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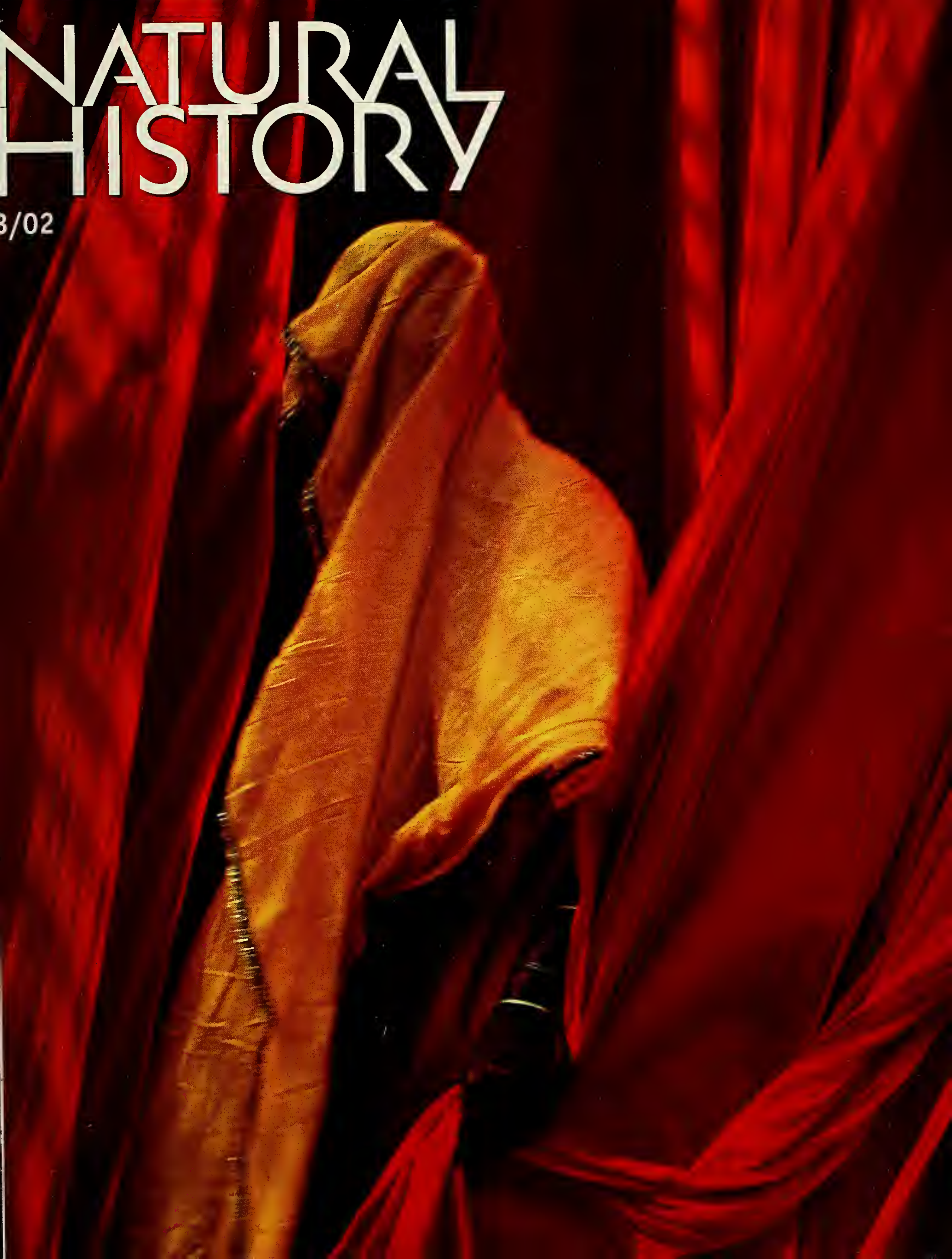

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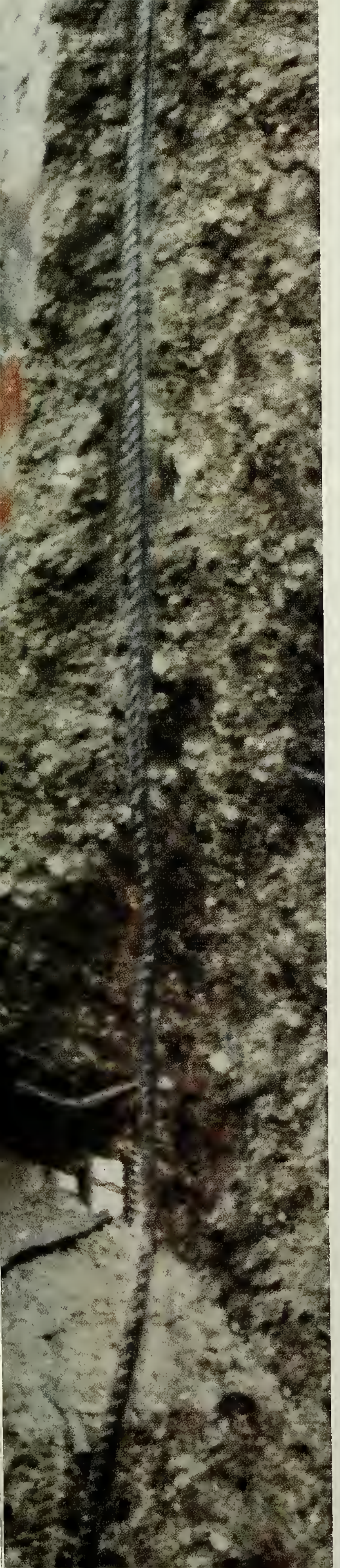

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NATURAL HISTORY

MARCH 2002 VOLUME 111 NUMBER 2

FEATURES

COVER Scene in a textile-dyeing factory in Rajasthan, India

A STORY ON THE HUMAN PERCEPTION OF COLOR BEGINS ON PAGE 64.

PHOTOGRAPH BY XAVIER ZIMBAROO

DEPARTMENTS

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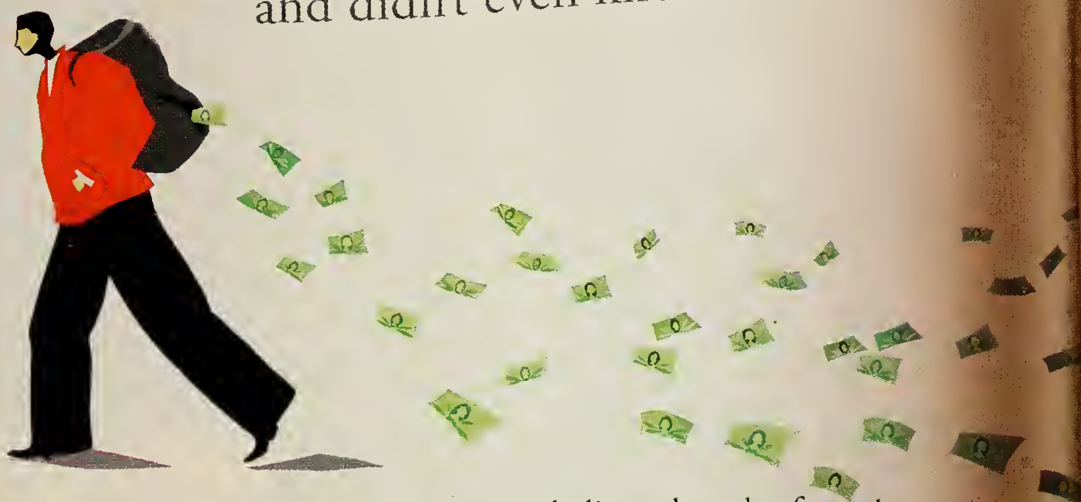
Chapter 8 Expenses

This is the story of the investor who lost $31,701 and didn't even know it.



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UP FRONT

On Earth and in the Heavens

Like many people, I have found myself inexplicably moved by displays of color in the natural world. I have been stopped in my tracks by the sight of a purple iris in the woods. By the milky green of spring's first oak leaves, the soft browns on a female pheasant, the pink of a *Tellina lineata* seashell. By marsh grasses in autumn, by a perfect blue sky after a snowfall, and, of course, by many a sunset.

In this issue of *Natural History,* two physicists address the self-evident yet puzzling phenomenon of color. What *is* color, anyway? Does it lie in the physiology of the beholder? Is it a property of sunlight? To what extent

NORMAN BARKER

does it inhere in the physical structure of the objects we see? Philip Ball ("Seeing Red . . . and Yellow . . . and Green . . . and," page 64) discusses how we see and use color here on Earth, and Neil deGrasse Tyson contemplates celestial hues, which one usually needs a telescope to appreciate fully ("Colors of the Cosmos," page 49).

We humans have unusually well developed color vision, a capacity that may have evolved, as Philip Ball suggests, for important reasons related to survival. Perhaps that's why nature's colors command our attention—and our emotions. Our sense that we ought to pause respectfully and take note of natural hues is epitomized by a mildly *off*-color, yet reverent, observation by a character in an Alice Walker novel: "God gets pissed off if you walk by the color purple in a field somewhere and don't notice."—*Ellen Goldensohn*

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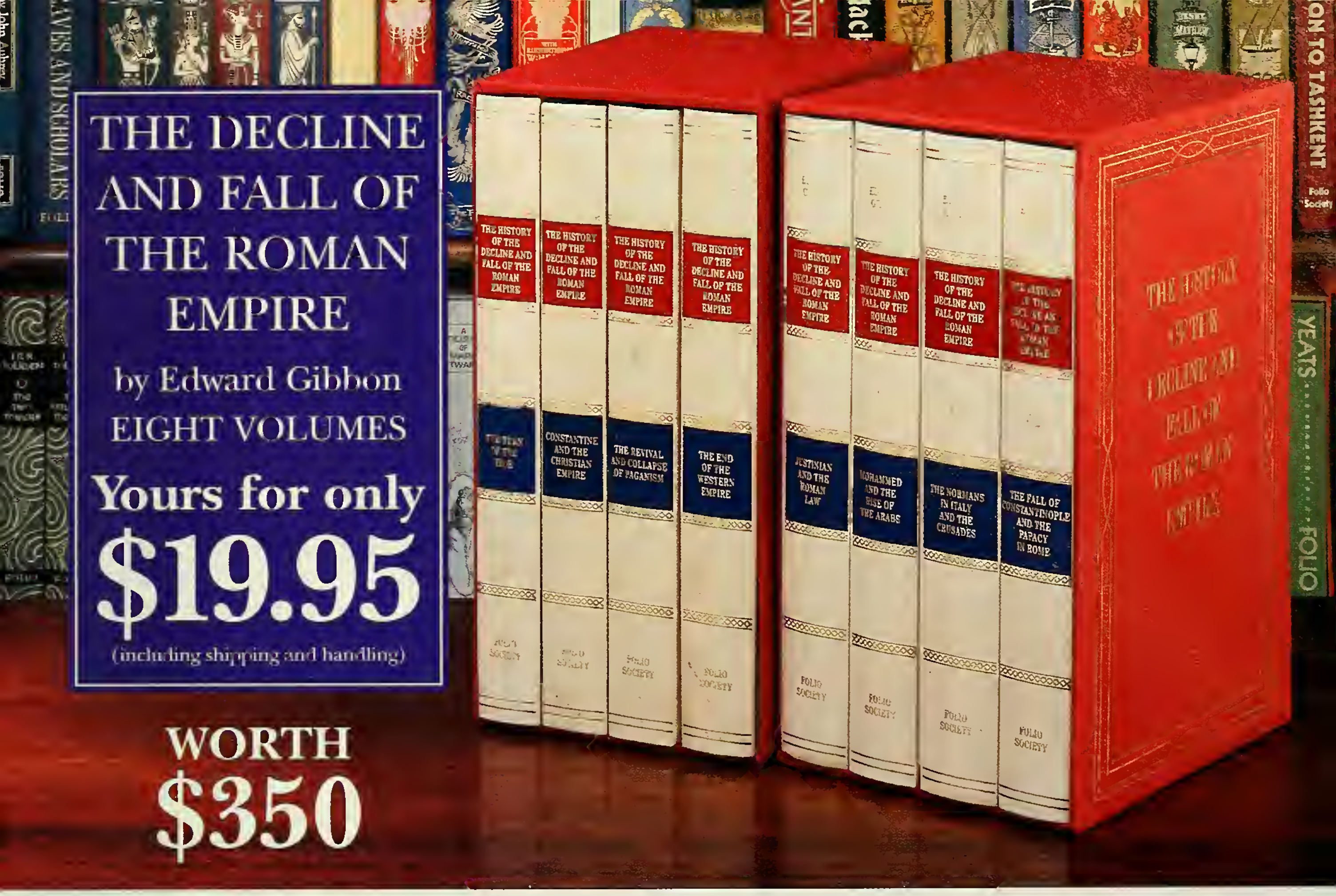

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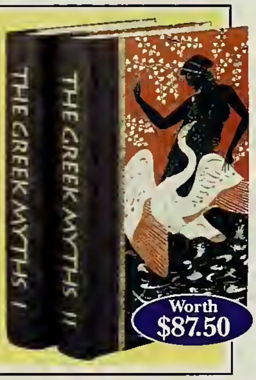

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LETTERS

Before and After

I thoroughly enjoyed reading Robert M. Sapolsky's article "What Do Females Want?" ("Findings," 12/01–1/02), on female mate choice. But I wonder why he focused all of his attention on precopulatory

FRANS LANTING; MINDEN PICTURES

choice, considering the fact that much recent research has revealed that female choice often occurs at the postcopulatory stage. For example, a recent study suggests that female crickets, having mated with many males, "choose" the sperm from males to whom they are least related (*Nature* 415:71, 2002). Females appear to have chemical and other cues, beyond secondary sexual characters, by which to assess mate quality.

