espinazo del Diablo, or "spine of the devil," we encountered a massive gridlock of vehicles stranded by black ice. Motorists huddled around makeshift fires dotting the sides of the highway. It wasn't until late the following morning, after the sun had melted the ice and a pathway was opened through the maze of stalled vehicles, that we were able to continue on our way. Arriving at our study site later that day, we realized we weren't the only victims of the cold. Some madrone trees and their caterpillar colonies had escaped damage, but throughout the forest we saw pockets of frost-damaged madrone trees with colonies of dead, frozen caterpillars hanging from the branches. Records we obtained from a local weather station indicated that the colonies had probably been killed shortly before our arrival, when temperatures fell to as low as 9°F night after night for more than two weeks. Madrone caterpillars push the physiological limits of insects in dealing with cold temperatures, and although they can resist freezing during most winters, they are clearly susceptible to prolonged spells of severe cold.

The madrone caterpillar is one of some 300 species of caterpillars that live in social groups. (More than 140,000 Lepidoptera species exist worldwide.) According to Peter Kevan and Robert Bye, who studied the insect's general life history in the early 1990s, the Aztecs called it *xiquipilchiuhpapálotl,* or "butterfly that makes a pouch." The brilliant white, baglike nests that house the colonies are typically six to eight inches in diameter and are constructed of pure silk. Native peoples used these tightly woven shelters to make containers and fabric. The conspicuous nests, which can number twenty or thirty per tree,

Eucheira socialis, the butterfly that develops from the madrone caterpillar, lays her eggs on a madrone leaf. Females usually mate and deposit their eggs on the same day they leave the nest as adults. Mission accomplished, they soon perish.



TERRENCE D. FITZGERALD

also attracted the attention of the explorer Alexander von Humboldt during his travels in Mexico in the early 1800s. Von Humboldt observed the caterpillars and used the nest material as parchment, signing his name in 1804 on a section cut from a nest.

While the bag nests are feats of caterpillar architecture, the insects' enduring family bonds and the recently discovered fact that the colonies are composed largely of males are what make the madrone caterpillar unique, so far, among social caterpillars. Each colony consists of up to several hundred siblings that remain together for nearly a year, pupating as a group and then transforming into butterflies while still sequestered in the nest. The female butterfly lays her cluster of eggs on a madrone leaf during the rainy season, in June or July. The young caterpillars hatch from these eggs in about three weeks and remain together to forage and to spin silk; eventually they cover a few leaves in a veil of silk, creating a primary nest within which they will rest between bouts of feeding. As fall approaches, the caterpillars quicken the pace of their spinning and create a secondary nest that completely engulfs the primary one. The walls of this outer nest are highly fortified, consisting of tens of thousands of strands of silk so tightly woven that the nest will hold water and a sharp instrument is needed to penetrate its walls. The caterpillars will spend the rest of their larval lives—some eight months—in the expanded nest, leaving it only to feed. (Some other lepidopterans have a lengthy larval stage, but most spend far less time as caterpillars than the madrones do. In the tent caterpillars of eastern North America, for example, the larval stage lasts eight weeks.) To feed, madrone caterpillars enter and exit the nest through a small opening at the bottom. Otherwise the nest is an impenetrable fortress, excluding birds, wasps, and most other predators that might find the caterpillars a tasty meal.

Although the primary function of the nest may be to protect its inhabitants from their natural enemies, our studies show that the structure is also essential for caterpillar growth during the winter. At our study site, evening temperatures begin to fall below freezing in October and continue to do so until the following May. From December to February, nighttime lows average 18°F. The days are relatively warm, but the temperature plummets when the sun sets. By the time darkness envelops the forest, the temperature on a typical night will have already fallen to 41°F or less—chilly enough to bring the activity of most insects to a standstill. Yet this is just when the colonies of the madrone caterpillar stir to life.

Our nocturnal fieldwork revealed that the caterpillars leave the nest each evening at dusk. After adding silk to the nest's outer walls, they travel up to ten feet away on the tree and feed until early morning. Usually they return to the nest before dawn, their guts packed with leaves. If the overnight temperature falls below a certain level—known as an insect's chill-coma temperature—all activity ceases, and the inert caterpillars are able to return to the nest only after basking in the rays of the early morning sun. Chill-coma temperatures vary among insects; that of the madrone caterpillar is 28°F. Only one other caterpillar—a subarctic species—is known to have a chill-coma temperature this low. Even when overnight temperatures remain above freezing, however, the physiology of the caterpillars is taxed: at 77°F, madrone caterpillars travel three feet in less than three minutes, but at 41°F, they take half an hour to cover the same distance. So why do these caterpillars press their limits at night, when they could bask in the sun and feed efficiently and at leisure during the day? One explanation is that nocturnal foraging may have evolved in this species in response to predators that are active during the day.

Each colony consists of up to several hundred siblings that remain together for nearly a year.

Although they feed by night, madrone caterpillars cannot digest their food until morning, because they need heat to process what they take in. Like miniature greenhouses, the nests trap the radiant heat of the morning sun, and the caterpillars within the nest are able to warm their bodies rapidly to the relatively high temperature needed to drive the processes of digestion and growth. The temperature of the interior of one nest that we measured in January rose from 25°F to 75°F in just one hour, exceeding the outside air temperature by 30°.

Studies that Dessie Underwood conducted with Arthur Shapiro at about the same time as we were doing our thermal ecology research showed that in colonies of madrone caterpillars, brothers outnumber their sisters by as many as four to one and that, even for their numbers, these males do a disproportionate amount of work involving nest construction and maintenance. Such strongly biased sex ratios are rarely encountered in insects; when they are, as in ants and bees, females predominate. Underwood and Shapiro observed madrone caterpillars over six generations. The persistence of the uneven sex ratio over these generations suggested that producing more males than females is advantageous to the colony as a whole. With their numerous brothers doing most of the work, sisters can save energy and use the nutrients they take in to fuel the maturation of their ovaries. The leaves of the madrone tree contain little nitrogen, which is necessary to build proteins, and the colony will benefit if the females channel this nutrient into the production of eggs—that is, the next generation of madrone caterpillars—rather than silk. At maturity, the female caterpillars weigh up to twice as much as their hardworking brothers.

CHRISTIAN HEEB; GNASS PHOTO IMAGES

TERRENCE D. FITZGERALD

Madrone caterpillars live at elevations of about 8,000 feet in Mexico's Sierra Madre Occidental range. Below: In autumn, some of the caterpillars, typically males, blaze a silk trail along tree branches leading from the nest to patches of leaves they will harvest in winter.

In addition to constructing an efficient heat-trapping nest, the caterpillars prepare for winter by laying down an extensive network of silken trails from the nest to food sources. Because they slow down in the cold, the caterpillars would be unable to travel very far from the nest if they had to blaze new trails in the dead of winter. They solve this problem by establishing the trails before cold weather sets in. By late fall, prominent silk pathways issue in all directions from the nest, each leading to a patch of leaves the caterpillars will harvest during the winter. The energetic males are usually the first to venture forth in autumn, and they secrete most of the silk that marks the pathways along the tree's branches.

Silk helps the caterpillars move more rapidly and obtain purchase on the madrone's smooth limbs, from which they might otherwise slip during their cold-induced nighttime lethargy. To find their way along these paths, however, the caterpillars depend not on the silk but on a pheromone. Each evening, the first caterpillars to head out (again, usually males) lay down fresh stimulant by intermittently brushing against the silk path with the tips of their abdomens and secreting the pheromone. Once established, the chemical trail is followed and reinforced by their colony mates. Critical to foraging success, it not only enables the larvae to stay together during their trips away from the nest but, like pebbles dropped on the forest floor by a traveler, also allows them to find their way back home. Studies show that the caterpillars can detect the pheromone at concentrations of far less than a billionth of a gram per millimeter of trail.

By the time warm weather returns in the spring and the caterpillars prepare to pupate, they will have gathered enough food and stored sufficient energy during their nightly forays to sustain them for the brief remainder of their lives. At this point the colonies of most species of social caterpillars disband, and individual larvae seek secluded pupation sites, but madrone caterpillars retain their social bonds and pupate en masse inside the nest. Prior to metamorphosis, the caterpillars pack together and suspend themselves by the tips of their abdomens from the inner walls. (At this stage the insects are plump and nutritious; indigenous peoples collect mature nests, extract the pupae, and then roast and consume this conveniently packaged food source.) The reproductive success of a colony—its success at passing on its genes to a new generation—can be largely gauged by the weight of its female pupae. When Underwood and Shapiro created experimental colonies with different ratios of male to female caterpillars, they found that male-biased colonies produced the largest pupae.

Having performed their critical role in the success of the colony, many males perish before they have a chance to pupate. On spring days, numerous caterpillars can be found lying listlessly on the outer surface of their nests, where they wither and die. Underwood and Shapiro found that almost all these individuals are males, with no indications of disease, predation, parasitism, or any other clear cause of death. Their studies have shown that males spend less time feeding than their sisters do and occasionally spend the whole night spinning and moving about the nest without venturing out

By late fall, prominent silk pathways issue in all directions from the nest.

to feed. Perhaps the ones that die prematurely are undernourished and simply lack the physiological resources necessary to fuel the metamorphoses that would convert them into pupae and adults.

The communal nest, below, serves as both a fortress and a solar-heated retreat. Opposite: Snug within the shelter by day, the caterpillars leave to forage at nightfall, following pheromone-laced silk paths.

ROBERT AND LINDA MITCHELL

After several weeks of transformation within the nest, the butterflies emerge from their pupal cases. Now, in the final and most fleeting phase of their lives, the insects abandon their habit of moving about only under the cover of darkness. One by one, the mature males and egg-laden females work their way through the nest's opening to the sun-filled world outside. Not all manage to escape. Some die in the attempt to break free of an unyielding pupal case, and occasionally we find a nest choked with dead butterflies at an obstructed opening.

Despite the death of many males in the caterpillar stage, they still outnumber females as adults and are likely to encounter stiff competition as they fly about the madrone trees in search of mates. After surviving a long winter as caterpillars, the *E. socialis* butterflies have only a few days in the sun. The females commonly mate and deposit their complement of eggs on the same day they escape from their nest, and, being spent, they die shortly thereafter. The males, too, live just several days. Still, they will have completed their mission. In only a few weeks' time, madrone caterpillar young, adapted to the rigors of winter nights in the Sierra Madre, will replace them in a new cycle of life. □

Story by John Malcolm Russell ~ Photographs by Alexandra Avakian

Robbing the Archaeological Cradle

In the aftermath of the Gulf War, Iraq's ancient heritage has landed on the endangered list.

A guard stands at the entrance to Hatra, an Iraqi site that has been subject to looting. Hatra's buildings belong to the period when the Iranian empire of Parthia enveloped much of Iraq.

Virtually all of Iraq is an archaeological site, so the 1990–91 Gulf War inevitably took a toll on the remains of ancient settlements, some well known and others still awaiting discovery and exploration. One of these sites was Ur of the Chaldees, the reputed birthplace of Abraham, where excavations in the 1920s and 1930s had yielded a great temple complex as well as royal tombs packed with sacrificed servants and gold treasures rivaling the riches of Tutankhamen. Bombing and strafing left four large craters in the temple precinct and some 400 holes in the temple's great ziggurat, or stepped tower. Far worse, following the cease-fire and the imposition of sanctions, the weakened Iraqi authorities were powerless to protect most of the country's museums and archaeological sites from looting and theft. Even now, a decade later, the nation's Department of Antiquities and Heritage is short of needed resources. As a result, thousands of artifacts have been smuggled out of Iraq and offered on the international market. Furthermore, in the course of an emergency agricultural development program aimed at averting food shortages, the Iraqis have bulldozed, plowed, inundated, and irrigated countless ancient sites. What is being lost is not only Iraq's heritage but the world's.

Called Mesopotamia by the Greeks and variously Sumer, Akkad, Babylonia, and Assyria by its own ancient inhabitants, Iraq has an excellent claim to be the cradle of Western civilization. The emergence of complex communities was accompanied by developments such as writing, the wheel, irrigation agriculture, cities, monumental architecture, state-sponsored warfare, organized religion, written laws, kingship, a wealthy class, imperialism, centrally organized production of hand-crafted goods, and large-scale trade. By and large, the first eleven chapters of Genesis are set in southern Iraq, in the land of Shinar (Babylonia). *Eden,* the Sumerian word meaning "steppe," was the name of a district in Sumer, or southern Babylonia. Mesopotamian royal gardens, notably the Hanging Gardens of Babylon, may have inspired the story of the Garden of Eden. According to Genesis, the first cities founded in Shinar after the flood were Babel (Babylon), Erech (Uruk), and Accad (Akkad), while the first cities in Assyria (northern Iraq) were Calah (Kalhu, now Nimrud) and Nineveh. With the exception of Akkad, well-

preserved remains of all these cities can be seen in Iraq today.

Archaeologists were relatively slow to tackle the region's countless tells, the earth mounds that mark the sites of ancient settlements. Consisting largely of the accumulated remains of mud-brick buildings, they were less enticing than the standing stone ruins of ancient Egypt, Greece, and Rome, and their historic identity was not always apparent, even to local inhabitants. The first archaeologists to explore them were Paul-Émile Botta, a French diplomat, and Austen Henry Layard, an adventurous English lawyer. In the mid-nineteenth century they both probed mounds in and near present-day Mosul, a city in northern Iraq that embraces the site of ancient Nineveh. Between the two of them, they uncovered the remains of five Assyrian palaces.

