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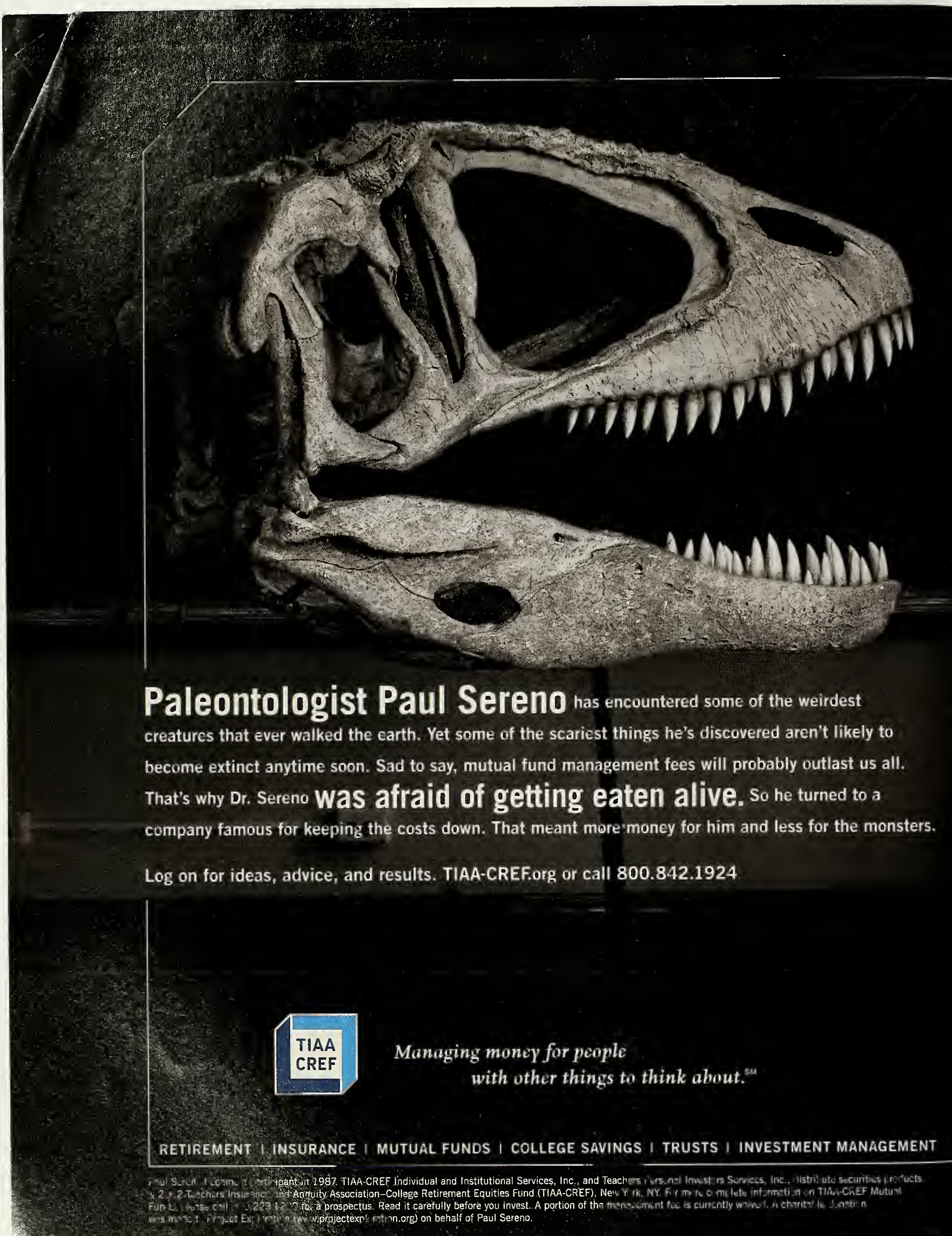
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NATURAL HISTORY

SEPTEMBER 2002 VOLUME 111 NUMBER 7

FEATURES

COVER Seedpod of a milkweed. Despite its protective toxins, the plant harbors diverse herbivorous insects.

STORY BEGINS ON PAGE 48

PHOTOGRAPH BY MANUEL DOS PASSOS
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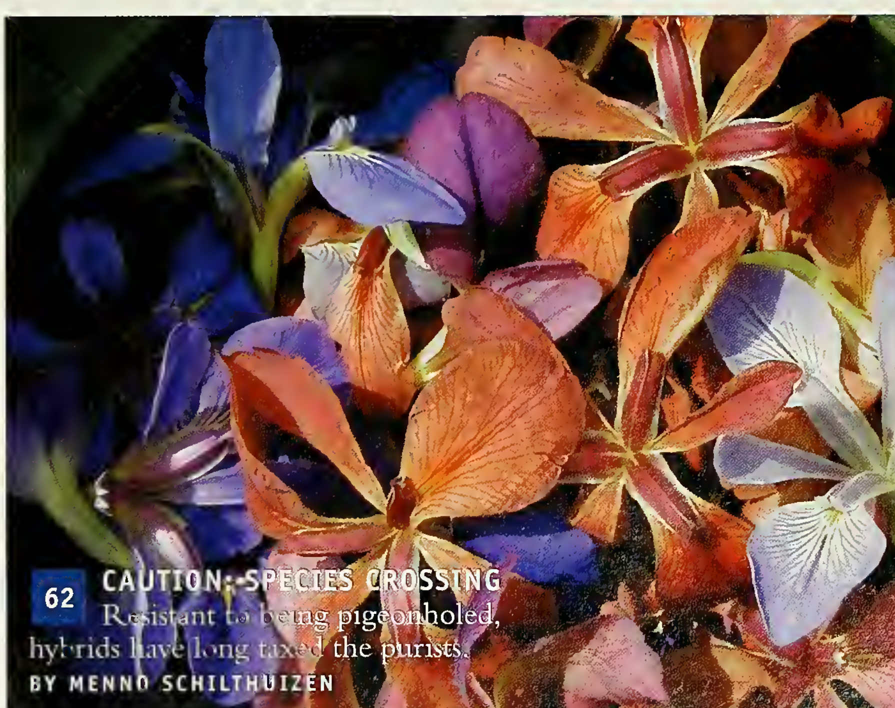

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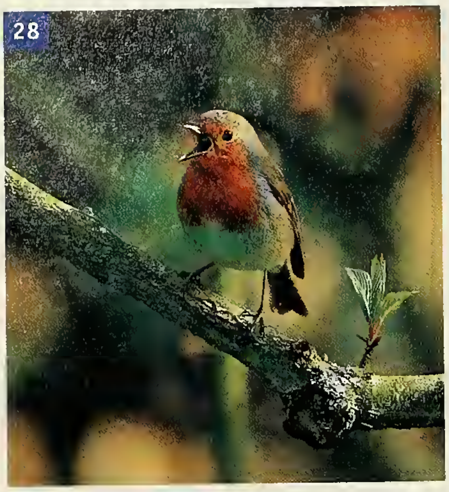
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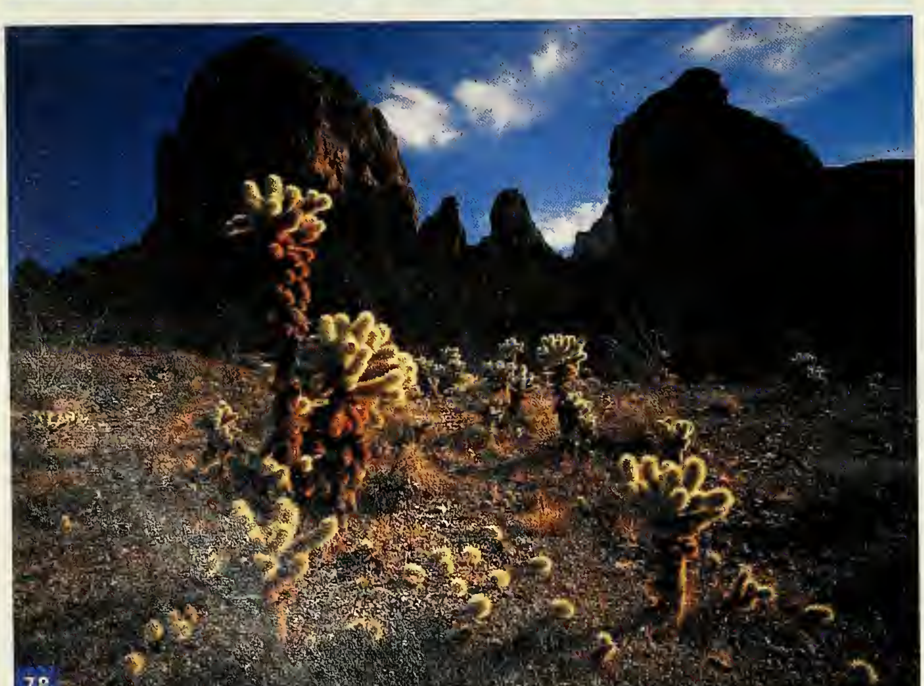
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UP FRONT

Waiting to Inhale

Many years ago, a friend invited me for a midwinter visit to her rented beach cottage on a Caribbean island. It was to be my first experience of non-temperate-zone nature. I planned to swim out into the turquoise waters and observe the bright reef fishes and exotic invertebrates known to me only from television.

Readying myself for my first snorkeling lesson, I put on the mask and arranged my lips around the snorkel's mouthpiece. "Just float face-down and start breathing normally," my friend instructed me. "If you hear water coming down the tube, throw your head back and blow out." I crouched and dipped my masked face into the sea but couldn't inhale: overpowering instinct told me not to breathe while my face was submerged. It took several tries before rationality prevailed and I entrusted my life to a curved plastic pipe.

Learning to snorkel was rewarding, but it also taught me that I am no amphibian. Although we humans can be taught to swim, and although our babies have a "diving reflex," we are irrevocably terrestrial. Yes, some of our fellow mammals—whales, dolphins, beavers, otters, manatees, seals—spend much of their time underwater, but they are not amphibious in the respiratory sense; they are just exceptionally good at holding their breath. Avian swimmers such as penguins and puffins and ducks and cormorants, as well as sea turtles and other water-dwelling reptiles, must also come up for air. Even frogs, toads, and salamanders—officially dubbed Amphibia by taxonomists—are usually committed to lungs, and thus to air breathing, once they've reached adult form.

MARK DEEBLE & VICTORIA STONE; OXFORD SCIENTIFIC FILMS

An African mudskipper

So to me, mudskippers—among the very few fish that make daily transitions from water to land—are particularly astounding. Not only can these fish (which live on coastal mudflats from Africa to Australia) breathe both in the air and underwater, they flip-flop from one lifestyle to another with every change of tide. Until recently, more was known about the aboveground habits of these fish than about their subtidal existence. But thanks to technology, twenty-first-century naturalists can go where no naturalists have gone before. In this issue, Heather Lee and Jeffrey Graham report on what it takes for a fish to survive in two worlds. To find out, turn to page 42 for "Their Game Is Mud."—*Ellen Goldensohn*

NATURAL HISTORY

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CONTRIBUTORS

Heather J. Lee ("Their Game Is Mud," page 42) decided by the age of eight that she would become a marine biologist, never mind having grown up in Chicago with "no saltwater in sight." Now a Ph.D. candidate at the Scripps Institution of Oceanography in La Jolla, California, she's near plenty of ocean. When not underwater or wading through mud, she rides high on her quarter horse, Jet. **Jeffrey B. Graham** is a physiologist and marine biologist at Scripps. His book *Air-Breathing Fishes* (Academic Press, 1997) stems from "a career-long interest in the origin of terrestrial vertebrates." In addition to mulling over our early prehistory, he spends his time painting in oils and enjoying his grandchildren. Lee and Graham thank the National Science Foundation and the University of California's Pacific Rim Research Program for the opportunity to become so intimately involved with mudskipper habitat; returning each day from their fieldwork muddied from head to toe, says Lee, they often inspire both curiosity and laughter from the locals.

Anurag A. Agrawal ("Once Upon a Milkweed," page 48) is an assistant professor of botany at the University of Toronto. He studies milkweed at Joker's Hill, a field station owned by the university and situated north of Toronto. Some of his other research projects take him south, to the Bahamas, for example, where he is investigating the effects of hurricanes on plants. Committed to his research, Agrawal, left, confesses that he also enjoys eating the organisms he studies; he has even tested out monarch excrement (or frass, as it's known in entomological, not culinary, circles) as a pizza topping. An associate professor of biological sciences at Western Michigan University, co-author **Stephen B. Malcolm** dates his interest in animal-plant interactions back to 1971, when, as an undergraduate, he read an article by the legendary entomologist Miriam Rothschild about aphids that feed on poisonous plants and become toxic themselves. He has been investigating the milkweed community ever since and reports that he, too, has eaten milkweed insects and tasted milkweed leaves and latex, using his tongue as a toxin sensor. Malcolm is also interested in assessing the possible effects of biotechnology (genetically engineered crops, for instance) on monarchs and other nontarget insects.

Dorothy Harley Eber ("Recording the Spirit World," page 54) first saw Inuit prints in a 1960 exhibition at the Montreal Museum of Fine Arts. Ten years later, she went to Baffin Island's Cape Dorset community on assignment to write about some of the artists who created these early graphics. For the past thirty-plus years, she has returned to the Arctic regularly to do fieldwork—researching archival photographs and recording oral histories not only about Inuit graphics but also about the Inuit's whaling practices and legal system. Her most recent book, *Images of Justice* (McGill–Queens University Press), a legal history of the Northwest Territories as traced through the Yellowknife courthouse collection of Inuit sculpture, grew out of a January 1990 article for *Natural History*. "I attempted," writes Eber, "to show through interviews how society and life in the North have evolved since the move from the camps to the settlements in the 1950s and 1960s."

Menno Schilthuizen ("Caution: Species Crossing," page 62) came across one or two natural hybrids during a teenage bug-collecting phase but only developed full-blown hybridophilia as a graduate student, while doing fieldwork on land snails on the island of Crete. Before that experience, he says, "the natural world had seemed a nicely organized place." Walking through a field and observing the snail shells' shape change with every step he took, though, shook up his tidy view of nature, which he now sees as more of a "free-for-all where evolution rules and nothing is permanent." Born in the Netherlands, Schilthuizen is associate professor of invertebrate systematics at the University of Malaysia Sabah's Institute for Tropical Biology and Conservation in Kota Kinabalu. He is the author of *Frogs, Flies, and Dandelions: Speciation—The Evolution of New Species* (Oxford University Press, 2001).

As for why he devotes so much time to the lethal box jellyfish, **Jamie Seymour** ("One Touch of Venom," page 72) says, "Why wouldn't you want to work on an animal that's 96 percent water, doesn't have a brain as such but can use visual images, swims at high speeds, and causes death in minutes?" Seymour, left, is a senior lecturer in the School of Tropical Biology at James Cook University in Queensland, Australia. His major area of research is the seasonal variations in populations of box jellies, other cnidarians, and tropical insects. He is also director of an organization that links and publicizes medical and biological research on the box jellyfish. Photographer **Paul A. Sutherland** learned to snorkel at the age of four in Saudi Arabia, where his father was a U.S. foreign service officer. After attending college in the United States, Sutherland returned to the Middle East and worked in the oil fields there for six years. A full-time photographer since 1996 (www.sutherlandimages.com), he specializes in the underwater world and has made more than 2,500 dives. "Every time I get in the water," he says, "the rest of the world ceases to exist."

From just twenty feet away, **Staffan Widstrand** ("The Natural Moment," page 86) spent hours watching and photographing a bull moose as it shed—and occasionally devoured—its velvet. The moose in Sarek National Park in Swedish Lapland, says Widstrand, "are used to having people around since they were calves." A native of Sweden, Widstrand has been a professional photographer and writer since 1985 and has traveled just about everywhere. He and photographer/writer Magnus Elander have collaborated on books about ecotourism as well as the polar North. One of their current projects involves the five large carnivores of northern forests: wolves, bears, lynxes, wolverines, and humans. A book, *The Big Five* (Max Strom Publishers), with text by Elander and Johan Lewenhaupt and photos by Elander and Widstrand, is due out later this year.

LETTERS

Wasp Roundup

Joe Coelho's article about cicada killers ("Spurred On to Greater Depths," 7/02–8/02) intrigued me because I was absolutely terrorized by these giant wasps as a child growing up in New Jersey. Are they poisonous? Do they sting? If so, how easy is it to disturb them so that they would?
Mimi Torchia Boothby
Seattle, Washington

In Joe Coelho's interesting article, he states that the female lays her eggs on paralyzed cicadas to provide nutrition for the larvae, supplying one cicada for each male larva and two for each female larva. But how does the female wasp know the gender of the offspring that will hatch from an egg?
Steve Griffith
Blue Springs, Missouri


JOHN HEIDECKER; NATURE PHOTOS

A cicada killer drags paralyzed prey to its burrow.

JOE COELHO REPLIES: I have dug cicada killers out of their burrows, and rather than fly out and sting me, they remained in the very end of the tunnel, making a loud buzzing noise. When they do sting, it feels like a pinprick and is not dangerous unless a person is allergic to the venom.

The female controls the sex of her offspring. If she fertilizes the egg (using sperm stored in her spermatheca), the resulting larva will be female. If she does not, it will be male.

Not Quite Ubiquitous

I was interested in the article "Avian Quick-Change Artists" (6/02) because house finches are the most common finches at my parents' bird feeders. But according to the maps in the article, we live in a part of the country where the finches aren't (just north of Bismarck, North Dakota). These birds began showing up almost immediately when the feeders were set up in 1998.
Mike Creech
via e-mail

ALEXANDER V. BADYAEV REPLIES: House finches will come to feeders in many places not indicated on the maps (derived from Breeding Bird Survey data), because either there is no confirmed nesting in those locations or the birds are found in low and unpredictable numbers. In fall and early winter, house finches commonly congregate at feeders well beyond their nesting areas and outside of towns, but they don't nest in those habitats.

New Identity

The last photo accompanying "Little Loggers Make a Big Difference" (5/02) shows a kestrel attacking what is the longest-tailed, biggest-eyed "vole" I ever saw. No doubt a mutant—or a vole mimicking a mouse in good Darwinian style.
Keith Nelson
Camp Meeker, California

THE EDITORS REPLY: The mislabel is an editorial error; the rodent is a mouse.

We also failed to notice (until it was pointed out to us after the May issue was published) the evidence of animal cruelty in this photograph: the mouse had been tied down. Had we been aware of that, we would not have used the picture.

Movie Rebuff

I enjoyed Neil deGrasse Tyson's recounting of some of Hollywood's astronomical howlers ("Universe," 6/02). But I'm afraid Mr. Tyson made a howler of his own in writing about the movie *Titanic.* Yes, producer James Cameron was correct in not having smoke coming from the fourth funnel of the ill-fated ship, but not because he was "aware that only three of the vessel's four engines were used on that maiden voyage. . . ." The ship had only three engines. The fourth funnel was simply for show. Now, if only they had spent that money on making the watertight bulkheads one deck higher!
James H. Hastings
Rapid City, South Dakota

Shedding Light

I would like to clear up a misconception in Charles Liu's article "Good Morning, Starshine" (7/02–8/02): that when the universe was young, both ultraviolet and "visible" light were absorbed by hydrogen atoms. It is true that before the hydrogen in the universe was ionized, the universe was opaque to ultraviolet light, consisting of high-energy photons. However, hydrogen, even un-ionized hydrogen in the early universe, would have been transparent to visible light, consisting of lower-energy photons. At the end of what astronomers refer to as the Dark Age, when the first stars and quasars formed, the universe also became transparent to ultraviolet light.
Michael Strauss
Department of Astrophysical Sciences
Princeton University
Princeton, New Jersey

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

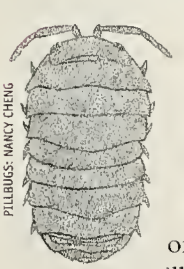
AT THE MUSEUM

Young Naturalist Awards 2002

For the American Museum of Natural History's fifth annual Young Naturalist Awards, students in grades 7 through 12 were invited to embark on an expedition that focused on a topic in biology, earth science, or astronomy and to document and analyze their observations. The winning entries (selected from more than 700) are summarized below. Full-length versions are available in a catalog published by the Museum's National Center for Science Literacy, Education, and Technology and can also be read online at www.amnh.org/nationalcenter/youngnaturalistawards/.

PAINTED LADY POLLINATING RABBIT BRUSH: ELSPETH IRALU

Pillbugs: Little Creatures in My Backyard, *by Nancy Cheng (Wichita High School East, Wichita, KS; Grade 11)*
Last April, looking among the crocuses, hyacinths, and tulips in her family's garden, Nancy Cheng noticed that the *Hosta* plants (also known as plantain lilies) were in "pitiful shreds" and were "dotted with holes, like some irregular green variety of Swiss cheese." The *Hosta* had been ravaged by a swarm of "roly-polies," or pillbugs. She resolved to find out about these tiny crustaceans, which are less than two-thirds of an inch long. When she conducted a dietary-preference experiment, Nancy observed that pillbugs make no distinction between lawn clippings and young plant shoots. She thereby figured out a way that pillbugs could harmlessly coexist with a garden's plants.



PILLBUGS: NANCY CHENG

Deformed Frogs: The Big Mystery, *by John DeLeo (W. T. Clarke Middle School, Westbury, NY; Grade 7)*
During annual summer visits to his uncle's house in Vermont, John DeLeo does a lot of frog hunting (mostly leopard frogs and American toads) in a large pool beside the Green River. "Because frogs are so sensitive to their environment, they may be good early indicators of an ecosystem going bad," he explains. When John began finding deformed frogs, he decided to look for potential causes, coming up with the following four possibilities: chemicals, invasion by a trematode, increased ultraviolet radiation caused by ozone depletion, and predation during the tadpole stage.

Investigating the Effects of Water Pollution on *Daphnia magna,* *by Mauree Gibson (Central Lee School, Donnellson, IA; Grade 8)*
When Mauree Gibson began to study the minute crustaceans named *Daphnia magna* (members of a group known as water fleas), she discovered her "new best friends." Species of *Daphnia,* she

(Continued on page 18)

VINTNERS TALES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Russian Dolls


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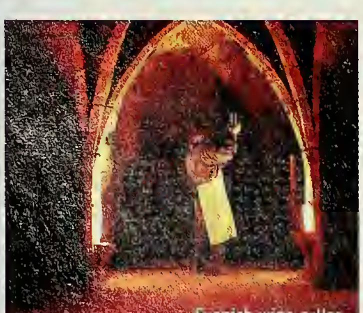
Spanish wine cellar

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MON 30 JUN · *Bordeaux*

Explore the provincial capital and the lovely town of St Emilion, before transitting the River Gironde this evening.

TUE 1 JUL · *Nantes*

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TUE 22 JUL · *Stockholm*

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WED 23 JUL · *Turku*

After lunch explore the city and visit Turku Castle.

THU 24 JUL · *Helsinki*

From your central berth walk into Helsinki and discover its charms, or join an excursion to Sibelius Park and the impressive Uspensky Cathedral.