Trevor E. Pitcher
Toronto, Ontario

THE EDITORS REPLY: Robert Sapolsky focused on some surprising new findings on "male advertising" and how it influences precopulatory female choice. Please see our November 2000 cover story ("Hidden Choices of Females"), in which author Tim Birkhead discusses postcopulatory female choice. And thanks for drawing our attention to the cricket study.

The Moon and Saturn

In "The Sky in February" (2/02), Joe Rao writes about Saturn's occultation: "Saturn becomes obscured by the Moon's dark portion and reappears about an hour later from behind its bright limb. Depending on one's location, the Moon takes between 90 and 120 seconds to completely cover, and then uncover, the ball and rings of the planet." Should that be "minutes" rather than "seconds"? Or am I completely confused?

Alice Gomez
Albuquerque, New Mexico

JOE RAO REPLIES: When the Moon crosses in front of Saturn, it does indeed take just 90 to 120 seconds for it to completely cover both the planet's globe and its famous rings. Saturn is then out of view behind the Moon for about an hour, until it begins to reemerge. The planet and rings are fully uncovered again within two minutes.

This process is best observed with a telescope. To the unaided eye, the planet resembles a bright star, but when it begins to go behind the Moon it may seem to fade out gradually rather than wink out abruptly, as would the pinpoint of a star.

Simply Connect

What a sweet, utterly beautiful irony that in the same issue (2/02), Aparna Sreenivasan ("Keeping Up With the Cones") should write so well on Geerat Vermeij's first professional love—mollusks—and Vermeij ("Why Are There No Lobsters on Land or Bats at Sea?") should stretch himself even further to write so well as a professional geologist with his heart still in the sea. Over a long career, Vermeij has opened himself up to the worlds of science and the importance of making connections. I am grateful to him and also to the magazine's editors for being the connection makers that you obviously are.

Robert Badra
via e-mail

Match Point

In her article about Margaret Mead entitled "American Icon" ("At the Museum," 12/01–1/02), Nancy C. Lutkehaus says that in a 1995 AMNH publication, Mead was listed as one of the institution's treasures, "no. 38, right between the Folsom Point (treasure no. 37) and the Peregrine Falcon Diorama (treasure no. 39)." I'm a volunteer at the Denver Museum of Nature and Science, and I've checked with our curator: the Folsom Point has been in our possession, on our premises, since its discovery almost eighty years ago.

Carolyn Dain
via e-mail

LORANN S. A. PENDLETON OF AMNH'S ANTHROPOLOGY DIVISION REPLIES: Both museums have a real Folsom Point on display. The two institutions took part in a joint expedition to New Mexico, where the spear points were found near Folsom in 1927. At the time, the discovery of the flint projectiles in the remains of a 10,000-year-old now-extinct bison settled a debate as to how long ago humans had been present in North America.

There has been a long-standing question about who has the first of the two points found embedded in the bison's bone. We must admit, that honor goes to Denver. But ours was also found intact within the carcass, just as it appears in the display. Both points are real, both are original, and both changed New World history.

EDITORS' NOTE: The then-director of the Colorado Museum of Natural History, J. D. Figgins, wrote about the Folsom and other spear points in the May–June 1927 issue of *Natural History*. The list of treasures appears in the 1995 AMNH guidebook *Expedition: Treasures From 125 Years of Discovery*.

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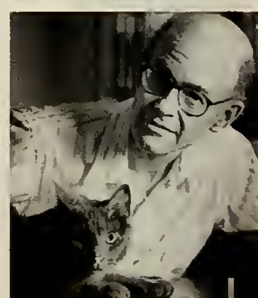
CONTRIBUTORS

Finnish zoologist **Arja Kaitala** ("The Bug That Lays the Golden Eggs," page 32) was drawn to Spain to study the golden egg bug by this species' unusual egg-carrying behavior. Aware of the findings by **Robert L. Smith** concerning paternal care in giant water bugs, she expected to find

that the father golden egg bugs, or at least other close kin, cared for the embryos, thereby ensuring the perpetuation of their own genetic heritage. The situation turned out to be far more puzzling. Smith can't help wondering if there's just something surreal about the Catalonian region of Spain, where he and Kaitala study the bugs: it's the birthplace of the flamboyant artist Salvador Dalí. Kaitala is a professor of zoology at the University of Oulu in northern Finland, and Smith is an associate professor of entomology at the University of Arizona in Tucson.

A freelance writer and consultant editor for *Nature,* **Philip Ball** ("Seeing Red . . . and Yellow . . . and Green . . . and," page 64) earned a Ph.D. in physics from the University of Bristol and has put his science background to good use in the writing of numerous books, including *Stories of the Invisible: A Guided Tour of Molecules*. When not working on a book (one under way is *Utopia Theory: The Physics of Society*), Ball runs the Homunculus Theatre Company, which joins chemistry to the more traditional theatrical arts, such as music, storytelling, and puppetry. Later this year the company will stage his play *The Sun and Moon Corrupted*. His current article was drawn in part from his new book, *Bright Earth: Art and the Invention of Color* (published in February by Farrar, Straus and Giroux, LLC; copyright © 2002 by Philip Ball; all rights reserved).

J. Albert C. Uy ("Say It With Bowers," page 76) credits the writings of evolutionary biologist Ernst Mayr with sparking his interest in how new species arise. As a doctoral student at the University of Maryland, Uy began to investigate mate choice and speciation in bowerbirds, working with Gerald Borgia, a specialist in that group of avian architects. Uy, who was born in the Philippines, has done fieldwork in Central America, Ecuador, and the bowerbird lands of Australia, Papua New Guinea, and Irian Jaya, Indonesia. Now a postgraduate fellow at the University of California, Santa Barbara, he is working on speciation in paradise-kingfishers and white-bearded manakins and looking at environmental factors that could drive changes in mating signals.



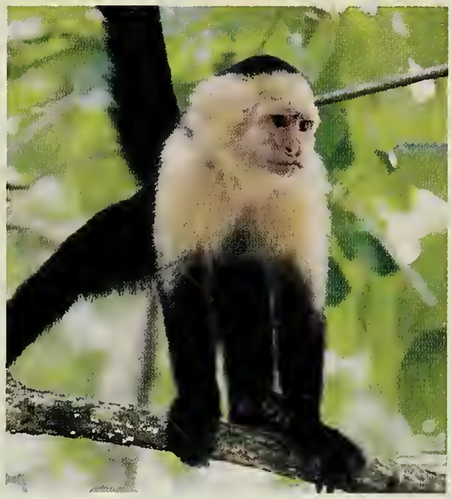
Biologist **Steven Vogel** ("A Short History of Muscle-Powered Machines," page 84)—who has worked at Duke University since 1966, after finishing graduate work at Harvard—has focused his career on biological fluid mechanics. Along the way he has studied how tiny insects fly, how moving squid refill between jet pulses, how burrows can be made to self-ventilate, how air passes through giant silkmoth antennae, and how leaves cope with problems of solar heating in very low winds and with drag in high winds (see his *Natural History* article "When Leaves Save the Tree," September 1993). In his forties he developed an addiction to book writing from which he hasn't recovered; the results so far include *Life in Moving Fluids, Life's Devices, Vital Circuits, Cats' Paws and Catapults,* and *Prime Mover: A Natural History of Muscle.*

Nicole Viloteau ("The Natural Moment," page 102) has spent twenty-five years exploring rainforests in search of her favorite photographic subjects: plants, amphibians, and reptiles. Despite the occasional snakebite, case of malaria, and run-in with poachers, Viloteau is passionate about nature photography, which allows her to combine her fine-arts training with her love of reptiles and also to call attention to what stands to be lost as rainforests are felled. This month's photograph of a snake (taken with a Nikon camera, macro lens, and hand-held flash) is from Viloteau's book *Secret Jungle* (Flammarion, 2001). She is currently at home in Paris, finishing a new, all-reptile volume.

The Sky *Is Calling*

Whether you're a novice or expert, birding is a fun, relaxing way to connect with nature. For the best birding destinations, around the country and around the world, and top equipment, read on.

Costa Rica is a naturalist's paradise, where you can hike through rainforest and see myriad wildlife or gaze at vast numbers of birds in their natural habitats.



Photos: Costa Rica Tourist Board

COSTA RICA *Resplendent Birding*

With 850 species of birds, Costa Rica accounts for one-tenth of the world's bird population.

Birds that have almost disappeared from other areas of the world, such as the endangered scarlet macaw and resplendent quetzal, still can be seen in Costa Rica with relative ease. This Central American country prides itself on its conservation and ecotourism efforts, making it one of the best places on earth to see vast numbers of birds in their natural habitats.

With more than 600 species of endemic birds and easily accessible birding areas, Costa Rica makes it easy for you to see several dozen species a day. The country offers four different habitats, ranging from the oak forest of the **Talamance Mountains** to the cloud forests of **Monteverde**, from **Braulio Carrillo National Park** to the lowland rainforest of the **Osa Peninsula**. Plus the many local birdwatching guides, safe, convenient trails, and specialized birding areas make Costa Rica a must for birders.

Birds to look for:

QUETZALS Many birdwatchers travel to Costa Rica simply to catch sight of the resplendent quetzal, whose name is derived from *quetzalli*, an Aztec word meaning "precious" or "beautiful." The male birds are even more flamboyant than the females, with fuzzy pink head plumage, a bright red belly, and two brilliant green tail plumes up to twenty-four inches long. The quetzal can be seen in the four national parks in which it is protected – **Braulio Carrillo**, **Poás**, **Chirripó**, and **La Amistad** – and the **Monteverde** and **Los Angeles** cloud forest reserves.

HUMMINGBIRDS More than fifty-one species of hummingbirds exist in Costa Rica, including the mangrove, green-crowned brilliant, purple-throated mountaingem, Buffon's plummeteer, and the beautiful fiery-throated hummingbird. Look for these beautiful little birds drinking nectar from flowers and beating their wings at more than 100 beats per minute.

MACAWS Two species of macaws inhabit Costa Rica: the scarlet macaw and the great green, or Buffon's, macaw. The scarlet macaw, whose population has declined dramatically, can be seen at the **Carara Biological Reserve**, **Palo Verde National Park**, **Santa Rosa National Park**, and forested parts of the **Gulf of Nicoya**. The coastal **Parque Nacional Corcovado** boasts more than 1,600 macaws, and as many as 40 may be seen at one time.

Other birds you might expect to see on a birding trip to Coast Rica include six species of toucan, boobies, the rare harpy eagle, pelicans, parakeets, jacamars, antbirds, oropendolas, woodpeckers, scarlet-thighed dacnis, violaceous trogons, tody motmots, lanceolated monlets, and lineated foliage-gleaners.