One, excavated by Layard in Nineveh, was the "palace without rival" of Sennacherib, a king of the Assyrian empire. The inner walls and courtyards were lined with two miles of sculptured stone

Dating from about 2100 B.C., Ur's ziggurat, or stepped tower, was excavated in the 1920s and 1930s.

slabs depicting the king's various campaigns, from the Persian Gulf to the Mediterranean. Sennacherib is best remembered for his unsuccessful siege of Jerusalem in 701 B.C. The siege was cut short, according to conflicting biblical accounts, either by the angel of the Lord or by a large bribe paid by the Judaean king. An inscription on a statue found in the doorway of Sennacherib's throne room also recounts the bribery tale, providing the first-known independent written account corresponding to a story in the Bible.

Within the palace Layard discovered thousands of clay cuneiform tablets, constituting the world's earliest-known comprehensive collection of written knowledge. In 1872 George Smith, a young Assyriologist at the British Museum, discovered that one of these tablets told the story of a great flood that had covered Earth. Suddenly it appeared that eyewitness accounts might be able to enrich the entire biblical narrative, if only the right tablets could be unearthed. This prospect precipitated a refocusing of archaeological attention in the last quarter of the nineteenth century—from art to tablets and from northern to southern Iraq, the setting of Genesis. Although little direct evidence for the historicity of the biblical accounts emerged from these excavations, they did reveal a previously

At Ur, the reputed birthplace of Abraham, excavators discovered a temple complex and royal tombs packed with gold treasures.

unknown civilization that had profoundly shaped the biblical texts.

At the turn of the twentieth century, German teams initiated extensive excavations at three major sites: Babylon, Ashur, and Uruk. In about 1750 B.C., Babylon was the capital of an empire under Hammurabi, a king whose law code recorded principles of justice still recognized today. More than a thousand years later, Babylon became the capital of an even greater empire under King Nebuchadrezzar II (Nebuchadnezzar), who reigned from about 605 to about 561 B.C. and is traditionally credited with establishing the Hanging Gardens of Babylon, one of the Seven Wonders of the World. The Tower of Babel, the great ziggurat beside Babylon's temple of Marduk, dates to this era. Its foundations are visible today. Babylon was also famous for its city wall, part of which—the polychrome brick Ishtar Gate—was carried off to Berlin by the German excavators. Two earlier versions of the gate, adorned with bulls and dragons in brick relief, still stand at the site.

In 587 B.C. Nebuchadrezzar II captured Jerusalem and herded its population east to Babylonia. Some biblical scholars believe that, after arriving in Babylon, the captives drew on the traditions of their conquerors to compose the story of a people that originated in Eden, survived the Flood, built the Tower of Babel, and then, in the person of a

DONALD HANSEN

A limestone statuette discovered in the Inanna Temple of Nippur depicts a woman with her hands clasped in worship. The figure was stolen from the Kirkuk regional museum in northern Iraq following the Gulf War and is still missing.

A woman makes bread in a bedouin camp at Nineveh, below. Behind her is the restored Nergal Gate, straddling the ruins of the city wall. Opposite page, bottom: An ivory furniture ornament from Kalhu, now in the Iraq Museum.

great patriarch, migrated westward to Israel. Abraham's journey became a source of inspiration for the exiled Judaeans.

The ancient city of Ashur, on the Tigris River in northern Iraq, gave its name to the god, the land, and the people of Assyria. Early in the second millennium B.C., Ashur grew wealthy through trade with Turkey, later becoming the center of an empire that encompassed all of what is now Iraq, Syria, Lebanon, Jordan, Israel, and Egypt, as well as large parts of Turkey and Iran. At Ashur the German excavators uncovered monuments and documents from the entire span of Assyrian history.

Uruk, in southern Iraq, often considered the world's first true city, is the place where writing first appeared. Its legendary king, Gilgamesh, is the subject of the oldest-known epic story, in which he

During the bombing of Baghdad, artifacts in the Iraq Museum were dispersed for safety to regional museums and to the vaults of the Central Bank. But the bank was bombed, and after the cease-fire, the regional museums were looted.

fails in his quest to elude death but achieves immortality by building Uruk's great city wall. So complete was the city's economic dominance of Mesopotamia from about 3500 to 3000 B.C. that mosaics made of baked clay cones, a feature considered evidence of an Uruk administrative or mercantile presence, are found from Turkey to Egypt. While the German archaeological work

SCALA/ART RESOURCE, NY

was permanently cut short at Babylon and Ashur by World War I, it was resumed at Uruk prior to World War II and again in 1953. Over the course of a century of excavations there, the German team has recovered more evidence for the rise of Mesopotamian civilization than is available from any other site. Discoveries there include early evidence of kingship

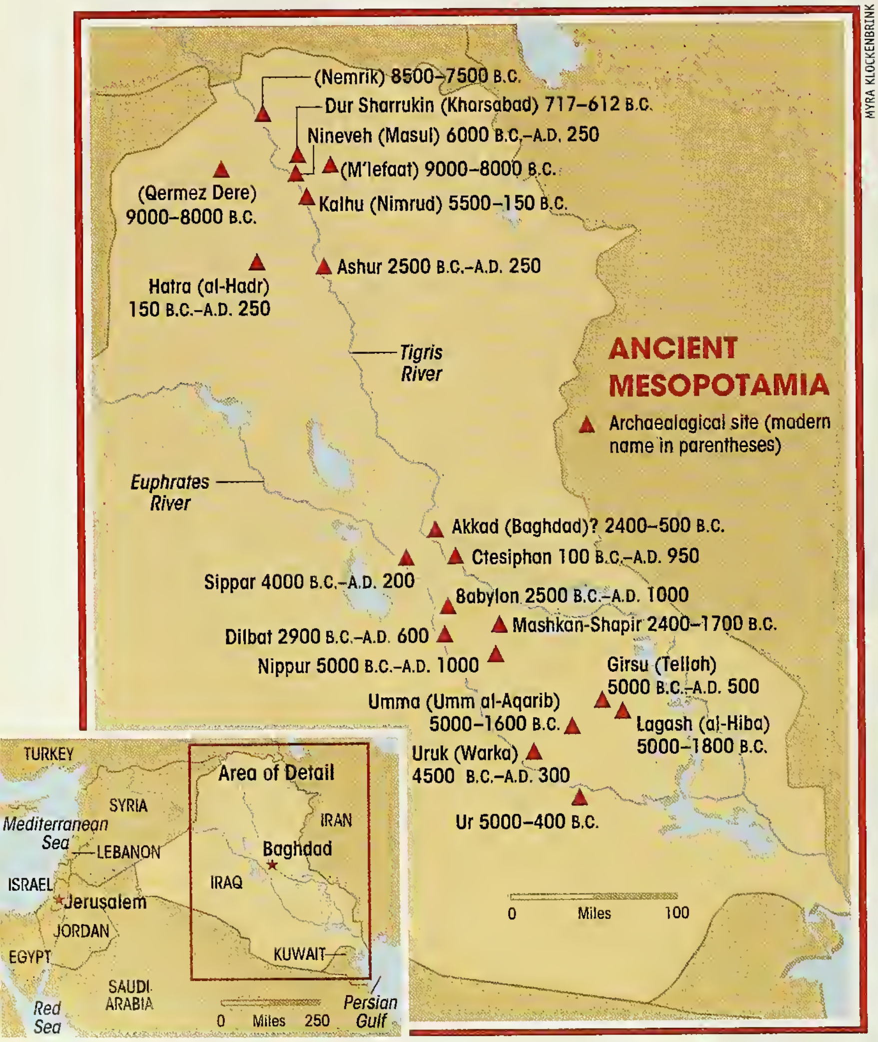
At Ashur, on the Tigris River, above, the Iraqi Department of Antiquities and Heritage has launched new excavations, in part to discourage looters.

and monumental architecture and clear representations of religious rituals.

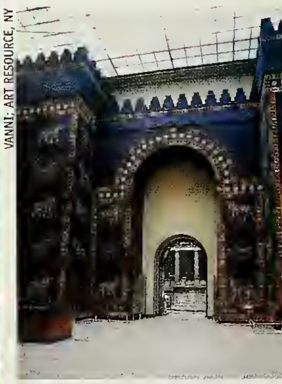
Prior to World War I, the area that is now Iraq was part of the Ottoman Empire. The excavations of Layard, Botta, and other foreign archaeologists in

The earth mounds that mark the region's ancient sites were less enticing to archaeologists than were the stone ruins of Egypt, Greece, and Rome.

the nineteenth century were carried out under permits issued by the government of the Ottoman sultan in Istanbul. At first the sultan showed little interest in ancient remains, and excavators in the mid-nineteenth century were allowed to export whatever they wished. This is when the British Museum and the Louvre acquired the bulk of their renowned Mesopotamian collections, which aroused



MYRA KLOCKENBRINK



VANNI; ART RESOURCE, NY

At the Iraq Museum in Baghdad, left, students view reliefs from Dur Sharrukin. Above: Babylon's Ishtar Gate, unearthed by German archaeologists before World War I, is displayed in Berlin's Pergamon Museum.

ERICH LESSING; ART RESOURCE, NY

Built of unreinforced brick, an arching vault at Ctesiphon, right, is all that remains of a sixth century A.D. audience hall, constructed when Iraq was part of Iran's Sāsānian Empire. Below: A winged deity that once guarded a palace door. Discovered at Dur Sharrukin, the alabaster relief was acquired by the Louvre in the 1850s.

great scholarly and public excitement. Stung by the loss of irreplaceable treasures from the empire and anxious to establish Istanbul as a center for the study of ancient art, the Ottoman statesman Hamdi Bey founded the Archaeological Museum of Istanbul in 1881. Thereafter, foreign archaeologists were obliged to share their discoveries with the museum, which divided duplicate finds with the excavators and had the right to retain unique pieces.

After World War I, Iraq became a separate state administered by Britain. With the energetic guidance of a British official, Gertrude Bell, who advocated that antiquities be retained by the country of origin, the Iraq Museum was founded in 1923 in Baghdad. Upon the end of the British mandate in 1932, Iraq began to take charge of its own patrimony. An antiquities law enacted in 1936 decreed that all the country's antiquities more than 200 years old, whether movable or immovable, above ground or below, were the property of the state and that none could be excavated, sold, or exported without government authorization. Initially, the Ottoman tradition of dividing duplicate finds with their excavators was still permitted, but amendments to the law in the 1970s eliminated this provision.

Artifacts from archaeological sites were now housed in the Iraq Museum, in the heart of downtown Baghdad, which accumulated the most important collection of Mesopotamian antiquities in the world: gold from Ur, ivories and gold from Kalhu, thousands of clay tablets, and major works of sculpture from all periods. The Iraqi Department of Antiquities and Heritage created a nationwide pro-

gram to educate the populace about their country's cultural history. The centerpiece was a network of regional museums, each of which displayed hundreds of objects chosen to provide a microcosm of Iraqi heritage. Largely as a result of the enthusiasm and cooperation engendered by this program, the plundering of archaeological sites was rare.

At the time of the Gulf War, archaeology was experiencing an extraordinary revival in Iraq, after a dry spell during the nation's 1980–88 war with Iran. Dozens of foreign and Iraqi teams were working at an unprecedented rate, often in response to threats posed by modern urban and agricultural development. At the ancient site of Sippar, just southwest of Baghdad, Iraqi archaeologists had discovered an extensive library from the late Babylonian empire. A wide variety of clay tablets (literary works, omens, incantations, astronomical records, mathematical exercises) were found, still arranged on the shelves. British and Polish teams in northern Iraq were excavating Nemrik, Qermez Dere, and M'lefaat, three of the oldest villages in the world. (These settlements, dating to about 8000 B.C., were contemporary with the first domestication of plants and animals

Robbers chopped off the human head of a colossal winged bull and sawed it into eleven pieces in an attempt to smuggle it abroad.

for subsistence purposes.) And at least five American teams had recently renewed or initiated fieldwork at the sites of Nippur, Lagash, Mashkan-Shapir, Dilbat, and Nineveh. Knowledge of Iraq's past was increasing exponentially.

When Iraq invaded Kuwait in the summer of 1990, virtually all archaeological activity ceased, and the war and subsequent imposition of UN sanctions have left Iraq's patrimony in peril. Not only is almost no money available for the preserva-

Hacked into pieces by plunderers of Dur Sharrukin, the human head of a winged bull, left, now rests in the Iraq Museum. Above: A guard shepherds visitors to Umma, a site heavily looted after the war.

tion of antiquities, but in addition, some Iraqi citizens, squeezed between ruinous inflation and shortages of basic necessities, have turned to looting and selling artifacts from excavated and unexcavated sites and even from museums. In the past few years, for example, robbers have hacked up the sculptured stone slabs from the palace of Sennacherib, which had been reconstructed as a museum in the 1960s, and some of the best-preserved fragments have been smuggled abroad to satisfy collectors.

Another affected site is Dur Sharrukin (modern Khorsabad), where Botta discovered the palace of the Assyrian ruler Sargon II (reigned 721–705 B.C.). Before the Gulf War, little of the building itself remained standing, and its monumental sculptures were on display in Baghdad and Paris. Immediately prior to the war, however, Iraqi archaeologists had excavated a colossal human-headed winged bull from one of the city gates. A few years later, robbers chopped off its head and sawed it into eleven pieces in an unsuccessful attempt to smuggle it abroad. The mutilated remains are now on display in the Iraq Museum, and ten of the perpetrators are reported to have been executed.