FRI 25-SAT 26 JUL · *St Petersburg*

Enjoy the best of St Petersburg, including the famed Hermitage and Peterhof Palace. On Friday evening join a supplementary excursion to see a performance at one of the city's superb theaters.

SUN 27 JUL · *At Sea – Tallinn*

Discover one of Europe's best medieval old towns as you stroll along winding cobbled streets.

MON 28 JUL · *At Sea – Riga*

Wander ashore this evening and perhaps enjoy a meal in one of the many pavement cafes.

TUE 29 JUL · *Riga*

Visit the Dome Cathedral in this picturesque city or choose an excursion to the beautiful Rundale Palace.

WED 30 JUL · *Gdynia (for Gdansk)*

Join a walking tour through this carefully restored atmospheric old town or opt for an excursion to Marlbork Castle, one-time headquarters of the Teutonic Knights.

THU 31 JUL · *Ronne*

Spend a delightful afternoon on the Danish island of Bornholm, to see its pretty houses and enchanting whitewashed round churches.

FRI 1 AUG · *Copenhagen*

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(Continued from page 14)
learned, are everything from fish food to barometers of toxicity in wetlands. Her research revealed mysterious growths on her tiny specimens and subsequently led her to consult with parasitologists Dieter Ebert in Switzerland and Kirsten Christoffersen in Denmark. While she hasn't yet figured out what the growths are, Mauree regards her work as "only the beginning."

A Beach Walk in New Mexico, *by Elspeth Iralu (Home School Program, Gallup, NM; Grade 9)*
"Today I went to New Mexico's seashore," writes Elspeth Iralu of a hike in landlocked New Mexico, to an area with huge boulders made entirely of seashells. Once home, Elspeth (who was also one of last year's winners) learned that the fragments she had collected were fossils from the Cretaceous Period, when all of Europe and half of North America were submerged in saltwater. "I was reminded that fossils are not just shells," she notes, "but evidence of a past ecosystem that has evolved into our present ecosystem."

Alien Plant Invaders, *by Katherine Jones (Cold Spring Harbor High School, Cold Spring Harbor, NY; Grade 11)*
Thirty-five percent of the approximately 3,200 plant species in New York State, Katherine Jones found out, are nonnatives such as garlic mustard, Japanese barberry, and kudzu, a "green leafy monster" that is almost unstoppable once it invades. Katherine made it her business to identify her own backyard's invaders—which include three fast-growing Norway maples (the species is from northern Europe) that grow at the edge of her garden and range from three to twenty feet high. Removal of a Norway maple is a large task, she laments, because "the entire root system must be removed or the tree will resprout." While Katherine has not found kudzu on the property, she keeps a watchful eye on a patch that is flourishing nearby.


KUDZU VINE: KATHERINE JONES

Turtle Basking in New York City, *by Lillian Lam (Abraham Lincoln High School, Brooklyn, NY; Grade 9)*
"Manhattan's own Central Park is home to a diverse ecosystem," writes Lillian Lam, by way of introducing her urban research project on turtles, particularly their basking behavior in the park's (you guessed it) Turtle Pond. Lillian's fascination with turtles began at age nine, when she received a red-eared slider as a pet. For this project, she focused on eastern painted turtles. During three expeditions to the pond, Lillian painstakingly observed and recorded turtle behavior, concluding that "conducting an expedition requires perseverance and thorough observation."

Salmon Creek: A Search for the Missing Salmon, *by Kristen Marini (Maple Grove Middle School, Battle Ground, WA; Grade 7)*
Kristen Marini wondered why salmon were disappearing from the little creek behind her house, a feeder stream of the Columbia River. So she intensively surveyed two eleven-square-yard sections of the surrounding forested ecosystem, counting each plant and also identifying species that inhabit the creek—from trout and salmon to crawdads, periwinkles, and larval caddis flies (which she describes as "little worms that glue themselves to a rock and put pebbles around themselves for protection"). Concluding that the area behind her house is healthy, Kristen is eager to test other localities nearby and to solve the ongoing mystery.

Habitat Selection for Nest Cups of the Pacific Golden Plover *(Pluvialis fulva)* in Nome, Alaska, *by Whitney Nekoba (Waiakea High School, Hilo, HI; Grade 10)*
Pacific golden plovers summer on the Seward Peninsula in western Alaska but winter in Hawaii. Since sixth grade, Whitney Nekoba has been observing wintering plovers near her home in Hilo, the capital of Hawaii Island. Last summer, however, she managed to talk her way into a research expedition to Nome, Alaska, with Brigham Young University biologist Phil Bruner and his wife, Andrea. Whitney was put in charge of examining the area surrounding twenty-one nest sites (called nest cups) on the tundra near Nome. She had to "identify general habitat features" and calculate the percentages of vascular plants, nonvascular plants (such as lichen and moss), and nonliving materials (rocks and soil) to determine whether the plovers are randomly or deliberately selecting where they lay their clutches of eggs, and what the evolutionary implications are.


MALE PACIFIC GOLDEN PLOVER: WHITNEY NEKOBA

Growing Up at Espenberg: Eggstatic About Foxes, *by Juliann Schamel (West Valley High School, Fairbanks, AK; Grade 12)*
Since she was ten, Juliann Schamel has

spent every summer in northwestern Alaska's remote Cape Espenberg (thought to be where humans first crossed over to North America), helping her parents study shorebirds and waterfowl. Juliann conducted her own research on the area's arctic and red foxes to find out the details of


ARCTIC FOX KIT: JULIANN SCHAMEL

their diets. Now off to college, she is nostalgic about the cape, "where the very dirt is alive and wriggling, where the land and water and fire and sky come together to create a fascinatingly living world."

Emit What You Eat: An Investigation of the Link Between Bovine Diet and Their Excreta Methane Emissions, *by Tavé van Zyl (Regiopolis Notre Dame, Kingston, Ontario; Grade 12)*
Living in eastern Canada, Tavé van Zyl is used to very cold winters, which sparked her interest in renewable sources of heat—specifically methane, or biogas. Inspired by the use of methane for heating as far back as the tenth century B.C. in Assyria, Tavé designed an apparatus to metabolize cow manure and produce methane gas through anaerobic digestion. "Whoever imagined," she writes, "how attractive this repulsive matter could eventually become?"

The Oxidation Potential of Mineral Assemblages in Rocks From New York and Washington State, *by Michael Williams-Pearson (Science Skills Center High School, Brooklyn, NY; Grade 12)*
While on an internship in Washington State, Michael Williams-Pearson collected many pounds of metamorphic rocks to compare with those from New York State. The minerals found together in the coarse-grained New York rocks include quartz, muscovite, hornblende, and biotite, all of which weather slowly. Rocks from Washington State formations, Michael determined, are fine grained and "from a low-grade metamorphism called a lower greenschist facies"—composed of fast-weathering chlorite, actinolite, albite, and calcite. His ultimate aim is "to find out about the rocks' potential use in construction engineering."

My Expedition to the Lava River Cave, *by Amy Withey (Our Lady of Perpetual Help, Scottsdale, AZ; Grade 8)*
Interested in the phenomenon of cave formation after volcanic eruptions, Amy Withey, a budding spelunker, explored 3,280-foot-long, 675,000-year-old Lava River Cave, near her home in Arizona. Among her many objectives were identifying different lava types (ripples, splashdowns, and lavasicles) and comparing the cave's formation with that of a limestone, or water-formed, cave.

A Study of the Indigenous, Endemic, and Exotic Fungi in the Pu'u Maka'ala Natural Area Reserve in Volcano, Hawaii, *by Kolea Zimmerman (Waiakea High School, Hilo, HI; Grade 10)*
Studying a pocket of Hawaiian rainforest in the Pu'u Maka'ala (*pu'u* is a hill or volcanic cone; *maka'ala* means "to be alert or vigilant") Natural Area Reserve, Kolea Zimmerman tried to figure out how pristine the ecosystem was. He surveyed and sketched the reserve's fungi and found sixteen species (all native); he also identified a variety of trees ('olapa, pilo, 'olomea, and kolea), birds (honeycreepers), and numerous insects. Kolea hopes that some of the fungi in his survey may become the source of new pharmaceuticals.

MUSEUM EVENTS IN SEPTEMBER

INSIDE AND OUTSIDE THE MUSEUM

University Without Walls 9/5 (telephone course): "Elephant Safari." 11:00 A.M., advance registration required. Details from DOROT at (212) 769-850 or toll-free at (877) 819-9147.

Workshop 9/7: Lenape Indian traditional dance workshop. Artist Autumn Wind Scott. No experience necessary; the whole family is welcome. Kaufmann Theater, 11:00 A.M.–12:00 noon, 1:00–2:00 P.M.

Performance 9/7: Lenape Indian dance and drumming performance. Kaufmann Theater, 3:00–4:30 P.M.

AMNH Book Club 9/8: Discussion of *The First Americans: In Pursuit of Archaeology's Greatest Mystery,* by James Adovasio and Jake Page. Portrait Room, 3:00–4:30 P.M.

Slide and video presentation and discussion 9/12 (Art/Science Collision series): "Thermography: The Philosophy of Pain." Pain specialist Matthew H. M. Lee and artist Nam June Paik discuss their collaboration in creating computerized infrared images to represent the human experience of pain. Discussion moderated by art critic Robert C. Morgan. Kaufmann Theater, 7:00 P.M.

Workshop 9/14: Japanese Taiko drumming. Led by members of the Soh Daiko group. Kaufmann Theater, 11:00 A.M.–12:00 noon.

Workshop 9/14: Okinawan and Japanese folk dance. Chieko Kojima and Mitsue Kinjo, members of Hanayui, an all-women group. Leonhardt People Center, 11:00 A.M.–12:00 noon.

Workshop 9/14: Japanese song. Led by Hanayui member Yoko Fujimoto. Calder Lab, 11:00 A.M.–12:00 noon.

Performance 9/14: Japanese festival sounds. Joint performance by the Hanayui and Soh Daiko groups. Kaufmann Theater, 3:00–4:00 P.M.

Lecture 9/24: "Eye of the Albatross: Vision of Hope and Survival." Carl Safina, of the National Audubon Society's Living Oceans Program, investigates encounters between humans and marine life. Kaufmann Theater, 7:00 P.M.

Lecture 9/26 (China Survey series): "China's Ancient History." Morris Rossabi, of Queens College and the Graduate Center of the City University of New York. Kaufmann Theater, 6:30 P.M.

Expedition 9/28: "The Archaeology of New York City." Archaeologist Susan Dublin leads a tour of Lower Manhattan. 10:00 A.M.–2:00 P.M.

Expedition 9/29: "Fall Migration in Prospect Park." Led by AMNH ornithologist Paul Sweet. 10:00 A.M.–2:00 P.M.

ASTRONOMY & COSMOLOGY

Course 9/4–12/11 (fourteen Wednesdays, except 10/16): "Introduction to Space Science—Matter, Motion, and Energy." Museum astrophysicists Neil deGrasse Tyson and Charles Liu. Advance registration only. Linder Theater, 6:30–8:30 P.M.

Course 9/5–10/10 (six Thursdays): "Stellar Death: The Meaning of Life From the Cosmic Perspective." Museum astrophysicist Orsola De Marco. Advance registration only. Linder Theater, 6:30–8:30 P.M.

Lecture 9/23 (Distinguished Authors in Astronomy series): "Seeing in the Dark." Amateur astronomer Timothy Ferris, author of a new book documenting amateur astronomers' contributions to the field. Space Theater, Hayden Planetarium, 7:30 P.M.

October's Celestial Highlights 9/24: Joe Rao, meteorologist and *Natural History* columnist. Space Theater, Hayden Planetarium, 6:30 P.M.

Lecture 9/30 (Frontiers in Astrophysics series): "The Cosmic Microwave Background Radiation." Astrophysicist John Carlstrom. Space Theater, Hayden Planetarium, 7:30 P.M.


MICHAEL DAMES

The Japanese folk-drumming group Soh Daiko

CHILDREN'S PROGRAMS

Workshop 9/7 (ages 4-6, each child with one adult): "Fly Me to the Moon." Experiments designed to explain lunar phenomena. Rose Center fourth-floor classroom, 10:30 A.M.–12:00 noon.

Workshop 9/7 (ages 4-6, each child with one adult): "I Want to Be an Astronaut." Learning about life in space through activities and role-playing. Rose Center fourth-floor classroom, 1:30–3:00 P.M.

Lecture 9/10 (Space Explorers: Astronomy for Young Adults series—ages 12 and up): "The Planets of Our Solar System." Space Theater, Hayden Planetarium, 4:30–5:45 P.M.

Workshop 9/21 (ages 8 and 9): "Explore a Microhabitat." Behavioral and observational studies of the community of creatures that inhabits a rotting log. Calder Lab, 2:00–4:00 P.M.

Workshop 9/22 (ages 7–9): "Space Camp." Learning about the life of an astronaut on the International Space Station. Rose Center fourth-floor classroom, 10:30 A.M.–12:00 noon.

Walking tour 9/28 (ages 9–11, each child with one adult): "South Street Seaport: The Life and Times of the Port." A tour of this historic district on the East River, from Pearl Street to Dover Street. 10:00 A.M.–12:00 noon.

Course 9/15–10/6 (four Sundays—ages 8–10): "Stars in My Eyes." Francine Jackson, of Brown University's Ladd Observatory, introduces basic concepts of astronomy. Room 319, 1:00–3:00 P.M.

Course 9/15–11/10 (eight Sundays, except 10/6—ages 10 and up): "Family Adventures in Astronomy." Hayden Planetarium instructor Craig Small. Rose Center fourth-floor classroom, 11:00 A.M.–1:00 P.M.

ALSO IN SEPTEMBER

Live jazz. "Starry Nights: Fridays Under the Sphere." Performances are free with Museum admission; tapas and beverages sold. Rose Center for Earth and Space. Two sets: 5:45 and 7:15 P.M.

Members' programs. For details, call (212) 769-5200.

IMAX films. *Kilimanjaro: To the Roof of Africa* and *Bears.* Samuel J. and Ethel LeFrak Theater, daily screenings from 10:30 A.M. through 4:30 P.M.

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.


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THE EVOLUTIONARY FRONT

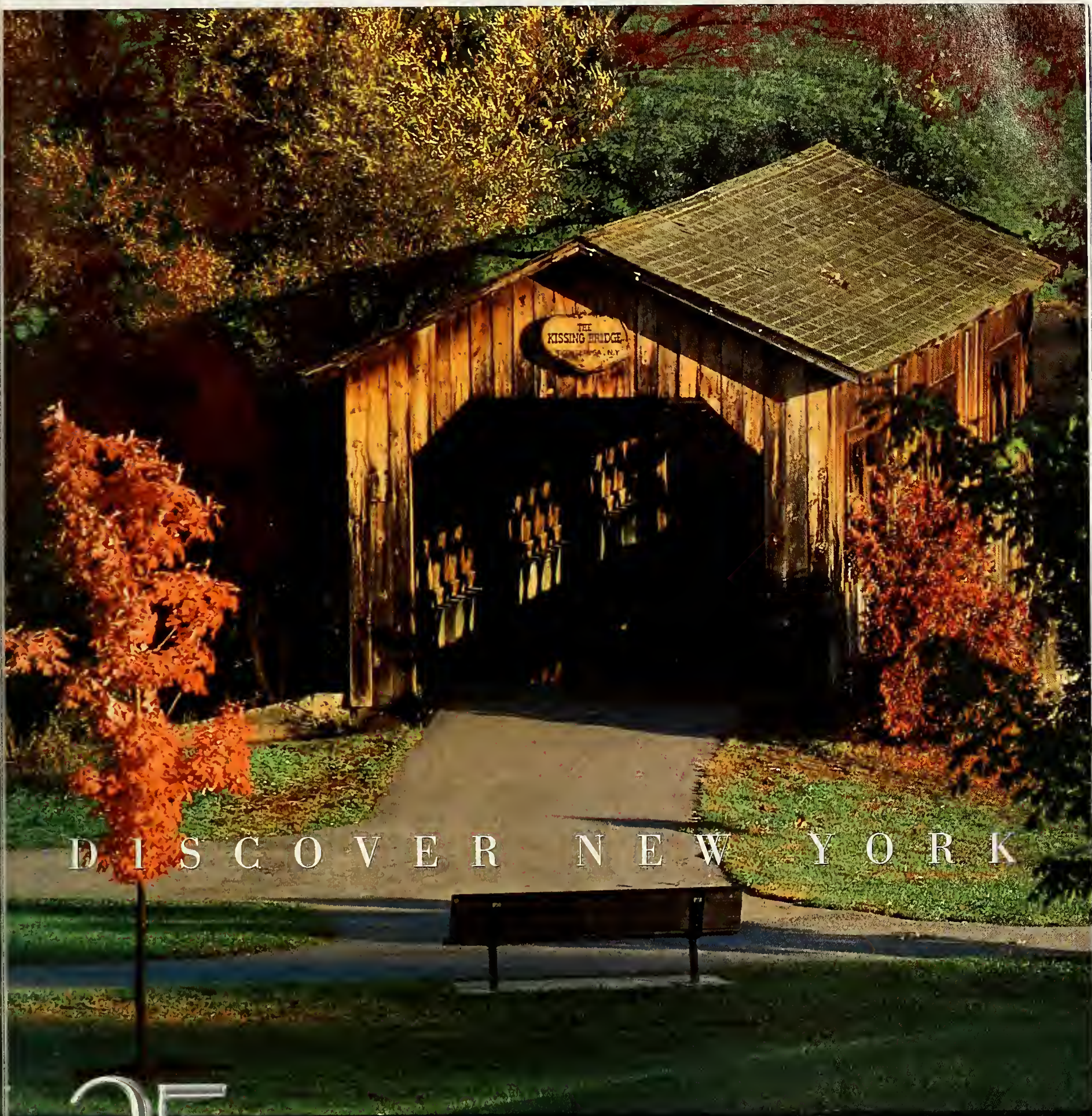
The Once and Future Male

Men will survive even after the pivotal genes that make them men disappear.

By Carl Zimmer

What does it mean to be a man? Part of the answer depends on where you ask the question. In some places, being a man may include spending Sundays watching football. In others, it may include completion of a rite of passage, such as getting buried up to your chin in an ant nest on your thirteenth birthday. Of course, there's some biology involved, too, and crucial to that biology is a peculiar chromosome called the Y. Men and women normally carry twenty-three pairs of chromosomes. Each pair consists of two matching chromosomes, with one exception: men normally have one chromosome called X paired with a dramatically smaller one called Y. Women, on the other hand, have two X's. A child (again, normally) inherits one chromosome from each matching pair belonging to each parent, including an X from its mother. From the father it re-

JAMES MARSH


THE
KISSING BRIDGE
DISCOVER NEW YORK

ceives either an X or a Y. If the father bequeaths a Y chromosome, the child will be a boy. Yet it's wise not to put too much faith in the simple equation Y = male. There are people who are XY, for example, but who look for all the world like women. That's because they have a faulty copy of a gene that builds a receptor for testosterone; as a result, their sex organs never get the signal to take on a male form.

The same kind of cautionary tale has emerged as scientists have begun to piece together the history of the Y chromosome. To be a man does not depend on some fixed, unchanging stretch of DNA. In vertebrate history alone, we have male ancestors going back at least 500 million years, but the Y chromosome is less than 310 million years old. And some of the genes on the Y chromosome that are now essential for making males may have emerged less than 170 million years ago. All the genes on the Y chromosome probably have only a few million years left before they vanish. But there will still be males. Strangest of all, it will be maleness itself that makes those male-making genes vanish.

The Y chromosome is as old as the mammalian lineage. It can be found today in just about every mammal, from human to elephant to bandicoot. But reptiles and birds, the closest living relatives of mammals, don't have a single Y among them. They rely on completely different ways of determining sex. Turtles and alligators, for instance, lay sexless eggs, which become either male or female depending on the temperature at which they incubate. Birds, like mammals, use sex-determining chromosomes, but theirs aren't related to ours. Biologists call them W and Z. While our two X's make a woman, two Z's make a male bird; a W and a Z make a female. Without any version of the Y to be found other than in mammals, there's only one conclusion to draw: our ancestors must have evolved after they branched off from the ancestors of birds and reptiles—a split that paleontologists think happened about 310 million years ago.

As the human genome has come into focus in the past few years, the Y has held on to its title as an oddball chromosome. It is a genomic runt, containing only 60,000 nucleotides, the organic compounds that make up DNA. (With 165,000 nucleotides, the X chromosome is nearly three times as long.) And when you look at the actual number of working genes on the Y, the difference is even more stark: the Y has only 50, while the X has 1,500. Yet X and Y are apparently cousins, descended from an ancestral pair of matching chromosomes. Scientists have

Three to six genes disappear from the Y chromosome every million years. At that rate, it has only 10 million years left.

discovered that a number of the Y genes have strikingly similar counterparts on the X chromosome. The simplest explanation for this is that a matching pair of chromosomes in some primordial mammal diverged to become the X and the Y.

Scientists suspect that these chromosomes began to part ways when one of them acquired a single gene that could turn a mammal into a male. Building a male is a complex business, probably requiring the cooperation of hundreds of genes, but a single gene can actually act like a trigger for an entire process. In 1990 a team led by Peter Goodfellow, then working at the Imperial Cancer Research Fund, discovered such a trigger in humans: a gene on the Y chromosome that they named *SRY*. If a Y-bearing sperm carries a defective copy of *SRY*—and it can take as little as one incorrect nucleotide to disable the gene—a child will grow into a female despite its Y chromosome. The reverse is true, too. In a neat experiment, a team headed by Robin Lovell-Badge at the National Institute for Medical Research in London plucked an *SRY* gene from a male mouse and added it to the paired X chromosomes of a fertilized mouse egg. The mouse embryo grew into a male.

SRY controls sex determination not just in humans and mice but in many other mammals, from dogs to kangaroos. But Jennifer Marshall Graves, a geneticist at the Australian National University in Canberra, and her colleagues have discovered that *SRY* is absent in monotremes, a group of mammals that branched off from the ancestors of all other living mammals about 170 million years ago. The modern representatives of this group, the platypus and the echidna, still manifest their ancient heritage: they lay eggs rather than bearing live young, and have a low, fluctuating body temperature—traits left over from mammals' reptilian ancestors. Monotremes do have Y chromosomes, and the males develop a penis and testicles and produce sperm. But they do not have the crucial gene on the Y that creates males in just about every other species of mammal.

Scientists are now searching for the trigger gene that actually does build male monotremes. In the meantime, Graves has come up with a surprising hypothesis concerning the early evolution of mammals (she presented it this past May in the journal *Trends in Genetics*). The story begins before the Y chromosome existed, when our ancestors—some kind of early mammal or perhaps a reptilian forerunner—used another system for determining sex. Somehow, one copy of a gene on what would become the X/Y chromosome pair changed into a form that happened to trigger the network of male-building genes. That trigger gene, according to Graves, may not have been *SRY*. Over the generations, males spread this trigger gene, and the old way of making males disappeared. During this time, the Y chromosome became increasingly distinctive and isolated.