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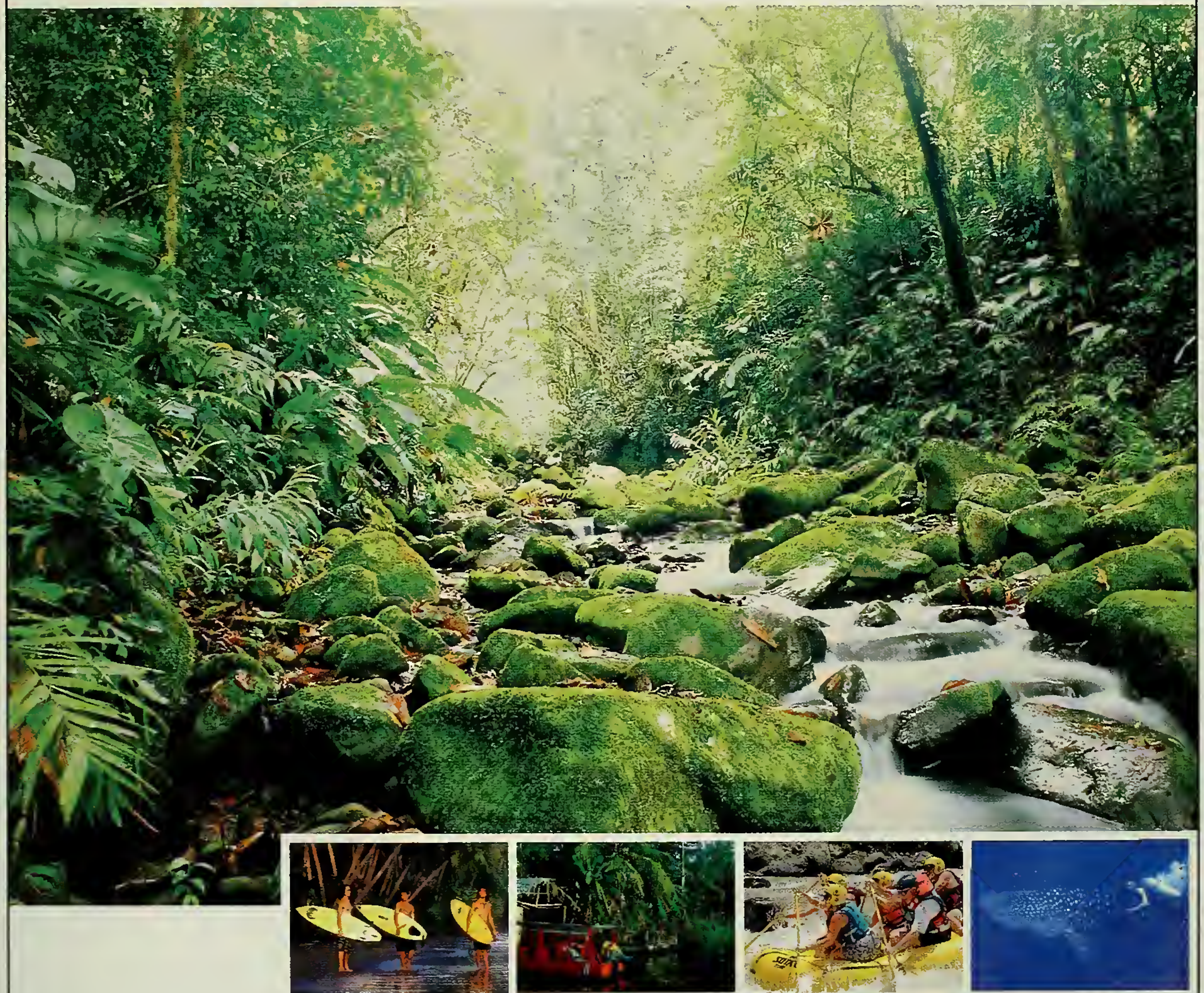

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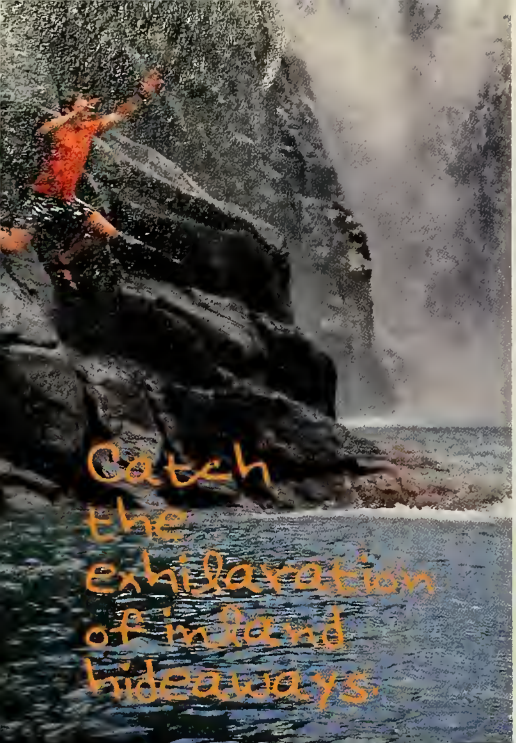

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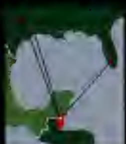

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BELIZE *A Birders' Paradise*

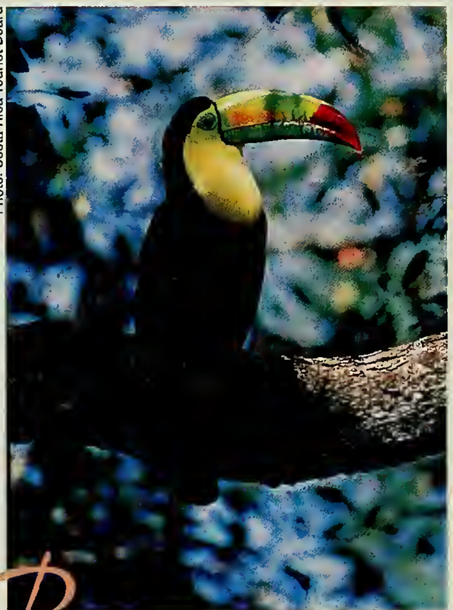

Photo: Costa Rica Tourist Board

Belize boasts more than 570 species of birds including the keel-billed toucan, its national bird.

Belize, a small, English-speaking Central American and Caribbean nation, is located on the **Central, Pacific,** and **Mississippi Flyways**, the paths birds use during migration. Birds from the north visit Belize during the winter months, while the summer months are great for spotting visitors from South America.

Belize's unique location makes it an ideal destination for birding, especially during the prime migration month of October. That's when you can see such rare transients as the yellow-billed cuckoo, American redstart, or ruby-throated hummingbird, along with the indigenous scarlet macaw, king vulture, and black catbird.

With one of the world's richest concentrations of bird species, huge areas of protected habitats, spectacular Maya ruins, tropical forests, coral and mangrove islands, and one of the longest barrier reefs in the world, Belize offers something for everyone.

These protected habitats are prime birding spots: **Blue Hole National Park, Cockscomb Basin Wildlife Sanctuary, Crooked Tree Wildlife Sanctuary, Guanacaste National Park, Man-o-War Caye, South Water Caye,** and **Monkey Bay Wildlife Sanctuary.**

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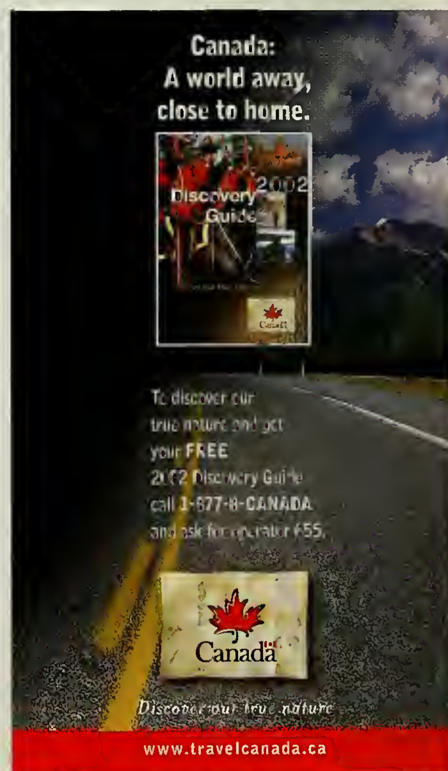

Welcome to New Brunswick, Canada...where bird-watchers answer the call of sandpipers, plovers, rare waterfowl, puffins and bald eagles! From island retreats to protected marshes, this is an ecological haven for hundreds of thousands of winged creatures.

Photos: Tourism New Brunswick

NEW BRUNSWICK

New Brunswick's Bay of Fundy, One of the Marine Wonders of the World, is a prime feeding ground for migrating birds. **Grand Manan Island**, at the mouth of the Bay, is home to more than 390 species of birds, and where John James Audubon, author of *Birds of America*, discovered and sketched entirely new bird species. Nearby **Machias Seal Island** is one of the few puffin colonies in the world where visitors can go ashore and view puffins in their natural habitat. Tour the gleaming mud flats of the **Irving Nature Park**, a 600-acre estuary acclaimed for its amazing bird staging area, or tour the wildlife reserve of **Cape Jourimain Nature Centre**, where over 170 species of birds are protected by the Canadian Wildlife Service. In August, you'll learn why bird-enthusiasts flock to **Johnson's Mills** and **Marys Point Bird Sanctuary**. Here tens of thousands of semi-palmated sandpipers and other shorebirds land to feed on the rich salt marshes that dominate the landscape. And visit the interpretive center of nearby **Fundy National Park** to discover why Fundy's ecosystem is so important to many of North America's rare birds.

Above: The Irving Eco-Centre, La Dune de Bouctouche
Right: The colorful puffin

Situated on one of North America's major migratory bird routes, the **Tantramar Marshes** offer prime nesting and feeding grounds for marsh hawks and hundreds of waterfowl. Constructed over 200 years ago, the marshes are the largest man-made agricultural land mass in Canada and home to the **Sackville Waterfowl Park**. This 55-acre park has a network of boardwalks and walkways that allows species such as the common snipe and the tree swallow to be observed without harming the lush grasses and wetland they thrive in. The **Irving Eco-Centre, La Dune de Bouctouche** also employs a boardwalk system along one of the last remaining white sand dunes on the northeastern coast of North America. Witness rare plants and see the tern and endangered piping plover nest in fragile marshes. Or head up north to picture-perfect **Heron Island** and **Miscou Island**, the site of the Oldest Lighthouse in Eastern Canada and home to all kinds of shore birds.

Welcome to the wonder of bird-watching in New Brunswick, Canada!

Photos: Newfoundland and Labrador Tourism

Above: Seabirds cluster at Cape St. Mary's Ecological Reserve, the most accessible seabird colony in North America. The bald eagle, left, is easily sighted in Newfoundland.

NEWFOUNDLAND & LABRADOR

Millions of birds. No zoom lens required.

Newfoundland – the place where the New World begins. Come feel the power of the Atlantic as it meets North America for the first time, at **Cape Spear**. Come to **St. John**'s and take a walk on Water Street, the oldest street in North America. Look out over a naturally sheltered harbor, where forty vessels lay anchored forty years before the *Mayflower* landed.

In **Labrador**, one of the last great wilderness areas on earth, 600,000 caribou, plus moose, wolves, lynx, porcupines, and polar bears roam on more than 300,000 square kilometers of unspoiled land.

Newfoundland is truly for the birds: gannes, murres, kittiwakes; storm-petrels, ospreys, gulls; razorbills, ravens, and "foxy toms." More than 350 species of birds make Newfoundland the seabird capital of North America. It is quite likely the best place in the world to view seabirds up close in their natural habitat. More than 95 percent of all the seabirds that congregate here gather in approachable protected reserves. Nowhere else are the cacophonous sounds and colorful personalities of these creatures so accessible.

At **Witless Bay Ecological Reserve** – a short drive from St. John – don your hat and look up. The Atlantic puffin nests here in staggering numbers; more than 90 percent of the continent's entire population of puffins lives in Newfoundland and Labrador. These stout, wobbly little "sea parrots" are amazing swimmers and fishers.