A bull's head decorates a lyre that was excavated from one of the rich burials in the royal cemetery at Ur and that is now in the Iraq Museum.

SCALA/ART RESOURCE, NY

At Kalhu, Layard excavated the site of the palace belonging to King Tiglath-pileser III (reigned

One of the tablets told the story of a great flood that covered Earth. Might eyewitness accounts exist to enrich the biblical narrative?

744–727 B.C.). The building had been dismantled by one of the king's successors, and its sculptured wall slabs stacked neatly in preparation for recarving. Recently, many of the slabs were stolen and cut up into smaller pieces, which are now appearing on the international art market. The fate of more than a hundred pounds of gold jewelry and other fabulous artifacts that Iraqi archaeologists excavated just before the Gulf War from the burial sites of four Assyrian queens remains unknown.

The site of Telloh ("the mound of tablets"), excavated by French archaeologists beginning in 1877, was the cult city Girsu in the ancient city-state of Lagash. Among the cuneiform records found there is an inscribed stele (upright stone slab) from about 2500 B.C. that constitutes the earliest known documentation of state-sponsored warfare. Lagash was competing with neighboring Umma for irrigation rights, and the dispute was settled by armies that rode into battle in war wagons, among the earliest documented wheeled vehicles. After the Gulf War, Telloh was apparently plundered, because previously unknown temple records from the site appear regularly for sale on the Internet.

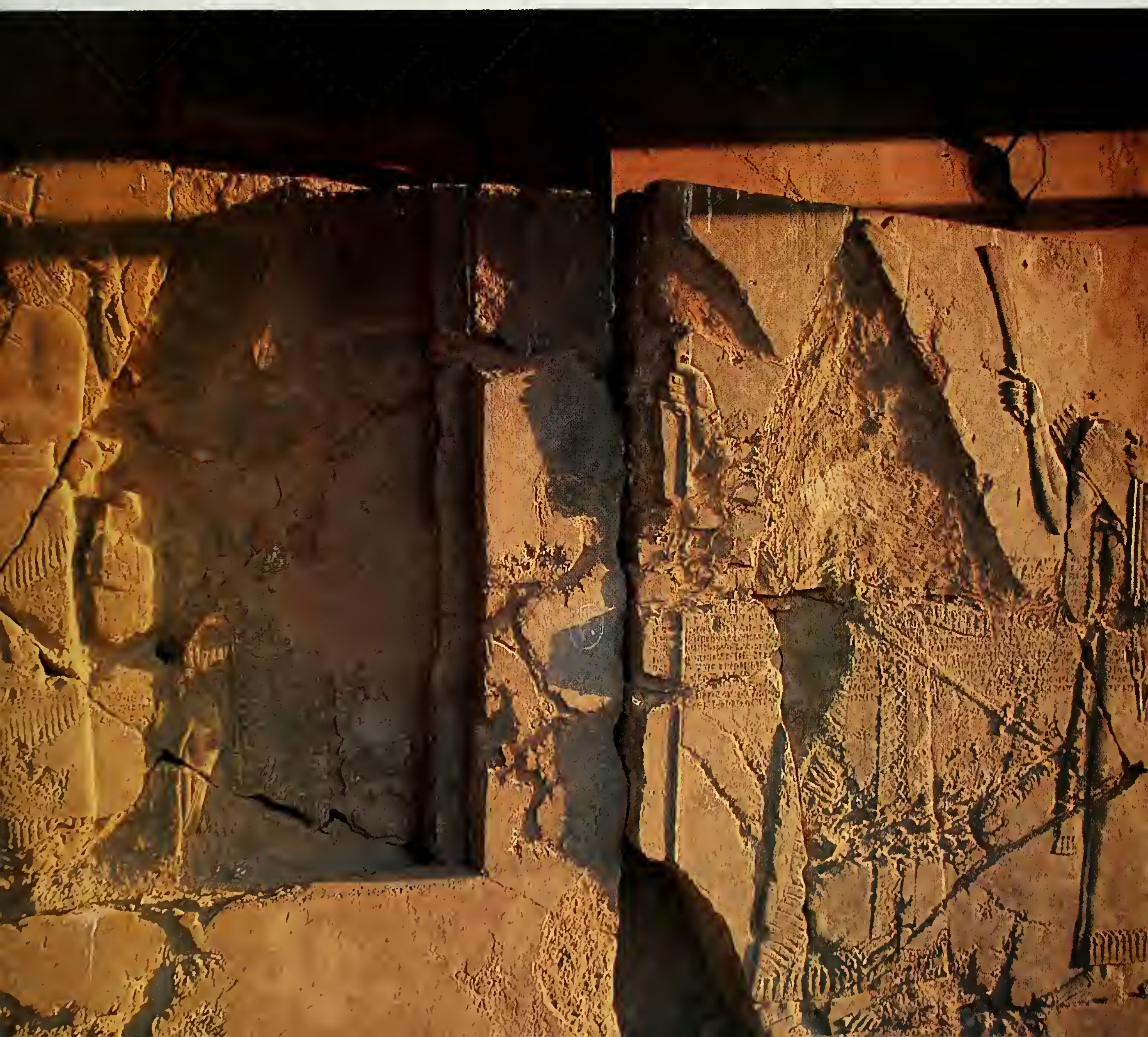
Lagash's rival, Umma, unexcavated before the war, recently fell prey to wholesale looting, resulting in large numbers of tablets from the site being offered on the antiquities market. In response, the Iraqi Department of Antiquities and Heritage initiated its own excavations at Umma and last year discovered a monumental palace or temple and a huge cemetery, described by the excavators as "a city of graves"—all dating from about 2500 B.C. Perhaps a

stele with Umma's version of the war with Lagash will eventually come to light.

During the bombing of Baghdad, the Iraq Museum was closed and its holdings dispersed for safety to the regional museums and the vaults of the Central Bank in Baghdad. The unanticipated sequel was that the bank was bombed, and during the uprisings that followed the cease-fire, at least seven of the regional museums were looted. The full extent of the losses is not yet known; however, some 4,000 objects have been reported missing from the regional museums. Last year the Iraq Museum reopened, but it may take years to evaluate and conserve the collections. Rebuilding the professional staff, diminished by hardships and cutbacks, is a major challenge, because the education of the upcoming generation has been disrupted.

Arguing that Iraq has not fulfilled the terms imposed by the cease-fire, the United States has consistently used its UN Security Council veto to maintain the sanctions. As a result, over the years, most kinds of nonhumanitarian assistance to Iraq have been blocked, including a planned UNESCO mission to assess damage and even a request to import photographic supplies to reproduce images of stolen artifacts for Interpol. The Department of Antiquities and Heritage has managed to protect and document a few major sites and to reopen the Iraq Museum, but for the most part, we are witnessing the destruction of a very promising past. Once gone, it can never be recovered. □

At Kalhu, in the throne room of King Ashurnasirpal II, archaeologist Mehti Baba points to an image of the king.



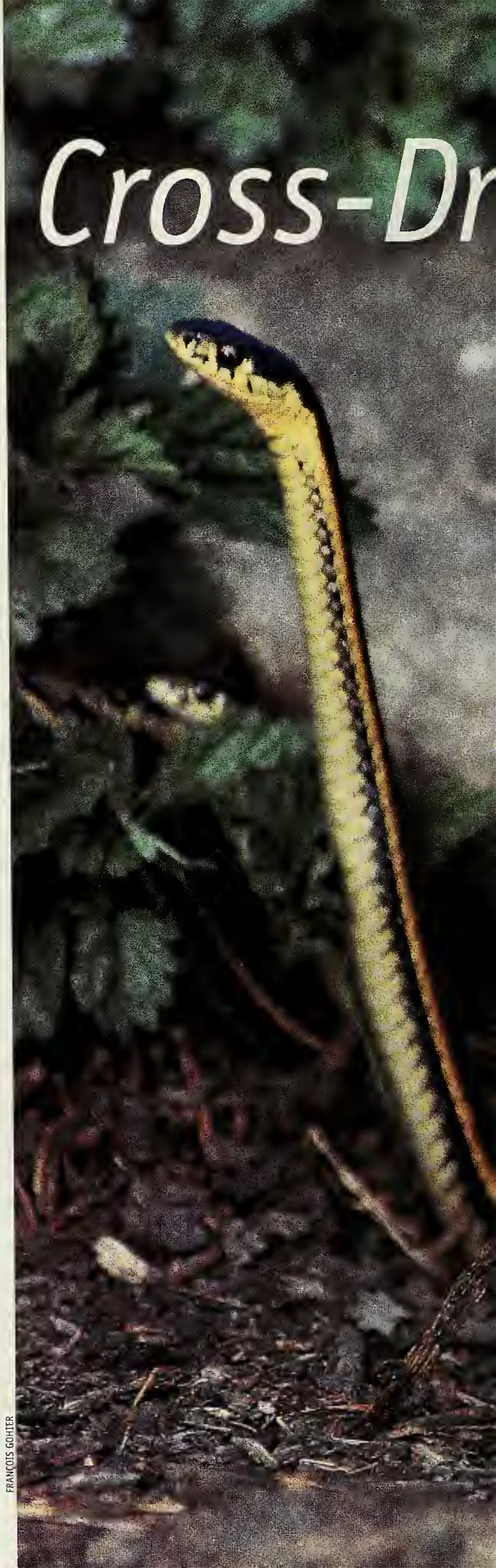
Serpentine Cross-Dr

Some male Manitoban garter snakes wear the alluring scent of females.

By Richard Shine and Robert Mason

Garter snakes may be the most common snakes in North America, but the subspecies known as the red-sided garter snake provides an uncommon annual spectacle. During the severe, six- to eight-month winters in Manitoba, Canada, these small, nonvenomous snakes sequester themselves in deep crevices to avoid freezing. Since such sites are rare in the barren, rocky region between Lake Manitoba and Lake Winnipeg, snakes that have dispersed across many miles in the summer gather by the thousands to spend the winter at the few suitable spots. Some of their major dens are located about seventy-five miles north of the city of Winnipeg and are surrounded by swampland that during the warmer months provides an abundance of frogs, the snake's favorite prey. When dens near swampland empty out in early spring, some of them disgorge more than 10,000 snakes from rocky depressions as small as sixteen feet long and six feet wide.

Over the past fifteen years, one of us (Bob Mason) has been visiting these dens in an attempt to understand the snakes' behavior. Males and females mass together in the same dens, emerging from hibernation between late April and the end of May. (In dens that receive more sunlight, the exodus can take place somewhat earlier.) Males emerge first. Having reached the surface, they stay close to the den for the better part of May. It's now mating season, and they're waiting to intercept the tardy females. As soon as a female appears, a seething ball of dozens (often hundreds) of amorous suitors forms



Seemingly charmed by the spring sunshine, dozens of red-sided garter snakes emerge from their winter den in Manitoba's Interlake region.

FRANÇOIS GOHIER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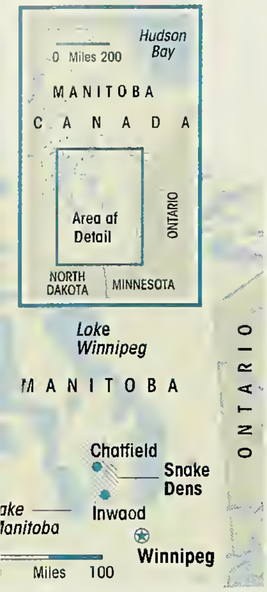


MYRA KLOCKENBRINK

around her. This rippling clot of snakes may move en masse over rocks and vegetation until the female has mated. Some "mating balls," however, contain no females. In 1985 Bob Mason, working with David Crews, of the University of Texas, reported that frenetic males frequently attempt to mate with certain other males that they evidently mistake for females. These "she-males," they observed, are indistinguishable in size and markings from ordinary males, and they also seek female mates—yet they attract other males by the score.

Female mimicry by males, although not common, occurs throughout the animal world. Among some anole lizards, for instance, males that are too small to defend a territory of their own may manage to live within a dominant male's territory if they can avoid conflicts by passing as females. Common sunfish produce two kinds of males—a large, dominant male that builds and defends a nest and tries to attract females to it, and a smaller male that resembles, and behaves like, a female. This female mimic swims between a mating pair just as the dominant male is about to fertilize the female's eggs and fertilizes some of them himself.

Manitoba's red-sided garter snakes, however, are the only snakes known to have males that mimic females. How does an amorous male garter snake tell a male from a female in the horde of snakes emerging in early spring from a large den? By sensing the pheromones that emanate from the animals' skin. When snakes flick their tongues in and out, they pick up chemical cues from the air, which they transfer to a sensory organ in the roof of the mouth. When a male tongue-flicks another snake, he instantly determines his neighbor's apparent gender by the scent of the lipids on its skin. Bob and David discovered the pheromone differences during their first year of collaboration, and a few years later they were able to synthesize the signaling chemical in the lab.