Then, about 170 million years ago, when the monotremes branched off, they kept their Y chromosome. Perhaps they continue, to this day, to use the original trigger gene. An ancestor of all the other living mammals (marsupials and placentals) took a different route, however. Sometime after the split, this branch acquired a brand-new trigger gene on the Y chromosome. This new gene was *SRY*, and according to Graves, it must have appeared no later than 130 million years ago, when the last common ancestor of all living mammals apart from monotremes is believed to have lived. *SRY* then spread, generation after generation, until it drove the older trigger gene extinct.

How the Y chromosome became so different from its partner is another element of this story. In cells that give rise to eggs and sperm, the chromosomes in each matching pair embrace and trade stretches of their DNA, a process called recombination. Initially, the X/Y pair-to-be swapped genes too. But as new genes that helped build male anatomy evolved in the X/Y pair, there would have been an advantage to keeping these male-building genes close together on the same chromosome, allowing them to form stable partnerships over millions of years.

One mechanism that would have ensured that these genes passed intact from one generation of males to the next was for the X and Y chromosomes to become increasingly isolated from each other. And as the Y became more isolated, male-building genes arising on that chromosome would have been especially favored. Over time, such genes were able to coevolve, forming into ever more effective coalitions. For example, many of these male-building genes on the Y chromosome began to be expressed in the testicles and nowhere else. Today, only a short stretch at one tip of the Y and X chromosomes can recombine—a vestige, presumably, of a far more intermingled past.

The Y chromosome we now inherit has a skimpy, junk-laden code. In the 1960s, biologist Susumo Ohno proposed that as the Y became isolated, evolution drove its decay. When a gene on a more typical chromosome mutates, the chromosome can still recombine with its twin. Children are equally likely to inherit either the mutant gene or its unchanged counterpart; this slows the spread of the mutant gene over the generations. But if a mutation strikes the solitary Y chromosome, it always gets passed down intact from a father to every one of his sons. And as the Y gathers up mutations, fewer and fewer of its genes continue to work; they lose their integrity and ultimately disappear or get overrun with junk DNA. In time, Ohno argued, only the handful of genes responsible for building males survived.

Scientists can't check Ohno's hypothesis by watching the DVD of the Y's life story, complete with quadraphonic sound. But it is possible to look for parallels elsewhere in nature. Consider, for instance, the fact that the sex chromosomes of birds function like a mirror image of our own. The W chromosome, which makes female birds, does not recombine. And like the Y in male mammals, the W of birds is a tiny wastrel compared with its Z counterpart. The same evolutionary process seems to be at work in both birds and mammals, although it is affecting different chromosomes.

The *SRY* trigger gene has ruled our male-making process for at least the past 130 million years, but that doesn't mean it has been frozen in time. On the contrary, it and many other genes on the Y chromosome have been evolving far faster than genes on other chromosomes. For one thing, Y chromosomes accumulate mutations quickly because they can't recombine. For another, because far more sperm are produced than eggs, the germ cells in males must divide many more times, increasing the potential for copying errors. And while X chromosomes get passed on to the next generation through either an egg or a sperm, a Y always goes the sperm route—and sperm cells provide a riskier environment. They have evolved into fast, lightweight swimmers; in the process, they've jettisoned most of the proteins that normal cells carry, including the enzymes that repair mutations.

> Two Z chromosomes make a male bird, and a Z and W make a female. Like our Y, the W chromosome is a wastrel.

Mutated genes provide raw material for natural selection, and here, too, genes on the Y have a knack for speed. The fertility of a male is the core of his reproductive fitness, and any mutation that improves it—for example, by making him more attractive to females or providing him with faster-swimming sperm—brings a huge evolutionary advantage. Scientists suspect that when a gene that gives its owner a big advantage appears on the Y, copies of the chromosome may spread through a species in a Darwinian eye blink. Our own species may have experienced this sort of selective sweep just 60,000 years ago (see "The Evolutionary Front: After You, Eve," March 2001).

The evolution of Y genes may be fast, but it's also reckless, and ultimately the chromosome as a whole is doomed. It has shrunk for millions of years and has lost almost all of its original genes. Consider, for example, the sperm-building gene *UBE1*. Almost all mammals use it, and our own distant ancestors no doubt used it as well. But Michael Mitchell, of the Faculty of Medicine at the University of the Mediterranean in Marseille, and his colleagues have found that we lack *UBE1*, as do chimps and some other primates. Some 40 million years ago, they propose, our primate ancestors lost the *UBE1* gene. Its job was taken up by another gene on another chromosome.

The path of evolution is usually so quirky and complex that scientists shy away from making predictions. But the future of the Y chromosome seems clear. Graves points out that, on average, three to six genes have disappeared from the Y every million years since the chromosome emerged. At that rate, the Y has only 10 million years left. It's an old chromosome, at death's door.

Yet the death of the Y doesn't mean the death of men. Men need only look to the mole vole for comfort. Burrowing through the soil of western Asia are two species of these rodents (*Ellobius tancrei* and *E. lutescens*) that have lost all the genes from their Y chromosome—in fact, they no longer have a Y chromosome at all. In one of these species, both males and females have been left with just the unpaired X; in the other, both sexes have two X's. No one knows how mole voles ended up being the first mammals to cross over into the Y-free future. But along the way, they must have evolved new genes—on other chromosomes—that are responsible for making males. One of those genes took over the job of *SRY*, and the chromosome on which it resides is probably on its way to becoming the new Y.

> Two species of mole voles that burrow within the soil of western Asia are the first mammals to have crossed over into the Y-free future.

If our species manages to survive for another 10 million years, our descendants will go on making men even after their Y chromosome vanishes. But the change may not be smooth. Graves speculates that several new systems for determining sex could emerge within the global human population. People conceived under one system might be genetically incompatible with those conceived under others. As a result, the human species could fragment into separate populations and, ultimately, separate species. Which of them will prefer football and which the ant nest, we'll have to wait and see.

Science writer Carl Zimmer is the author of Evolution: The Triumph of an Idea *(HarperCollins, 2001; paperback edition October 2002) and* Parasite Rex: Inside the Bizarre World of Nature's Most Dangerous Creatures *(Free Press, 2000; Touchstone Books, 2001).*

SAMPLINGS

By Stéphan Reebs

SEXY BILE Sex pheromones—chemicals released into the environment that attract members of the opposite sex—are well known in insects. Vertebrates, too, can broadcast chemical siren songs, but only at short range—or so it was thought until the recent discovery of a long-range sex pheromone in the eel-like fish known as the sea lamprey. During the reproductive season, male lampreys, which build nests in streams, exude a substance that draws females from long distances downstream. A team of biologists headed by Weiming Li, of Michigan State University, has identified this substance—a bile acid produced by the liver and probably released through the gills by special glands found only in breeding males. (The team's study determined that females are attracted by water that has washed over the head of a breeding male sea lamprey, but not by water that has touched only the rest of his body.) So far, all the sex pheromones found in fish have turned out to be steroids and prostaglandins. But because bile acids are more soluble (so they spread more evenly in water) and are produced in larger quantities, they retain an allure even after being dispersed over a long stretch of stream. Li and colleagues point out that tampering with this pheromone system might prove an environmentally friendly way to control sea lampreys in the Great Lakes watershed, where, since their unwelcome arrival through the Welland Canal early in the last century, they have caused much damage to commercial fish stocks. ("Bile Acid Secreted by Male Sea Lamprey That Acts as a Sex Pheromone," *Science* 296, 2002)


Lamprey feeding on common carp
DON & PAT VALENTI; DRK PHOTO

BIRD SEES, BIRD SINGS The morning burst of birdsong is called the dawn chorus. One feature of this chorus is the consistent order in which various species begin to sing. Robins, for example, always start singing earlier than house sparrows. The reason for this order is mysterious, but new research by British biologists has given a boost to the importance of one factor: the capacity to see well in low light. Robert J. Thomas, of the University of Bristol, and colleagues recorded the time and the light intensity at which fifty-seven bird species started singing in various European woodlands. They also captured a few individuals of each species to measure their eye diameter (larger eyes allow greater sensitivity and better resolution under low light). The researchers found that species with larger eyes, whether in absolute terms or relative to body size, tended to start singing at lower light intensities and therefore earlier during morning twilight. Other ornithologists had already proposed two hypotheses to explain a possible link between vision and song timing. First, since the function of much birdsong is to attract a mate, it makes sense for a waking male to delay singing until he can see well enough to interact with any females drawn by his performance. Second, perhaps singing between wake-up time and the onset of foraging is simply the birds' most worthwhile early-morning activity—more worthwhile than, say, preening or stretching. So if better-sighted species start foraging earlier than other species, they may begin singing earlier too. The British study suggests that these hypotheses are on the right track. ("Eye Size in Birds and the Timing of Song at Dawn," *Proceedings of the Royal Society of London* B 269, 2002)


A European robin gets an early start on the dawn chorus.
STEPHEN DALTON; NHPA

HIGH-ALTITUDE FIREWORKS For the first time, an electric discharge has been seen stretching all the way from the tops of thunderclouds (approximately ten miles above Earth) to the bottom of the ionosphere (about forty-four miles up). The phenomenon was videotaped by a team of researchers working at the Arecibo Observatory in Puerto Rico. Scientists already knew that electric flashes can illuminate the sky at these two distinct altitudes (such flashes are called blue jets and sprites, respectively), but a complete electric contact between the two regions had never before been witnessed. The researchers, led by Victor P. Pasko, of Penn State University, and Mark A. Stanley, of New Mexico Tech, submit that such high-energy zappings may significantly affect the distribution and movement of electric charges on our planet. ("Electrical Discharge From a Thundercloud Top to the Lower Ionosphere," *Nature* 416, 2002)

To see the videotaped flash, go to www.naturalhistory.com

ITSY-BITSY SUITOR If you compare your ability to run up a slope with that of a child, or your tree-climbing prowess with that of a squirrel, a biophysical truth will quickly become evident: smaller bodies fight gravity more easily than bigger ones. Three entomologists from the University of Kentucky recently employed this principle to address an intriguing question: Why are male spiders often smaller than females? In addition to other hypotheses (for example, that large size and female fecundity are linked), Jordi Moya-Laraño, Juraj Halaj, and David H. Wise suggest that when climbing is required, being small helps male spiders reach females more easily. The researchers predicted that the taller the spider's habitat (trees versus shrubs versus the ground, for instance), the higher an amorous male would have to climb, and the smaller the male would be relative to the female. They also predicted that this effect of habitat structure would be particularly acute in larger species. Lo and behold, a comparison of 112 spider species turned up just such a pattern. Now that these researchers have validated their "gravity hypothesis," the next step would be to check that small males do indeed outcompete bigger males in reaching and mating with females. It would also be necessary to test the idea that good climbing ability enables these eight-legged Romeos to escape more readily from any predators they may encounter while searching for a mate. ("Climbing to Reach Females: Romeo Should Be Small," *Evolution* 56:2, 2002)

A tiny male and a large female golden silk spider cling to the web before mating.

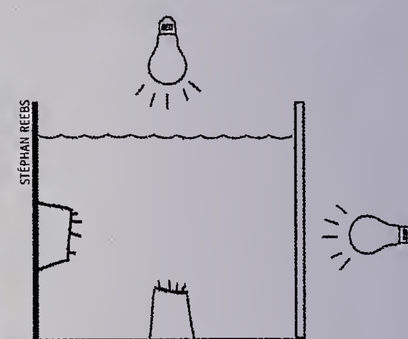
G. I. BERNARD; NHPA

WITH OR WITHOUT The eel catfish *(Channallabes apus)*, which lives in the rainforests of central Africa, spends its time slithering under the mud. This fish can detect worms that lie just beneath the surface of very moist soil, and it comes up to eat them. *C. apus* lacks pectoral and pelvic fins—an adaptation suited to its burrowing habits. Dominique Adriaens, of Ghent University in Belgium, was therefore surprised to find that a reproductive pair he was keeping in the laboratory produced two larvae with fully developed pectoral fins. When Adriaens and his colleagues examined adult eel catfish specimens from various museum collections, they found that about two-thirds also had pectoral fins, and a few even had both pectoral and pelvic fins. Interestingly, the bodies of individuals with both types of fins were shaped less like eels and more like the typical fish. Apparently, fin loss and body elongation in the eel catfish go together as adaptations for burrowing.

To demonstrate that limbs can be lost in the course of evolution, biology teachers often arrange illustrations of related species in a series to show gradual reduction in limb size or numbers. Adriaens's study provides a rare example of variation in limb numbers within a single species. ("Intraspecific Variation in Limblessness in Vertebrates: A Unique Example of Microevolution," *Biological Journal of the Linnean Society* 75, 2002)

EXPERIMENT OF THE MONTH

In the Red Sea, stony corals such as *Stylophora pistillata* and *Seriatopora hystrix* grow relatively tall and slender when attached to horizontal surfaces but stouter when growing sideways from vertical rock walls or the flanks of sunken ships. This difference was thought to be largely an effect of light, which strikes the tops of upward-growing corals and the sides of horizontal ones. However, Tel Aviv University biologist Efrat Meroz and colleagues suspected that gravity might also be at play. To test this idea, they forced young polyps (corals are colonies of individual polyps) to



STÉPHAN REEBS

grow from either the walls or the bottom of an aquarium, with light coming either from above, or from the side, or from both directions. No matter what the light orientation, they found, the polyps that grew sideways ended up stouter than the others. The researchers also grew polyps in a centrifuge that spun constantly for one month. That experiment, which used centrifugal force to simulate hypergravity, showed that the greater the force exerted on the polyp, and the more sideways its direction, the stouter the polyp became. Thus, gravity can now be added to the list of factors—such as water currents and light—known to affect pattern formation in sessile marine invertebrates. ("The Effect of Gravity on Coral Morphology," *Proceedings of the Royal Society of London* B 269, 2002)

Stéphan Reebs is a professor of biology at the Université de Moncton in New Brunswick, Canada, and the author of Fish Behavior in the Aquarium and in the Wild *(Cornell University Press).*

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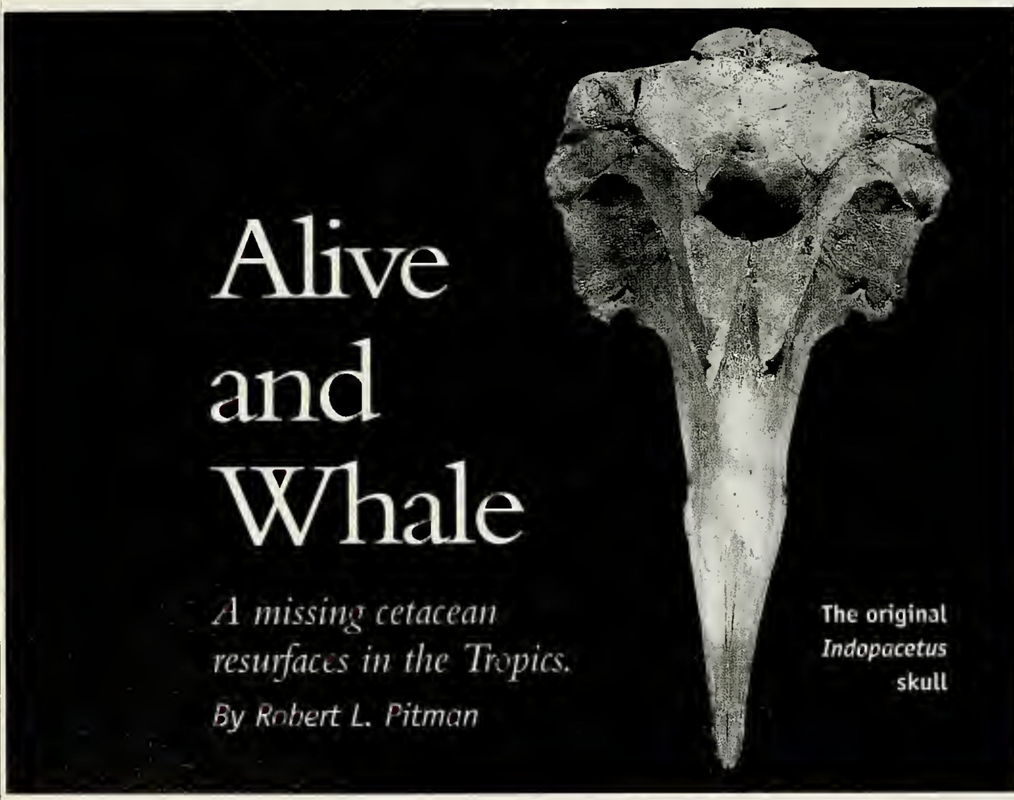

Alive and Whale

A missing cetacean resurfaces in the Tropics.

By Robert L. Pitman

The original *Indopacetus* skull

QUEENSLAND MUSEUM, AUSTRALIA

It had to be out there somewhere. It wasn't just a set of car keys that had gone missing—somehow an entire species of whale had been lost for more than a century.

The story picks up in 1882 with a worn skull found on a beach in Queensland, Australia. The specimen ended up in the Queensland Museum, but it was not until 1926 that Heber Albert Longman, the museum's director, recognized it as a new species of beaked whale. From the family Ziphiidae, these whales are so named because they have mouths like beaks, as dolphins do. But these would be large dolphins: members of some species range up to almost forty-two feet, although most individuals are only half that size. Longman named the new whale *Mesoplodon pacificus.* The genus name, derived from the Greek, means "armed with a middle tooth"; males of most species of *Mesoplodon* have a single large tooth that erupts from each side of the lower jawbone, halfway along its length. (Because heavy scarring is frequently found on adult males but never on females, scientists assume that males use these teeth as tusks to fight with other males for breeding privileges.) The name *pacificus* merely underscores the fact that the original specimen—the holotype—came from the Pacific coast of Australia.

For decades afterward, various authorities questioned the status of *M. pacificus* as a separate species, based as this was on a single specimen. Some suggested that the specimen could be a subspecies of True's beaked whale, *M. mirus* (a species with distinct populations in the North Atlantic and the southern oceans), or possibly a female southern bottlenose whale, *Hyperoodon planifrons.* It is a scientific truism that less data will always support more hypotheses.

Another seventy-three years elapsed before anyone found a second specimen. In 1955, another well-worn skull turned up, this time on the east coast of Africa, where Somalian fishermen found it on a beach. Although the find convinced even the skeptics that *M. pacificus* was indeed a different beast, it provided almost no new information about the animal. Beaked whales are probably the most poorly known group of large mammals alive today. They are shy and swim in deep waters, far offshore. If a vessel approaches within half a mile, they usually slip under the waves, diving for half an hour or more, and are typically never seen again. Even a researcher like me, who has spent his life counting and identifying whales and dolphins while traveling the oceans of the world, sees beaked whales only occasionally. I can rarely identify members of this family with certainty and can almost never photograph them. Several species of beaked whales have never been identified alive in the wild; practically everything known about most of them is based on stranded animals. And among these, *M. pacificus* was the rarest of the rare—just two skulls found on two beaches.

In 1968 Joseph C. Moore, then a curator at the Field Museum in Chicago, published a preliminary taxonomic review of the five living genera of beaked whales known at that time. He considered *M. pacificus* not only a valid species but one distinct enough from the other eleven species of *Mesoplodon* to deserve its own genus, for which he coined the name *Indopacetus,* to reflect the fact that the species was now known to occur in the Indian Ocean as well as in the Pacific. (I can only hope a different subspecies doesn't show up in the Atlantic—*Indopacetus pacificus atlanticus?*) However, many cetologists did not accept Moore's assessment, and several suggested that until more specimens became available, the

whale was probably best left in the genus *Mesoplodon*.

And so, nearly a hundred years had passed since the holotype specimen had been dragged off an Australian beach, and Longman's beaked whale, as it had become known, had revealed itself to science only twice, offering up just two damaged skulls. This left plenty of room for questions: Was the animal extinct or just exceedingly rare? How was it related to other whales? Where did it live, and what did it look like? Based on skull size, it was estimated to be about twenty-three feet long. For those seeking the whale, the ocean was an immense haystack, but this was still an awfully big needle.

At some point during a search for a whale, the story must shift offshore. In 1966, while conducting biological surveys at sea in the central Pacific for the Smithsonian Institution, Ken Balcomb, now at the Center for Whale Research on San Juan Island (off the north coast of Washington State), photographed a herd of twenty-five to thirty-five unidentified beaked whales near the equator. They were grayish brown in color, and some had a conspicuous tan forehead, known as a melon. Between the prominent melon and the beak was a crease, which placed the species within a distinct subset of beaked whales—the bottlenoses. The animals that Balcomb photographed were also larger than most species of beaked whales; researchers estimated them to be between twenty-three and thirty feet long. Exactly which species they were, however, was unknown. Balcomb had taken remarkably good photos, but the experts who examined them in order to identify the whales could only shrug their shoulders.

As the years went by, a handful of other sightings of bottlenose whales in the Tropics came trickling in, and scientists gradually accepted that they were probably southern bottlenose whales, a fairly common species but one normally found only in Antarctic waters. Was it odd that a species often seen in the company of icebergs was also to be found in the Tropics? Perhaps, but other whales, such as humpbacks and sperm whales, cover a similar range of latitudes and are equally at home with a backdrop of penguins or of palm trees. I myself had seen bottlenose whales in the Tropics at least ten times, and southern bottlenose whales in Antarctica dozens of times, and the two groups looked very similar to me. But they were always so far away, and fleeting glimpses were all they ever allowed, so I couldn't be sure if they actually were the same species.

Over the years, photographs of both the tropical and the Antarctic animals began to accumulate. One day five years ago, as I sat comparing some photos I had recently taken of southern bottlenose whales with some published photos of the tropical animals, I had one of those moments of stunned revelation that field researchers live for. The color patterns and body shapes had clear and consistent differences. The tropical animals had longer beaks and a different color patterning on the head; their calves had white rather than dark flanks. I realized that the bottlenose whale in the Tropics was not the southern bottlenose whale.

We compiled all that was known about Indopacetus, *which didn't take long. Descriptions of these whales are invariably terse.*

So what was it?

The twenty species of beaked whales known by 1997 were grouped into six genera. The photographed animals could belong to one of just a few species; the whales in the other groups were either too small or had the wrong color pattern, the wrong head shape, or the wrong dorsal fin. My colleagues and I made a quick review of our options and found only two possibilities: the tropical cetacean had to be either a new species or the enigmatic whale Longman had described seventy-five years earlier.

We compiled all that was known about *Indopacetus*, which didn't take long. Handbooks and field guides on whales and dolphins invariably offer only one terse paragraph about the genus. Not only does it always receive the shortest written account (pointing out its status as the least-known whale in the lot), but it is usually the only species not given a photo or illustration. Sometimes the text is accompanied by a dotted outline of a generic beaked whale (for the readers to color in if more information becomes available?) or an "artist's conception" of one (if you had only part of a bird skull in hand, would you draw a peacock or a pigeon?). All we knew for certain was that this was a fairly large beaked whale, that it was found in the tropical Indian and Pacific Oceans, and that it was probably a rare species. Not much to go on, but the information matched what we knew about our mystery whale, and when we wrote up our paper in 1999 describing the physical features, sighting locations, and other biological observations recorded during the preceding thirty years, we suggested that the whale might just be *Indopacetus pacificus*.