Go inland to see falcons and hawks, boreal owls, and the place where the eagle has landed. The province is home to one of the largest American bald eagle populations in North America.

At **Cape St. Mary's Ecological Reserve**, the gannet population is so tightly clustered you almost wonder if the birds will land on each other. Hoping to see a Leach's storm-petrel? Try **Baccalieu Island**, home to seven million Leach's storm-petrels, the largest colony of these birds in the world.

Dozens of tours all over the province combine whale watching with birdwatching. Humpbacks visit Newfoundland and Labrador from May to September, arriving to feed on capelin, krill, sand lance, and squid. They'll give you a wave with their flukes before a deep dive for dinner and offer a flipper salute when the mood strikes them.

Icebergs are thrown in for free. Ten-thousand-year-old mountains of fresh water, calved from the massive glaciers of Greenland and the Arctic, glide past in spring and early summer. Humpbacks, caribou, plus birds by the millions. Flights arriving daily. Only in Newfoundland and Labrador.

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WEST VIRGINIA *Almost Heaven for Birders*

With 1.3 million acres devoted to public wildlife-associated recreation and 316 species of birds, **West Virginia** is a haven for wildlife and birders alike. There are lots of opportunities for birding, from the banks of the **Ohio River** to the **Appalachian Mountains**, but the best birding is found in three national forests in eastern West Virginia: **Monongahela, George Washington**, and **Jefferson**.

The **Monongahela National Forest**, which includes most of West Virginia's **Allegheny Mountains**, boasts a 230-species bird-list including warblers, a wide variety of migratory hawks, and songbirds. Birding is best here during spring, summer, and fall.

In the southern part of the Monongahela Forest, **Watoga State Park** shelters a variety of wetland birds, including American woodcocks, wood ducks, and Louisiana and northern waterthrushes. Also within Monongahela, **Cranberry Glades** is home to at least six species of birds – Swainson's and hermit thrushes, mourning warbler, northern waterthrush, swamp sparrow, and purple finch.

Don't miss the **Hanging Rock Raptor Observatory**, a monitoring point for hawk, eagle, falcon, and osprey migration along the birds' eastern route.

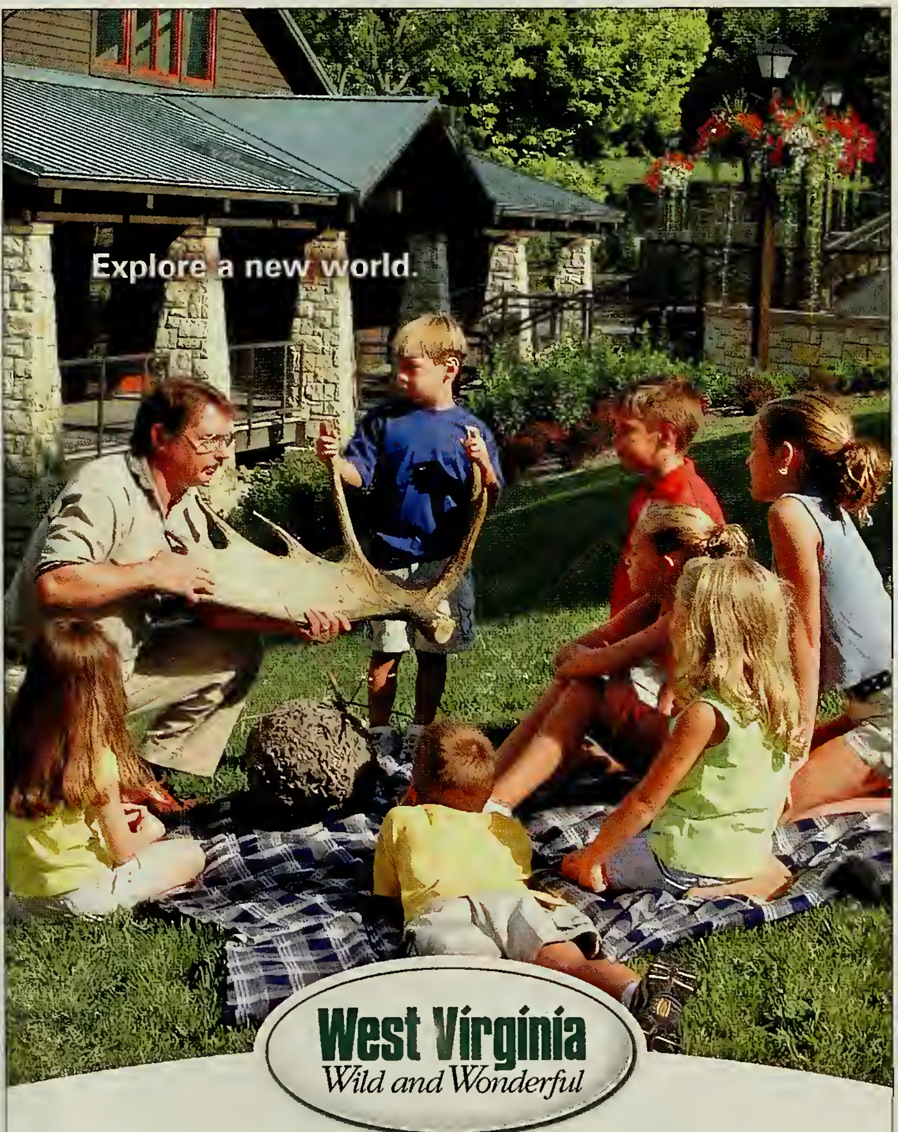
Non-birding points of interest include **Harper's Ferry**, a restored 1850s town just on the border of Maryland and Virginia; **Lewisburg**, the oldest and most attractive town in West Virginia; and the state's capital city, **Charleston**. Those interested in glassmaking, Civil War history, railroad history, and in simply enjoying the fall foliage will also have lots to do in West Virginia.

BLOCK ISLAND
Secluded Splendor

Block Island, Rhode Island, may be small, but it is one of the premier birding spots on the East Coast.

Thanks to Block Island's aggressive protection of its avian habitats, both the serious and novice birder will enjoy exceptional viewing. At **The Block Island Refuge** one can see diverse species, especially during the spring and fall migrations.

Plus, Block Island offers old New England charm, exquisite restaurants and quaint shops. The island is only accessible by ferry or boat, adding to its secluded appeal.



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AMERICAN CRUISE LINES *Trips Through History*

Photo: American Cruise Lines

Block Island is only five miles long and three miles wide, but it's an exceptional spot for birding.

Voyage through America's historic inland waterways, along lazy rivers, secluded inlets and coves, bustling bays, and quiet intracoastal waters, while immersing yourself in the country's rich history, cuisine, and natural beauty. **American Cruise Line** trips are ideal for birders thanks to their wildlife-oriented itineraries, large observation decks, and on-board naturalists and historians.

As you wind your way along scenic waterways, you'll have an unobstructed view of the local birdlife. Then hop off at historic seaports, rustic villages, and picturesque cities for naturalist-led excursions. Upon your return, dine on American's best local specialties, created by American Cruise Line's culinary-institute-trained chefs, before retiring to your oversized stateroom.

Itineraries ideal for birders are: **New England Islands, Historic Antebellum South, Maine Coast and Harbors, Great Rivers of Florida, Mid-Atlantic Inland Passage, Hudson River, Historic Chesapeake Bay, East Coast Inland Passage,** and **Historic Long Island Sound.**

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Block Island

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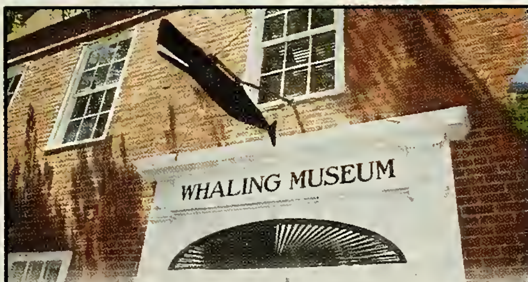

Discover the magical seafaring heritage of New England's rustic seaport villages and quaint island towns! Spend 8 days "harbor hopping" to Block Island, Martha's Vineyard and Nantucket Island in the comfort of a brand new, 31-stateroom cruise ship. Your ship will dock in the heart of each port, just steps away from historic whaling museums, charming village shops, scenic bluffs and cobblestone streets. Don't miss this opportunity to explore the cultural riches of New England with American Cruise Lines.

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Photo: Norwegian Tourist Board

Wander through the narrow streets of Bergen, founded by Hanseatic traders in the twelfth century.

LITTLE ST. SIMONS ISLAND *Big On Shorebirds*

If it's shorebirds you are looking for, then **Little St. Simons Island** is the place for you. Regarded as one of the best locations for birding on the Georgia Coast, this island has seven miles of pristine beaches, 10,000 acres of undeveloped wilderness, and thirty-seven species of shorebirds. Located along the **Atlantic Flyway**, Little St. Simons Island has more than 280 bird species, including oystercatchers, piping plovers, and greater and lesser yellowlegs.

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Your journey begins in the west coast maritime city of Bergen, which originated in the twelfth century. This historic seaport, which once drew merchant ships from all over the Atlantic and Baltic seaboards, is famous for its picturesque wharf section, Bryggen.

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NORWAY
Naturally Splendid

The land of the midnight sun, the aurora borealis blazing across the winter night sky, the picture-perfect fjords that wind their way into the country from the coast: It's nature that makes **Norway** truly extraordinary.

This spectacularly beautiful country is home to a variety of birds and wildlife. About 240 different species of birds, both endemic and migratory, nest in Norway. Mostly you'll find immense numbers of sea birds nesting in the cliffs along the coast, but you can also see birds in the **Oslo** woods and spot eagles and puffins during a **North Cape** birdwatching safari.

In summer, enjoy sunsets at 10:30 p.m. and sunrise at 3:00 a.m. During the dark winter months, the aurora borealis flames across the heavens. It's Norway, naturally.

Photo: Per Eide/Norwegian Tourist Board

Norway's transparent high-mountain fjords, formed by glaciers, connect inland areas with the open sea.

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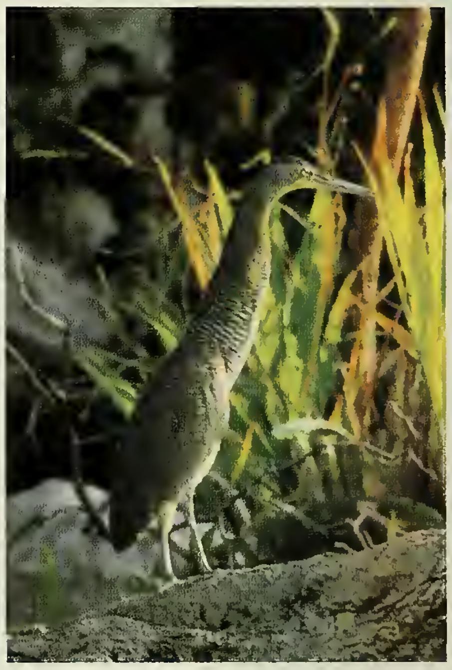
Photo: Costa Rica Tourist Board

Get close: Take a good pair of binoculars on your birding adventure.

GETTING YOUR SIGHTS

Wild birds rarely let us get close enough to get a good look, so choosing a good pair of binoculars is crucial. Things to consider in making the decision are size (do you prefer full-size or compact?), magnification level (usually 7x, 8x, or 10x is good), lens size (usually 42), and ergonomics (are the binoculars comfortable on your nose and in your hand?).
Binocular Care Use a good optical cleaning brush rather than cleaning solutions, which may scratch lenses over time. Always keep the dust caps on when not in use.

ZEISS *Optical Pioneers*

For 155 years, **Zeiss** has been the epitome of optical pioneering, creating innovative products ideal for discriminating birders. Using only the finest glass and top-quality components, Zeiss binoculars feature accurate color, stunning contrast, crisp imagery, and a lifetime of satisfying performance.

Each model is rugged enough to endure the worst conditions the world has to offer. Plus Zeiss binoculars and monoculars are backed by a Limited Lifetime Transferable Warranty: the first ever for this class of optics.