Why do some males smell like females? At first the researchers hypothesized that a male's release of female chemicals might benefit him by confusing his rivals: the she-male would be the only male snake within a mating ball that knows who the real females are. At this stage of the game, Bob and David also thought that individual snakes remained either she-males or he-males throughout an entire mating season, if not an entire lifetime. There the story remained until Rick Shine came from Australia in 1997 to visit Bob at the garter snake dens. Rick became so intrigued with the abundance of female mimics he saw there that he returned the following year with two research assistants from the

Garter Snake Grottoes

Each spring in central Manitoba, tens of thousands of red-sided garter snakes *(Thamnophis sirtalis parietalis)* emerge from their rocky dens in the bleak countryside between Lake Winnipeg and Lake Manitoba. The mass emergence attracts busloads of schoolchildren and tourists from southern Manitoba and beyond. On Mother's Day, Winnipeg youngsters traditionally take their moms on excursions to view the springtime fertility spectacle. While many residents of the towns of Inwood, Narcisse, and Chatfield view with fascination the garter snakes' migrations, others wish the snakes would gather elsewhere. One summer, according to local residents, a young couple built a house over a rock crevice that they thought would make a perfect natural cellar. When autumn arrived, so did a few thousand garter snakes, returning to their traditional winter den. The couple soon decided they had better relocate their home to a less snaky location.

FRANÇOIS GOHIER

Until the early 1980s, some local collectors scooped up thousands of the snakes and sold them to pet dealers in the United States, England, and Germany. Scientists and wildlife officials became concerned, and in 1988 commercial collecting was banned, but many snakes were still being killed in traffic as they crossed a major highway near the Narcisse dens. Last year the Manitoba Department of Natural Resources (now the Manitoba Department of Conservation) installed a series of pipes under the road. But how to get the snakes to use them? Bob Mason's experiments showed that if garter snake pheromones were applied to the floor of the culverts, the snakes would follow the chemical trails. The technique is working: this fall thousands of garter snakes crossed safely under the highway.—*R. M. and R. S.*

NIC BISHOP

In early May, masses of garter snakes, left, pour out of a rocky den in Manitoba. Males may linger near a den's entrance for days, waiting for the later-emerging females. Below: A newly emerged snake gapes as it takes in the first fresh air it has breathed in months.

FRANÇOIS GOHIER

University of Sydney, specifically to study the she-males, and our collaborative attack on this puzzle got under way.

First we attempted to quantify the attractiveness of individual snakes. Holding various "target" snakes by the tail, we crouched in the grass near a den and placed them in front of mate-searching males. We then recorded the mate-searchers' level of interest. Responses ranged from ignoring the target or rapidly flicking the tongue to aligning the body with that of the presented snake and trying to

She-males proved to be attractive to one another and sometimes even to themselves.

mate. With this simple method, we were able to confirm that she-males (which we had extracted from the center of mating balls) were indeed very attractive to ordinary males, though a bit less so than real females. Indeed, the she-males proved to be attractive to one another and sometimes even to themselves. (If a she-male accidentally encountered part of his own body, he might spend quite a bit of time busily courting himself!)

Next we investigated how she-maleness is produced. Did she-males obtain their coating of female pheromones through physical contact with true females, perhaps by rubbing against them during courtship? We soon discovered that even if we vigorously rubbed a he-male against a female, he remained unattractive to other males. We concluded that when males were attracted to she-males, they were reacting not to rubbed-on chemicals but to those naturally produced in the skin.

To learn more about how individual snakes react to she-males, we set up several nylon enclosures about three feet square near a den. We captured a number of she-males, he-males, and females, kept them in separate cloth bags overnight, and placed various combinations of snakes in the nylon pens the next day. To our astonishment (and initial dismay), although a few of the she-males we had collected the day before continued to elicit some interest from ordinary males, most had lost their allure. In other words, we had found that a she-male could switch its sexual identity within a twelve-hour period. Needing to ascertain that stress wasn't the cause of our captive snakes' unnatural behavior, we decided to return to a den to confirm this finding in free-ranging snakes.

This time we simply collected, measured, and examined a large sample of she-males and he-males, looking for characteristics that might give us a clue

BOTH PHOTOGRAPHS BY NIC BISHOP

In a swamp, right, a famished snake can dine on frogs after emerging from a long hibernation. Below: A young snake, stirring after its winter retreat, surveys the spring landscape.

to what was going on. Searching through hundreds of snakes clustered around the entrance to the den, Rick identified mating groups and examined each she-male and its ball of suitors. Eventually he spotted a pattern that had escaped prior observation. Most of the he-males were bright, glossy animals, but the she-males were often dull and dirty with grit. Once we recognized this fact, we had to account for it. The explanation, we thought, might be that she-maleness was all about the timing of reproduction in relation to hibernation. Perhaps it was a transitory phase that most—or perhaps all—male garter snakes passed through soon after they emerged from the den.

Indeed, since the same dirt can be seen on most females when they first reach the surface, the grit we observed on the she-males suggested that they, too, had just emerged from underground. And according to our measurements, the she-males were somewhat chubbier than the he-males. This was consistent with our "recent emergence" hypothesis, since we knew from studies of recaptured males that they rapidly lose weight during their frantic mate-searching and courtship activities. The hypothesis also fit in with Bob and David's original, and apparently paradoxical, finding that she-males tend to have a high testosterone level, since another recent study had shown that testosterone levels in male garter snakes are highest at emergence and fall off rapidly thereafter.

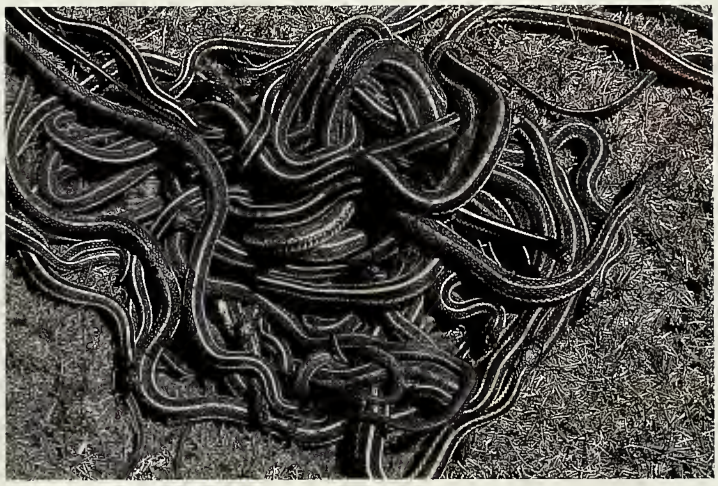
We further tested the idea by marking males as soon as they emerged. Sure enough, the marked males were she-males for a day or two and then rapidly reverted to he-maleness. So part of the puzzle was solved, but many others remained. One idea we considered was that hibernation could weaken the animals and that it might take a day or two for males to recover their strength and prepare for the frantic activity of mating. The huge numbers of emerging snakes allowed us to test the hypothesis that she-maleness is related to a recovery period. Indeed, our paint-marked she-males were weak and lethargic during the first day or two after emerging but began to move around actively at about the same time they switched off their production of female pheromones. We measured their strength by clipping their tails to a spring balance and letting them pull against it; she-males proved to be weaker than same-sized he-males. We measured their crawling speeds in a circular arena with a diameter of twelve feet and a circumference ringed with empty beer cans. After placing a snake at the center and prodding it, we recorded how long each one took to reach the edge of the circle. Again, the data confirmed the prediction: she-males moved much more slowly than he-males.

She-males tried to mate with females, but they were not very good at it.

If she-males are slow and weak, how good are they at courtship and mating? Again, we used the nylon enclosures to explore this question. When we put a she-male together with a female, it took him almost twice as long to persuade her to copulate as it did for a he-male to mate with a female in an adjacent pen. Whenever we put she-males and he-males together and then added a female, it was almost always one of the he-males that succeeded in copulating with her. She-males were indeed prepared to mate with females, but they were not very good at it, because they had not yet recovered from their long winter's inactivity.

In spite of all we have learned about these snakes, we still don't really know why male garter snakes mimic females when they first emerge from hibernation. Perhaps such mimicry helps draw their rivals' attention away from newly emerged females and buys them time to recover their full strength. Mimicry would thus both prevent she-males from wasting energy on half-hearted attempts to mate and encourage other males to expend energy and sperm on fruitless courtship. In another recent study, we found that she-males seem to assess their chances of mating, and if many large and healthy he-males are vying for the same female, the she-males do not attempt vigorous courtship.

The more questions we answer about these ubiquitous little reptiles, the more new questions arise. When one first peers into a Manitoban den and sees thousands of red-sided garter snakes writhing around—looking for all the world like live spaghetti—their behavior appears chaotic. But we have come to appreciate that these animals behave with extraordinary subtlety. What we have learned about males distracting their fellows by wearing feminine perfume may be just the first step toward elucidating one of nature's more intriguing mating systems. □



Dozens of male garter snakes create a mating ball, left, by surrounding a single female—or perhaps a she-male. Two males, below, try to align their bodies with a chubby she-male as they compete to mate with it.

BOTH PHOTOGRAPHS BY FRANÇOIS GOHIER

A Man and His

Capistrate à longue queue.

HAND-COLORED LITHOGRAPH FROM *HISTOIRE NATURELLE DES MAMMIFERES*, BY ÉTIENNE GEOFFROY SAINT-HILAIRE AND FRÉDÉRIC CUVIER. MEGAN CARLOUGH; AMNH.

Menagerie

By Richard W. Burkhardt Jr.

Frédéric Cuvier

Shortly after the French Revolution, a young chemist and naturalist became the world's first scientific superintendent of a national, public zoo.

"The menageries that have existed up to the present have always been regarded as institutions of extravagance rather than institutions of utility." So wrote Frédéric Cuvier in 1804, introducing his guidebook to the new menagerie of the National Museum of Natural History in Paris. No one in France at the time would have doubted his claim. The royal menagerie at Versailles, established in the seventeenth century by Louis XIV, had long been notorious for its wastefulness, and just prior to the Revolution, while the French people struggled to keep themselves from starving, it was alleged that a dromedary (some said an elephant) at Versailles was treated to six bottles of burgundy a day.

What would a truly useful menagerie be like? This question arose in the early years of the Revolution, at the same time that the future of the old Jardin et Cabinet du Roi (the king's botanical garden and natural history collection) hung in the balance. Jacques-Henri Bernardin de Saint-Pierre—an author, a forerunner of the French romantic movement, and director of the garden from 1791 to 1793—suggested that a menagerie would allow one to observe the behavior of living animals, to acclimatize beneficial species from foreign lands, to cross domestic races, and to study the affinities between humans and animals. It would also serve a diplomatic function. When the powers of Africa and Asia made gifts of wild animals to the French nation (as was their custom), explained Bernardin, France had to be prepared to receive them properly. Killing the animals, or letting them die, and then exhibiting their skins or skeletons was obviously unacceptable. Bernardin therefore proposed that a new menagerie be established at the Jardin des Plantes (the politically expedient name for the place now that kings were out of style).

Frédéric Cuvier's interest in animal behavior encompassed small species, such as the North American fox squirrel (opposite page), as well as large.

In June 1793, by decree of the revolutionary government, the Jardin des Plantes and the Cabinet d'Histoire Naturelle were reconstituted as the Museum of Natural History. Its structure was democratic, its purposes utilitarian. Five months later, a menagerie became part of the establishment—but not as a direct result of Bernardin's earlier suggestions or of initiatives by the museum's new professor-administrators. During the Revolution and for decades before it, some people had made a living by exhibiting exotic animals on the streets of Paris. On November 3, 1793, the Paris police department, citing public safety, ordered that such animals be confiscated and "conducted right away to the Jardin des Plantes." It came as a complete surprise to the museum's professors when the police appeared at their gates the following day escorting a polar bear, a panther, a civet, a monkey, and the animals' ex-owner, who demanded to be compensated for his animals (and hired to care for them). Two days later, the professors found themselves confronting another polar bear, two mandrills, two agoutis, a tiger, a vulture, two eagles, and two more animal proprietors, who, like the first, were retained to care for the animals. The animals were kept in their cages and sheltered in an empty carriage house.

Other animals soon arrived in similar fashion, and the next spring, the four creatures still living at the Versailles menagerie—a lion, a dog that was the lion's companion, a quagga (a now-extinct relative of the zebra), and a spiral-horned African antelope called a bubalis or a cow of Barbary—were also transferred to Paris. While the antelope died almost immediately from injuries sustained during the move, the fraternal relations of the lion and the dog

Exotic animals once exhibited by their owners on the streets of Paris were confiscated and brought to the city's Jardin des Plantes.

were presented to the public as a moral lesson in how a ferocious beast could, under the proper circumstances, come to live in harmony with an animal of another species.

From the beginning, the new menagerie was a great attraction to the public. For the professor-administrators of the museum, however, it was an ongoing headache. Both the animals and the animal keepers seemed to need a full-time supervisor. The worst offender was Félix Cassal, controversial guardian of *les animaux féroces*. Cassal was finally sacked in 1803 after scheming to have a fellow worker killed. Simultaneously (though independently), the professors agreed to create a new post within the museum hierarchy—*garde* (superintendent) of the menagerie—and chose Frédéric Cuvier for the position. Then thirty years old, Cuvier had a minor reputation as a chemist and some experience as a naturalist. Also (and certainly figuring significantly in his selection), he was the younger brother of Georges Cuvier, the museum's famous professor of comparative anatomy and one of the most powerful scientists in Napoleonic France. All at once, Frédéric Cuvier found himself occupying a place that had never before existed in the world of natural history: scientific superintendent of a national, public zoo.