Given the rate at which information on the mysterious whale had accumulated during its first century of human recognition, my colleagues and I had no reason to expect that its identity would ever be resolved in our lifetimes. But it turned out that this species had waited in the wings long enough. Within six months of the publication of our paper, fisheries biologist Charles Anderson contacted me about a beaked whale stranded on a beach in the Maldives, in the northern Indian Ocean. It was an adult female with a near-term fetus; based on the descriptions in our paper, he was certain it was *Indopacetus*. At about the same time, Merel Dalebout, a

ROBERT L. PITMAN

Tropical bottlenose whales, seen alive in the Pacific—rather than on a museum shelf

doctoral candidate at the University of Auckland in New Zealand, had managed to extract and sequence some of the DNA from the *Indopacetus* holotype. She compared this genetic fingerprint with a tissue sample from the Maldivian whale and verified that the stranded animal was in fact *I. pacificus,* but the animal was too decomposed to compare with live animals we'd observed. Two months later, I received an e-mail from Graham Ross, of the Australian Biological Resources Study in Canberra, asking if I could identify the newborn whale in a photograph he'd attached. The animal clearly had the color pattern of the animals in our 1999 paper. I told him I was quite certain it belonged to the same species as the mystery whale we thought might be *I. pacificus.* Ross then told me that the newborn had been stranded on a beach in South Africa in 1976 and had originally been identified as a southern bottlenose, but that before he had contacted me, Dalebout had sequenced its DNA and determined that this whale, too, was *I. pacificus.* The link was forged—our tropical bottlenose whale was indeed Longman's long-lost whale!

For a hundred years, cetologists had nothing to work with but two skulls on the shelf. We now have specimen material from six individuals (including five skulls and one complete skeleton), records of more than two dozen sightings, numerous photographs of live animals in the field, recordings of their vocalizations, and (welcome to the twenty-first century) eight minutes of digital video footage. *Indopacetus* has suddenly become one of the better-known beaked whales, and future writers of cetacean field guides will have to christen another species as least known.

The search for the tropical bottlenose reinforced a scientific truism: less data will always support more hypotheses.

A curious thing is that *I. pacificus,* long before having been seen in the flesh either alive or dead, had acquired two common names. The first was Longman's beaked whale, a tribute to the describer; the second was Indopacific beaked whale, an alternative offered by those who oppose naming organisms after people (giving them a so-called patronymic). But this species may range beyond the Indian and Pacific Oceans, so in our paper we suggested "tropical bottlenose," which describes both the whale and its habitat.

In a world of declining biodiversity, we have discovered a missing whale still swimming in our oceans. *I. pacificus* may have been the largest animal left on the planet that had not been identified alive in the wild. But within a generation, we humans have almost certainly condemned one—and perhaps more—species of whales and dolphins to extinction, and things aren't necessarily improving. An increasing number of nations are once again beginning to view cetaceans as a cash crop—timber to be clear-cut. For those of us with a passion for mammals that swim in the sea, confirming *I. pacificus* as a living species helps offset these losses somewhat, even if it is a rare, elusive species that few will ever get to see.

Robert L. Pitman, a marine ecologist with the National Oceanic and Atmospheric Administration, says he "just may have the best job in the world."

OUT THERE

When a Star Isn't Born

Billions of brown dwarfs illuminate our galaxy—softly.

By Charles Liu

Picture a cloud of hydrogen gas trillions of miles across (the Milky Way contains thousands of them). As the atoms and molecules stream and swirl about, the thicker clumps of gas in the cloud slowly collapse in on themselves. After many millions of years, dense gaseous spheres dot the cloud, each thousands or millions of times more massive than Earth. "Dense," of course, is a relative term—at this stage, these balls of gas are still about as rarefied as a good laboratory vacuum.

As the gas spheres—blobs, really—continue to collapse, their heat and magnetic fields slow down the rate of compression. But gravity eventually overcomes this resistance, and the blobs keep contracting, getting ever denser and hotter. At a critical point, nuclear fusion commences at their centers, turning millions of tons of hydrogen into helium each second. The energy released pushes outward, balancing the force of gravity and halting the collapse—and stars are born. Radiation from these new stars blows away the remaining free-floating gas, revealing a cluster of young stars. Finally, around each star, whatever debris remains does its own gravitational dance, eventually coalescing to form planets, moons, and comets.

This elegant picture of star formation has long guided astronomers' thinking, but now we know it is incomplete. While the new stars are lighting up the original cloud of hydrogen, smaller blobs of gas are collapsing too. But if they don't have at least 25,000 times the mass of Earth, nuclear fusion won't happen. Instead, the structural strength of these smaller blobs stops the process of contraction, and they never ignite. The result: brown dwarfs, stellar failures that emit mostly infrared light.

Whereas some folks consider brown dwarfs the duds of the galaxy, astronomers see beauty in these substellar embers. After all, we're always looking for a good challenge or a good mystery, and brown dwarfs provide both.

The challenge of brown dwarfs comes in finding them. Vastly outshone by their brighter stellar brethren, these not-quite-stars are extremely difficult to detect. Gliese 229B, the first brown dwarf found, was discovered by Ben Oppenheimer (now a member of the American Museum of Natural History's Department of Astrophysics) and his colleagues in 1995. Since then, more than a hundred others have been detected, but billions of brown dwarfs are thought to exist in our galaxy alone.

As for the mystery—well, almost everything about brown dwarfs is mysterious. Let's focus on one puzzle: Where do they hang out? Most stars have companions, so one might expect lots of brown dwarfs to reside in binary- or multiple-star systems. Indeed, searches around intermediate-mass, Sun-like stars have revealed some of the currently known brown dwarfs. However, these searches have also shown that only a few of them orbit within a half-billion miles of their stellar companions (which is about how far Jupiter is from the Sun). Most of them orbit at more than 3 billion miles from their partners (the distance between the Sun and Neptune). This gap, called a "brown dwarf desert," had

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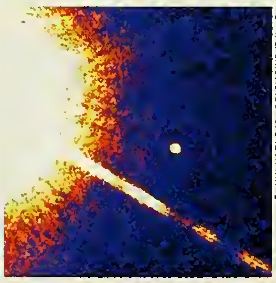


S. KULKARNI/D. GOLIMOWSKI/NASA

Above: Brown dwarf Gliese 229B (seen with its larger companion) was discovered in 1995. The Pleiades, left, may host many brown dwarfs.

no apparent explanation, and it led astronomers to propose that brown dwarfs don't form the way bona fide stars do—a potentially significant glitch in the standard theory of star formation.

Very recently, though, a group of astronomers, headed by Laird Close, of the University of Arizona, has brought brown dwarfs into sharper focus with innovative observational technology. Close, like Oppenheimer, is a leader in astronomical adaptive optics—the business of making super-sharp images by negating the blurring effects of Earth's atmosphere.

Using an adaptive-optics system that is sensitized to infrared light and mounted on the 320-inch Gemini North Telescope in Hawaii, Close and his team have found a dozen new brown dwarfs in binary systems. As it turns out, many of them have orbits that fall within the supposed brown dwarf desert, apparently resolving this brown dwarf formation quandary.

However, these binary systems don't contain stars of intermediate mass. Instead, the brown dwarfs appear with tiny M-dwarfs, the feeblest of stars, which have just barely enough mass to harbor nuclear fusion at their cores. Little guys, it seems, prefer to stick together around the galactic neighborhood.

Perhaps the most interesting thing about brown dwarfs is what they can tell us about our own origins. Since they bridge the traditional categories of what we call stars and planets, they give us key insights into the births of both their larger and smaller cousins. Far from being just failed stars littering the cosmos, gently glowing brown dwarfs may someday show us how Sun-like stars beget Earth-like planets.

Charles Liu is an astrophysicist with the Hayden Planetarium. He is also affiliated with Barnard College as a research scientist in the Department of Physics and Astronomy.

THE SKY IN SEPTEMBER

By Joe Rao

Mercury spends most of September too near the Sun to be seen from Earth. On the 27th it reaches inferior conjunction.

Venus begins September shining low in the west-southwest after sundown, less than 1° from Spica, in Virgo, and sinks a little deeper into the glow of twilight every day. The planet reaches greatest brilliancy (magnitude -4.5) on September 26. By the 30th, it sets well before the end of twilight. Most of Venus's sunlit hemisphere faces away from Earth, leaving us with a lovely waning crescent; through a telescope, observers can see it growing rapidly thinner and longer as the month progresses. For laypersons, a crescent Venus is a favorite telescopic sight, although a few people will insist that the planet is the Moon, even when our satellite is in a different phase or not visible at all. The late George Lovi, a well-known Hayden Planetarium astronomy lecturer and author, once had just such an experience while conducting a public event at the Brooklyn College Observatory. The telescope was pointed right at Venus, yet one student insisted he was seeing the Moon. When Lovi commented that the Moon wasn't even in the sky, the student replied, "So what? Doesn't a telescope show you things you can't see without it?"

Mars is still too near the Sun to be readily seen for much of this month. Ocher-hued and resembling a second-magnitude star, it appears above the east-northeastern horizon about one and a half hours before sunup in late September.

Jupiter rises at about 3:45 A.M. local daylight time at the start of the month but comes up about ninety minutes earlier by the end. The largest planet, it now resides in Cancer; looking for Jupiter with your binoculars early in September reveals the pretty Beehive star cluster just above it. The planet passes about 1° south of this spattering of faint stars (also known as Praesepe or M44) on the 4th. The same morning, a crescent Moon hovers nearby.

Saturn slowly becomes more visible during the late evening. Rising at about 12:45 A.M. local daylight time on September 1, it is up before midnight by the 13th and just before 11:00 P.M. by month's end. At the start of September it passes out of Taurus and into the club of Orion. On the 21st, Saturn reaches western quadrature—90° west of the Sun. The planet's shadow, now highly visible, is cast on the wide-open rings, and the effect suggests an image in 3-D. Saturn is the yellowish zero-magnitude "star" below and to the right of the last-quarter Moon on the night of September 28–29.

The Moon is new on September 6 at 11:10 P.M., waxing to first quarter on September 13 at 2:08 P.M. Full Moon comes on the 21st at 9:59 A.M. Since this is the full Moon closest to the autumnal equinox, it is designated the harvest Moon. It wanes to last quarter on September 29 at 1:03 P.M.

The autumnal equinox occurs at 12:55 A.M. on September 23, when the Sun crosses the equator into the Southern Hemisphere.

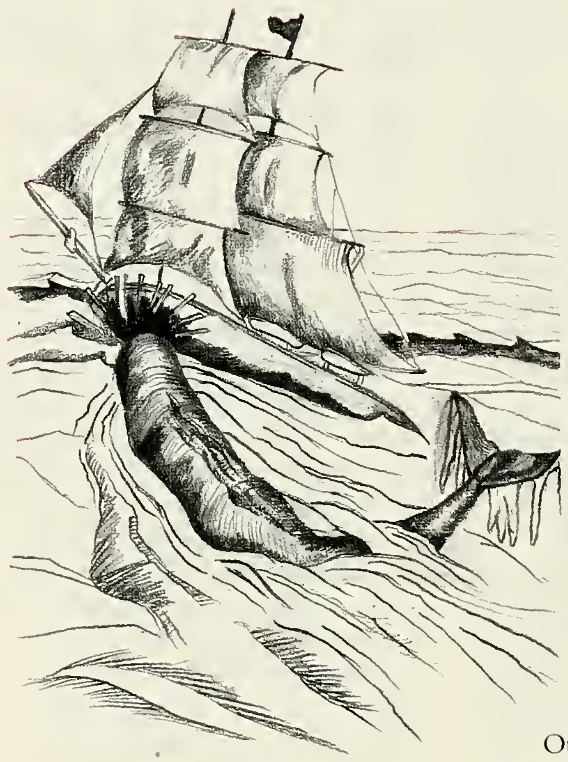
Unless otherwise noted, all times are given in Eastern Daylight Time.

BIOMECHANICS

Fat Heads Sink Ships

Protected by an internal "fender," a sperm whale can deliver a killing blow with its head.

Story by Adam Summers
Illustrations by Pog Summers



In 1851 an enraged sperm whale smashed into the bow of the whaling ship *Ann Alexander,* causing it to sink in just minutes. The event resulted in a big boost in sales for the just-published *Moby-Dick,* Herman Melville's fictional account of a white sperm whale that is pursued by, but eventually sinks, the whaleship *Pequod.* (The 1820 sinking of another whaler, the *Essex,* by a sperm whale had inspired Melville's tale.)

Sperm whales *(Physeter macrocephalus)* are the largest of the toothed whales; mature males weigh more than forty tons and stretch fifty feet from nose to fluke. But the whaling ships that sailed out of Nantucket in the mid-nineteenth century were ninety feet long and weighed nearly 250 tons. Why would a whale seek out a collision with such a ship, and—more to the point—what enables it to survive? (To bring the question down to a more comprehensible scale, imagine your 40-pound child dashing headlong into the side of a 250-pound beached rowboat, staving a large hole in its side, then calmly picking herself up and wandering off.) The answer may be intimately connected—anatomically speaking—with the very reason the sperm whale was considered such a desirable catch.

P. macrocephalus was prized by whalers because in addition to the oil that could be rendered from its blubber, a large quantity of higher-quality oil—spermaceti oil—could be ladled out of the enormous, thick-skinned, fiber-reinforced bulb that forms a sort of forehead. This structure, known as the spermaceti organ, has two oil-filled chambers, one of which has room for as much as 500 gallons of spermaceti oil. (The sperm whale's spermaceti organ is so big that it sometimes seems to *be* the head; on the big males, however, it plainly juts out beyond the jaw.) This organ evolved at least 20 million years ago—clearly not to sink ships. Scientists have speculated that the bulb may focus the whale's vocalizations into a tight beam, capable of sonically stunning prey, or that it may cause the sounds to resonate, thereby increasing the appeal of a whale's song to potential mates. Another theory holds that because the oil is less dense than water, the spermaceti organ is important in buoyancy control. Recently, University of Utah researchers David Carrier and Stephen Deban, together with undergraduate Jason Otterstrom, proposed a pugilistic function: they think the spermaceti organ is a head-mounted boxing glove, used for combat between males.

Many other whale species also have fat-filled forehead fenders, and some have been seen using them as battering rams against their fellows. The Utah biologists observed that forehead size is closely correlated with a common measure of male-to-male aggression: sexual size dimorphism. (From fish to frogs to felines, species in which males are considerably larger than females tend to be those in which males fight for the privilege of mating; the greater the size difference between the sexes, the more competition between males.) In the species that the researchers compared, those with the most striking sexual size dimorphism were also those with the largest spermaceti organ relative to the rest of the body. A big, oil-filled forehead seems to be associated with male aggression, at least in some species. But just *how* is harder to determine.

Carrier and his group used anatomical information, including the size and shape of the spermaceti organ and of the skeleton that supports it, to build a mathematical model of imaginary collisions between jousting whales. Their goal was to see whether this organ is suited for delivering a useful broadside punch while simultaneously protecting the aggressor's noggin.

In a collision, it is not speed but rather the change in speed over time—the acceleration—that causes injury. The force on an object is the product of its mass multiplied by its acceleration. Thus, the same change in speed will exert more force on a heavier object than on a lighter one: a 3,000-pound car will be hit 100 percent harder than a 1,500-pound one when slowing from sixty miles an hour to zero upon colliding with a wall. The key to surviving a high-speed collision is to make the crash last as long as possible. Automobile designers don't aim to build cars as strong as tanks; they build cars to collapse in a controlled fashion that uses up as much of the collision's energy as possible without compromising the passenger compartment.

In accordance with this principle, an empty, blown eggshell dropped onto my counter from a height of eighteen inches will not break, while a fresh egg, differing from the blown one only in mass (and in not having two tiny holes), will make a small mess. A mouse will survive a drop of several stories and land with a force of about 170 g, or 170 times the acceleration of gravity; a 10-g car crash will break human bones; and a sperm whale will suffer destructive, possibly fatal injuries at just 2 g. (The acceleration due to gravity is 32 feet per second per second.)

So how might all this pertain to a sperm whale set on slamming into a rival? First, it's helpful to take a closer look at the whale's putative battering ram. The spermaceti organ actually consists of two main chambers: a lower section called the junk, which is filled with its own oil plus baffles of connective tissue, and, atop the junk, a chamber often called the case, containing the valuable spermaceti oil. The whole organ sits on the wide upper jaw and the dished-out skull behind it. The posterior six cervical vertebrae are fused, providing a few more feet of solid, bony support.

A head-on collision between whales would be a fender bender, with each animal's spermaceti organ cushioning the blow. But if a male could manage to thump a rival in the brisket or the chops, the outcome would be very different. A conservative estimate is that the spermaceti organ is ten times better at absorbing energy than the (relatively!) thin layer of fatty tissue that covers the rest of the whale. The model created by the Utah researchers predicts that in a broadside collision, the aggressor would experience less than 0.5 g while inflicting a dangerous, or even fatal, blow of more than 2 g. The smart thing for the intended victim to do is either move quickly out of harm's way or turn to face the danger head-on. Compared with the graceful sperm whale, nineteenth-century whaleships were slow, clumsy, and oblivious to threats from below. To the whales that sent them to the bottom of the sea, the *Essex*, the *Ann Alexander*, and the fictional *Pequod* must have seemed punch-drunk opponents just begging to be blindsided—dream targets for an angry sperm whale.

Adam Summers is an assistant professor of ecology and evolutionary biology at the University of California, Irvine (asummers@uci.edu).

Male sperm whales may butt one another when competing for mates. The case, or spermaceti sac (valued by Nantucket whalers for its oil), together with the chamber below it, called the junk (containing connective tissue and a different oil), cushion the head.

Their Game Is Mud

Skipping and jumping across the shore at low tide, mudskippers give new meaning to the phrase "fish out of water."

The coastal mangrove forests and mudflats of northeastern Australia are rather inconvenient places to visit. Occupied by man-eating crocodiles and bloodsucking insects, and offering only a muddy quagmire for footing, the habitat definitely challenges the mobility of a pair of biologists. But the organisms we seek thrive here. They skip across the surface of the mudflats, scamper over mangrove roots, and dive into their burrows at the slightest sign of danger or as the high tide reclaims their habitat twice each day.

The nimble, bulb-eyed creatures we study are mudskippers—amphibious fishes that inhabit Old World mudflats and mangrove forests from West Africa eastward to Papua New Guinea. Members of the diverse goby family, the twenty-five mudskipper species are classified, on the basis of body traits and behavior, into four genera: *Scartelaos, Boleophthalmus, Periophthalmus,* and *Periophthalmodon*. Mudskippers are the only fish to conduct many of their major activities—including feeding, courting, and defending territories—on land. In order to manage these feats, they rely on a number of evolutionary specializations. Their prominent eyes, for example, are so well modified for clear aerial vision that their ability to see underwater is diminished. Beneath each eye is a water-filled cup formed from skin folds; as a mudskipper's eyes become dehydrated by exposure to the air, they can be retracted into this cup to be moistened. With their leglike fins, mudskippers can walk, climb, and leap when out of the

On the north-central coast of Australia, *Periophthalmus minutus* build mud turrets at the entrances of their burrows.

HEATHER J. LEE

RUOSO CYRIL/BIOS/PETER ARNOLD, INC.

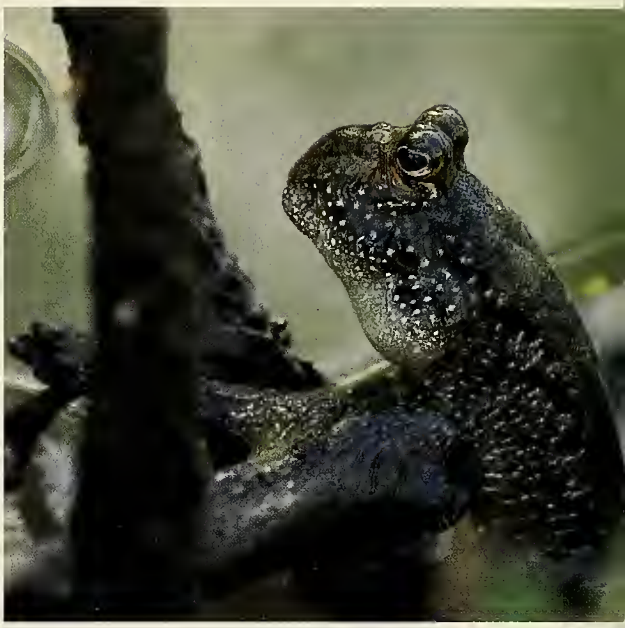
By Heather J. Lee and Jeffrey B. Graham

water, and thanks to structural modifications in their skin and gill chambers, they are able to breathe both in water and in air. Indeed, observing these creatures encourages one to conjure up images of the first vertebrates that came ashore some 360 million years ago. Describing the mudskipper in his essay "The Snout," renowned naturalist Loren Eiseley wrote, "Of a different tribe and a different time he is, nevertheless, oddly reminiscent of the [ancestral vertebrate]." Many biologists have investigated mudskipper specializations in order to understand the sequence of changes that enabled those early vertebrates to make the transition to life on land. From an evolutionary perspective, of course, mudskippers are very distantly related to the ancestral fishes that gave rise to terrestrial vertebrates. But, as Eiseley noted, "There are things down there still coming ashore." Like our own ancient ancestors, a number of modern species have begun to come ashore, independently developing the capacity for both air-breathing and amphibious life.

Although the aboveground activities of mudskippers first caught the attention of naturalists some 300

Widely gaping mouths and fully flared dorsal fins are sure signs that mudskippers are prepared to vigorously defend their mudflat territories.

IVAN POLUNIN; NHPA



EIICHI KURASAWA/PPS; PHOTO RESEARCHERS, INC.

In Southeast Asia, *Periophthalmodon* lie in a pool at a burrow entrance, above left. Above right: Like other mudskipper species, *Periophthalmus* climbs easily with leglike fins.

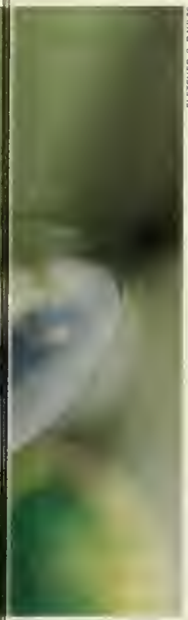
years ago, little is known about their behavior below the surface. The ability to leave the water has enabled the fish to exploit shallow mudflats, but for many mudskipper species the watery burrow is still home base, from which it launches terrestrial forays and to which it retreats when threatened by predators. At low tide, mudskippers are at risk of being preyed upon by shorebirds as well as by a variety of other terrestrial animals, including snakes and mammals. At high tide, many mudskipper species take cover in their submerged burrows to avoid being attacked by predatory fish that cruise the shallows. Besides serving as a refuge, a burrow can also be used as a nursery for developing eggs: members of the genera *Boleophthalmus* and *Periophthalmus* are known to lay eggs in burrows, and quite possibly this occurs in the other two genera as well. Seemingly essential to the safety of both adults and young, burrowing nevertheless comes with a danger of its own—the water inside the burrow is perilously low in oxygen. Mudskippers must somehow tolerate or overcome this oxygen shortage, not only for their own sake but for that of their developing eggs.