Now Zeiss is also a pioneer in avian conservation. On January 17, 2002, Zeiss announced that the search for the ivory-billed woodpecker will begin in southeastern Louisiana. A team of five official searchers and other birding experts will spend 30 days in the **Pearl River Wildlife Management Area**, conducting the most extensive search in decades for the ivory-billed woodpecker in this part of the state. This bird is widely believed to have been extinct for at least 50 years.

Photo: Eagle Optics

The new Ranger Platinum Class series is "as clear and bright as a crisp midwestern morning," says Father Tom, above.

EAGLE OPTICS
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Birding experts agree that **Eagle Optics** provides the highest quality, durability, reliability, and service for birding and outdoor equipment. Eagle not only carries a full line of optical gear from all major manufacturers but also puts its experience and knowledge to work for you — designing products like the exciting Ranger Platinum Class.

Plus Eagle Optics donates time, equipment, expert personnel, and much-needed funding to a variety of organizations, including Operation Migration, International Migratory Bird Day, and numerous festivals such as the Florida Birding Festival and the Rio Grand Valley Birding Festival.

SWIFT
Real World Performance

For the past five years **Swift Instruments, Inc.** has called on birdwatcher Warren Harrington, a conservation officer in Marshfield, Massachusetts, to field-test new binoculars under "real world conditions."

Harrington, who began his birding career back in 1950, has spent every vacation birding — from the jungles of **Borneo** to the frozen tip of **Argentina, Tierra del Fuego**.

"When you have just one chance to identify the birds of a remote area of the world, you want binoculars that are going to stand up under all types of conditions," Harrington explained.

For his latest trip, Swift asked Harrington to test the new waterproof 820 Swift Audubon binocular, a good idea when traveling by dugout canoe.

Harrington's latest adventure was shared with his new bride, Ellie. Swift asked her to field-test the Swift Audubon roof prism binoculars, a lighter, smaller binocular. Both performed flawlessly in the humid tropical climate. The Harringtons traveled to **Chan Chich** in Belize, where Warren increased his life list to 3,760 and Ellie brought her total up to 713.

They were able to add footnotes to their list: one crocodile and the south end of a jaguar heading north...

IN SUM


New Caledonian crow

GAVIN R. HUNT

CROWS SHOW THE RIGHT STUFF The recent discovery of a right-side visual preference in a species of crow has challenged the belief that we're the only creature with a predictable—and overwhelming—bent for taking one side. Certain populations of parrots favor a particular foot when manipulating their food, and some wild chimpanzees favor a particular hand, but this crow and humans are the only known examples of entire species with a right-sided preference in manipulatory tasks.

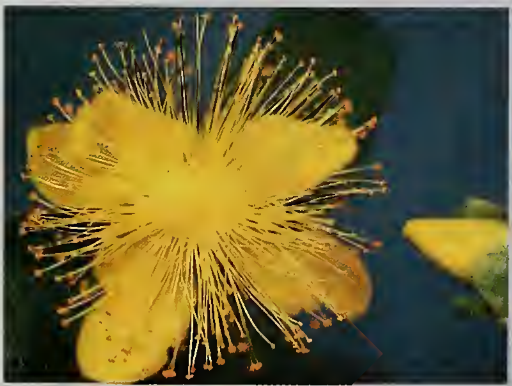
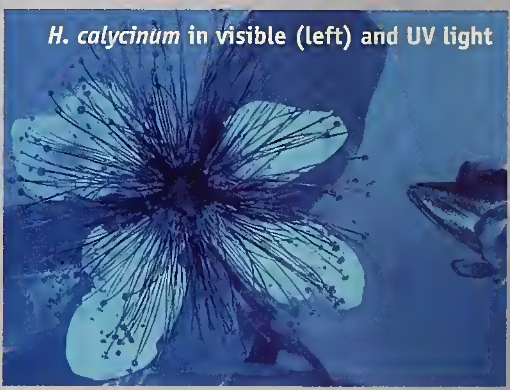
With its beak, the New Caledonian crow *(Corvus moneduloides)*, a native of the South Pacific island of Grande Terre, the main island of New Caledonia, constructs tools from leaves of the pandanus tree, using them to pluck insects from rainforest vegetation. This corvine do-it-yourselfer sometimes fashions the tool from the left edge of a leaf and sometimes from the right. An unmistakable mark—known as a counterpart—remains on the leaf edge, recording the crow's choice of working direction. When cutting a tool from a leaf's left edge, the crow turns the right side of its head (and its right eye) toward the leaf, and vice versa when it cuts the leaf's right edge.

Psychologists Gavin R. Hunt and colleagues at the University of Auckland in New Zealand collected more than 3,700 of these counterparts on Grande Terre. They found that all across the island, crows preferred to make tools from left leaf edges, even when the leaves grew in a direction that would have made it easier to work at the right. Working at the left edge allows a crow to keep its right eye on the complex task at hand.

Previously scientists suggested that human right-handedness might be a consequence of the evolution of language, since language and right-handedness are both predominantly controlled by the left side of our brain. But the new finding supports the idea that right-handedness in a species is an adaptation for the efficient programming of complex sequential processes—including language and the construction of crow tools. ("Laterality in Tool Manufacture by Crows," *Nature* 414, 2001)—*Kirsten L. Weir*

NEW LIGHT ON UV When we look at *Hypericum calycinum*—a flower in the Saint-John's-wort family—we see a uniformly yellow blossom. When insects look at it, they see a patterned blossom. Made by ultraviolet-absorbing pigments, such patterns are present on the "facial" surfaces of many flowers; they're thought to be among the distinguishing features that draw pollinators.

What's surprising about *H. calycinum*, according to Matthew Gronquist and colleagues at Cornell University, is that as well as having a combination of UV pigments where we (or insects) might expect to find them, it also has them—in extraordinarily high concentrations—in unexpected places, namely the anthers and ovarian wall. Moreover, the pigments that are most concentrated at these unlikely locations are in the category known as DIPs (dearomatized isoprenylated phloroglucinols), which were not previously shown to function in floral UV patterning. They were, however, known to repel both mites and aphids, and new tests show that one DIP (hypercalin A) is in fact toxic to a caterpillar. So, say the researchers, chances are that UV pigments perform dual functions in *H. calycinum:* giving the come-hither to would-be pollinators while also warning off would-be predators. ("Attractive and Defensive Functions of the Ultraviolet Pigments of a Flower *[Hypericum calycinum]*," *Proceedings of the National Academy of Sciences* 98:24, 2001)



***H. calycinum* in visible (left) and UV light**

THOMAS EISNER; CORNELL UNIVERSITY

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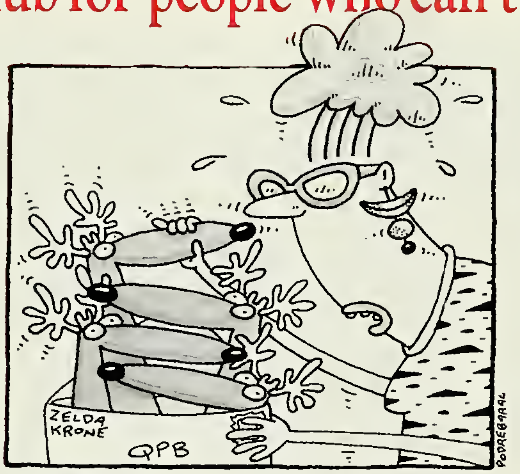

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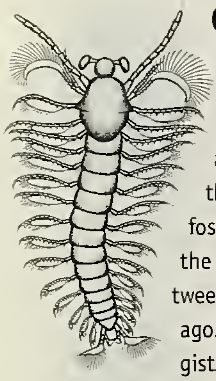


CRUSTY CRUSTACEAN

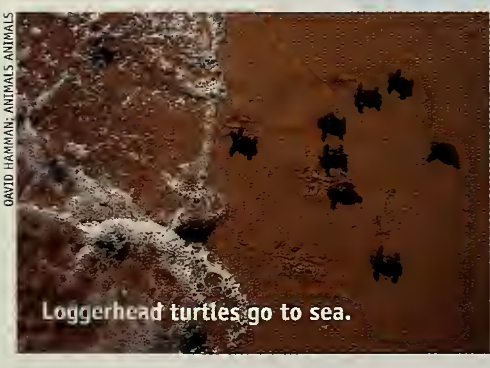
Crustaceans are a large and varied crew, with some 39,000 species living today and many more known from their fossil remains. The oldest fossil crustaceans date back to the Late Cambrian Epoch, between 512 and 505 million years ago. Now a team of paleontologists has found a fossilized arthropod they're betting is an early member of the subphylum Crustacea. If they're right, that would make it the oldest known crustacean, dating back 540–520 million years, to the Early Cambrian.

Paleontologist Jun-Yuan Chen, of China's Nanjing Institute of Geology and Palaeontology, and colleagues examined more than 130 fossils of the newly discovered arthropod, which they named *Ercaia minuscula*. The tiny creature, averaging just two to three millimeters in length, shares with early noncrustacean arthropods such characteristics as forked appendages. But, say the researchers, other features that suggest "crustacean affinities"—including five pairs of head appendages rather than the four pairs seen in most other Early Cambrian arthropods—probably peg the creature as a crustacean. ("The Origin of Crustaceans: New Evidence From the Early Cambrian of China," *Proceedings of the Royal Society of London* B 268, 2001)—*Kirsten L. Weir*

ANIMAL MAGNETISM

As soon as they dig themselves out of their sandy nests on the shores of eastern Florida, hatchling loggerhead sea turtles *(Caretta caretta)* set out on a 9,000-mile journey lasting anywhere from six to twelve years. Migrating in the circular system of currents known as the North Atlantic Gyre, they first head east toward Portugal, then south past northern Africa, and finally west, back to Florida, where they may spend another five to ten years maturing.

AFTER LOHMANN LAB



Loggerhead turtles go to sea.

DAVID HAMMAN; ANIMALS ANIMALS

A turtle that strays just slightly north of this migration route can be swept farther east, past Great Britain and into fatally frigid waters; if it ventures too far south, the turtle will be carried away by southern currents and never return home. Fortunately, hatchling turtles come equipped with a built-in navigational system, according to new research by biologist Kenneth J. Lohmann, of the University of North Carolina, and his colleagues.

Previous studies of baby loggerheads showed that the turtles can detect certain geomagnetic features. But a question remained: Can turtles tell what oceanic region they're in by identifying its unique magnetic field? To find out, the researchers surrounded a pool of water with computer-controlled coils mimicking the magnetic fields of three specific locations along the loggerheads' migratory route (see map above), then used electronic tracking to find out which way the turtles swam when the magnetic fields were altered.

Sure enough, the turtles paddled in different directions when exposed to different magnetic fields. Turtles experiencing magnetic fields like those off the coast of northern Florida, for example, swam east-southeast, as turtles should if they are to have any hope of hitting the North Atlantic Gyre. And they managed this without ever having spent a single day in the ocean. ("Regional Magnetic Fields as Navigational Markers for Sea Turtles," *Science* 294, 2001)—*Kirsten L Weir*

SMELLS LIKE HOME

Fish and houseguests supposedly stink after three days. Yet in that same interval, the parasitic wasp *Polistes sulcifer* can take over the home of a closely related species, adopting an odor that pleases its hosts. Native to the Caspian Basin in central Asia, the parasitic wasp exploits the fact that many social insects distinguish friend from foe via smell; the invaders succeed by assuming the very particular odor of the colony they have usurped.

To show that having the correct odor is necessary for a *P. sulcifer* wasp to be accepted by its typical victim, *P. dominulus*, Matthew F. Sledge and colleagues at the University of Florence in Italy exposed *P. dominulus* to several different groups of wasps: nest-mate parasites and workers, foreign parasites and workers, and lures (dead *P. dominulus* queens to which extracts of hydrocarbon molecules from the cuticles of each of those kinds of wasps had been applied). The tested wasps rarely attacked the nest mates or the lures that had been treated with their smells, but they were significantly more aggressive toward foreign-smelling wasps and lures. How the parasites come to smell like their hosts is not clear. The authors suggest that the invaders pick up *P. dominulus* hydrocarbons through either grooming or food exchanges with the host wasps—or even from the nest material—rather than by producing the chemicals themselves. If the hosts have any defenses against such parasitism, they have not been investigated. ("Recognition of Social Parasites as Nest-Mates: Adoption of Colony-Specific Host Cuticular Odours by the Paper Wasp Parasite *Polistes sulcifer*," *Proceedings of the Royal Society of London* B 248, 2001)—*T. J. Kelleher*

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FINDINGS

Phyllomorpha laciniata

The Bug That Lays the Golden Eggs

An insect's odd looks are nothing compared with its odd behavior.