Historically, what is particularly interesting about Cuvier's new post is that it complicated an ongoing debate among natural historians over who was best situated to speak authoritatively about the processes and products of nature. The debate assumed different forms in different contexts, but mostly it was waged between field naturalists on the one hand and cabinet naturalists, or museum specialists, on the other. Cabinet naturalists (Georges Cuvier, for example) maintained that only by working with collections of preserved specimens could one systematically compare the various products of nature and gain a full understanding of the similarities and differences among them. Field naturalists, by contrast, prided themselves on their familiarity with living animals and plants studied in the organisms' natural settings. Frédéric Cuvier found himself occupying a post that with respect to these two camps was neither fish nor fowl. Unlike a field naturalist, he would be observing his animals within the confines of a metropolitan zoo; unlike a cabinet naturalist, he would have the task of caring for and studying animals that were alive and kicking—and in some cases quite dangerous.

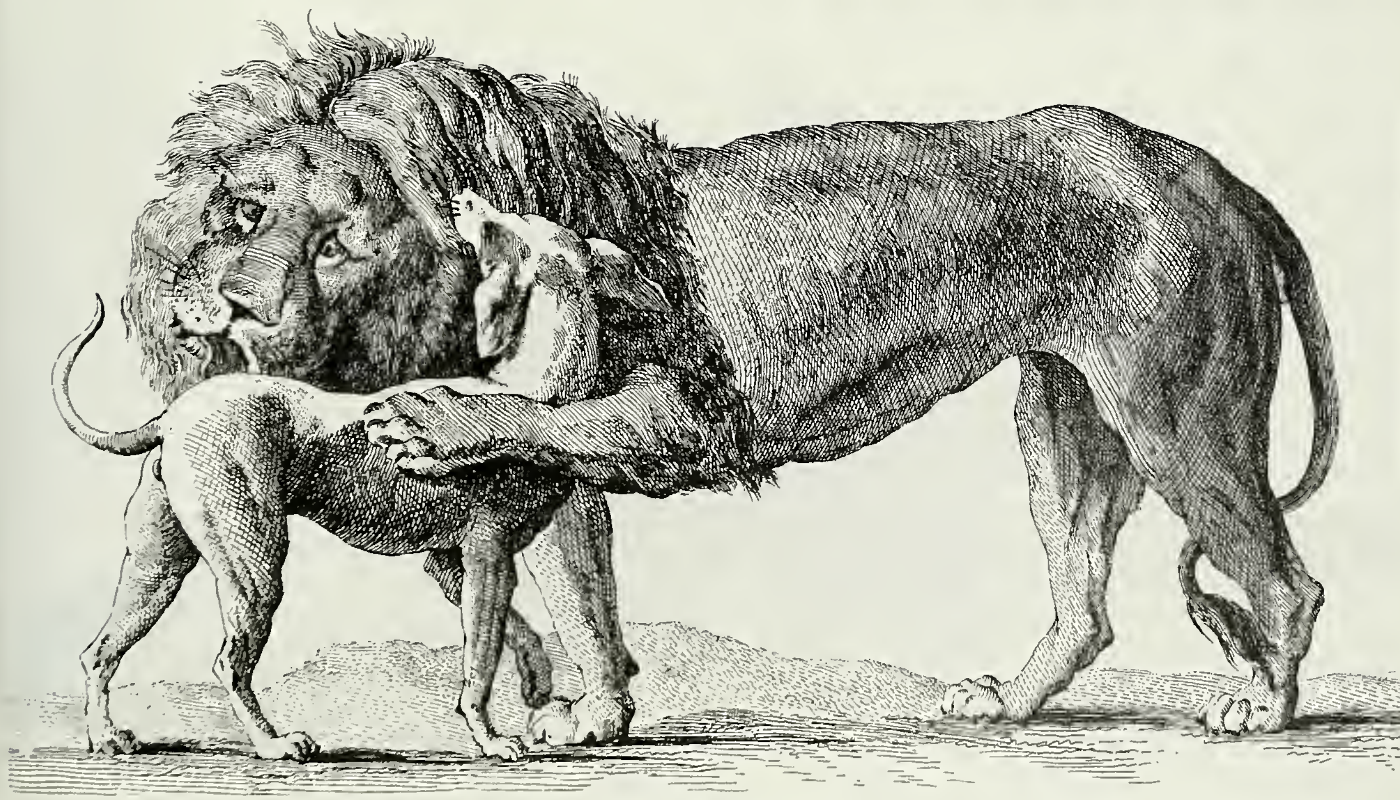
Indeed, Cuvier's new job did not promise to be easy. Now the guardian of more than a hundred mammals and nearly as many birds, Cuvier had virtually no place to turn for guidance. Who knew what sorts of shelters creatures from other climates needed to survive in northern Europe? How was one to feed them and keep them in good health? As *le garde* lamented in his 1804 guidebook, "There is practically no way of responding to these questions and a hundred others like them. Nothing has been written, nearly nothing has been seen, everything remains to be done." (He was no doubt exaggerating slightly, but having himself decried the wasteful royal menageries of the past, he was not disposed to admit that useful things might have been learned at such places as Versailles or the Schönbrunn animal park in Vienna.)

He indeed had much to learn. Thanks to the efforts of naturalist voyagers, naval officers, colonial administrators, merchants, and other travelers, animals of all shapes and sizes would continue to arrive at the menagerie. From North America came squirrels and raccoons, bears and bison, eagles and an elk. From other corners of the globe came cockatoos, kangaroos, gerbils, jaguars, parrots, panthers, turtledoves, tapirs, mandrills, mongooses, and more.

The fraternal relations of a lion and its canine companion were presented to the zoo-going public as a moral lesson in living together harmoniously.

Beyond the question of caring for these exotic creatures was the issue of whether anything of value to natural history could be learned by studying animals in captivity. Many naturalists doubted it, but Frédéric Cuvier, the former student of chemistry, argued that menageries could be for zoologists what laboratories were for chemists. In one of his most optimistic moments, he suggested that zoo studies might one day render field studies unnecessary. Having learned the general faculties and dispositions of an animal from studying it in captivity, he said, the naturalist would be able to deter-

Early problems at the zoo included animal keeper Félix Cassal, right, who was fired for planning the murder of one of his coworkers.



mine "even in advance" how others of its species would act in their native surroundings.

A number of obstacles stood in the way of the younger Cuvier's plans, however. For one thing, the museum was run by its professors, and not only was Frédéric Cuvier not a professor, but his brother Georges advised him that aspiring to become one would be inappropriate as long as Georges re-

In his most optimistic moments, Frédéric Cuvier thought that studying the behavior of captive animals might render fieldwork unnecessary.

mained a professor there. Occupying the position of superintendent, Frédéric lacked the authority to develop and teach a course on his subject. In addition, he was officially subordinate to Étienne Geoffroy Saint-Hilaire, the museum's professor of birds and mammals, with whom his relationship progressively deteriorated during the 1820s—a casualty of clashes between Geoffroy and the elder Cuvier over Geoffroy's bold claim that all animals were built on a single plan.

The living conditions of the animals in the menagerie also posed problems for Frédéric Cuvier. The quarters were often so confining and the

ALL IMAGES ON THESE PAGES FROM *HISTOIRE NATURELLE DES MAMMIFÈRES*. MEGAN CARLOUGH; AMNH.

Merchants and other travelers sent animals of all sizes and shapes to the menagerie: porcupines and parrots, tigers and turtledoves, gerbils and jaguars.

daily routines so monotonous that the animals failed to display the full range of their habits or abilities. Writing of the menagerie's raccoons, for example, Cuvier acknowledged that to know what they were fully capable of, "it would be necessary to see them under other conditions, that is to say sufficiently free and under circumstances sufficiently diverse, so their faculties could be in some measure developed."

Even when one of the animals displayed interesting behavior, keeping it alive long enough to study it thoroughly was frequently a problem—at least for Cuvier. The death of a menagerie animal was rarely perceived as a setback by the museum's other zoologists, since their work began when they were presented with creatures that were no longer living. Deaths at the menagerie were a major source of specimens for the cabinets of comparative anatomy and natural history. As for births, these were treasured events; many exotic species displayed a reluctance to mate or failed to reproduce under the conditions of captivity.

Cuvier was impressed by the trainability of seals, above right, as well as by their behavioral rigidity: accustomed to eating sole, one animal starved to death rather than eat anything else.

Undeterred by the problems confronting him, Cuvier remained optimistic, ambitious even, convinced that the study of living animals in the menagerie had much to offer. He believed that it should be possible to study not only such topics as hybridization and acclimatization but also questions of development, such as how newborn animals distinguish objects at a distance. He insisted that, as products of the brain, the mental phenomena of instinct and intelligence were just as susceptible to experimentation as was the functioning of

any other organ. Accordingly, he set out to study the mental capacities of a variety of animals.

Cuvier's first such investigation was of an animal not actually confined at the zoo. In 1810 he published an account of a young female orangutan he had observed for several months in the home of an attorney who was attempting to nurse the creature back to health for a naval officer friend (the officer had brought the animal to Paris as a gift for the Empress Joséphine). What impressed Cuvier most about the orangutan was her circumspection, which he believed was necessary because "nature has given the orangutan rather little means of defense." She was said to have exercised considerable caution when first on board ship, holding tight to lines and other attachments as the vessel rolled. Once in Paris, she acted in ways Cuvier interpreted as signs of intelligent self-defense. "Often she found herself tired out by the numerous visits she received; then she hid herself completely under her blanket and only came out from under it after the curious had left; she never did that when she was surrounded by people she knew."

Cuvier also credited the orangutan with the capacity to generalize. He observed, for instance, that if she wanted to stay in a tree, she would shake the branches when someone tried to climb up and get her. Cuvier concluded that prior experience had taught her that the fear of falling would discourage her pursuer. Likewise, when she moved a chair in order to reach and open a lock and when she took care to cover herself at night, Cuvier saw this as her exhibiting, in addition to the ability to generalize, "the awareness of a future need."

As impressed as he was by the orangutan's abilities, Cuvier took care to state that the ape was surely "not a man." This was not a matter, he insisted, of any differences between the sense organs of orangutans and humans. The orangutan, he said, had "senses as numerous and at least as delicate as ours." Cuvier maintained that the mental faculties distinguishing the higher animals from one another depend on brainpower and, likewise, that the brain

In 1838 Frédéric Cuvier died suddenly, leaving his observations on animal behavior scattered and the synthesis he hoped to write unfinished.

HISTOIRE NATURELLE DES MAMMIFÈRES. MEGAN CARLOUGH; AMNH.

One of the rare and treasured births in the early days of the Paris zoo was that of a female white-fronted lemur.

is "the principal cause of the intellectual qualities that distinguish us from the animals."

At the zoo, Cuvier also studied the intelligence of seals. He was struck both by how readily these animals could be trained and by the tenacity with which they clung to the habits they formed: "I was never able to make the animals I observed eat any other species of fish than that with which we first fed them. One never wanted to eat anything but herrings; another ate only sole. The first even preferred salted herrings to other fresh species; the second actually died of hunger because we were unable to feed him sole owing to the seasonal storms that temporarily suspended fishing."

To investigate the relative roles of instinct and intelligence in shaping animal behavior, Cuvier reared a number of beavers in isolation from others of their kind. He found that these solitary, untutored individuals still displayed an instinctive tendency to build when provided with willow branches, straw, and earth. Beaver dams, he decided, are not the result of projects the animals undertake intelligently but instead are merely "the fruits of an industry that is entirely mechanical."

Cuvier was also eager to compare animals that had been successfully domesticated with others that had not. One of his subjects was a male bison sent to Paris from the United States in 1819. Bison had been touted as excellent candidates for domestication in France—infinitely stronger than oxen as beasts of burden and, when hybridized with cows, great producers of milk. Cuvier succeeded in mating a cow with the menagerie's bison, but the ensuing pregnancy came to a disastrous end. The cow suffered for eight days before a forced delivery was attempted. The calf died in the operation; the cow died four days later. Cuvier tersely reported the results to the professors: "The infant resembled entirely a young bison; it has been stuffed."

Hating to see animals suffer, he never attempted such a mating again. He also decided that bison were unsuitable as farm animals: every time one turned one's back on the menagerie's bison, it attacked. This and other experiences with many species of animals led Cuvier to conclude that herbivores (especially adult males) are not by nature more gentle than carnivores and that domestication is possible only in species already instinctively disposed to sociability.

Georges Cuvier died unexpectedly in May 1832 from an illness diagnosed as acute myelitis, and his position as professor of comparative

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anatomy was filled in a matter of days, as was the museum's custom. Frédéric waited respectfully until the end of July to put forward his own case, asking for the creation of a new professorship devoted to the study of "living animals and their education." He offered the following justification for his proposal: "Since I have been in charge of the menagerie, all my researches, all my works, have been directed principally toward the knowledge of living animals, toward the means of observing them, of submitting them to planned experiments in order to understand the laws of their existence, as well as the nature of the modifications these laws can undergo." After five and a half years of institutional infighting, Frédéric Cuvier received his long-awaited chair at the museum in December 1837. Sadly, however, only eight months later, he suddenly became ill and died. His symptoms were much like those of the disease that had killed his brother. On his deathbed, Frédéric, accustomed to living in the shadow of his more famous sibling, requested that he be identified on his tombstone simply as "brother of Georges Cuvier."