How do these fish manage to wait out high tide in the oxygen-poor water within their burrows?

The two of us have traveled around the world in an effort to unravel the details of mudskipper burrows, including how these fish manage to wait out high tide in the stagnant burrow water and how delicate mudskipper embryos manage to develop properly in this environment.

Working with Atsushi Ishimatsu, Toru Takita, and graduate student Naoko Itoki, all of Nagasaki University, and with Tatsusuke Takeda, of Kyushu University, we observed the mudflats of Japan's Ariake Bay being transformed into a backdrop for the captivating courtship spectacle of *Periophthalmus modestus*. Each spring, the males carve up the available surface into individual territories and excavate burrows up to two feet deep. The burrow is shaped like a j (or sometimes a y, with two entrances), whose upturned lower tip will become the spawning chamber, where the eggs are deposited.

Its burrow prepared, the male sets about finding a mate. At low tide during *P. modestus*'s spawning season, which runs from late May through early August, males perform an enticing courtship dance for an audience of females. As if dressing for their performance, the males turn from drab brown to a pale beige color that contrasts with the darker mud. Each male tries to lure an egg-swollen female to his territory and down into his burrow. In his effort to capture a female's attention, he puffs out his cheeks, mouth, and gill chambers by filling them with air; he also arches his back, points his tail fin, and sinuously wriggles his body. As a potential mate draws near, he continues to display, slowly drawing her to his burrow and pausing periodically to be sure she has not lost interest and fallen under the spell of a rival male. The suitor then dips into the burrow and quickly reappears, enticing the female, so it seems, to come and enjoy the comforts of his accommoda-



FLETCHER & BAYLIS

tions. If she hesitates, the male again pops in and out of his lair until she is finally tempted inside. Having lured her below, the male returns to the burrow entrance to "lock the door" with a mud plug.

Researchers have previously demonstrated that after being fertilized, the eggs are somehow embedded in the mud walls of the spawning chamber, where they take about a week to develop. But we have little information about what actually happens once the pair enters the burrow and descends into the burrow water toward the spawning chamber. To observe the developing eggs and the egg-care behavior, Ishimatsu's team has been using an endoscopic camera inserted into the mud above the tip of the spawning chamber; with this device, they are making the first-ever observations of the mudskippers' underground world.

Once the eggs have completed development, the tiny, transparent, newly-hatched larvae drop into the burrow water and from there make their way to the open ocean. During the first hours of a larva's planktonic existence, it is sustained by a small yolk sac. After about forty-five days, the juvenile fish returns to settle on the mudflat and begin its amphibious adult life. The Ishimatsu team's studies of spawning and egg care in *P. modestus,* along with other ongoing work, promise to contribute to an understanding of how the larvae survive after hatching in the oxygen-poor burrow water and how the fish journey to the open sea.

To compare the behavior of *P. modestus* with that of other mudskippers, we first traveled to the northern reaches of Queensland, Australia, in 1999. As many as six species live together on the mudflats of Black Soil Creek's isolated mangrove forests, and we arrived there to the sounds of snapping shrimp and armies of soldier crabs marching over the mud. The local *Periophthalmus* were busy outside their burrows, decorating the entrances. We discovered that *P. argentilineatus* excavates a moat around its burrow and builds a turret at the entrance, in contrast to the simpler burrow openings made by *P.*

Specializations in their skin, mouth, and gill chambers allow mudskippers to breathe both in water and in air. By coming ashore to share a habitat with terrestrial creatures, they can avoid competition with other fish.

modestus. Both turret and moat are adorned with the signature of mudskipper construction: identical-sized pellets that originate as mouthfuls of mud. Another species, *P. minutus*, shares parts of its habitat with *P. argentilineatus* but uses a different mode of exterior decoration. Its burrows have up to four entrances, each of which is enclosed in a turret several

The male of one species tries to attract females with a maneuver that has been termed the "tail-stand-and-sideways-flop."

inches high; these turrets are durable enough to withstand being submerged at high tide.

We do not yet know the biological importance of turrets and moats. Envisioning the mudflat surface from a mudskipper's perspective, we suspect that moats may deter other species from entering the burrow complex and that turrets could serve as observation posts from which to spot predators or prey. In the early morning hours, we have seen *P. minutus* lounging just inside the mouth of a turret, which, as shown by our measurements, can be as much as 7° C warmer than the burrow's depths. It may be that the structure provides the fish with a safe place to warm up efficiently in preparation for the day's activities.

Details of mudskipper burrowing were beginning to come into focus, but we wanted to compare our findings about *Periophthalmus* with what is known about another mudskipper, *Scartelaos histophorus*—the bearded, or walking, goby. The Australian coastal town of Cardwell is famous not only for tasty prawns and mud crabs but also for the dense bearded-goby population that inhabits the mudflat bordering the town. The city's public pier provides an excellent vantage point from which to observe thousands of the fish as they race around at low tide, their long dorsal fins bobbing up and down like bumper-car antennas. Males staunchly defend territories roughly one to three feet in diameter. In areas with a high density of fish, the territories are crowded together and, as University of California marine biologist Nancy Aguilar reports, become pentagonal or hexagonal in shape. Low mud walls sometimes mark their perimeters. Defending his turf from other males, the resident male uses a combination of threat displays and direct confrontations that culminates in the loser retreating or being chased away.

When not protecting his territory, a male *Scartelaos* tries to attract a female by performing an ostentatious maneuver that Australian marine biologist Norman Milward terms the "tail-stand-and-sideways-flop." The fish "stands" briefly on its tail fin before flopping sideways onto the mud. To woo a mate, a diligent fish may do tail-stands again and again—we've witnessed eighty-three flips in a row. If courtship is successful, the pair shares a territory and a burrow; the two fish maintain contact by occasionally aligning themselves and wriggling their bodies together, and they appear to communicate with each other by flagging with their dorsal fins as they move about the territory, feeding on plankton and algae (other species eat crustaceans, insects, and worms. The male keeps track of the female as they travel, and if she strays too far, he herds her back toward the burrow.

As the rising tide covers the mudflat, the bearded gobies retreat to the safety of their burrows, where they remain until the tide recedes again. As is the case for *Periophthalmus* burrows, the water inside those of *Scartelaos* is low in oxygen, and the fish compensate for this by laying in a supply of air to last through the high tide. Much like farmers lugging bucket after bucket to fill a trough with water, both male and female bearded gobies repeatedly gulp air and transport it into the burrow, creating an underground air pocket. We were able to observe the fish gulping air at the surface, but we didn't know exactly what was happening inside the bur-

EIICHI KURASAWA/PPS; PHOTO RESEARCHERS, INC.

MARK NEWMAN; BRUCE COLEMAN, INC.

Mudskippers' eyes are so well adapted to aerial vision that the fish see better above water than below it. Cuplike skin structures below the eyes allow them to be continually remoistened.

rows. To find out, we developed an artificial mudskipper-burrow system while working at the Australian Institute of Marine Science and at the Scripps Institution of Oceanography in La Jolla, California. Our construction, the first of its kind, was equipped with a viewing porthole through which we could watch the fish create an air pocket. A bearded goby with a mouthful of air must swim vigorously to overcome buoyancy; once inside the burrow, we observed, it floats against the ceiling until the mouthful is released. The fish may then either settle to the floor of the burrow, make immediate use of the reserve by taking a breath of air, or return to the surface to collect another gulp. This air pocket is probably essential to *Scartelaos* when confined in their burrows at high tide and would thus be doubly important for mating pairs. We further suspect that pairs may lay their eggs in or near the air pocket. Ishimatsu and his colleagues have found that in *P. modestus,* an air reserve may be essential for proper egg development, and we hope that our experimental system will soon provide similar findings for *Scartelaos* as well as answers to other questions.

In a 1961 paper describing the natural history of a mudskipper, zoologists Robert C. Stebbins and Margaret Kalk wrote, "Watching these gobies one can readily appreciate the survival value of the terrestrial habit." By coming ashore, mudskippers have gained an advantage over their aquatic relatives in avoiding competition with other fish and in searching for food. But mudskippers are still fish, and they remain tied to the water—which, because of their knack for burrowing, is never far away. □

To impress a potential mate, some mudskippers, such as this *Boleophthalmus* species, perform acrobatic maneuvers.

Blossoms of the common milkweed, *Asclepias syriaca*

BILL LEA: DEMBINSKY PHOTO ASSOCIATES

Once Upon a Milkweed

In this complex community, one insect's poison may be another's meal.

By Anurag A. Agrawal and Stephen B. Malcolm

Snap a milkweed stem, and your fingertips will quickly be covered by the white sap for which the plant is named. This is no mother's milk, however, but a latex exuded by specialized structures, called laticifers, that are found throughout the plant. The latex is sticky and also contains powerful heart poisons known as cardenolides. Together, these traits serve the purpose (if one may be forgiven for imputing purposefulness to a plant) of discouraging herbivores—by sealing up an attacker's mouth or, if that fails, by poisoning it.

As doctors and herbalists have long known, what is toxic in one context may be curative in another. Indeed, the scientific name for plants in the milkweed genus is *Asclepias,* after the Greek god of medicine. Milkweed has traditionally been appreciated for the medical benefits that its cardenolides can bestow when properly handled. These compounds affect the movement of sodium and potassium ions in the cells of all animals; by favoring the flow of sodium ions into the cells, they can lead to an increase in the force with which the heart contracts and therefore play a vital role in treating congestive heart failure and atrial fibrillation.

Such a powerful plant might be expected to live in splendid isolation, unbothered by the hordes of insects that attack less well defended plants. In fact, the eleven species of milkweed that grow abundantly in abandoned agricultural fields throughout eastern North America are host to a rich and diverse community of insects. Some of these herbivores manage to avoid the cardenolides, which are present not only in the latex but also in phloem and other plant parts. Other herbivores consume these toxins with no ill effect—even storing the potent cardenolides in their tissues and thus gaining some protection from their own enemies.

The insects that consume milkweed occupy just about every conceivable feeding niche. Aphids drink the phloem sap, beetles and caterpillars chew the leaves, tiny fly larvae live and feed within the leaves, bugs eat the seeds, weevils bore through the stem and eat the pith within, and beetle larvae bore through the roots. How can we reconcile all this feasting with the plant's famed toxicity? With our students at the University of Toronto and Western Michigan University and our postdoctoral associate, Peter Van Zandt, we have been testing hypotheses about how these insects avoid or co-opt milkweed's defenses.

As this issue goes to press, silky milkweed seeds are bursting out of their crescent-shaped pods. Watching them float, shimmering, through the air makes us eager for spring, the start of our next field season.

ROD PLANCK: DEMBINSKY PHOTO ASSOCIATES

Able to tolerate the toxins in milkweed, the monarch butterfly caterpillar becomes poisonous itself after feeding on the plant for a while. Its bright colors warn predators of its toxicity.

ANURAG AGRAWAL

When a milkweed is colonized by aphids, it responds by increasing its production of toxins. Like monarch caterpillars, however, aphids are undeterred by poisons, and the toxicity they acquire from the plant may help protect them from their own predators and parasites.

ANURAG AGRAWAL

Having changed its color to blend in with its surroundings, a crab spider dines undisturbed on toxic aphids living in a cluster of milkweed blossoms. Such meals exact a price, however: after chowing down on toxic aphids, spiders spin asymmetrical webs.

PETER VAN ZANDT

Swamp milkweed leaf beetle *(Labidomera clivicollis)* larvae of various stages feed together. Several generations of this beetle may be born in a single season.

ANURAG AGRAWAL

A sticky white droplet of latex oozes out where an adult *Labidomera* beetle has severed a leaf vein. Beyond the cut, the beetle can feed without gumming up its feet and mouthparts.

ANURAG AGRAWAL

For a monarch caterpillar, ingesting milkweed poisons is not a surefire defense against a predatory stinkbug, which harpoons its victims before sucking up the body fluids.

ANURAG AGRAWAL

Shortly after hatching from clutches of up to 400 eggs, larvae of the tussock moth *(Euchaetias egle)* start nibbling on milkweed leaves. The latex dramatically slows the growth of these larvae, but feeding in groups helps them overwhelm the plant's defenses.

RUNK/SCHOENBERGER; GRANT HEILMAN PHOTOGRAPHY

Tussock moth larvae that are not killed by parasitic wasps and predators turn into brightly marked caterpillars. These older, solitary larvae move from milkweed plant to milkweed plant.

ANURAG AGRAWAL

As the weevil *Rhyssomatus lineaticollis* drills holes in a milkweed stem, latex gushes out. This causes a temporary reduction in latex pressure in the areas above and below the holes, making egg laying a less sticky proposition for the weevil.

E. R. DEGGINGER; BRUCE COLEMAN INC

Small milkweed bugs *(Lygaeus kalmii)* can sometimes be found in large numbers on milkweed plants, where they mate. Late in the season, they also eat the seeds.

Clumps of milkweed bloom in abandoned fields and along roadsides throughout eastern North America. Many plants in a clump are clones, the products of asexual reproduction—suggesting that just a few seeds colonize each patch.

FRED HABEGGER; GRANT HEILMAN PHOTOGRAPHY

In North America, monarch butterflies lay their eggs on and drink the nectar of numerous milkweed species, including the bright orange *Asclepias tuberosa,* known to gardeners as butterfly weed.

STEVE MASLOWSKI; PHOTO RESEARCHERS, INC.

After emerging from (and consuming) its egg case, a young monarch caterpillar must graze through a thick bed of leaf hairs before it can begin chomping on the milkweed leaf itself. The reward for its first bite is likely to be a faceful of sticky latex.

SHARON CUMMINGS; DEMBINSKY PHOTO ASSOCIATES

Adult red milkweed beetles *(Tetraopes tetrophthalmus)* feed and mate on the plant's leaves and flowers but lay their eggs inside grass stems nearby (this stem has been opened up to reveal the eggs). After hatching, the larvae drop to the ground, where they seek out milkweed roots to eat.

ANURAG AGRAWAL

Feeding on a milkweed leaf, tiny aphids (some winged, some wingless) are "tended" by an ant, which feeds on the sweet honeydew excreted by the aphids. Such ant-aphid associations are uncommon on milkweed, perhaps because the honeydew contains cardenolides that are toxic to most ants.

ANURAG AGRAWAL

DOUG LOCKE; DEMBINSKY PHOTO ASSOCIATES

A monarch caterpillar creates its own window of opportunity on the leaf of a swamp milkweed, *Asclepias incarnata*.

Recording the Spirit World

Contemporary Inuit prints and drawings depict the animism at the heart and soul of a lost hunting culture.

By Dorothy Harley Eber

In those days they had no doctors or nurses. Or expert people like zoologists to say why the animals were scarce," recounts Bibian Neeveeovak of Taloyoak, today believed to be the oldest person residing on the coast of the Canadian Arctic Ocean. "Sometimes the sealers couldn't make catches, so some of the shamans would try to see what was holding them back."

In the era before missionaries brought Christianity to the far north, shamans, or *angakkuit,* were the regulators of the Inuit world, the mediators between humans and the spirit realm. They were said to fly through the air to faraway places, assume animal forms, cure human sickness, and make animals plentiful when people were hungry. Back then, shamans gained their powers either through inheritance or a "calling" or rigorous initiation. While some shamans were good, others were bad. The good shamans were regarded almost as gods.

MYRA KLOCKENBRINK

The Inuit first came in contact with missionaries as early as 1771 on the Labrador coast and as late as the 1950s in parts of the central Arctic, but the arrival of the Reverend E. J. Peck and the establishment of an Anglican mission on Blacklead Island in Cumberland Sound in 1894 began the spread of Christianity above Hudson Strait. The Inuit adopted Christianity enthusiastically, but for a long while after the missionaries came, shamanism and the new religion coexisted. Peck learned much about shamanic practices and, beginning in 1897, shared information with Franz Boas, who was then developing the infant science of anthropology at the American Museum of Natural History and at Columbia University.

Until recently, much of Peck's data remained unpublished, stored among his letters and papers in the archives of the Anglican Church of Canada. But in the recent book *Representing Tuurngait* (published by Nunavut Arctic College, on Baffin Island), three anthropologists present excerpts from these papers as well as Peck's list of 347 *tuurngait,* or spirit helpers, including their names, habitats, and physical descriptions (a list he had apparently worked on for about twenty years). According to an article Peck wrote in 1924, the Inuit "believe that many animals, like human beings, possess souls, and that many inanimate objects, such as rocks, mountains, icebergs, etc. have together with animate objects, what is called their *inua,* i.e., owner or being. . . . These spirits, so the magicians say, have power over the souls of animals, and when solicited by the magicians can make such an easy prey for the hunters."

All photographs courtesy of the Department of Indian and Northern Affairs, Canada

Qadruhuaq, the Mysterious Helper, by Simon Tookoome (1934–). Stonecut and stencil by the artist, 1972. Baker Lake.

Although much attenuated, the hunting culture persisted into the mid-twentieth century, but during the 1950s and 1960s, disease, famine, and starvation drove the Inuit, with Canadian government encouragement, into settlements. These grew up chiefly around old fur-trading posts, where Inuit trappers had bartered skins for goods. The trappers now had to learn to deal with money. As a way to help support people whose traditional way of life was falling apart, the government encouraged carving and introduced art and handicraft programs. What was not foreseen was the explosion of talent these make-work art programs would bring about.

In 1957, writer and artist James Houston, then the government's northern service officer at Cape Dorset, initiated experiments in graphic arts. He distributed paper and pencils in the settlements and camps and asked the Inuit to try their hand at drawing. Under his enthusiastic tutelage, three Cape Dorset men—Osuitok Ipeelee, Kananginak Pootoogook, and Iyola Kingwatsiak—then began their adventures in printmaking, turning the community's drawings into prints by cutting stencils out of sealskins and making linocuts from floor tiles brought in for the building of Houston's house. As these materials proved difficult to work with, stonecuts and paper stencils were used instead and eventually became the benchmark for Inuit graphics.

Since then, print-making has spread to communities across the Arctic. Cape Dorset, Puvirnituq, some small Nunavik (Arctic Quebec) hamlets, Holman, Baker Lake, Pangnirtung, and Clyde River have all produced annual or periodic catalogs of their collections. Besides doing stonecuts, stencils, and combinations of the two, the printmakers create etchings, engravings, and lithographs. Although there are regional distinctions as well as great stylistic differences between individual artists, the graphics generally celebrate what the Inuit artists call "the old way." In interviews, some prefer not to talk about the old religion or to go into detail about what the artists' images depict; others speak freely, believing that the shamans and the *tuurngait* deserve to be remembered. Both the stories and the pictures created by the Inuit transport one to an older world.

Right: *Transforming His Image*, by Ekidluaq Komoartok (1923–91). Stencil by Jackoposie Tiglik, 1987. Pangnirtung.

The World of Man and the World of Animals Come Together in the Shaman, by Simon Tookoome (1934–). Stonecut and stencil by the artist, 1973. Baker Lake.

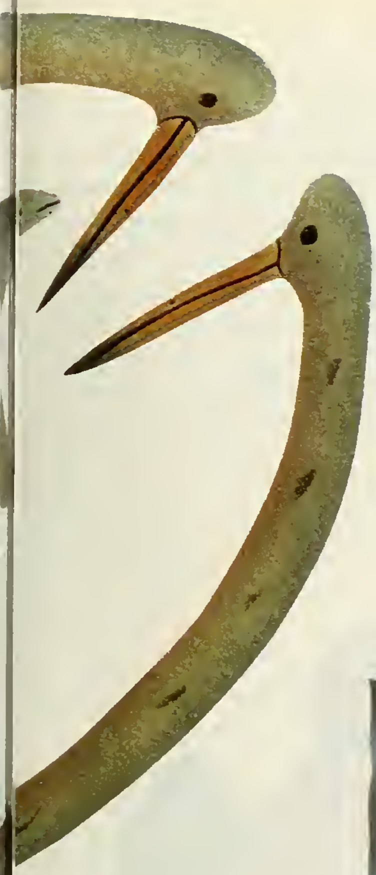
THE *TUURNGAIT*—SPIRIT HELPERS

The Reverend E. J. Peck recorded descriptions of many *tuurngait* in the Baffin Island area, all of them fantastical in appearance. During his historic 1921–24 expeditions across the North American Arctic, explorer and ethnologist Knud Rasmussen got shamans to make simple pencil drawings of their own *tuurngait*. In contemporary Inuit graphics, the spirits, for the most part, appear in vivid color, as in the work of Simon Tookoome, of Baker Lake, and others. "My mother's stories are coming out through me," Simon says.

A shaman might receive *tuurngait* through inheritance from another shaman or perhaps as gifts from his tutor at the time of initiation, and he might have to suffer greatly at that time to induce a spirit to come to him. But a helping spirit would come to the shaman of its own volition.

"They say the spirit chooses," says Tommy Anguttitauruq, a legal interpreter who grew up in the Perry River area. "Sometimes in different regions a person becoming a shaman had to go through very very unpleasant things. Some would suffer for a long time—they might be asking for a spirit to help them for days and days. I believe the mind focuses on the spirit, nothing but the spirit, for days and days; finally the spirit agrees to help. After that it becomes quite easy to ask the spirit for help."

THE DRUM DANCE



For millennia, drumbeats sounded across the Arctic during gatherings in the giant snow houses *(qaqqiit)* at *silliitut*—the term used by the people of southwestern Baffin Island for the time of the full midwinter moon and a great celebration of fecundity and renewal of life. Pauta Saila, of Cape Dorset, describes events of his youth that took place in a *qaqqiq* built for this occasion: "In those days, around the time of Christmas Day, they used to build a giant igloo so they could have celebrations with the shaman people. First, they would hunt together. Then five men, perhaps, would build a big igloo for the festival. They would have four *quliit* [stone seal-oil lamps] around the sides and one in the

My Great Grandmother Was a Shaman, by Thomasee Alikatuktuk (1953–). Stencil by the artist, 1992. Pangnirtung.

middle. In the giant igloo they would do the singing and dancing, hoping that when they went hunting the singing and dancing would help them draw the animals.

"Yes, it is true we used to have drumming here. For some of the drummings, not all of the drummings, the drummers wore masks from skins with tattoos around the holes. It is true that the drumbeat carries a meaning. . . . In the old days when they caught big whales by kayak, they'd drum to draw the animal—to make it easy catching. The same as in the army, when the commander gave the order, there'd be a quick action."

A POWERFUL SPIRIT

Polar bears were said to be particularly powerful spirits. "I've heard there were shamans who seemed to have the polar bear right in their body," says Pauta Saila, known for his carvings of dancing bears. "The way I heard it, these persons who had a polar bear for a spirit moved like the polar bear moves and had the polar bear's voice in their bodies." Bad shamans (those who used "mind concentration" to kill opponents or to cause corporal afflictions) were said to favor bears as *tuurngait*. In 1959 in Cape Dorset, when the artist Niviaksiak fell down and died while tracking a polar bear, there was speculation about the cause of death. "He wasn't sick at all," a relative recalls. "Maybe he had a heart attack, but some people thought that *nanook*—the bear—was not really *nanook*. Maybe that bear was the spirit of an Inuit shaman."