Story by Arja Kaitala and Robert L. Smith ~ Photographs by Robert L. Smith

Stretching from the Pyrenees to the Mediterranean Sea, the Catalonian region of northeastern Spain is a sunlit land of flowering meadows and rocky crags, vineyards and ancient fieldstone walls, lollipop-like pines and spreading cork oaks. But to us, its main attraction is the golden egg bug *(Phyllomorpha laciniata)*, a small, plant-sucking insect festooned with elaborate spines. Even the most jaded entomologist would concede that this bug looks pretty bizarre.

The fancy spines help the bug blend in with dried parts of its host plant, *Paronychia argentea* (sometimes called Algerian tea), a member of the carnation family. Finding golden egg bugs in the field can thus present a real challenge to the researcher. The more daunting task, however, is explaining their behavior. Most species of bugs lay their eggs on foliage or other locations in their habitat, and very few tend the eggs in any way. Female golden egg bugs, by contrast, usually lay their eggs on other adults of their own kind, which carry them around until the young nymphs hatch. Evolutionary theory would suggest that egg carrying has evolved in golden egg bugs because it ensures that more offspring survive. But exactly how does it help them? A

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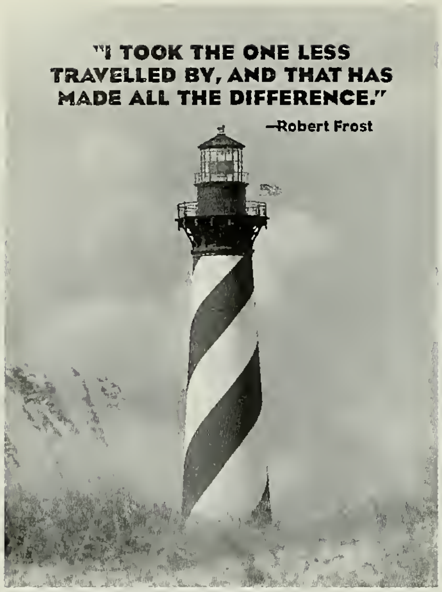

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further expectation is that the bugs would have evolved to provide care (in the form of egg carrying) for their own progeny, which perpetuate their genetic heritage, rather than for unrelated individuals. But is that the case?

The golden egg bug ranges over most of the Mediterranean countries; the first description of the species, from 1894, was based on observations in southern France. The early accounts of this "leaf-footed bug" include drawings of individuals carrying a few eggs haphazardly stuck to their back. The sketchy comments that accompany the drawings indicate that both males and females carry eggs. This pattern contrasts with the behavior documented among certain species of giant water bugs, in which only the male carries the eggs (as many as 140 can be neatly packed on his back). In the case of the water bug, the eggs a male carries are those he has fertilized; he therefore has a stake in their survival. The male not only carries the eggs but keeps them well aerated in the water, which is essential to the embryos' survival (see "Daddy Water Bugs," by Robert L. Smith, February 1980).

Golden egg bugs and giant water bugs are only distantly related, but the convergence of their unusual egg-carrying behavior makes them ripe for comparison. Because of our two specialties (Kaitala's being the golden egg bugs, Smith's the water bugs), we have collaborated on some recent golden egg bug research, which also involves other colleagues and Kaitala's students. We have set out to explore a number of questions: Is the attachment of eggs to bugs (instead of, say, to vegetation) inadvertent or deliberate, obligatory or optional? Are the egg carriers willing recipients, reluctant, or just plain oblivious? Are males or females more likely to carry eggs? What is the genetic relationship of bugs to the embryos they carry? Are costs associated with carrying eggs? Do carriers do anything special for the eggs? Can egg carrying be considered parental care, or is it something else? Are the offspring of females that attach their eggs to other bugs much more likely to survive?

Earlier work by the Kaitala team had determined how eggs were distributed within a population. The vast majority of bugs collected by the team carried between one and thirty eggs, with the average being five (counting still-attached empty shells). The eggs were attached with strong glue, most often to the bugs' backs but not infrequently to their undersides, legs, heads, and even antennae. Females carried almost one-third of the eggs, males slightly more than two-thirds.

Most of these eggs were gold colored, but some were white and a few pearly black. Tracking the eggs' development revealed that all white eggs soon turn yellow, then deepen in color to a golden sheen. Thus, white was the color of freshly laid eggs—a fact later confirmed by observing bugs depositing their eggs. A couple of weeks after being laid, a golden egg produces a tiny, cottony hatchling. Young bug nymphs hatch in the spring and abandon their carriers, leaving the empty eggshells behind, still attached. Nymphs feed on their host plant's flowers and molt five times. The fifth molt produces winged adults that spend the winter buried in plant litter. There they await the spring, dispersing widely at the beginning of the new reproductive season.

And what about a black egg? It gives rise to something quite different—a small wasp. What has happened

A courting male is apt to end up with an egg glued onto him by the object of his advances—usually on his back, but often on his head, a leg, or even an antenna.

here is that a parasitic hymenopteran has injected her tiny egg into a golden egg. The wasp larva has grown within the egg, feeding on and ultimately destroying the golden egg bug embryo.

Laboratory and field observations, together with some experiments, have thrown light on how and where eggs are deposited. Females ready to lay fertilized eggs always seem eager to lay them on other bugs, regardless of their sex. Potential female recipients are often able to resist being encumbered, and they can also simply avoid other females, but males, in their persistent attempts to copulate with females, find escaping this burden difficult. Despite his resistance, a courting male is apt to end up with an egg attached to him by the object of his advances, and even so, he will only infrequently be rewarded with copulation. Chances are that most or even all the eggs a male receives have been fertilized by rival males.

In one experiment, we captured females from the field and removed any eggs affixed to them. Half the females were immediately preserved and dissected, and the other half were sequestered together in an enclosure containing host plants. A day later, we removed the bugs in the second group from their arena and counted their attached eggs; we then preserved and dissected these bugs as well. In comparing the two groups, we found that the females taken directly from the field had several eggs in their oviducts, while those that had spent time in the enclosure had fewer or none. Apparently the relatively crowded conditions in the enclosure made it easier for the females to find carriers for their eggs, which they were quick to unload. Conversely, this suggests that in the natural setting, where bugs are less densely distributed, females find it more difficult to locate carriers and prefer to retain mature eggs rather than lay them on their host plant.

When a courted female permits mating, the pair remain coupled, end

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to end, for many hours, even a day. They move together very slowly, inevitably in the direction preferred by the female; being larger, she drags her mate bumping along behind her. Many insects engage in similarly protracted copulations, and the duration is usually controlled by the male, which holds on to the female's genitalia until he is ready to release her. In general, marathon copulations typically serve male reproductive interests, since the female cannot mate with other males in the meantime, and the copulating male is able to deliver large quantities of sperm into her storage organs. This probably holds true for golden egg bugs as well.

Pairs of mating golden egg bugs provide excellent targets for any previously mated female looking for a place to lay her eggs. She will follow such pairs around, taking advantage of their awkward circumstance to lay eggs on both participants. This behavior explains how otherwise resistant females come to carry a third of the eggs.

Females, of course, are never the mothers of the eggs they carry, because they cannot lay eggs on themselves. But what about male egg carriers? Male giant water bugs that carry and brood eggs always insist on copulating with females several times before they will stand still to receive eggs. Over the course of receiving a clutch of eggs, they also repeatedly interrupt the egg laying for additional couplings. This kind of control over the process means that recipient males are virtually certain to be the fathers of the embryos they carry. This is not the case with male golden egg bugs, however. Molecular genetic studies conducted at Stockholm University on a sampling of males confirmed that they had fathered only a very small percentage of the eggs they carried.

Either egg carrying is a rare form of altruism, or the females have succeeded in exploiting others of their species—much as parasites exploit their hosts.

We therefore conclude that egg carrying in golden egg bugs cannot be considered parental care. In addition, whatever its benefits may be, egg carrying appears to be a purely passive behavior. Hundreds of hours of observations have failed to reveal any nurturing duties comparable to the active aeration of the eggs that is done by male giant water bugs.

A mating pair, above, remains coupled for hours, improving the chances that the male (right) will transfer sufficient sperm to father offspring. The eggs the male carries, however, were probably fertilized by a rival.

Xavier Espadaler, a professor of biology at the University of Barcelona and a member of our research group, is the leading expert on the systematics and ecology of Iberian ants. Not surprisingly, he was at least as excited by the ants found at our study site as he was by the golden egg bugs. This was our good fortune, because his favorite insects proved to be the crucial ecological element in clarifying the advantage that female golden egg bugs derive by laying their eggs on other bugs.

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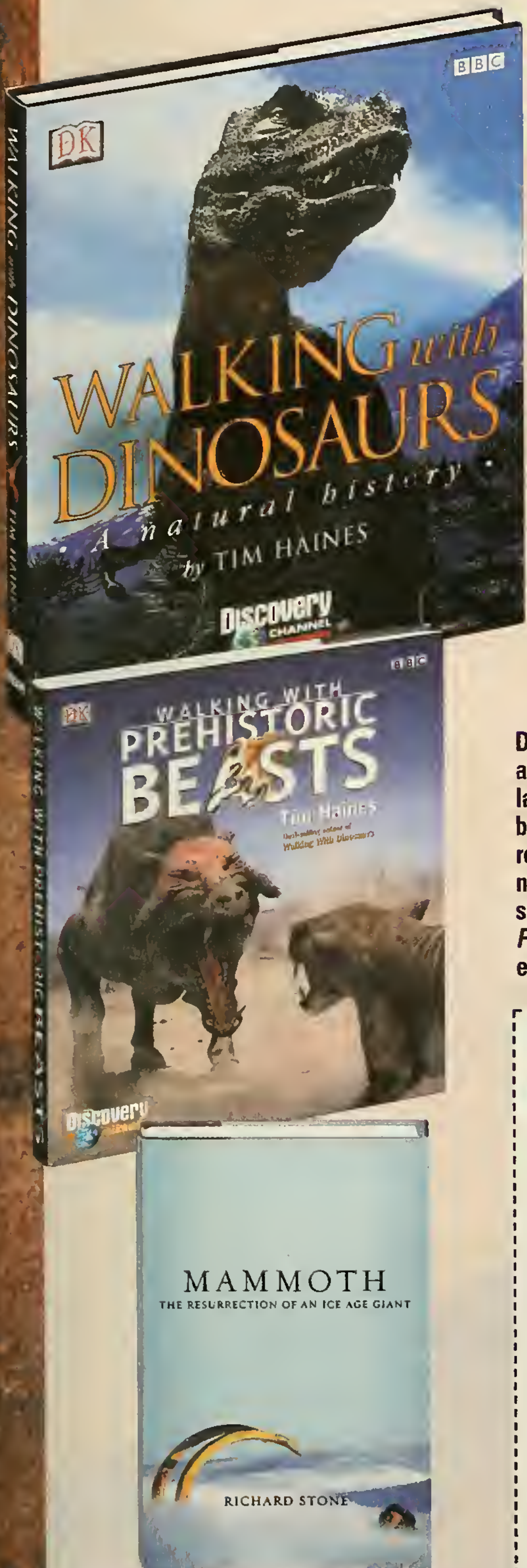

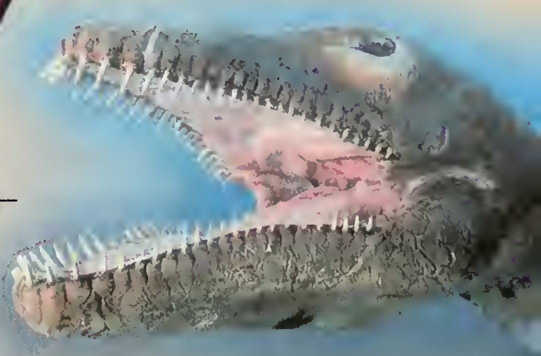

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A bookspan club Natural History March '02 RS291/V411/27

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Espadaler found that seven ant species regularly visit the host plant. Each species exhibits its own distinct pattern of behavior, and each uses slightly different resources (two, for example, seek out the flowers for nectar and are apparently the plant's primary pollinators). But most, we discovered, share a common taste for the high-protein eggs of the golden egg bug. We removed eggs from bugs, placed the eggs on flowers of the host plant, and then observed their fate. Ants usually discovered the eggs within minutes or hours, and no ant we observed ever failed to appropriate an unattached egg she encountered. Our conclusion: In the natural habitat, eggs that are not carried are likely to get gobbled up by ants. Although they are not absolutely invulnerable, carried eggs have much higher rates of survival.