In the early 1820s Frédéric Cuvier had expressed his intention to write a general work on the causes of animal actions. Such a work would have been invaluable, for no other naturalist in the first half of the nineteenth century studied mammalian behavior with the same care and breadth that he did. Unfortunately, at his death, his observations remained scattered and his synthesis unfinished. Frédéric Cuvier's pioneering efforts to establish a science of animal behavior failed to take hold.

As zoos were set up in other capitals and major urban centers—such as London (1827), Amsterdam (1838), and Berlin (1844), to name just a few—the menagerie in Paris ceased to be the world's finest collection of living animals. Though none of these others surpassed the Paris zoo of Frédéric Cuvier's day as a study site (and although the issue of whether it was better to study animals in the wild or in captivity remained unresolved), Cuvier was not the only nineteenth-century zoologist to take an interest in the behavior of zoo animals. In 1838, only a few weeks after Frédéric Cuvier's death, Charles Darwin visited the London zoo and, as he wrote in his notebook, "endeavoured to classify the expressions of monkeys." □

Opening thirty-five years after the Paris zoo, the London zoo proved equally popular with members of the public, including Charles Darwin.

ZOOLOGICAL SOCIETY OF LONDON

ROBERT M. PECK

INTERVIEW

A Conversation With Alexander F. Skutch

A naturalist who has revealed the private lives of Neotropical birds

For almost three-quarters of a century, naturalist Alexander F. Skutch has studied the wildlife of Central America, particularly its birds. Of his eighteen books, the most recent is Harmony and Conflict in the Living World, *illustrated by Dana Gardner and published last year by the University of Oklahoma Press. His autobiographical accounts* A Naturalist in Costa Rica *(1971) and* A Naturalist on a Tropical Farm *(1980) have become classics. Now ninety-six, the Maryland-born Skutch lives at Los Cosingos, a 178-acre farm he bought in southern Costa Rica more than sixty years ago. Skutch, who prefers the company of wild things to the hubbub of the outside world, has not owned an automobile since his college days and lives without benefit of electricity or a telephone in the house he built himself. Until the 1970s, when a gravity-fed water line was brought to the house, Skutch relied on a nearby stream for drinking, washing, and bathing. He grows corn, bananas, yuca, and other crops and prides himself on being almost entirely self-sufficient. A lifelong vegetarian, Skutch feels strongly about treading lightly on the Earth. On a warm afternoon at the start of last year's rainy season, naturalist and historian Robert McCracken Peck, a Fellow of the Academy of Natural Sciences in Philadelphia, visited with Skutch, who put aside work on his latest manuscript (a treatise advocating "biocompatibility," or peaceful coexistence between humans and the rest of Earth's species) to reflect on his long and remarkably productive life.*

RMP: *When you first came to the Tropics, it was as a botanist, not as an ornithologist. What inspired you to switch your primary focus from plants to birds?*

AFS: My first visit to the Tropics was to Jamaica, where Duncan S. Johnson, my professor of botany at Johns Hopkins University, led a party of his graduate students and friends. To earn my steamship passage and return, I stayed and worked on a banana plantation owned by the United Fruit Company. There I made a study of the banana leaf, which became the foundation of the doctoral dissertation that earned me my Ph.D. in 1928. Later that year I went to the fruit company's small research station in western Panama to continue my studies of the banana plant. For six months I worked in a small laboratory amid the bananas. In front of the window where I sat at my microscope, examining bits of banana leaves, a rufous-tailed hummingbird built her nest and raised her brood. I found this, and the many other birds that nested in the garden, so fascinating that I decided to learn more about tropical American birds. After my return to the United States, I delved into the literature and found that nearly every species had been collected, named, and minutely described but that very little was known about their habits. I concluded that I could do nothing more important and satisfying than to learn the intimate details of their lives.

RMP: *You have written that you ultimately chose to settle in Costa Rica because of its rich Neotropical birdlife and because the country has been more peaceful than its neighbors. What are the biggest changes you've noticed during your tenure in the country?*

AFS: The soaring population of Costa Rica, from less than a million when I arrived in 1935 to more than three and a half million today, has caused great changes. I was attracted to the southern Pacific quarter of Costa Rica by the large expanses of unspoiled forest, nearly all of which have since been destroyed. Fortunately, a very generous amount of forest countrywide is now being protected in national parks and refuges.

RMP: *Much of your professional life has focused on birds. What do you consider your most important contribution to ornithology?*

AFS: Writing about the life histories of many tropical birds, whose nesting and other habits were previously little known or completely unknown—and, in particular, calling attention to the prevalence of cooperative breeding (helpers at the nest) in birds. My first paper on the subject, published in the *Auk* in 1935, was about three species of cooperative breeders that I watched in Guatemala. My second paper on this, "Helpers Among Birds," which appeared in the *Condor* in 1961, more effectively called attention to this behavior.

RMP: *Who are the naturalist-writers you most admire?*

AFS: Of all the writers I have read, my attitude toward nature has been closest to that of Plutarch, who believed in the integrity of nonhuman creatures. Charles Darwin, Alfred Russel Wallace, William H. Hudson, Henry Walter Bates, Thomas Belt, Frank Chapman, and David and Barbara Snow—they all write well and report fresh observations and/or interpretations.

RMP: *What advice would you give to a young person considering a career in ornithology today?*

AFS: Learn a little Spanish or Portuguese and go to tropical America to study the habits of little-known Neotropical birds; treat the birds that you watch with the respect due to sensitive, feeling creatures; and publish your findings without the needless excess of probability estimates that are making today's ornithological papers hardly readable. Ornithology should not be dominated by mathematics, which is more appropriate for physics and astronomy.

RMP: *If you had an opportunity to start over again, would you focus on something else?*

AFS: I would choose the same career, certainly in tropical America and probably in Costa Rica, which has a rich avifauna and on the whole has treated me well. I would study the migratory birds that winter in the Tropics. Although many of these birds have been thoroughly studied in North America and Europe—their "summering grounds"—their lives in the Tropics are still very poorly understood.

EXCERPT

Color attracts color, especially in the Tropics. To the bright red blossoms of the flame-of-the-forest trees were added the scarlet, orange, yellow, glittering green, deep blue, and turquoise of the tanagers, orioles, honeycreepers, hummingbirds, and other feathered visitors that probed the trumpet flowers for insects and nectar or hunted through the foliage for caterpillars and spiders. What a brilliant display the birds and flowers made in the bright beams of the rising sun!


ROBERT M. PECK

Sometimes, when I stood watching the birds in one of these trees while the sun still hung low above the wooded ridge across the river, a flock of great scarlet macaws came from the east, as though riding down the level sunbeams. Two by two they flew, with steady, laborious wing beats, their long tails streaming like slender pennants behind their heavy bodies, their scarlet underplumage glowing vividly where touched by the horizontal rays. As the macaws passed overhead, their raucous shouts made them as objectionable to the ear as they were pleasing to the eye. Often these flamboyant birds flew directly above the crown of a flame-of-the-forest tree, in a gorgeous display such as one expects of tropical nature.

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MUSEUM EVENTS

FEBRUARY 8

Lecture: "The Ecology of Zebra Sociality and Conservation: Different Stripes for Different Types" ("Earthwatch at the Museum" series). Daniel Rubenstein, of Princeton University. 7:00 P.M., Kaufmann Theater.

FEBRUARY 13

Isaac Asimov Memorial Panel Debate: "The Theory of Everything." Inaugural of an annual forum of celebrated scientists discussing questions on the forefront of scientific discovery. This year's speakers are physicists Brian Greene, Columbia University; Lisa Randall, MIT; S. James Gates, University of Maryland; Lawrence Krauss, Case Western Reserve University; and 1979 Nobel laureate Sheldon Glashow, Harvard University. 7:30 P.M., IMAX Theater.

FEBRUARY 17

Lecture: "The 'Juicy' Earth" ("Water: Earth, Air, and Fire" series). Rosamond Kinzler, of AMNH's National Center for Science Literacy, Education, and Technology, speaks on the role of water in the formation of continents and in plate tectonics. 1:30 P.M., Linder Theater.

FEBRUARY 19

Online expedition: MayaQuest 2001, at www.classroom.com. Students can join a four-week course exploring ancient Mayan civilization and contemporary Mayan cultures. Participants set the team's weekly course and, together with scientists, solve ethical dilemmas and investigate actual scientific, cultural, and historical mysteries. Sponsored by Classroom Connect in partnership with AMNH.

FEBRUARY 24

Identification Day: AMNH staff provide information on the history and classification of all materials presented. No appraisals. 1:00–4:30 P.M., Birds of the World Hall (second floor).


COMPUTER SIMULATION BY MOLLY LENORE; AMNH

At the Museum's new Weston Pavilion entrance on Columbus Avenue, scheduled to open at the end of January, visitors can see a monumental steel sculpture based on an instrument called an armillary sphere. Historically, this device enabled astronomers to locate planets and stars at a given time with respect to Earth. The sculpture features our galaxy, sectioned into octants—a symbolic guide to future space navigation. The sphere was conceived by the Museum's Department of Exhibition under the direction of its vice president David Harvey.

FEBRUARY 26

Lecture: "Turn Left at Orion: One Hundred Night Sky Objects" ("Distinguished Authors in Astronomy" series). Tour of the night sky—and talk on some of its mysteries—by Guy Consolmagno, an astronomer at the Vatican Observatory, and Dan Davis, a geoscientist at SUNY Stonybrook. 7:30 P.M., Space Theater, Hayden Planetarium.

DURING FEBRUARY

"African Diaspora Celebration: Fusions, Faces, and Footprints." During Black History Month, AMNH presents free weekend programs on race and identity, the influence of jazz, and African American dance traditions. 1:00–5:00 P.M., Leonhardt People Center. For information, call (212) 769-5315.

Online newsletter for Center for Biodiversity and Conservation: research.amnh.org/biodiversity/webletter.html.

Planetarium courses: "How to Choose a Telescope," "The Science of the Rose Center," and many others. For a complete schedule, call (212) 769-5100 or visit www.amnh.org/education/.

Films at the IMAX Theater: *Dolphins* (marine mammals in the wild, with a soundtrack by Sting) and *Ocean Oasis* (the biodiversity of the Baja California peninsula).

The American Museum of Natural History is located at Central Park West and 79th Street in New York City. For listings of events, exhibitions, and hours, call (212) 769-5100 or visit the Museum's Web site at www.amnh.org. Space Show tickets, retail products, and Museum memberships are also available online.

REVIEW

Long Live the !Kung

A touchstone for students of humanity's past, hunter-gatherer societies forge their own destinies. *By Meredith F. Small*


MARJORIE SHOSTAK; ANTHRO-PHOTO FILE

Nisa in 1971

When Marjorie Shostak died in 1996, anthropology lost two compelling voices—Shostak, a keen observer and passionate writer, and Nisa, whose words and personality fill Shostak's narratives about the lives of !Kung women. In 1969 Shostak joined a team of Harvard University anthropologists who had begun a long-term study of the !Kung San (Bushmen) six years earlier. She spent twenty months interviewing !Kung women in the Dobe area of northwestern Botswana, in the northern Kalahari Desert. Fifty-year-old Nisa, whose stories seemed to Shostak "larger and more important than the details they comprised," stood out.

First published in 1981, *Nisa: The Life and Words of a !Kung Woman* is not just an ethnographic account of a people but a singular tale told in Nisa's own words. The book became a classic, selling over 200,000 copies. I doubt there is a single anthropology or women's studies student in the past two decades who hasn't been assigned this book. Now *Return to Nisa* chronicles the story of Shostak's month-long visit to the !Kung in 1989. No standard anthropology text, this is a personal memoir, haunted by Shostak's battle with breast cancer.

Nisa: The Life and Words of a !Kung Woman, *by Marjorie Shostak (Harvard University Press, reprint, 2000; $16.95)*
Return to Nisa, *by Marjorie Shostak (Harvard University Press, 2000; $24.95)*
The Cambridge Encyclopedia of Hunters and Gatherers, *edited by Richard B. Lee and Richard Daly (Cambridge University Press, 1999; $125)*

"My future had been cast into deep, threatening shadow; the present turned in on itself as my daily experience acquired a brutal, slashing edge," she writes, referring to her cancer diagnosis and mastectomy in 1988. Although she wanted to see Nisa again, she had to consider the consequences of an extended separation from her husband and children (including a two-year-old who had been weaned early, after Shostak's cancer was diagnosed). Yet Africa called in a way familiar only to those who have spent time in the field: "The decision to go had preceded the practical, starting with a need, the need to return: to see, to taste, to smell, to experience again, perhaps even to heal."

Shostak sets out for Dobe once more, but the romantic vision of a quest soon evaporates. This time, Nisa's people are more concerned with their own affairs than with talking to Shostak, and Shostak is exhausted by illness and travel. Her relationship with Nisa is full of ambiguity. "Nisa seems to have so little compassion, at least for me," Shostak writes. "She likes me because I have rewarded her for our work. She has no idea of what I feel. I don't even think she likes me in any real sense. I sometimes wonder if I even like her." On this trip, Shostak is drawn to anything that might pull the evil from her body. She hires the healer Kxoma to perform a ceremonial trance dance and hires Nisa (also a healer) to perform a drum dance. For Shostak these are spiritual moments; for the !Kung they are performances, and everyone wants to be paid. Here we have fieldwork, warts and all.