Bear Spirit, by Mayureak Ashoona (1946–). Lithograph by Aoudla Pudlat, 1979. Cape Dorset.

HELPING SPIRITS

"I heard about the animals and birds who were able to form themselves into human images—or humans into birds and animals," says artist Jessie Oonark, whose father was a shaman. As their helping spirits, the shamans "might use animals, anything that grows," says Osuitok Ipeelee, one of the first artists in Cape Dorset. "It was well known that the animals the shamans controlled had the ability to turn into humans. . . . When a shaman was using his magic he had a real change of personality. When the animals entered into him he'd be chanting loudly; if a shaman was turning into a certain animal, he'd make that animal sound. Once he was filled inside, he'd begin to change; his face and his skin followed."

Osuitok remembers the woman shaman Atsutoongwa, one of whose spirits was seaweed. "I once heard her voice making the sound the seaweed makes when it moves in the saltwater. They say the seaweeds have voices like the sounds of certain winds. When there's a light wind and the wind noise mixes with the stream noise, it seems to make sense. They say it's the same with the seaweed underwater. When there are many seaweeds they make a beautiful sound—only the shaman knows that sound."

A Shaman's Helping Spirits, by Jessie Oonark (1906–85). Stonecut and stencil by Thomas Sivuraq, 1971. Baker Lake.

HEAD LIFTING

Through *qilaniq*—the practice of divination by head lifting, with the answers depending on whether the head was heavy or easily lifted—the shaman could discover the transgressions that had caused illness or the animals' failure to give themselves to the hunters.

George Best, one of Martin Frobisher's captains on the Northwest Passage voyages (1576–78), described a similar practice when he wrote about encounters with the Inuit on Baffin Island: "These people are great enchaunters and use manye charmes of Witchcraft. For when their

The Shaman Seeks an Answer, by Mark Emerak (1901–83). Stencil by Mona Ohoveluk Kuneyuna, 1987. Holman.

heads do ake, they tye a great stone with a string unto a sticke, and with certaine prayers & wordes done to the sticke, they lifte up the stone from the ground, which sometimes with all a mans force they cannot stir, & sometimes againe they lifte as easily as a feather, and hope thereby with certain ceremonious words to have ease and helpe."

SHAMANIC TRANSFORMATION

Tommy Anguttitauruq, from the Perry River area, describes the shamanic transformation of his grandfather Alikamik into a huge Canada goose during a time of sickness. Tommy and the other children were sent out from the large family tent to a small tent nearby while Alikamik performed rites to cure Tommy's sick uncle. "My other uncle—he was probably a teenager and the oldest person—was holding the entrance of the tent so we would not go out. . . . I started hear-

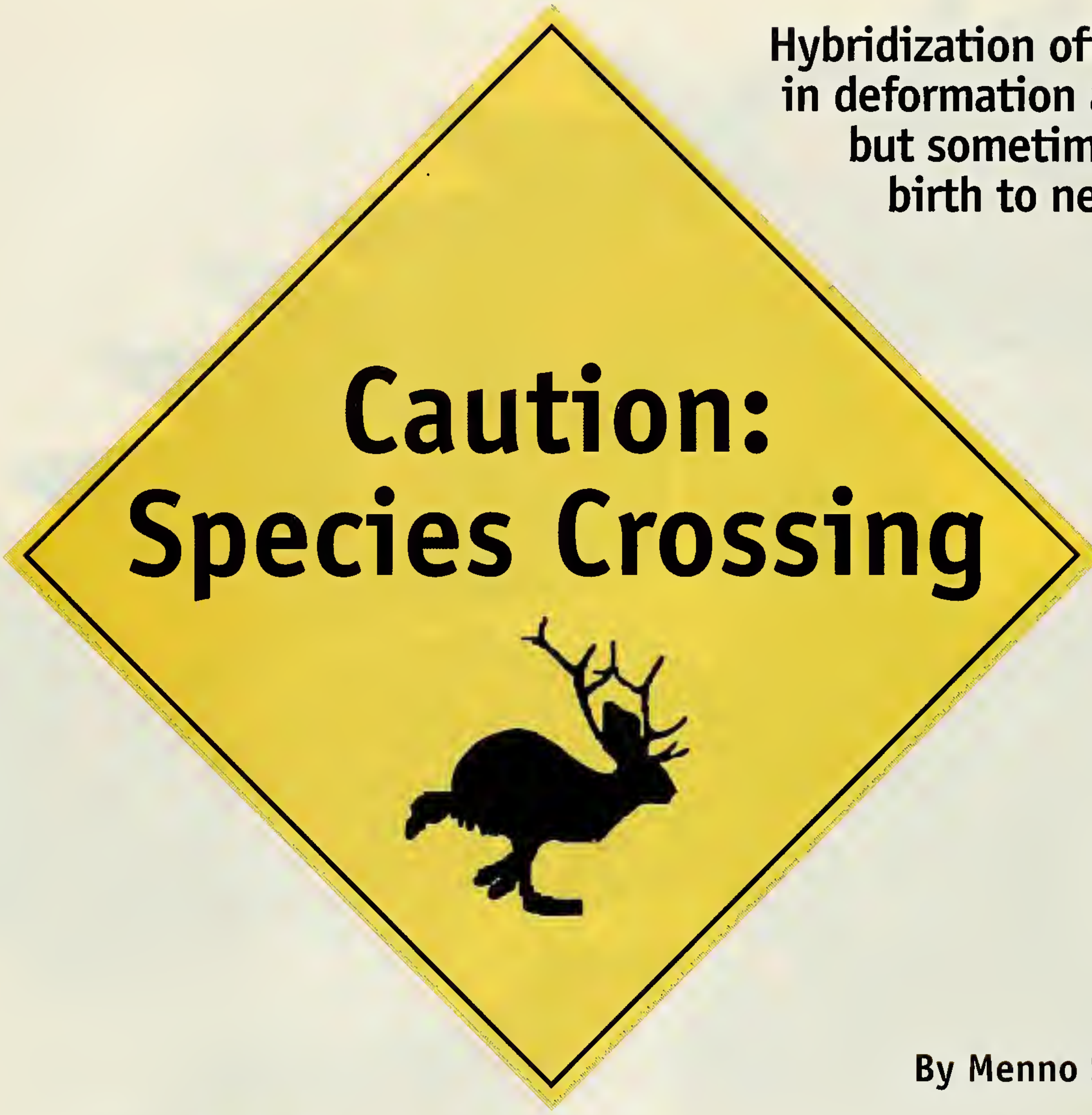
ing a Canada goose. . . . As soon as the door came open I rushed out, and there was my grandfather in front of the tent about forty yards away. I can see him clearly. He was standing on one leg and the other leg was up in the air, looking sort of like a Canada goose tail. He was waving his arms, making the Canada goose sounds. His parka looked strange. The fringe seemed so wide; there were fringes all the way from the armpits. And his neck seemed extra long. He resembled a goose, but at the same time he was human. I was probably imagining it, but that's the way I saw it."

According to Inuit belief, transgressions of laws and taboos brought about illness and bad fortune. Tommy heard that "Alikamik flew around in the area to see what was causing the sickness and discovered a man had drowned a caribou in a pond and made the animal suffer." The patient recovered. "He works at the power plant today." □

Assisted by Magic, by Helen Kalvak (1901–84). Stencil by Ida Aivek, 1980–81. Holman.

Hybridization often results in deformation and death, but sometimes it gives birth to new species.

Caution: Species Crossing



By Menno Schilthuizen

What do you get if you cross a carrier pigeon with a woodpecker? Or a bear with a vampire? Riddles like these can be heard in schoolyards and at children's parties all over the world. Science fiction, too, employs hybrids—offspring from the crossing of two different species. Think of the movie *The Fly,* in which the accidental hybridization of Jeff Goldblum (or, in the original, David Hedison) with a housefly has disastrous consequences. In both riddle and sci-fi, hybrids are often portrayed as ridiculous or grotesque—and sometimes dangerous.

In nature, hybridization is usually less dramatic, occurring between taxonomic neighbors: horses and donkeys, lions and tigers. But even at this level—members of the same genus or family—hybrids have long had a bad reputation, as suggested in the very word. The Latin *hybrida* derives from the Greek *hubris,* meaning "arrogance or insolence against the gods." Many naturalists and scientists still implicitly hold to the Platonic idea that every species has an "essence" that can be maintained only if members of the species mate solely among themselves and thus keep genetic pollution at bay.

Hybridization upsets such a nicely pigeonholed view of the natural world. Traditionally, museum curators have often ignored hybrid specimens or put them in a box marked Unidentified, because their collections followed the Linnaean binomial naming system, with every species given a genus and a species name—for example, *Canis familiaris* for domestic dog. Hybrids have no place in such a system. Botanical gardens and zoos, as well as museums, prefer to display the "pure" species rather than confusing mixtures. Interestingly, in the terrarium trade, the "unnaturalness" of hybrid lizards and snakes makes them special in the eyes of many people, who are willing to pay high prices for them.

Their ambiguous taxonomic status also means that hybrids do not enjoy much protection under environmental law. The U.S. Endangered Species Act of 1973 (ESA) did not mention hybrids. In fact, protection of hybrids was actively discouraged, the concern being that hybridization with a more common species might actually edge an endangered one closer to extinction. Later, the Fish and Wildlife Service and the National Marine Fisheries Service took pity on hybrids, noting that hybridization is often a natural phenomenon and that the existing "rigid standards . . . should be revisited." A new hybrids policy was proposed in 1996 (the proposal sought to substitute "intercross" for the loaded term "hybrid"), but it was never officially adopted. As a result, there still are no official guidelines for dealing with hybrids under the ESA—which is bad news for animals such as the red wolf. According to some genetic studies, this endangered canid is the result of hybridization between the gray wolf and the coyote and hence may not qualify for the federal captive breeding and reintroduction program from which it currently benefits.

What is it about hybrids that has made people so dismissive of them? One source of the disrespect is that they appear to flout the near-sacred boundaries between species. Another is that hybrids, in fact, often *are* inferior. A mule may inherit "its size and strength from the horse, and its surefootedness and supreme sense of self-preservation from the donkey," as Paul and Betsy Hutchins wrote in the authoritative *Modern Mule,* but in many cases, a hybrid is a very troubled creature. Problems often begin before birth. In a hybrid embryo, the genetic instructions from one parent will steer the developing organism in certain directions, while the gene set from the other may steer it in quite different, even contradictory, directions. Often the instructions are so incompatible that embryonic development can't go forward. If the incompatibility is less severe, the hybrid may be born with a form somewhere between the two parents. Sometimes this is harmless enough. For instance, the Greek land snail *Albinaria spratti* has coarse, wavy ribs on its shell, whereas *A. hippolyti*

EVA SUTTON

Our fascination with mixed species is evident in children's riddles, science fiction, and the work of artists such as New York–based Eva Sutton.

VICTOR ENGLEBERT

A mule (perhaps the best-known example of so-called hybrid vigor) inherits its size and strength from its horse mother and its surefootedness from its donkey father. These traits have long made mules appreciated by the Amish and other farming communities.

has straight, threadlike lines. Hybrids of the two have shells adorned with riblets that are not really coarse but also not very thin, and only a little bit wavy. Oblivious to their unorthodox appearance, the hybrids appear to go about their business normally (though there is no evidence that they breed).

But sometimes disaster ensues from hybridization. In large, permanent bodies of water in the lowlands of eastern Europe, for example, lives *Bombina bombina*, the European fire-bellied toad, so called because of the red splotches on its belly. Western and southern Europe, as well as the mountains of Hungary, Poland, and Slovakia, are home to a close relative, the yellow-bellied toad, *Bombina variegata*. Along a central European front, the two species hybridize, but the hybrids suffer from a whole range of defects, many of which are lethal at the embryonic stage. Those that survive to become tadpoles often have misshapen mouths and are unable to feed properly. Those that make it to adulthood suffer from skeletal abnormalities: ribs fused to vertebrae, reduced numbers of vertebrae, and asymmetry in the sacral region. All in all, these hybrids are often eliminated by a form of natural selection that is termed "endogenous selection"—it's not the outer environment, but the animals' own inner environment, so to speak, that does them in.

Many problems that plague hybrids stem from causes that are less visible than a deformed spine but no less harmful: genetic parasites. These stretches of DNA, often termed "mobile genetic elements," move in and out of chromosomes of their own accord. To the host, mobile genetic elements are a nuisance, because when they copy and reinsert themselves right in the middle of an important gene, the gene's function is disrupted. Some organisms, however, have developed a defense against these marauding bits of genomic material. During fertilization, when mobile genetic elements are most active, such organisms release into the egg cell some as-yet-undetermined factors that mop up any loose copies of "selfish" DNA. Although scientists do not yet know how widespread this type of genetic grooming is, they have confirmed it in, for example, fruit flies and maize plants.

Here again, hybrids may miss out. If the genetic contribution of a hybrid's father includes mobile elements to which the mother's species has never been exposed, the hybrid egg cell will not have the appropriate defenses. Crosses between different species or strains of *Drosophila* fruit flies, for instance, often result in increased mutation rates, deformed chromosomes, and sterility—all caused by genetic elements indiscriminately inserting themselves here and there in the host's genome.

Even when hybrids live long enough to breed—whether among themselves or with members of either parental species—problems are likely to arise. Both parental species would have evolved their own networks of genes responsible for such defenses against external threats as possessing sharp spines or emitting a foul odor. With each hybrid generation, these networks are likely to become broken up and scrambled. Partial sets of different defense systems are as useless to an organism as the loose components of two different types of machine guns are to a soldier.

Many of the problems that can plague hybrids stem from an invisible cause: genetic parasites.

This is the situation in which cottonwood hybrids find themselves. Along the banks of rivers that originate in the Rocky Mountains and flow through the Canadian province of Alberta as well as through Utah, Colorado, Arizona, and New Mexico, several species of these trees hybridize, forming expansive zones containing all kinds of intermediate individuals. In 1989 Thomas Whitham, of Northern Arizona University in Flagstaff, reported that cottonwoods in hybrid zones are far more susceptible to attack by *Pemphigus betae.* In early spring, these aphids form pouch-shaped galls on the hybrids' leaves; living and breeding within the galls, the insects feed on the trees' nutritious sap stream. Recently, Kevin Floate and Greg Martinsen, working with Whitham, found that per-tree aphid densities were 8 to 119 times higher in hybrid zones.

With so much working against them, one might expect hybrids to be pretty rare in nature. Not so. Hybrids occur everywhere scientists look, from blue whales (which mix with fin whales) to the finches and iguanas on Darwin's Galápagos Islands. About 12 percent of European butterfly species hybridize with one another, and in several groups of birds (birds of paradise, ducks, and North American warblers, to name a few), the figure is as high as 25 percent. Hybridization is also widespread among plants: a conservative estimate puts the level at no less than 20 percent. These are staggering figures. Why has nature not developed more effective policing against such dangerous liaisons?

Despite the well-documented problems of hybridization, recent evidence suggests that, in fact, many hybrid individuals are remarkably successful in the struggle for life. In 1995 Michael Arnold and Scott Hodges, working at the University of Georgia, reviewed forty-four cases of hybridization in fifteen different genera of plants and animals and noted that in only 30 percent of these did hybrids score lower than pure individuals in overall fitness (gauged from a combination of survival and fertility rates). In all the other cases, hybrids fared at least as well as the purebreds, and sometimes even better. Apparently, having complete sets of genes from two (rather than one) species may sometimes increase an organism's genetic versatility and thus be an asset rather than a liability.

Thus, under certain circumstances, hybrids are actually favored by natural selection. At the beginning of the last century, two species of goatsbeard plants, *Tragopogon dubius* and *T. porrifolius,* were accidentally brought from Europe to the western United States, where they spread over large areas. In 1949 Marion Ownbey, a botanist at Washington State University in Pullman, discovered (along a stretch of railroad track) fifty-nine plants that turned out to be hybrids between the two. Because of a doubling of their chromosome number, these hybrids could no longer cross with the parental species but only among themselves—which they did not hesitate to do. By 1990 they were thriving by the thousands in an area measuring more than 700

The northern pintail and the mallard are two of North America's most abundant ducks. When a male from either species mates with a female of the other, the resulting hybrid combines the elegance and sophisticated markings of the pintail with the familiar sturdiness of the mallard.

Male northern pintail

Male mallard

Hybrid

square miles. Genetically isolated from their progenitors, the hybrids are now actually considered a new species, *T. mirus*.

The interesting thing about *T. mirus,* according to Pamela Soltis, Ownbey's successor at the university, is that it grows in areas that are out-of-bounds for the species from which it was derived. *T. porrifolius* grows in wet, shady places, and *T. dubius* grows in dry, sunny places, while the hybrid species forms large bushes in all the intermediate habitats: spots that are just a little wet or only somewhat dry, and not too sunny but not too shady either. Rather than endangering the integrity of two species, hybridization has here created a third. According to recent evidence, between 5 and 10 percent of all species of plants may have evolved this way.

Hybrid organisms are intriguing in and of themselves, and researchers can spend many productive hours trying to understand why some prove successful and others do not. But studying the areas where hybrids are found has also become popular in recent

P. LA TOURRETTE; VIREO

Male Bullock's oriole

years. As English evolutionary biologist Godfrey Hewitt has remarked, "Hybrid zones are natural laboratories for evolutionary studies." Hundreds of hybrid zones are known already. They tend to be in places where species that originally evolved in isolation meet up during a subsequent period of range expansion. For example, during the Pleistocene Epoch, when northern Europe was covered with

What is a species, anyway?

Species (the word means "form" or "kind" in Latin) are to biology what elements are to chemistry. The concept of species is relevant in almost every area of biological study, from ecology to genetics. Hence, one might expect that biologists know exactly when a particular "form" should be given species status, but in fact, there is much disagreement. Disregarding Darwin's warning not to try to "define the undefinable," theoreticians have come up with many definitions.

Until recently, one of the most popular was the "biological species concept." The most common expression of this idea is that a species is a group of individuals capable of breeding with one another. Put more technically, different species are genetically isolated from one another—usually kept apart by one or more "reproductive isolating mechanisms," some mechanical, some behavioral. For example, many North American species of giant silk moths do not interbreed because they mate at different times of day. The idea of genetic isolation has been challenged in recent years, however, as DNA analysis has revealed that genes often leak between species (as a result of occasional hybridization or even being shuttled by viruses).

Another proposed definition is that a species consists of all the descendants of one particular common ancestor. Thus, some primatologists think that even though the orangutans of Sumatra and Borneo are able to interbreed, they should be classified as separate species because genetic analysis has shown that they occupy two different branches in the evolutionary tree. But this definition, too, presents problems. For instance, detailed study of the DNA of the barnacle goose has located its origin on a twig of the Canada goose's family tree. According to the common-ancestor definition, then, these two geese are members of the same species. But based on the barnacle goose's looks and behavior, most ornithologists agree that it deserves separate species status.

Lately, many biologists have come to realize that the concept of species cannot be captured in such strict definitions, and they are gravitating toward the view that species are distinct clusters of genes. In other words, any collection of individuals that share a similar genetic makeup could qualify as a species. In theory, this would include species that—odd as it may sound—have evolved independently several times. If species are just particular sets of genes, then given the right selection pressures, fairly simple rearrangements could crop up more than once. This view is by no means universally accepted, but its lack of rigidity is appealing. In this regard, it is reminiscent of Darwin's advice simply to follow "the opinion of naturalists having sound judgement."

I. VEZO; VIREO

B. SCHORRE; VIREO

On the Great Plains of North America, the Bullock's and Baltimore orioles interbreed freely, forming an extensive hybrid zone.

glaciers, many species' ranges shrank, and only scattered southern populations survived, maintaining their foothold in the milder, ice-free pockets. Some of these populations evolved into new species during their aeons of isolation. When the ice retreated, about 10,000 years ago, the newly evolved species spread northward, made contact with their long-lost relatives, and sometimes bred with them. This is how the *Bombina* hybrid zone came into being.

Hybrid zones are complex places. Early in a zone's history, it will contain only purebred individuals and what are known as "primary" hybrids (the offspring of purebred individuals belonging to two different species). Unless these primary hybrids are sterile, they will go on to breed—perhaps with a purebred individual, perhaps with another hybrid. Subsequent generations will produce all manner of "secondary" hybrids: the mixed offspring of mixed offspring. Hybrid zones normally show a smooth genetic blending, with populations on the edge carrying mainly genes from the pure species nearby, and populations in the center having a more or less equal mix of genes from both species.

Up to 10 percent of all wild plants species may have evolved via hybridization.

Mathematically inclined biologists such as Nick Barton, of the University of Edinburgh in Scotland, have developed formulas for extracting evolutionary history from hybrid zones. The zone between the European fire-bellied toad and the yellow-bellied toad, for example, follows a tortuous, 3,000-mile route from eastern Germany to the Black Sea. Nowhere is it broader than about 6 miles; usually it is less. This zone, says Barton, has probably always had more or less the same length and breadth. The balance is maintained because the hybrid toads that are eliminated by endogenous natural selection—remember, they often have skeletal deformities—are replaced by new ones as pure individuals continue to stream in from either side (the toads move half a mile from birthplace to breeding site). Since the early 1980s, Barton and his colleague Jacek Szymura, of Jagiellonian University in Kraków, Poland, have genetically fingerprinted thousands of toads from the hybrid zone. On the basis of this wealth of data, the researchers have built up a very accurate picture of the strength of natural selection in this situation; on average, they find, a hybrid toad is half

The taxonomic status of the red wolf has long been controversial, with some claiming it is a species, others a subspecies of gray wolf, and still others a crossbreed of the gray wolf and the coyote.

TIM FITZHARRIS; MINDEN PICTURES

TOM & PAT LEESON

TOM & PAT LEESON

VOLLRATH WIESE

On the island of Crete, the snail (center) that results from the interbreeding of the subspecies *Albinaria hippolyti hippolyti* (left) and *A. hippolyti harmonia* (right) is thought to be less hardy than either of its parents.

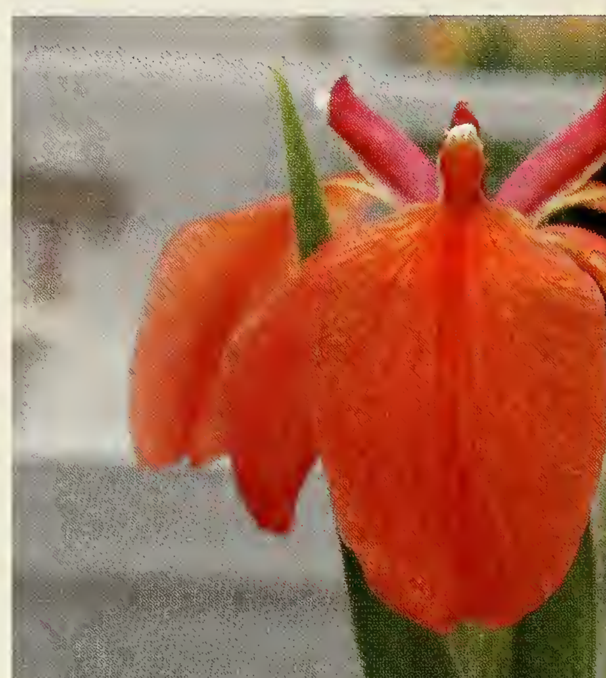
as fit as a purebred individual, meaning that it contributes only half as many offspring to the next generation. Barton and Szymura have even estimated how many genes (about fifty-five) are involved in the genetic problems the hybrids experience. Although the fate of hybrid zones is hard to predict, Barton thinks many are quite stable and likely to remain in place until another ice age pushes the two species into separate refuges.