We presume that an adult bug encumbered with eggs suffers some increased risk to its own survival. For one thing, we noted that, compared with unencumbered bugs, egg carriers are much more conspicuous to researchers interested in collecting golden egg bugs, and they are probably equally noticeable to other vertebrate predators, especially birds. We also found that one particularly aggressive predatory ant species tended to attack bugs carrying eggs, and gangs of these ants could succeed in killing them. On the other hand, a bug "racing" experiment conducted in a natural arena ingeniously designed by Minna Miettinen, of Stockholm University, and Rogelio Macías Ordóñez, of the University of Veracruz, showed no statistical difference in rates of locomotion between free bugs and those loaded with eggs. Apparently, the burden of weight added by attached eggs is itself inconsequential.

The assistance bestowed on unrelated adults in raising their offspring—thus giving them a competitive advantage—constitutes the real biological cost of egg carrying. And these individuals do indeed appear to be unrelated. DNA studies, as well as the observation that the bugs disperse widely before reproducing in the spring, assure us that this is not a case of kin selection (in which one individual helps closely related kin and thus, in effect, helps perpetuate something close to its own genetic heritage). Either egg-carrying bugs are exhibiting a rare form of altruism, or females have succeeded in exploiting others of their species—much as parasites exploit their hosts—by attaching eggs to them. However you view this situation, it is intrinsically unstable from an evolutionary standpoint and will not likely be tolerated in the long run by natural selection. While no one can foresee the course of evolution, one possibility is that golden egg bug males will find a way to ensure their paternity of the eggs they carry, turning exploitation to their own advantage.

So what did golden egg bugs do before they began laying eggs on other golden egg bugs? Let's ask a relative. *Phyllomorpha lacerata*, a sister species, lives in the eastern Mediterranean and inland Turkey. It is the only other species in the genus, and its behavior is very different. Females of *P. lacerata* lay their eggs exclusively on their host plant. This is probably the ancestral behavior.

The fact that egg carrying is absent in the golden egg bug's sister species and in other close lineages suggests that this behavior pattern arose relatively recently. In addition, some variation has been noted between different golden egg bug populations. Piedad Reguera and Montserrat Gomendio, researchers from the National Museum of Natural Sciences in Madrid, have observed that their bugs carry fewer eggs than ours do. One possibility is that the bugs near Madrid are laying more eggs on host plants. And working at a site in the mountains of Sicily, Giovanni Mineo, of the University of Palermo, reports that his golden egg bugs lay their eggs on plants, although in this case the plants are not the usual *Paronychia argentea,* which is not present at this site. Such variation suggests that the ancestral pattern has been only partially abandoned, and is further evidence that the species' egg-carrying behavior is a relatively new and unstable trait.

An ant discovers a tasty egg.

Evolutionary biologists look for finely tuned adaptive behavior in the animals they study, and that is what they usually find, because most patterns of behavior have a long evolutionary history. For example, various kinds of egg-carrying and brooding behavior appear throughout a whole family of giant water bugs, and these adaptations seem to have been perfected over a period of at least 150 million years. But golden egg bug social behavior is fascinating for its seeming imperfection. What we see here is a system in flux—a snapshot of an evolutionary work-in-progress, with a fuzzy future. □

IN THE FIELD

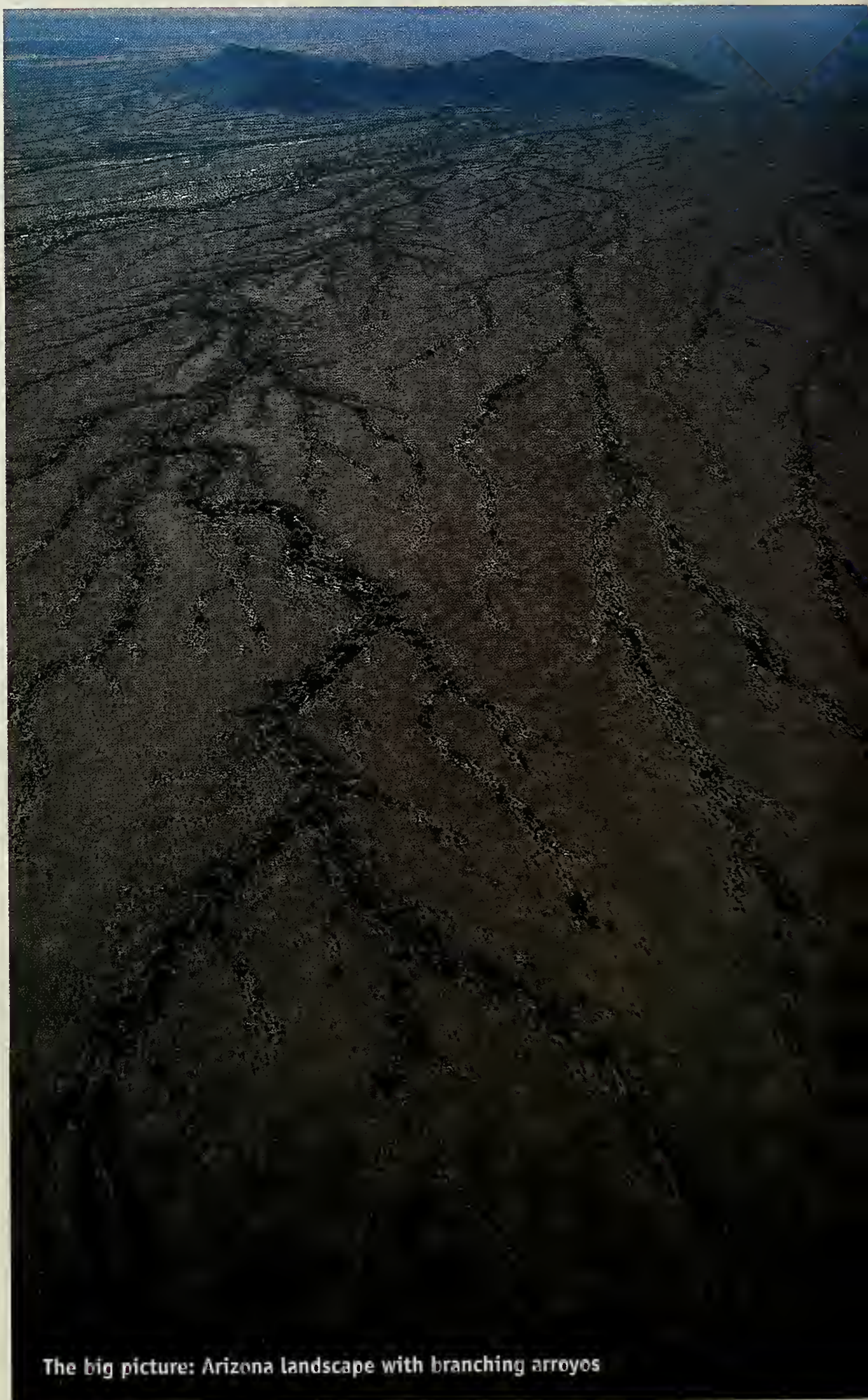
Life Lines in the Sand

After winter rain, arroyos become the desert's green arteries.

By Peter J. Marchand

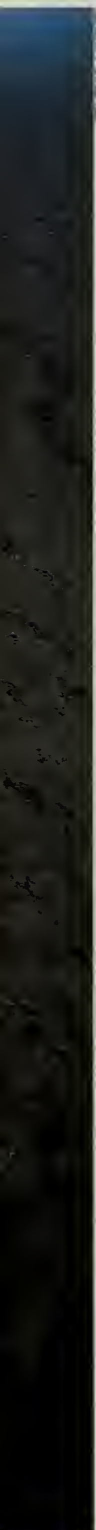
The people of the Sonoran Desert have a name for winter rains. *Las equipatas,* they call them. Unlike the violent thunderstorms of summer, which squander water in widely scattered torrents, these gentler rains come in a procession of "little packages" from December to March and soak into the land, swelling every desert pore with liquid life. In parts of the southern desert, *las equipatas* may drop only an inch or two of rain all winter, but in a wonderful collaboration with arroyos—the normally dry streambeds, or washes, that concentrate runoff as they fan across the desert—temporary relief is brought to the parched land.

Now, in early spring, the winter rains are abating. As ground moisture is pulled back into the dry atmosphere, ephemeral wildflowers slowly fade from the upland slopes, signaling harder times to come. Vibrant strands of green, however, continue to mark the course of the dry washes through the desert. Occasionally the thin lines of foliage broaden into oases of denser vegetation where a depression in the underlying bedrock traps water a little longer or where a rare groundwater seep moistens the sand beneath the surface. As I gaze across southern California's Colorado Desert (named after the Colorado River), one of the most arid regions on the continent, I am struck by how big a difference even a few extra days' worth of



The big picture: Arizona landscape with branching arroyos moisture makes along the arroyos.

Arroyos are estimated to occupy less than 5 percent of the desert landscape in the lower Colorado watershed of Arizona and California, but this figure belies the ecological significance of the usually dry stream channels. Plants such as desert willow, chuparosa, blue palo verde, and smoke trees are found almost exclusively along these washes. The smoke trees—mere wisps of gray-green that look as if they could dissipate into the air at any moment—are so well adapted to this special habitat that they are rarely found beyond the gravelly arroyo bottoms. Only by tumbling downstream during occasional flooding is the hard seed coat of this species abraded sufficiently to allow its germination.



JIM WARK; AIRPHOTO

Wherever there are trees in the desert, there is bound to be a concentration of animal activity. Ninety percent of the region's birdlife is found in this linear habitat, including the tiny verdin, with its distinctive spherical nest, and the stately phainopepla, a flycatcher that thrives on the berries of parasitic mistletoe growing on ironweed and mesquite trees. Dimples and scratches in the sand also reveal the presence of numerous small mammals, including kangaroo rats, ground squirrels, pocket mice, and wood rats. Tracks of kit foxes and coyotes commonly crisscross the wash bottoms; the hoof marks of collared peccaries are often stamped over everything. (Collared peccaries, or javelinas, may be the agents most responsible for moving leguminous tree seeds back upstream. In one study, these omnivores were found to spend nearly half their time in the vicinity of arroyos where, during the summer months, almost a quarter of their diet consisted of pods from palo verde, mesquite, and other trees.)

JACK DYKINGA

***Phacelia* flowers bloom under a dry smoke tree in southern California.**

In my desert explorations I have sat stone still in the early morning as a bobcat stalked past me down the center of a wash, alternately melting into and materializing out of the dappled shade of palo verde trees. I have encountered Gila monsters working the shoulders of the arroyos in spring, searching in their lumbering way for quail eggs or the nests of burrowing mammals. These predatory lizards take advantage of other animals' nesting time to store up fat in their robust tails. The energy will see the Gila monsters through the rest of the year, during which time they are relatively inactive. Judging by the thickness of their tails, some of the lizards find the arroyo banks fertile ground. Twice I have stepped over western diamondback rattlesnakes that were waiting under the cover of overhanging rocks to ambush small prey. One night not long ago, I intercepted a mountain lion in a dry wash. I had been surveying bats, and in the gleam of my light I spotted the big cat's green eyeshine moving away from me.