Return to Nisa offers no neat package of connection and redemption, but Shostak does tell a compelling tale of her need to revisit a place and a people who represented a defining period in her life. She also looks at the pressures that are moving the !Kung away from hunting and gathering: the border war between Botswana and Namibia that slices through their ancestral land and separates families; the scarcity of game; the acquisition of cows, which requires a more settled life; and interruptions in the transmission of skills from the elder to the younger generations.

Shostak finds that the !Kung respond to these changes with a certain resilience—a characteristic not only of the !Kung but of other peoples like them, according to *The Cambridge Encyclopedia of Hunters and Gatherers.* In what has proved to be the most successful pattern of adaptation in human history, people have hunted and gathered for millions of years, turning to sedentary agriculture only 12,000 years ago and to industrialization (with its disconnection from the land) a mere 200 years ago. Indeed, the globe is dotted with groups that still partly rely on foraging.

The encyclopedia's eighty-eight contributors present the history, ecological setting, economy, political organization, social organization, spirituality, and current status of more than fifty societies from seven geographical areas. Described as generally egalitarian, cooperative, and on the move, these people readily split into small groups or temporarily gather together as circumstances demand. They still forage in forests, across savannas, and on ice packs but also utilize the goods and services of sedentary neighbors, incorporating modern food and tools into the hunting and gathering life.

MARJORIE SHOSTAK; ANTHRO-PHOTO FILE

Marjorie Shostak and Nisa in 1989

All, of course, have been affected by the pressures of colonization, the loss of land, and political strife. Remarkably, many groups have recently banded together to preserve their way of life. "Far from being simply the cast-offs of creation or victims of history, the foraging peoples have become political actors in their own right, mounting land claims cases, participating in the environmental movement, and lobbying for their rights with governments and the UN," write editors Richard B. Lee, a University of Toronto anthropologist who was part of the first team to study the !Kung, and Richard Daly, an anthropologist who works on aboriginal rights cases in British Columbia. Such a political voice might allow these groups to survive in the modern, electronically interconnected world—and to survive in the way *they* choose.

Historically, Westerners have either vilified hunters and gatherers as savages or they have worshiped them as living testimonies of ancient and more "natural" modes of existence. Anthropologists have always been interested in them as windows to our past. But as *Nisa, Return to Nisa,* and *The Cambridge Encyclopedia of Hunters and Gatherers* demonstrate, these people are not museum specimens but members of dynamic societies, both connected to the past and moving forward.

Meredith F. Small is a writer and a professor of anthropology at Cornell University.

nature.net

Glowing Dinos

By Robert Anderson

Organisms that produce their own light are predominantly a marine phenomenon. Terrestrial bioluminescence is a rarity limited to a few insects (such as fireflies) and to certain earthworms and fungi. The reason for this disparity is simple, according to the Bioluminescence Web Page (lifesci.ucsb.edu/~biolum/), maintained at the University of California, Santa Barbara: the glow that animals generate themselves is the only source of light in the deep ocean, our planet's largest habitat.

Biologists can exchange new research findings at this site, but there's also plenty for the layperson. It explains in simple terms how organisms mix molecules called luciferins with luciferases to produce light. We are cautioned against confusing bioluminescence with fluorescence and phosphorescence. A gallery of glowing marine creatures reveals the beauty and wide range of species that illuminate the oceans. Certain squids adjust the color of their luminescence to match moonlight or sunlight; like fireflies, certain crustaceans send coded light messages at mating time; and the black dragonfish, a deep-sea dweller, has evolved its own "night vision" equipment. Most creatures emit a bluish green glow, but this dragonfish can shine red light on its prey that is visible to its eyes alone.

Bioluminescent comb jelly

STEVEN HADDOCK

The highlight of the site, however, has to be the section on how to grow your own dinos, or dinoflagellates. (On the main page, click on "Organisms" and then on "Dinoflagellates.") These single-celled organisms, which swim free as plankton, are by far the most common bioluminescent creatures on the planet. The section also suggests a number of experiments you can perform with your jar of blue-flashing dinos.

Robert Anderson is a freelance science writer living in Los Angeles.

PHOTOGRAPHY

Crossing Over: Where Art and Science Meet, *by Stephen Jay Gould and Rosamond Wolff Purcell (Three Rivers Press, 2000; $27.50)*

ROSAMOND PURCELL

Nature Out of Place: Biological Invasions in the Global Age, *by Jason Van Driesche and Roy Van Driesche (Island Press, 2000; $29.95)*

Tinkering With Eden: A Natural History of Exotics in America, *by Kim Todd (W. W. Norton, 2001; $27.95)*

Invasive Species in a Changing World, *edited by Harold A. Mooney and Richard J. Hobbs (Island Press, 2000; $55)*

Virtually no place on Earth remains isolated from migrant faunal, floral, or microbial species. Three books zero in on the ecological problems, dangers, costs, and even benefits associated with such bioinvasions.

The Living Wild, *by Art Wolfe; edited by Michelle A. Gilders (Wildlands Press, 2000; $55)*

Wildlife photographer Wolfe's striking portraits of 140 species of animals and their habitats are accompanied by essays written by scientists and conservationists William Conway, Richard Dawkins, Jane Goodall, John C. Sawhill, and George B. Schaller.

Reaping the Wind: How Mechanical Wizards, Visionaries, and Profiteers Helped Shape Our Energy Future, *by Peter Asmus (Island Press, 2000; $24.95)*

"The winds blowing on just 6 percent of the windiest land sites in the United States (excluding Hawaii and Alaska) could supply one and one-half times the entire nation's electricity needs," writes journalist Asmus in his account of the stormy history of attempts to create U.S. markets for wind power.

Beneath Our Feet: The Rocks of Planet Earth, *by Ron Vernon (Cambridge University Press, 2000; $29.95)*

The surface of our planet is a mass of vividly patterned inorganic chemical compounds that are aggregated into solids with names such as olivine, gabbro, basalt, and breccia. Here is a guidebook to that glittering ground.

No Man's Garden: Thoreau and a New Vision for Civilization and Nature, *by Daniel B. Botkin (Island Press, 2000; $24.95)*

Ecologist Botkin meditates on how Thoreau's approach to knowledge can help us not only make thoughtful contact with the natural world but also deal with revolutionary developments in biology and computer science.

Half a Brain Is Enough: The Story of Nico, *by Antonio M. Battro (Cambridge University Press, 2001; $19.95)*

A neuroscientist tells the story of the successful "sculpting" of three-year-old Nico's brain following radical surgery to cure severe epilepsy.

The books mentioned are usually available in the Museum Shop or through the Museum's Web site, www.amnh.org.

UNIVERSE

The Beginning of Science

Reports that physicists are nearing the final frontier of knowledge have been greatly exaggerated.

By Neil de Grasse Tyson

The success of known physical laws at explaining the world around us has consistently bred some confident and even cocky attitudes toward the state of human knowledge. Even Nobel laureates and other esteemed scientists have embarrassed themselves by proclaiming that the end of science was near.

The distinguished astronomer Simon Newcomb, one of the founders of the American Astronomical Society, noted in 1888, "We are probably nearing the limit of all we can know about astronomy." Another famous end-of-science prediction was delivered in 1894, in a speech given by the future Nobelist Albert A. Michelson at the dedication of the University of Chicago's Ryerson Physical Laboratory:

> *The more important fundamental laws and facts of physical science have all been discovered, and these are now so firmly established that the possibility of their ever being supplanted in consequence of new discoveries is exceedingly remote. . . . Our future discoveries must be looked for in the sixth place of decimals.*

Even the great physicist William Thomson—aka Lord Kelvin, father of the branch of physics called thermodynamics—fell victim to his own confidence in 1900 with the claim "There is nothing new to be discovered in physics now. All that remains is more and more precise measurement." His comments were expressed at a time when the so-called luminiferous ether was still the presumed medium in which light traveled through space, and when the slight difference be-

ROBERT GROSSMAN

tween the observed and the predicted paths of Mercury around the Sun was a real and unsolved problem. But a century ago such details were considered minor, requiring for their resolution perhaps only slight adjustments to recognized physical laws. Indeed, Lord Kelvin referred to problems such as these as "small clouds on the horizon."

In a 1924 lecture, the physicist Max Planck reflected on advice given to him as a student in 1874:

> *When I began my physical studies and sought advice from my venerable teacher Philipp von Jolly . . . he portrayed to me physics as a highly developed, almost fully matured science. . . . Possibly in one or another nook there would perhaps be a dust particle or a small bubble to be examined and classified, but the system as a whole stood there fairly secured, and theoretical physics approached visibly that degree of perfection which, for example, geometry has had already for centuries.*

Planck, who sowed the first seeds of the quantum revolution, initially had no reason to doubt his teacher's views. But in 1900, when the classical understanding of how matter radiates energy could not be reconciled with experimental evidence, Planck became a reluctant revolutionary by suggesting the existence of the quantum, an indivisible unit of energy. His suggestion heralded a new era of physics: the next thirty years would see the formulation of the theories of relativity and quantum mechanics and the recognition that we live in an expanding universe.

With so many of his predecessors having proved myopic, you'd think that the brilliant and prolific physicist Richard Feynman would have known better. But in his 1965 book *The Character of Physical Law*, he declares,

> *We are very lucky to be living in an age in which we are still making discoveries. . . . The age in which we live is the age in which we are discovering the fundamental laws of nature, and that day will never come again. It is very exciting, it is marvelous, but this excitement will have to go.*

I claim no special knowledge of when and where the end of science might come or whether an end exists at all. What I do know is that our species is dumber than we normally admit to ourselves. This limitation of our mental faculties—but not necessarily of science itself—makes clear to me that we have only just begun to figure out the universe.

Let's assume that human beings are the smartest species now living on Earth. Let's further assume, for the sake of discussion, that our capacity to do abstract mathematics makes us the only smart species ever to have lived.

What are the chances that this first and only smart species in the history of life on Earth has enough smarts to understand all there is to know about the universe? Chimpanzees are an evolutionary hair's-width from us, yet I think we can agree that no amount of tutelage will ever leave a chimp fluent in trigonometry. Now imagine a species on Earth, or anywhere else, that is as smart compared with humans as humans are compared with chimps. How much of the universe might its average (let alone its cleverest) members figure out?

Tic-tac-toe fans know that the game's rules are simple enough to allow you to win or tie every time—if you know which opening moves to make. But young children play the game feeling that the outcome is remote and unknowable. The rules of engagement for chess are also clear and simple, but the challenge of predicting your opponent's upcoming sequence of moves grows exponentially by midgame. With this level of complexity, most smart and talented adults find chess quite challenging and play it as though the end were a mystery. So, is the universe to us a game of tic-tac-toe or a game of chess?

Let's consider Isaac Newton, who leads my list of the smartest people who ever lived. (I am not alone here. An inscription on a bust of Newton at Trinity College in Cambridge, England, proclaims "*Qui genus humanum ingenio superavit,*" which loosely translates from Latin as "Of all humans, there is no greater intellect.") How did Newton regard his own brilliance?

> *I do not know what I appear to the world; but to myself I seem to have been only like a boy playing on a seashore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay undiscovered before me.*

The game that is our universe has revealed some of its rules, but much of the cosmos still behaves mysteriously—perhaps abiding by regulations not yet deduced or perhaps awaiting a clever application of the laws we already know.

The distinction between the knowledge of objects and phenomena and the knowledge of the laws that control them is central to any perception that science might be coming to an end. The discovery of life on the planet Mars or beneath the floating ice sheets of Jupiter's moon Europa would be the greatest news story yet. You can bet, however, that the physics and chemistry of molecules found there would be the same as the physics and chemistry of molecules here on Earth. No new laws necessary.

But let's peek at the underbelly of modern astrophysics and expose our contemporary ignorance by pointing to a few unsolved problems—the solutions to which, for all we know, await the discovery of entirely new branches of physics.

Newton's laws of motion and gravity looked good for 200 years, until they needed to be modified by Einstein's theories of motion and gravity—the relativity theories. Relativity now reigns supreme. Quantum mechanics, the description of the atomic and nuclear universe, also reigns supreme—except that in its present form, it cannot be reconciled with Einstein's theory of gravity. Both theories predict different phenomena for the domain in which they overlap.

Something's got to give.

Either there's a part missing from Einstein's gravity that would enable it to accept the tenets of quantum mechanics, or there's a part missing from quantum mechanics that would enable it to accept Einstein's gravity. Or maybe there's a third option: a larger, inclusive theory that supplants them both.

Let's peek at the underbelly of modern astrophysics and expose our contemporary ignorance by pointing to a few unsolved problems.

Indeed, string theory has been invented and called upon to do just that. It attempts to reduce all matter, all energy, and all their interactions to the existence of higher-dimensional vibrating strings of energy. String theory holds that different modes of vibration reveal themselves in our measly four dimensions of space and time as different particles and forces. Although string theory has had its adherents for more than twenty years, its claims continue to lie beyond our current capacity to verify by experiment. Skepticism is rampant, but many scientists remain hopeful.

Let's continue to probe our ignorance. While our confidence in the big-bang description of the origin of the universe is very great, we can only speculate what lies beyond our cosmic horizon, 13 billion light years away. We can only guess what happened before the big bang or why there should have been a big bang in the first place.