The shape of a hybrid zone turns out to depend on two biological forces: endogenous natural selection against hybrids and the migration patterns (or, as geneticists call it, gene flow) of individuals. The closer to home organisms remain, the smaller a hybrid zone will be. For example, hybrid zones between different species of land snails, with their proverbially slow locomotion, are usually very narrow. While studying *Albinaria* on the Mediterranean island of Crete, I would stumble across hybrid zones that were on average just 330 yards wide (and sometimes as narrow as 60). As I walked through the mountainous shrubland, strewn with the limestone boulders on which these snails can typically be found, I could quite literally see the shape of the shells on the rocks change with every step. By contrast, zones between interbreeding bird species, as might be expected, are very wide. On the Great Plains of North America, some ten pairs of bird species form hybrid zones with widths of up to 600 miles. Three such pairs are the black-headed and rose-breasted grosbeaks, the Indigo and lazuli buntings, and the Baltimore and Bullock's orioles.

The center of a hybrid zone can be especially interesting. There, the genetic spheres of influence of both pure species are roughly equal in strength, and the hybrids usually derive about half their genes from one species and half from the other. The area is thus plagued with genetic incompatibilities, and endogenous natural selection is at its most severe. As a result—though this may seem paradoxical at first—hybrids are often hard to find in the heart of the hybrid zone. I remember the first time I walked through the hybrid zone between the Cretan snails

Iris brevicaulis

AMY BOUCK



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The yellow-bellied toad, left, and the European fire-bellied toad, right, hybridize over a 3,000-mile-long, 6-mile-wide area in central Europe. The offspring of these matings are often deformed; many die as embryos.

Albinaria hippolyti hippolyti and *A. hippolyti harmonia.* At the edge of the zone, snail density was impressive, with as many as forty snails on a single rock. Further into the zone, the density dropped off markedly, and by the time I reached the center, hardly any snails were to be seen.

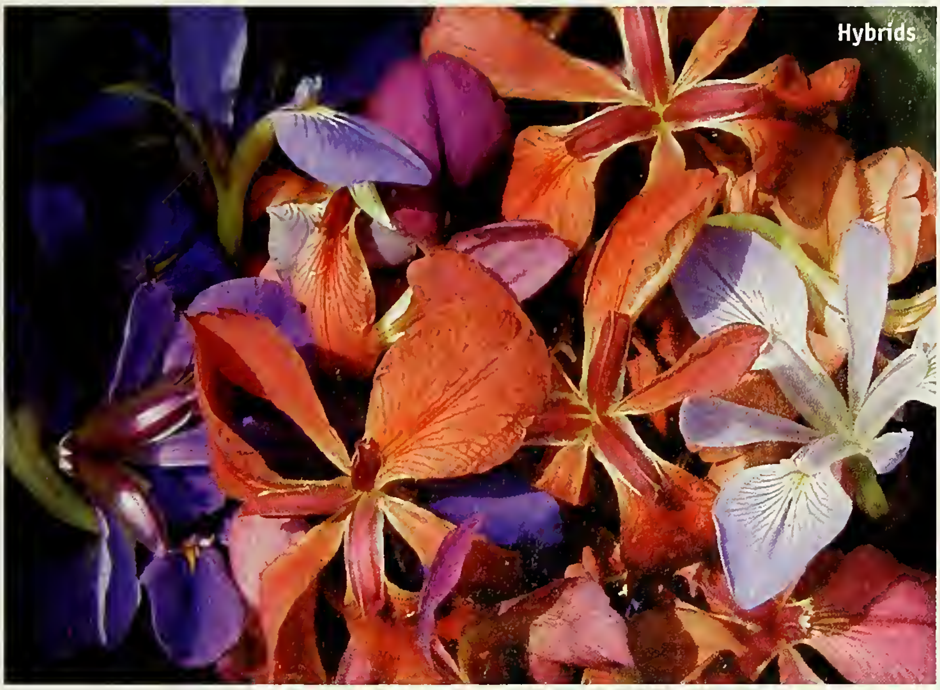
Paradoxically, hybrids are often very hard to find in the heart of a hybrid zone.

Snails and other shelled animals sometimes serve as particularly informative logbooks of evolutionary change. On the Bahamian island of Great Inagua lives a barrel-shaped tree snail called *Cerion rubicundum.* As the late Stephen Jay Gould, of Harvard University, and Glenn Goodfriend, of the Carnegie Institution of Washington, wrote in a 1996 *Science* article, fossils from the island indicate that some 17,000 years ago, *C. rubicundum* hadn't yet arrived. At that time, another *Cerion* snail lived on Great Inagua: *C. excelsior,* a tall, slender species no longer found on the island (though it still lives elsewhere in the region, such as on the islands of Mayaguana and East Plana Cay). Fossils from Great Inagua tell a story of *C. excelsior* being hybridized out of existence. As the new arrival (which probably came from one of the nearby islands, where it is common) gained a foothold, its influence in the population became stronger and stronger. Fossils from 5,000 years ago still include a variety of intermediate forms. By 3,000 years ago, the shells had become almost indistinguishable from those of the island's modern inhabitants. Today, all that remains of *C. excelsior* on Great Inagua are a few traces of its DNA in *C. rubicundum*'s genome.

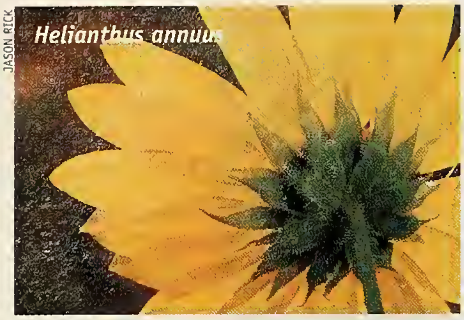
In the age of genomics, hybrids should enjoy

AMY BOUCK

AMY BOUCK



***Iris brevicaulis* and *I. fulva* have different primary pollinators—bumblebees and hummingbirds, respectively—which helps limit interbreeding in the wild. Crossbreeding in the lab or for horticultural purposes, however, produces a rich variety of blossoms, right.**



JASON RICK

JASON RICK

JASON RICK

MALIE RICH-GRIFFIN

Hybridization in nature between two wild sunflowers, left and center, led to the natural evolution of a third species, right. Differences among the species, though hard for the untutored eye to discern, are evident in the green bracts on the flowers' undersides.

even greater popularity with biologists. The genetic mapping of plant species whose origins, like those of the goatsbeards, are rooted in a hybridization event can reveal exactly which genes come from which of the two parent species. For example, studies of hybrid sunflower species show that certain gene combinations are matches made in heaven—guaranteed to boost a hybrid's chances of survival—whereas other combinations are recipes for disaster. This helps explain why the success of hybrids is so variable and also why some species can, and others cannot, interbreed.

Insights like these should deepen our understanding of one of the biggest evolutionary issues of all—how new species arise. Charles Darwin devoted an entire chapter of the *Origin of Species* to hybridism. In it, he wondered why certain hybrids enjoy "an excess of fertility" while others—and here Darwin was quoting a Mr. Salter—die "without any obvious cause, apparently from mere inability to live." Nearly all the embryos in eggs laid by hybrid chickens, Salter had found, failed to mature, and most of the few that did hatch died within just a few days. Darwin would definitely have applauded hybrids' current surge in popularity as an object of biological study.

So what *do* you get if you cross a carrier pigeon with a woodpecker? Answer: a bird that knocks before delivering a message. (Don't say you weren't warned.) □


CARR CLIFTON; MINDEN PICTURES

Hybrid cottonwood trees growing along Utah's Green River and in other parts of the West are more vulnerable to aphid attacks than are "pure" cottonwoods.

Cultivated sunflowers sometimes hybridize with wild ones, providing a potential pathway for bioengineered genes to enter wild populations.

One Touch of Venom

A box jellyfish is a killer without peer.

Found in the waters off northern Australia, the box jellyfish *Chironex fleckeri* is not the only marine invertebrate to use venom, but it is the possessor of arguably the most lethal venom in the world. In the past half century, sixty-five Australians have been killed by it. *C. fleckeri*'s body (or bell) can grow to a foot wide and can support as many as sixty tentacles, each more than seven feet long, each capable of delivering a fatal touch. Since 1995 I've been studying why and how this jellyfish uses such high-octane venom.

Most jellies feed on plankton. But once *C. fleckeri*'s bell reaches a diameter of four inches, this jelly begins to feed on fish. Its venom seems tailor-made for attacking the nervous and cardiac systems of vertebrates: when *C. fleckeri* selects prey, it can sign their death warrant with a single flick of a tentacle, whose every inch contains 2.5 million stinging nematocysts—specialized cells that are ripe with venom.

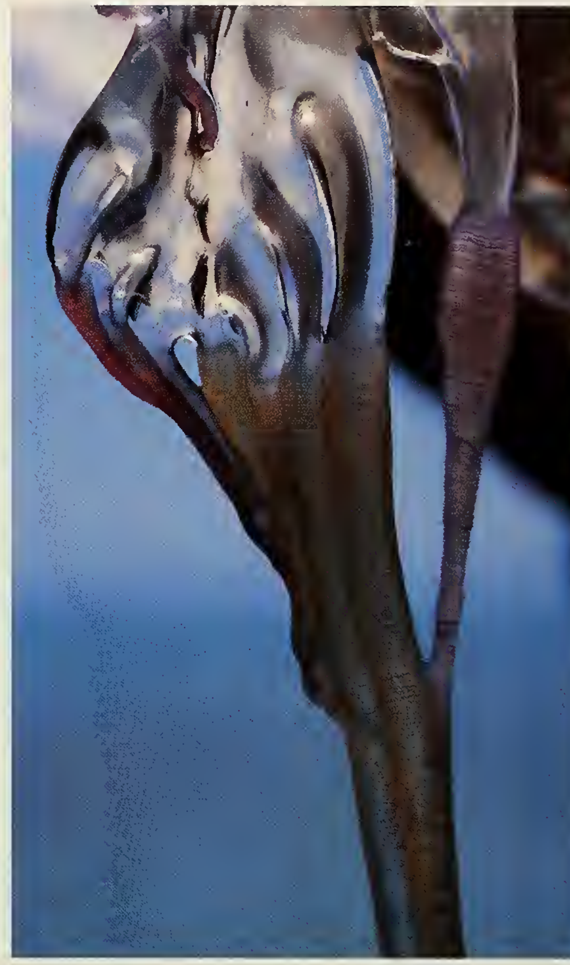
C. fleckeri, unlike the typical jellyfish, is a fine swimmer. Some individuals have been clocked at speeds of up to two and a half knots—useful if you want to pursue fish. Having nabbed its prey, the box jellyfish moves the captive to its stomach for predigestion. Surprisingly, however, the absorption of organic matter does not take place there. Instead, the semidigested broth is directed to canals lining the interior walls of each tentacle, where nutrient uptake then occurs. Why this process in *C. fleckeri* (and most other box jellies) but not in other species of jellyfish? The answer lies in its high energy demands: its metabolic rate is ten times greater than that of other jellyfishes. The standard jellyfish stomach is a simple, pouchlike affair. That's fine if your principal food is plankton, but not much use if you're trying to feed on fish. The canals inside *C. fleckeri*'s tentacles (which bear an uncanny resemblance to the villi that line vertebrate digestive systems) dramatically increase the internal surface area of the tentacles, allowing more organic matter to be absorbed in less time than would be possible with a conventional jellyfish digestive system.

In the world of jellyfish, *C. fleckeri*—fast on its tentacles, furious with its venom—is in a league of its own.

A *C. fleckeri* box jellyfish, opposite, has trapped one fish in its bell, another in its tentacles. Above: The jelly's danger to humans is made clear at a beach in northeastern Australia.

Text by Jamie Seymour ~ Photographs by Paul A. Sutherland

The author, right, inspects a box jellyfish that he will track with an ultrasonic transmitter. Below right: The transmitter is glued to the jelly. Even a juvenile *C. fleckeri,* below left, uses stinging cells to catch its dinner of plankton.



R. HARTWICK; BEN CROPP PRODUCTIONS

Populations of jellyfish that sting severely have burgeoned recently in Australian waters and elsewhere. *C. fleckeri*'s tentacles, above, are packed with stinging cells. Left: Barely visible, box jellies can come close without potential victims noticing. Opposite page: One of many still-unidentified species that may well be as lethal as *C. fleckeri*.

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THIS LAND

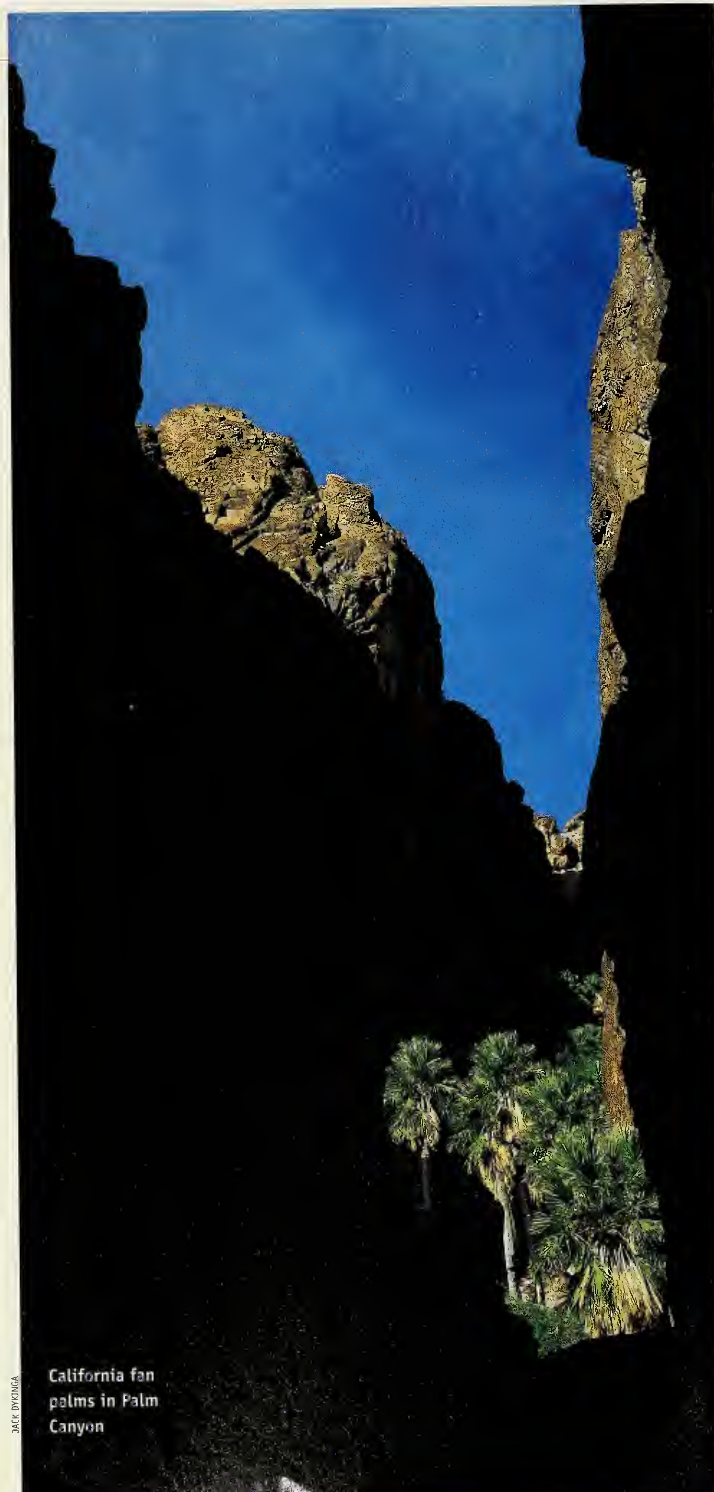
The Trail to Palm Canyon

Set aside for sheep, an Arizona refuge also shelters some unexpected plants.

By Robert H. Mohlenbrock

About fifty miles northeast of Yuma, Arizona, and largely surrounded by an army proving ground, the Kofa National Wildlife Refuge embraces a thousand-square-mile area, most of which is classified as wilderness. The terrain includes the dry, brown, rugged Kofa Mountains and portions of other nearby ranges, along with surrounding Sonoran Desert flats. The only roads are unpaved, left over from past mining operations. The name "Kofa," in fact, is an abbreviation of the name for the area's largest abandoned mine, the King of Arizona. One rough road that runs through the northern end of the refuge provides access to Crystal Hill, where rock hounds may collect a limited quantity of rocks and minerals.

Managed by the U.S. Fish and Wildlife Service, the refuge was established in 1939 to protect the area's dwindling population of desert bighorn sheep, at that time estimated to consist of as few as a hundred animals. Here, as in other regions of the Southwest, this subspecies of bighorn sheep had been decimated by diseases, excessive hunting, loss of habitat, and competition with livestock. Since the sheep may need to drink water every three days during the summer, numerous artificial water holes and water tanks were constructed to aid in this population's



JACK DYKINGA

California fan palms in Palm Canyon

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Teddy-bear cholla

JACK DYKINGA

JOE LEMONNIER

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http://ifw2irm2.irm1.r2.fws.gov/refuges/arizona/kofa.html

recovery. Today, systematic surveys show there are more than 800 bighorns in the refuge.

Possessing remarkable climbing skills, the sheep usually stay in the upper reaches of the mountains, the highest of which is 4,877-foot Signal Peak. As ruminants, they are able to subsist on dry, often spiny vegetation that would seem to have little food value. Both males and females have horns, but the males' horns boast an amazing full curl and may measure more than thirty inches from base to tip.

Although the Kofa National Wildlife Refuge was created to protect the sheep, it also protects two stands of the rare California fan palm. The best time to visit the refuge is between October and March, when the temperatures are cooler. A gravel road off U.S. Route 95 crosses seven miles of desert to the Palm Canyon trailhead. The rocky, narrow trail to the palms goes through Sonoran Desert habitat, crossing several dry washes that carry water only after a torrential downpour—an infrequent occurrence. After a gradual climb for half a mile, hikers reach a vantage point offering a view of Palm Canyon and a few of its trees. Only hardened hikers should tackle the remaining half-mile up to the palms. For most people, the view from down below is satisfying enough.

Fishtail Canyon, the next canyon southeast of Palm Canyon, harbors a few more California fan palms. The only other stand in Arizona is in the Hieroglyphic Mountains, near Phoenix. These isolated populations are apparently remnants from a time when Arizona was wetter and cooler. Other stands exist in Nevada, California, and Mexico. In California the trees may reach a height of sixty feet, and as their lower leaves die, they hang down to the ground in a dense mass, forming what looks like a petticoat or skirt around the trunk. In Palm Canyon and Fishtail Canyon, however, the palms are only twenty to thirty feet tall and sometimes do not form petticoats of dead fronds. Botanists have not yet determined the reasons for these differences.

HABITATS

Canyon. Although the California fan palm is the major attraction, another rarity is the Kofa barberry, a three-foot-tall shrub known only from the Kofa Mountains and from the Ajo Mountains, farther south. Its leaves are divided into three shiny, spiny-toothed, hollylike leaflets; clusters of small, yellow-green flowers appear in June and July. Other canyon plants are desert-olive and skunkbush—both small shrubs—and bear grass, a robust plant related to yucca.

Desert flat. Saguaro grows here, along with numerous smaller cacti, including teddy-bear cholla, beaver-tail cactus, California barrel cactus, hedgehog cactus, and various prickly pear cacti. The most common shrubs are creosote bush, ocotillo, and bur sage. Others are catclaw acacia, whitethorn acacia, rigid spinyherb, white ratany, and two extremely spiny species known as crucifixion thorns. Wildflowers: gold poppy, whitestem milkweed, fiddleneck, Douglas nightshade, brittlebush, trixis, horsfordia, California buckwheat, various species of phacelia.


Desert bighorn lambs

TED LEVIN; ANIMALS ANIMALS

Desert wash. Foothill palo verde and ironwood—two small trees in the legume family—almost always dominate the dry streambeds. Shrubs are desert holly and Anderson wolfberry. Wildflowers: coyote tobacco, yellow paper daisy, Emory's rock daisy.

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.

AMNH Volunteer Supports the Museum's Future *and* Her Own Retirement

"Growing up in New York, of course some of my earliest and happiest childhood memories are of visits to the Museum." Thus for Selma Wiener began a life that has been closely intertwined with science, including professional experience as a high school science teacher, a technician for medical research, and assistant to the editor of a major medical publication.

Over the past few years, Selma has expressed her love for the Museum in several important ways. She strengthened her membership support by participating in the Patrons Circle. Joining the Museum's corps of dedicated volunteers, she became editorial assistant to the Director of the Micropaleontology Press. She also included a bequest to the Museum in her estate plan.

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09/02

REVIEW

Oz (1999–2000), by Frank Moore

OIL ON CANVAS OVER FEATHER BOARD PANEL WITH ALUMINUM FRAME. COURTESY SPERONE WESTWATER, NY.

The Future: Perfect or Posthuman?

Two scientists offer different visions of a bioengineered world.

By Vaclav Smil

Book titles are frequently opaque, but in this instance they convey fairly accurately the differing mind-sets of two authors: Francis Fukuyama's worries about the profound, and indeed potentially terrible, consequences of human bioengineering versus Gregory Stock's eager anticipation of a world where nobody will be able to stop a person from choosing an embryo's genetic makeup. As always, personal history explains a great deal of this disparity. Fukuyama, immoderately tagged by the dustcover blurb as "our greatest social philosopher," is a professor of political economy at Johns Hopkins University's School of Advanced International Studies in Washington D.C., while Stock directs the Program on Medicine, Technology, and Society at UCLA.

Our Posthuman Future: *Consequences of the Biotechnology Revolution,* by Francis Fukuyama (Farrar, Straus and Giroux)

Redesigning Humans: *Our Inevitable Genetic Future,* by Gregory Stock (Houghton Mifflin)

Fukuyama became an intellectual celebrity in 1992 thanks to *The End of History and the Last Man,* in which he argued that human civilization had made no essential progress beyond the principles of the French Revolution. He also held that the collapse of communism marked the final stage of a convergence toward liberal democracy around the globe. The large number of people who disagreed with this caricature of human history grew even larger after 9/11. But Fukuyama remains unfazed as he labels Islamist radicalism "a desperate rearguard action" that will be overwhelmed by the broad tide of modernization (this, of course, begs the question, Why don't we just wait for the tide to cleanse Afghanistan and Saudi Arabia?). While Fukuyama is a newcomer to the world of genetic alteration, Stock is an old hand, the author of *Metaman: The Merging of Humans and Machines Into a Global Superorganism* (an idea that is to me as enticing as "the end of history"). These two men have produced books that sprout from two irreconcilable weltanschauungs—a philosopher's concern about the ever perilous path traveled by humanity and a techno-fixer's enthusiasm for "germinal choice technology" and "germline engineering" (Stock's preferred terms for the alteration of human genes).

Fukuyama argues that the most significant threat posed by contemporary biotechnology is the possibility that it will alter human nature and move us into a "posthuman" stage of history. The existence of definable human nature is central to his argument. This stable human "essence" (that is to say, what we are—regardless of whether it is really there or we simply believe it is there) provides a long-term foundation for our experiences as a species and constrains our political regimes and social arrangements. Altering this essence over time, albeit under the banner of human freedom, will lead us into very dangerous territory. While human nature is quite plastic and adaptable, it is "not infinitely malleable," and our species-specific range of emotional responses, writes Fukuyama, makes for a "safe harbor" that enables us to connect with the rest of humanity. Contaminating the notion of shared humanity by mixing human genes with those of other species—losing this safe harbor of our essence—may then lead to "malign consequences for liberal democracy and the nature of politics itself." We should not become slaves to inevitable progress when that progress is inimical to our human essence.

Stock, eager to merge machines with humans, would never make these connections. His vision is a peculiar mixture of hard-core science fiction and inexplicable naïveté. He assures us that, unlike nuclear weapons, the techniques that will bring about this epochal genetic shift "will be forgiving." This conclusion, so casually noted, is to me one of the most astonishing claims in the book. How can a scientist, aware of the unintended and unforeseen consequences of the twentieth century's scientific advances, be so sure—especially when predicting across the span of centuries? We are witnessing, according to Stock, nothing less than the birth of a new world, and we cannot hold it back.

We should not become slaves to inevitable progress when that progress is inimical to our human essence.

A thousand years from now, Stock writes, humans (and by qualifying this with "whoever or whatever they may be," he chillingly confirms Fukuyama's concerns) will look back incredulously on our primitive era, with its seventy- to eighty-year life spans, awful diseases, and conception outside a laboratory by an "unpredictable meeting of sperm and egg." As the world of perfectly designed, forever healthy, Methuselah-aged beings (or whatever they will be) beckons, future generations will refuse to remain "natural." The opportunities of germinal choice will "far outweigh the risks," and the techniques can be well protected against potential abuses and thrive in "a free-market environment with real individual choice." Again, what justifies this certainty? This hubris is as unacceptable as it is dangerous, and so—even as a scientist keenly aware of the rich promise of genetic engineering and very much in favor of exploiting some of its truly miraculous potential—I find myself siding with Fukuyama.

I may disagree with some of his generalizations, but Fukuyama is right to reject the unrestricted pursuit of scientific inquiry and to argue against the inevitability of scientific progress regardless of its direction. He is right when he calls for thoughtful regulation of human genetic engineering, starting at national levels, because experience has shown that efforts to control the pace of worrisome developments (nuclear proliferation, the selling of human body parts, widespread trade in biological and chemical weapons) are not self-defeating. And he is right when he affirms that the protection of values we cherish as a species necessitates that we think hard and move cautiously lest we surrender our humanity and enter a posthuman world.

But both books suffer from too much speculation; the actual outcome may not resemble either of the two visions. The fate of nuclear energy, a technique initially seen as no less a profound transformer of civilization than bioengineering is today, provides a revealing analogy. More than half a century after its liberation, nuclear energy does not energize everything in our civilization, but it has not destroyed it either. The invention has been useful: nuclear weapons helped keep the global peace during the cold war, and fission reactors now generate nearly a fifth of the world's electricity. But the invention has also brought enormous worries about proliferation, accidents, terrorist attacks, and long-term disposal of wastes. And so it may be with genetic engineering: its tools may in the long run prove much less powerful than they seem today, and our worries much exaggerated. Fifty years from now, we may live with a mixture of welcome benefits, perilous side effects, and continuing concerns—being no closer to the resolution of that grand challenge of just being human.

Vaclav Smil teaches in the University of Manitoba's geography department. In 2001, he was presented with the AAAS Award for Public Understanding of Science and Technology by the American Association for the Advancement of Science. His most recent book is The Earth's Biosphere: Evolution, Dynamics, and Change *(MIT Press).*

BOOKSHELF

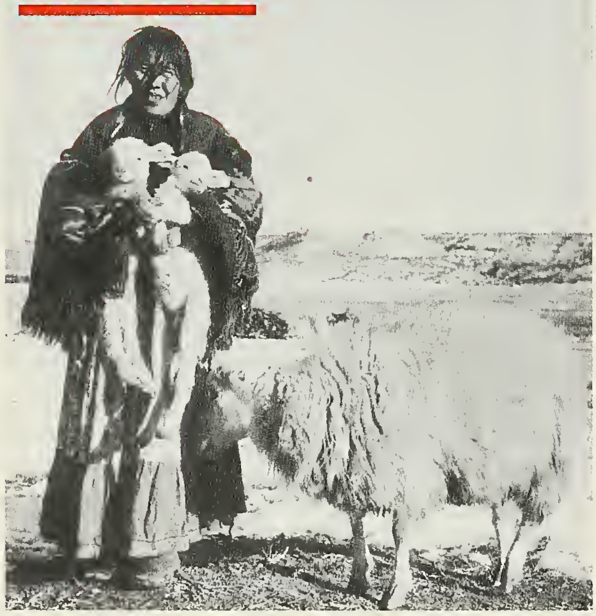
As hurricane season approaches, we would do well to remember past weather events by reading Willie Drye's **Storm of the Century:** *The Labor Day Hurricane of 1935* (National Geographic Society) and David Toomey's **Stormchasers:** *The Hurricane Hunters and Their Fateful Flight Into Hurricane Janet* (W. W. Norton).

Death occurs in every season, and in **What Is Death?** *A Scientist Looks at the Cycle of Life* (John Wiley & Sons), New York University biologist Tyler Volk examines this ultimate fact of nature from biological, personal, and social points of view. In **Cradle to Cradle:** *Remaking the Way We Make Things* (North Point Press), environmental designers William McDonough and Michael Braungart explore how we can imitate nature's system of perpetual recycling, in which "the very concept of waste does not exist."

What makes us who we are? Rose E. Frisch, in **Female Fertility and the Body Fat Connection** (University of Chicago Press), illuminates how and why a critical fatness level underlies women's reproductive health from menstruation to menopause. In **Memories Are Made of This:** *How Memory Works in Humans and Animals* (Columbia University Press), Rusiko Bourtchouladze addresses this significant attribute of mind, examining such topics as the importance of genes in memory.

Human curiosity about nonhuman animals takes many forms. Our fascination with collecting living specimens is detailed in **Zoo:** *A History of Zoological Gardens in the West* (Reaktion Books), by Eric Baratay and Elisabeth Hardouin-Fugier, and in **Animal Attractions:** *Nature on Display in American Zoos* (Princeton University Press), by Elizabeth Hanson. Two new books address a particularly charismatic species, the giant panda. Susan Lumpkin and John Seidensticker, in **Giant Pandas** (Smithsonian Institution Press), portray this animal's natural history as well as its "meteoric rise to superstar status" when French missionary Père Armand David sent the first specimen to the National Museum of Natural History in Paris 130 years ago. In **Giant Pandas in the Wild:** *Saving an Endangered Species* (Aperture), Lü Zhi, who began her research in 1985, chronicles the daily lives of more than twenty individuals in some of China's thirty-four reserves.

PHOTOGRAPHY



JOHN COLLIER JR.

Photographing Navajos: *John Collier Jr. on the Reservation, 1948–1953,* essays by C. Stewart Doty, Dale S. Mudge, and Herbert John Benally; photographs by John Collier Jr. (University of New Mexico Press)

The books mentioned are available in the Museum Shop, (212) 769-5150.

nature.net

You Are Here

By Robert Anderson

After years of studying what happened in the first second after the big bang, British astrophysicist Richard Powell decided to create a Web site showing how we fit into the cosmos. "I wanted to see for myself what the universe looked like, and I thought maybe some other people out there might also be interested." Indeed they might. The result of his painstaking efforts, "An Atlas of the Universe" (anzwers.org/free/universe/index.html), is fascinating.

Powell starts his tour with the solar system—which, we learn, is only 0.00000000000000000000000000000000000001 percent of the observable universe—and works his way outward. With each expanded slice of space, he provides quite a bit of information (for even more, check out his links to other sites). I learned, for example, that our galaxy, the Milky Way, is in the process of ripping apart a tiny galactic neighbor, Sagittarius Dwarf, and there's evidence that it has gobbled up others in the past.

The tour keeps going, taking us through the Local Group of galaxies, the Virgo Supercluster, the neighboring superclusters, and finally the observable universe. This cosmic horizon has a radius of 15 billion light-years, and Powell explains its dimensions this way: "The light from more distant objects simply has not had time to reach us. For this reason, everybody in the universe is at the middle of their own visible universe about 15 billion light-years in radius. The true size of the universe has to be much larger than this." Makes one feel kind of small, but at least we are once again at the center of the universe, if only the observable one.

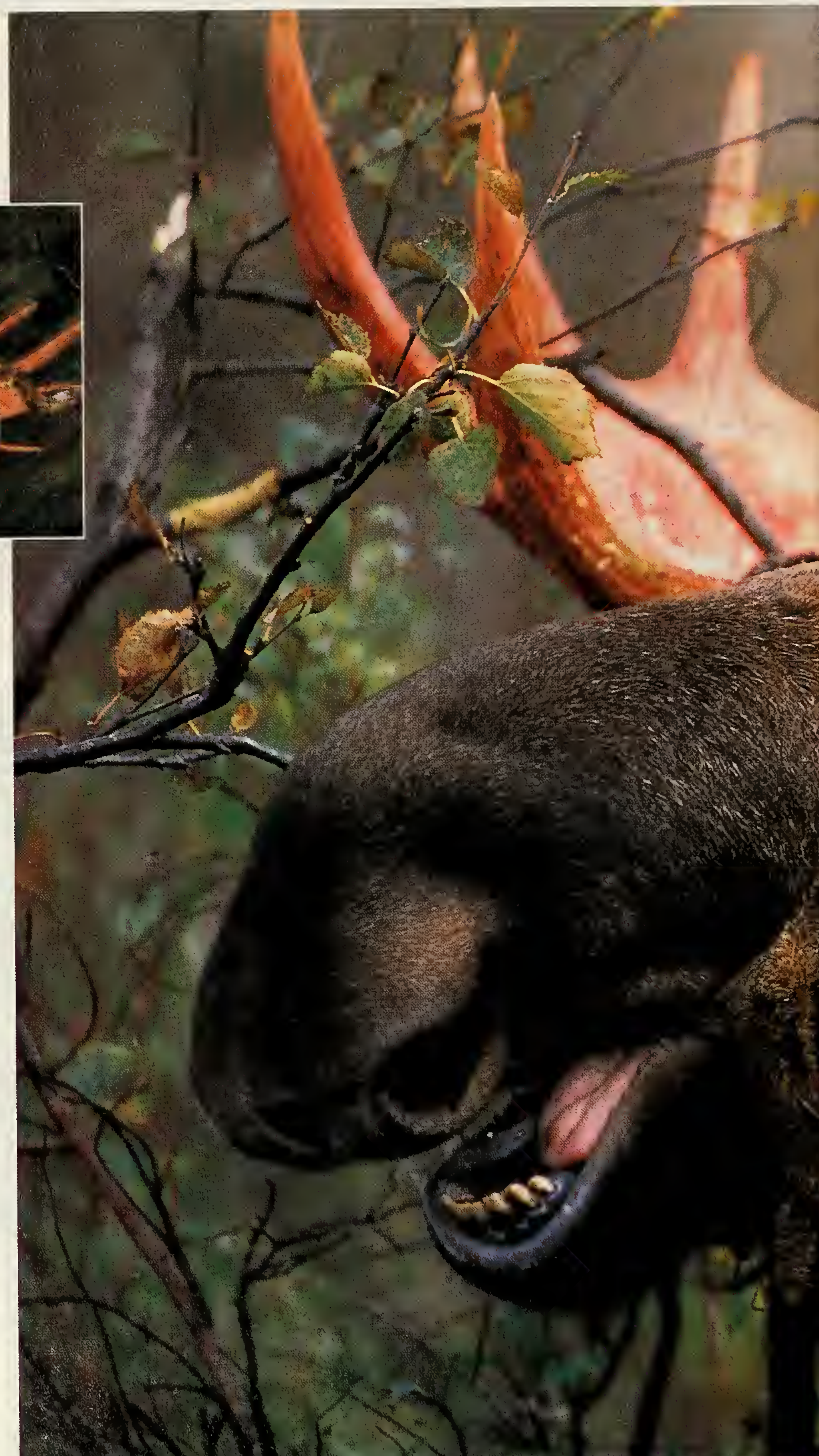
Robert Anderson is a freelance science writer living in Los Angeles.

EXPLORER GUIDE

THE NATURAL MOMENT

Crowning Gory

Photographs by
Staffan Widstrand



Come September, a bull moose has more than a few clues that autumn and its imperatives are near. Days are shorter, air cooler, antlers itchier. After casting off the old set in winter, bulls sprout new antlers, channeling minerals—mostly calcium and phosphorus—and other nutrients to the growing headgear, which is fed by a rich network of blood vessels. By summer the males are "in velvet," their hardening antlers sheathed in sensitive, living tissue. The bull shown here, a resident of Sarek National Park in northern Sweden, demonstrates the next stage: shedding.

A sure sign that the autumnal rutting season has begun are skeins of velvet strewn on the ground and hanging from vegetation and from the moose themselves. Photographer Staffan Widstrand, who watched this animal at close range, says that, unlike most moose in Sweden, "the bull and a handful of others in this protected park are not the least shy of humans," being accustomed only to hikers, not hunters. To loosen the veined velvet, the bull first thrashed its head around in stands of birch trees and *Salix* bushes (inset), but according to Widstrand, the whole shedding process took about six hours. "Usually it is done at night," he added, "but this bull was kind enough to do it by day. The antlers are still very red, but

after a day or two they will be a pale yellow-brown." Then they can serve to intimidate or fight with other bulls and to impress cows ready to mate.

So is this moose actually munching on the tatters? "Yes," says Widstrand, "it ate some of the velvet. I don't know whether it tasted good, had nutritional value, or was just a way to get it out of his eyes."—*Judy Rice*

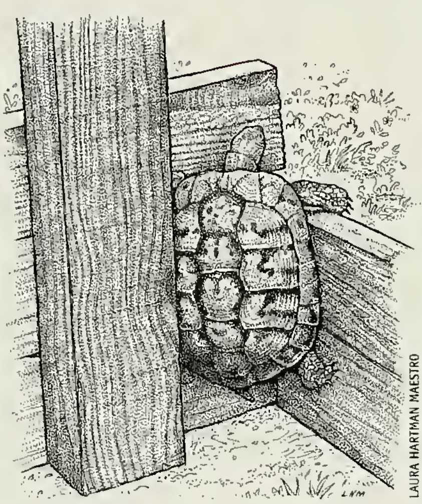
ENDPAPER

BEYOND THE PALE

By H. Robert Bustard

In a large garden in a small town in central Scotland, I breed several types of tortoises—a feat deemed well-nigh impossible by some of my southern English colleagues, who consider Scotland to be just a stone's throw from the Arctic Circle. My tortoises, however, are not just fit and healthy. They are also very active and rather bright, as one individual impressed upon me last summer.

My tortoises wander freely within large enclosures separated by wooden fencing that is low enough for me to step over but high enough, supposedly, to keep the animals within bounds. One morning in June, as I was checking and feeding my livestock, I noticed a female Hermann's tortoise *(Testudo hermanni)* basking happily in the area designated for the sulcata tortoises *(Geochelone sulcata)*. This struck me as odd, because the fence between the Hermanns' and the sulcatas' areas is relatively high, the sulcata being a very large tortoise. I duly replaced the errant female in her own neighborhood and did a quick check for holes or gaps around the enclosure boundary but found none.



LAURA HARTMAN MAESTRO

Later that same day, enjoying my afternoon tea in the garden, I saw the same female heading for the corner where the two areas abut. I had recently done some work on this corner after one of my sulcata females discovered a novel way of scaling the fence—but that's another story. Suffice it to say that in order to raise a section of the fencing by an extra board-width, I had inserted a wooden post into the ground on the Hermanns' side. This post stood about four and a half inches from the corner of the pen—a distance wider by a couple of inches than the width of an adult Hermann's. The renovated corner was three boards high on one side and two boards high on the other.

As I watched, the female Hermann's marched right into the corner and stood up as tall as she could—about nine inches—on her hind legs. More than ten inches high on the three-board side, the fence was quite a challenge for the tortoise to scale, but that detail certainly didn't put her off. The bottom board on the lower, two-board side was not entirely in line with the others and jutted out a tiny fraction. She carefully placed her right hind foot on this little ledge and raised herself enough to get a none-too-secure hold on the very edge of the top board with her right front foot.

Fascinated, I wondered what she would do next. I could see no other footholds. Imagine my amazement when she started using what I can only describe as the kind of technique used by climbers to tackle a rock chimney. She braced her shell against the post and pushed upward, with her back legs scrambling and her front legs clinging. By alternately pushing and bracing, she managed to get herself well off the ground. But she was still facing the extra board I had added to the fence, and I couldn't see any way around that obstacle.

I was wrong. Undaunted by the (I thought) insurmountable piece of wood in front of her, she started to turn her whole body to the right, toward the side where there was no extra board. Now, though, she could not wedge herself between the post and the higher, third board and thus risked falling back down to ground level.

Persistence and tenacity, not to say downright stubbornness, are qualities that all tortoise owners will recognize. This female was no exception.

She fell back and tried again several times until, as I silently urged her on, she finally managed to get a toehold with her right front foot on top of the lower, two-board side of the corner. Then she pushed off the post with a hind foot and, bit by bit, edged her weight up and onto the top of the fence, whereupon she launched herself over and into her neighbors' paddock.

I have kept tortoises since I was a young boy and know they are notorious escape artists, finding openings where none appear to be. But I had never witnessed such a complicated and difficult escape routine—evidently rapidly learned—that was used to such good effect.

Although her area affords abundant food, shelter, companionship, places to bask, and everything else a Hermann's tortoise might want, this intrepid female continues to think the grass is greener on the other side and regularly tackles the climb, perhaps getting a little bit more efficient and quicker each time. Now, that might be an interesting study for future research . . .

H. Robert Bustard is a Scottish herpetologist with a special interest in crocodilians and chelonians.

Lighting Technology for eye comfort

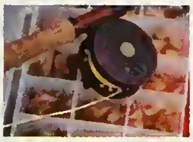
A floor lamp that spreads sunshine all over a room

The VERILUX® HappyEyes® Floor Lamp brings many of the benefits of natural daylight indoors for glare-free lighting that's perfect for a variety of indoor activities.

The VERILUX® HappyEyes® Floor Lamp will change the way you see and feel about your living or work spaces.

Ever since the first human went into a dark cave and built a fire, people have realized the importance of proper indoor lighting. Unfortunately, since Edison invented the light bulb, lighting technology has remained relatively prehistoric. Modern light fixtures do little to combat many symptoms of improper lighting, such as eye strain, dryness or burning. As more and more of us spend longer hours in front of a computer monitor, the results are compounded. And the effects of indoor lighting are not necessarily limited to physical well being. Many people believe that the quantity and quality of light can play a part in one's mood and work performance. Now VERILUX®, a leader in healthy lighting since 1956 has developed a better way to bring the positive benefits of natural sunlight indoors.

Use the VERILUX® HappyEyes® Floor Lamp...



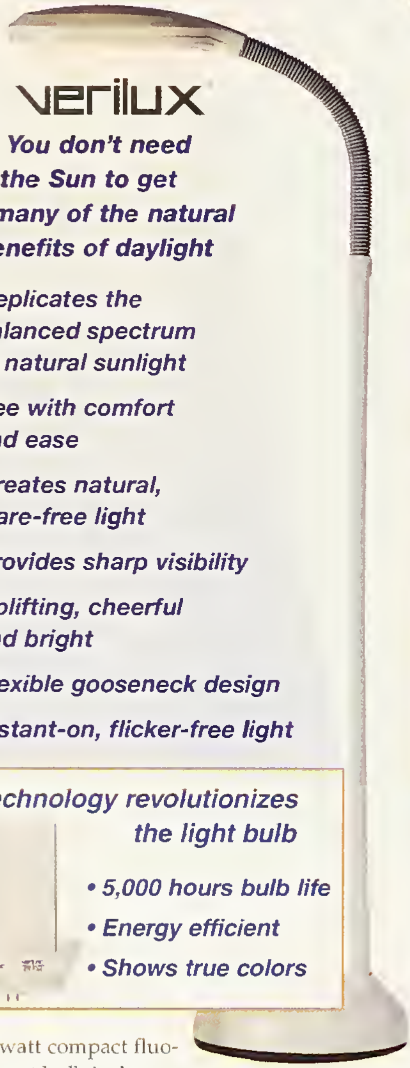
...for hobbies...

...for reading...

...for working...

...and when you need a good source of light for close-up tasks.

The VERILUX® HappyEyes® Floor Lamp will change the way you see and feel about your living or work spaces. Studies show that sunshine can lift your mood and your energy levels, but as we all know the sun, unfortunately, does not always shine. So to bring the benefits of natural daylight indoors, VERILUX, The Healthy Lighting Company™, created the VERILUX HappyEyes Floor Lamp that simulates the balanced spectrum of daylight. You will see with more comfort and ease as this lamp provides sharp visibility for close tasks and reduces eyestrain. Its 27-watt compact fluorescent bulb is the equivalent to a 150-watt ordinary light bulb. This makes it perfect for activities such as reading, writing, sewing and needlepoint, and especially for aging eyes. For artists, the VERILUX HappyEyes Floor Lamp can bring a source of natural light into a studio, and show the true colors of a work. This lamp has a flexible gooseneck design for maximum efficiency, and an "Instant On" switch that is flicker-free. The high fidelity electronics, ergonomically correct design, and bulb that lasts five times longer than an ordinary bulb make this product a must-see.



verilux

You don't need the Sun to get many of the natural benefits of daylight

- *Replicates the balanced spectrum of natural sunlight*
- *See with comfort and ease*
- *Creates natural, glare-free light*
- *Provides sharp visibility*
- *Uplifting, cheerful and bright*
- *Flexible gooseneck design*
- *Instant-on, flicker-free light*

Technology revolutionizes the light bulb

- *5,000 hours bulb life*
- *Energy efficient*
- *Shows true colors*

This light can change the way you live and work

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—Karen R. CA

It really brightens up my office, Thank you.
—Jan L. GA

I use my computer all the time and WOW what a difference. I just put it up and I can see!
—Kathy N. CA

It is really nice and eliminates the glare!
—Nita P. CA

It is a nice sunny product for a windowless office.
—Edith L. NJ

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