Want some more ignorance?

We have computer models that can account for the formation of galaxies in the early universe. But those same models fail when we use them to account for today's large-scale cosmic structures. A coherent description of the formation and evolution of galaxies continues to elude us. We seem to be missing some important pieces of the puzzle.

We still don't know what kind of chemistry enabled inanimate matter to assemble into life as we know it. Is there some mechanism or law of chemical self-organization that escapes our awareness? We have nothing with which to compare our Earth-based biology, and thus we cannot evaluate what is essential and what is irrelevant to the formation of life.

Ever since Edwin Hubble's seminal work during the 1920s, we've been aware that the universe is expanding. But we've only just learned that the universe is also accelerating, due to some antigravity pressure we call dark energy. No known physical process can account for this pressure.

And at the end of the day, no matter how confident we are in our observations, our experiments, or our theories, we must acknowledge that 90 percent of the gravity in the cosmos comes from some unknown, mysterious source whose identity eludes every means we have ever devised to observe the universe. As far as we can tell, it's not made of ordinary stuff such as electrons, protons, and neutrons or of any form of matter or energy that interacts with them. We call this offending substance dark matter, and it remains the greatest enigma of modern astrophysics.

Does any of this sound like the end of science? Does any of this sound like we are on top of the situation? Does any of this sound like it's time to congratulate ourselves? To me it sounds like we're all stupid, helpless idiots, no different from our kissing cousins, the chimpanzees, trying to learn the Pythagorean theorem.

Maybe I'm being a little hard on *Homo sapiens*. Perhaps the question should not be how smart an individual of a species is but how smart our collective brainpower makes us. Among humans, discoveries made by some are routinely shared with others through conferences, journals, books, the broadcast media, and, of course, the Internet. While natural selection drives Darwinian evolution, the growth of human culture is largely Lamarckian: new generations of humans inherit the acquired discoveries of generations past, enabling cosmic insight to grow slowly, but without limit.

With our unique capacity to stockpile and communicate knowledge, we continually transcend our own intellectual limits. Each discovery of science adds a rung to a ladder of knowledge whose beginning is in plain view but whose end is not in sight—we are building the ladder as we go along. By any measure of the ladder's height, we are closer to the beginning of science than to its end.

Neil de Grasse Tyson, an astrophysicist, is the Frederick P. Rose Director of the Hayden Planetarium at the American Museum of Natural History and is also a visiting research scientist at Princeton University. His memoir, The Sky Is Not the Limit: Adventures of an Urban Astrophysicist, *was published last year by Doubleday.*

THE NATURAL MOMENT

Sea Bear

Polar bears are seagoing hunters that roam vast areas of the Arctic, pursuing a movable feast of seals, narwhals, beluga whales, and walruses. Individuals may range over 116,000 square miles. As the pack ice breaks up during the summer months, many bears head for land, returning to the sea when it freezes again in October and November.

Although it evolved from land-dwelling brown bears only 300,000 years ago, the white bear is superbly adapted to life on the frozen sea. In winter, when the ice is solid, polar bears may hunt by locating holes in the ice at which sea mammals breathe. When they surface, seals and whales leave a scent in the air that polar bears can detect from a distance of several miles downwind. In spring, the seals' breeding season, mother seals and their pups take refuge in agloos—little snow lairs atop the sea ice. Bears pounce on these refuges, killing or stunning the pups and occasionally the adults.

This photograph was taken on the northern tip of Baffin Island, near a long crack in the sea ice where photographer Paul Nicklen and his Inuit guide had set up camp to wait out a storm. As he strolled along the crack about a mile from his base, Nicklen suddenly spotted the bear walking in the direction of the camp—perhaps drawn by the aroma of some seal meat that was stored there. After a few minutes, the animal slipped into the water to make a more stealthy approach to the larder. Nicklen raced ahead to the tent, grabbed his camera, and returned to the water's edge to wait for the bear to emerge. As it surfaced right in front of Nicklen, his guide became alarmed and ran over to drive off the animal. Unperturbed, Nicklen clicked away, enjoying a moment of quiet communion with the bear as it took in the situation, reconsidered its intentions, shook off some water, and submerged again.—*Richard Milner*

Photograph by **Paul Nicklen**

ENDPAPER

Insect From the Underground

By Alan Burdick

In *The Time Machine,* published in 1895, H.G. Wells envisions a human race divided. Aboveground, in a city of daylight, live the Eloi, while the bloodthirsty Morlocks toil in tunnels far below the ground. A century later, two real-life British geneticists have discovered an entomological analogue: a mosquito that is closely related to the one inhabiting the daytime streets of London but that lives exclusively in the tunnels of the London Underground. Unlike their upstairs brethren, which bite only birds, members of this subterranean race show a distinct affinity for human blood.

"They're quite voracious biters," says Richard Nichols, of Queen Mary and Westfield College at the University of London. "It's not that any one bite is all that bad, it's just that they all seem to want to get a bit of you."

The subterranean mosquitoes have been known for many decades; during World War II, Londoners who sought belowground shelter from the Blitz found themselves assaulted by the insects. Biologists named the attackers *Culex molestus,* presuming that they belonged to a species distinct from the aboveground *C. pipiens.* But until Nichols came along, the genetics had never been sorted out. He decided to unravel the mystery.


TRANSPORT FOR LONDON

Finsbury Park Station

The research legwork fell to Nichols's then-doctoral student Katherine Byrne, now a geneticist at the Institute of Zoology in London. After midnight, when the trains had shut down, Byrne followed maintenance workers into the subway's bustling underworld, where she soon discovered an ideal environment for mosquitoes. "The temperature is warm and virtually constant," Byrne says. "There's no rain, no snow: it's great for a year-round life cycle." The polluted pools of water, ranging from "pretty nasty" to "hideous," are prime mosquito-breeding sites. As with all mosquitoes, only the females—the egg layers—seek out blood, feeding on rats and pinstriped rat-racers alike. The males get by on what Byrne calls soluble nutrition: decaying rubbish, perspired salts, bits of hair, and "fluff," a thin haze of flaked-off human skin so pervasive in the Underground that specialized workers ("defluffers") must regularly clean it from the train's conduction rail.

By night, Byrne scavenged grim subterranean puddles for mosquito larvae. By day, she lurked aboveground in tony gardens and backyards, collecting specimens from water-filled buckets and beery vats of compost. Taking her larval captives—*C. pipiens* from upstairs and *C. molestus* from downstairs—she returned to the lab to raise them.

As adults, Byrne's subjects proved fascinating. Although the two varieties look identical, their habits differ sharply. *C. pipiens* hibernates in winter; *C. molestus* breeds year-round in the warm subway, but it cannot survive the cold. *C. pipiens* must swarm in the open before mating, whereas *C. molestus* thrives in confined spaces. When Byrne crossbred the two varieties, none produced viable eggs—suggesting that *C. molestus* is reproductively isolated, the traditional signature of a new species. (Given the great differences in their behavior, Byrne notes, *C. pipiens* and *C. molestus* probably rarely meet or mate "in the wild.")

Analyzing the DNA, Byrne and Nichols found that different colonies of the underground mosquitoes are more genetically similar to one another than to their aboveground brethren. A specimen of *C. molestus* discovered at Euston, on the Victoria line, is more closely related to a specimen found at Finsbury Park, miles away on the same line, than it is to a visibly identical specimen of *C. pipiens* captured just upstairs at Euston. In short, subterranean sites are being established by other underground mosquitoes, not by mosquitoes from above. How do the mosquitoes spread through the Underground? "We think that the trains act as pistons, pushing cushions of air"—and mosquitoes—"ahead of them," Nichols says.

And the insects continue to evolve. Byrne and Nichols have identified three genetically distinct subvarieties of *C. molestus,* each one unique to a different subway line: Victoria, Bakerloo, and Central. The other lines of the Underground probably harbor subvarieties of their own, Byrne adds, "and I'm sure they exist in sewers, though I've not been to look."

Alan Burdick is a writer/producer for AMNH's Science Bulletins.

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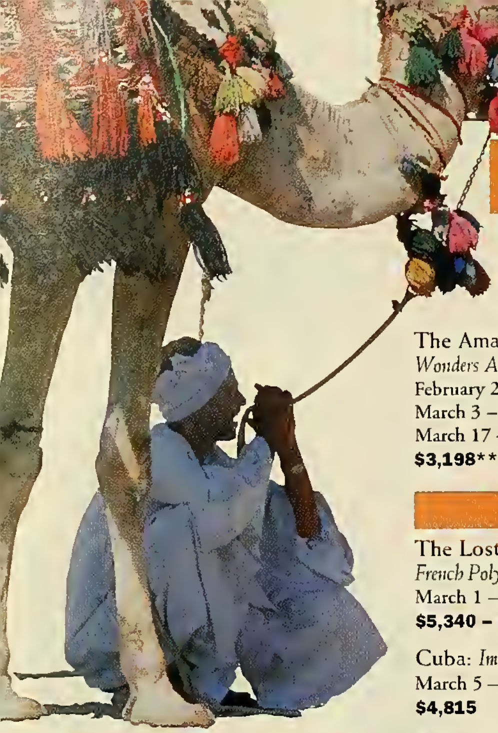

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The Lost Islands of Tahiti: *Exploring French Polynesia Aboard the* Paul Gauguin
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Exploring Southeast Asia: *Thailand, Cambodia, Malaysia, Singapore, and Hong Kong*
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$6,690 - $7,490**

Indian Ocean Odyssey: *South Africa, Madagascar, and the Seychelles Aboard the* Hanseatic
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$9,975 - $17,475

APRIL 2001

Egypt and the Nile: *Aboard the M.S.* Nile Sovereign
April 22 – May 6, 2001
$5,780

Sicily: *Crossroads of Mediterranean Civilizations Aboard the* Harmony
April 25 – May 5, 2001
$5,395 - $6,895

MAY 2001

Springtime in Japan: *Exploring Temples, Gardens, and Traditional Cultures Aboard the* Clipper Odyssey
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$7,990 - $11,690

Classical Greece & The Parthenon Sculptures
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$5,490

Historic Cities of the Sea: *Greece, Sicily, Sardinia, Malta, Tunisia, and Spain Aboard the* Clelia II
May 9 – 20, 2001
$6,695 - $12,595

Africa's Wilderness by *Rovos Rail: South Africa, Zimbabwe, Botswana, and Namibia*
May 16 – 30, 2001
$8,495

JUNE 2001

Madagascar: *Witnessing the Total Solar Eclipse*
June 8 – 24, 2001
$6,295

Fire & Ice I: *The Kuril Islands and Kamchatka Peninsula Aboard the* Clipper Odyssey
June 18 – 30, 2001
$6,490 - $10,690

National Parks of the West Private Jet Expedition: *Mt Rushmore, Grand Teton, Yellowstone, Glacier National Park, Columbia River Gorge & Mt. Hood, Grand Canyon, Bryce Canyon, Zion National Park, and Mesa Verde*
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$16,950

China for Families: *Beijing, Xi'an, Yangtze River, and Shanghai*
June 19 – July 3, 2001
$5,990 - $6,390**

North America's Great Lakes: *From Chicago to Toronto Aboard* Le Levant
June 24 – July 2, 2001
$3,890 - $5,390

Fire & Ice II: *Kamchatka Peninsula and the Aleutian Islands Aboard the* Clipper Odyssey
June 28 – July 11, 2001
$7,990 - $12,690

Wildlife of the Galapagos Islands: *A Family Adventure Aboard the* Santa Cruz
June 30 – July 10, 2001
$3,280 - $5,790

JULY 2001

Family Dinosaur Discovery: *In the Grand Valley of the Colorado River*
July 7 – 13, 2001
$1,745 - $2,650

Inside Iceland: *Discovering Vikings and Volcanoes*
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Voyage to the North Pole: *Aboard the* Yamal
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$17,950 - $23,950

Voyage to the Lands of Gods and Heroes: *A Family Journey to the Ancien Mediterranean Aboard the* Clelia II
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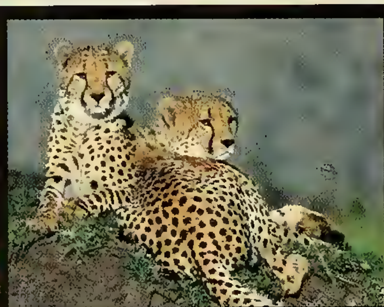
$3,745 - $10,645



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$2,045

Tuscany: *A Summer Family Adventure*
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$3,750 – $5,290

Family Alaska Expedition: *Aboard the* Wilderness Adventurer
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$2,790 – $4,890

Undiscovered Greece: *Hidden Islands, Villages, and Ancient Sites Aboard the* Callisto
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$4,295 – $5,595

Family Dinosaur Discovery: *In the Grand Valley of the Colorado River*
August 18 – 24, 2001
$1,745 – $2,650

The Outer Islands of Britain and Ireland: *Aboard the* Song of Flower
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$5,995 – $11,495

China & The Yangtze River: *Beijing, Xi'an, Yangtze River, Guilin, and Shanghai*
August 28 – September 13, 2001
$6,790 – $7,390**

The Elbe River: *A Journey from Prague to Berlin Aboard the* Katharina Von Bora
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$5,790 – $6,390

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In Search of the Source of the Nile: *From London to Zanzibar, Tanzania, Uganda, and Khartoum*
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$12,980

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