Arroyos have long played a role in both the natural and cultural history of the desert Southwest. Most arroyos in the lower Colorado Desert carve their way south into Mexico, but they are not simply one-way conduits sending runoff now and then across the border. In the months, or sometimes even years, between flows, a silent countercurrent moves in the opposite direction. Along the washes of Organ Pipe Cactus National Monument, as well as in other arroyos, *Sapium biloculare,* the Mexican jumping bean, fingers its way

JIM WARK; AIRPHOTO. INSET: ROB & ANN SIMPSON

Kit fox

Even when moisture evaporates, streambeds attract wildlife and serve as desert pathways.

northward into the United States, accompanied by a handful of other species, including the tiger rattlesnake. And plants and animals are not all.

One night I camped on the edge of an arroyo near Arizona's southern border. The moon was past full, but still bright in the hours after midnight. Restless, I turned over in my sleeping bag at one point and opened my eyes just in time to see the shadow of a man moving past me, headed north. All along the dry streambeds of this desert, ancient petroglyphs chipped into the rocks tell of the arroyos' frequent use in the past by humans on the move, and little has changed. In an uncharted desert, arroyos are the roads—critical dispersal corridors for plants, animals, and humans.

In a remote corner of the Sonoran Desert, a handful of Tohono O'odham farmers still practice an ancient form of floodwater agriculture, damming arroyos with brush weirs, causing runoff to fan out and soak in just long enough to bring a fast-growing crop of desert tepary beans to fruition. Although arroyos may carry water only a few hours per year, they are a lifeline, sustaining remarkable diversity in a seemingly penurious land. In a desert full of contradictions, bone-dry yet shaped everywhere by running water, the arroyos run deep.

Peter J. Marchand is a research ecologist at the Catamount Institute on the north slope of Pike's Peak in Woodland Park, Colorado.

Collared peccary and prickly pear

G. C. KELLEY; PHOTO RESEARCHERS, INC.

Maryland Weekend Getaway

This spring, take a much-deserved getaway to a state that offers outdoor activities, unique attractions, and historical landmarks within a 200-mile radius.

Photo: Mi[illegible]n Evans

A hiker's paradise, Garrett County

Maryland

If you're craving a weekend getaway that has a bit of everything — history, culture, art, and the outdoors — then Maryland is the answer.

Two hundred miles south of New York City, forty miles south of Philadelphia, and adjacent to Washington D.C., Maryland is an easily accessible destination by car or train. If you're farther away, you might fly into Baltimore/Washington International Airport for a long weekend of fun.

Maryland is blessed with the surf and sand of **Atlantic beaches**, a sailing paradise on the **Chesapeake Bay**, and the rugged mountains of the **Western Region**. Each part of the state is unique and beautiful. Where do you start? It's up to you and your idea of the perfect getaway.

A good way to learn about the state is to visit www.mdisfun.org, the **Maryland Office of Tourism**'s informative web site. From there, you can plan your trip, find destination ideas, or order a free Maryland Travel Kit, which includes a travel guide, map of the state, calendar of events, and Free Stuff Guide. To speak directly with a Maryland travel operator, call **1-800-MDISFUN (1-800-634-7386)**. With the weekend traveler in mind, the Tourism office has created three-day tours focusing on Maryland's greatest treasures, including maps and descriptions of "sights to see." You can trace the historic **National Road**, follow **the path of the British invasion**, walk the **fields of Civil War battles**, or stroll the streets of **Annapolis**. Other itineraries take you along the shores of the Chesapeake Bay and the Atlantic Ocean.

For an outdoor adventure, consider the **Appalachian Mountain Region** of **Garrett County**. Here you can climb Maryland's highest mountain, **Backbone**, or hike a piece of the Appalachian Trail. History buffs might prefer the Capital

Region of **Frederick** and **Prince George's Counties**, where they can explore life within the state three centuries ago. Maryland's **Southern Region** is a naturalist's delight: both **Calvert** and **Charles Counties** are filled with forests, fields, ponds, swamps, and beaches.

For a mix of attractions, try the **Central Region**, home to the historic capital of **Annapolis** and to the state's largest city, **Baltimore**, as well as picturesque waterfront villages along the Chesapeake, historic mill towns, and the gently rolling hills of horse country.

The **Eastern Region** is known for its many historic and natural landmarks. Discover these by bicycling or driving on quiet country roads. In **Worcester**, **Dorchester**, and **Wicomico Counties**, explore the rivers, creeks, inlets, and bays by boat.

Photo: Maryland Office of Tourism

Assateague Island, a 37-mile barrier island known for the wild ponies that roam its beaches and dunes

Visitors to scenic Friendship Park, overlooking the Nanjemoy Creek, may take advantage of a new nature trail that opens this spring.

Charles County

Charles County (800-766-3386; www.explorecharlescomd.com)**, in the state's southern portion, has more than 321 species of birds and the second largest population of bald eagles in the state of Maryland. **Friendship Park** in Nanjemoy boasts miles of scenic marshes that abound with wildlife. Here, you can canoe or kayak along the winding **Nanjemoy Creek**, where you're likely to find many nesting sites for bald eagles.

Charles County also has a rich historical heritage. **The Afro-American Heritage Society (301-843-0371)** in **LaPlata**, open by appointment only, depicts the life and history of African-Americans in Charles County from 1658 to present, with various artifacts from the time of slavery. If you plan to spend some extra time in the area, spend a few nights at nearby **Linden (301-934-9003)**, a bed-and-breakfast that is listed on the National Register of Historic Places.

Near Waldorf, visit the **Dr. Samuel A. Mudd Home Museum**, which chronicles the life of the doctor who, in 1865, treated the leg of John Wilkes Booth, President Abraham Lincoln's assassin. The museum is open for public tours from the first weekend of April to late November. You can stay just down the road from the Mudd Home at the **Shady Oaks of Serenity (301-932-8864 or 800-597-0924)**.

Calvert County

Calvert County (800-331-9771; www.co.ca.md.us) has attractions that existed long before it was founded in 1654. Visitors can dig deep into the past on the beach at **Calvert Cliffs**, where prehistoric sharks' teeth and other fossils have been found along the shoreline. Examples of the prehistoric creatures whose fossils have been found at the cliffs are at the **Calvert Marine Museum** in **Solomons**.

Garrett County and Deep Creek Lake

If you're looking to do a little fishing during your vacation, **Garrett County** offers excellent fishing for brown, rainbow, and brook trout, with a multitude of native brook trout streams **(301-387-4FUN; www.garrett chamber.com)**. The **Casselman River** also provides anglers with numerous opportunities. While on the river, make a stop at the **Casselman River Bridge**. Originally constructed in 1813–14, the bridge once served the old National Road that linked Cumberland, Maryland, with the Ohio River.

For a relaxing excursion, spend an afternoon boating or fishing on **Deep Creek Lake**, Maryland's largest freshwater lake and a major fishing center.

Deep Creek Lake is Western Maryland's premier destination resort, offering a wide variety of outdoor recreational activities. Summertime activities include biking, hiking, boating, water skiing, swimming, golfing, horseback riding, and scenic airplane rides.

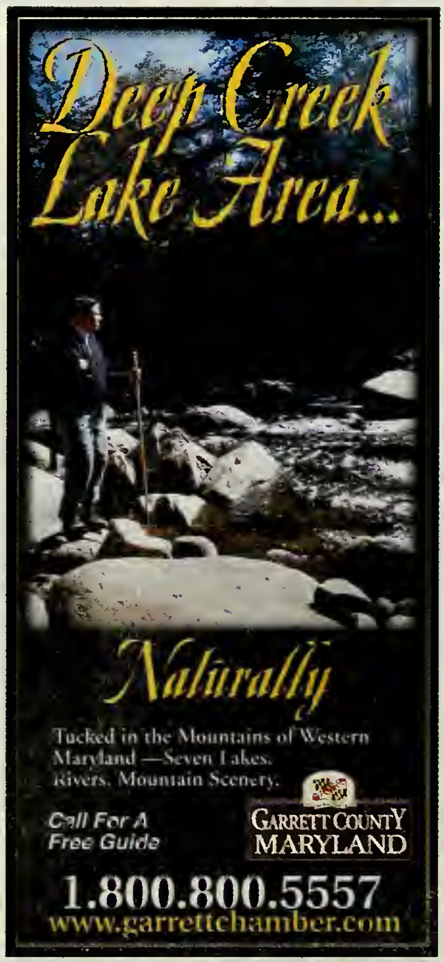
Frederick County

History buffs will enjoy **Frederick County (800-999-3613; www.visitfrederick.org)**, a region that connects Maryland's urban centers to its mountain region. The **City of Frederick**, which is more than 250 years old, offers walking tours that focus on such topics as the Civil War and Frederick's haunted sites. Costumed guides tell the stories of the many buildings within the 50-block historic district, as well as the famous people who worked and lived there. Stop by the **Frederick Visitor Center** on Church Street **(301-228-2888)** for information on the city's sights.

If shopping is your idea of the perfect vacation, there are plenty of boutiques in the city itself, and Maryland's antiques capital, **New Market**, is a short drive away. Largely unchanged from its early days as a nineteenth-century pike town, Frederick now has dozens of antique shops. After a day of shopping, stop by **Mealey's Inn Restaurant (310-865-5688)**.

Dorchester County

In **Dorchester County (800-522-TOUR; www.tourdorchester.org)**, on the **Eastern Shore**, visit the scenic port town of **Cambridge**. Cambridge has many historic homes, buildings, and museums with agricultural, maritime, industrial, and Native American displays. Near Cambridge, the **Blackwater National Wildlife Refuge** is an important nesting and feeding area for wild geese, osprey, swans, owls, muskrats, rare Delmarva fox squirrels, and bald eagles.



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MARYLAND
WELCOME

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Prince George's County

Two hundred years ago, **Prince George's County (888-925-8300; www.visitprincegeorges.com)** donated land that was used to build the nation's capital — but the county kept the best for itself.

A visit to Prince George's might begin at the 12,000-acre **Patuxent Wildlife Research Center**, at the **National Wildlife Visitor's Center** in **Laurel,** which directs important research on endangered species. President Franklin D. Roosevelt established this refuge, which offers fishing, hunting, birdwatching, and educational programs, in 1936. It is open daily (10:00–5:30 p.m), and there are many hotels in nearby Laurel, including **Comfort Suites (301-206-2600)**, **Fairfield Inn (301-498-8900)**, and **Quality Inn & Suites (301-725-8800)**.

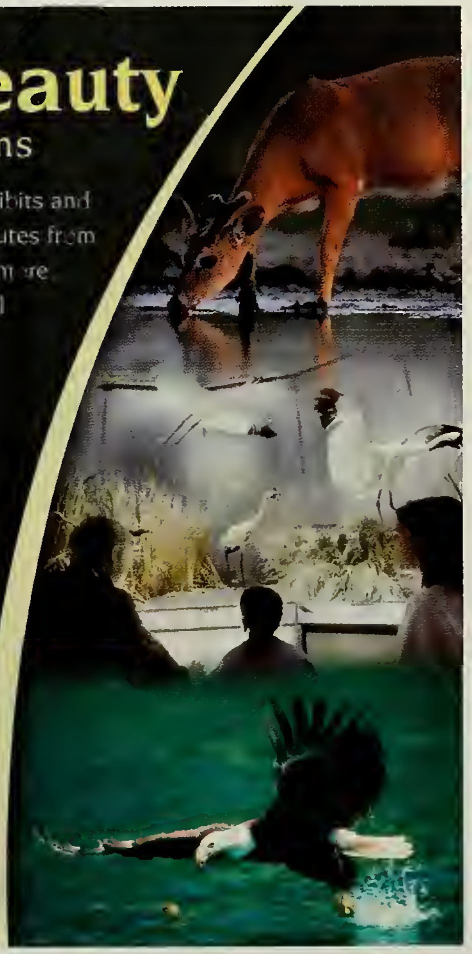
Another gem in Prince George's County is the **Merkle Wildlife Sanctuary** in **Upper Marlborough**. The Merkle sanctuary serves as the wintering ground for several thousand Canada geese, the largest concentration of these birds on the western shore of the Chesapeake Bay. Started in 1932 to ensure nesting and wintering grounds for Canada geese, the sanctuary overlooks the **Patuxent River** just south of **Jug Bay**. Nearly 2,000 acres of land are dedicated to wildlife habitat and waterfowl management. The Visitor Center, open daily from 10:00 a.m. to 4:00 p.m., features exhibits on native wildlife, including displays on the life cycle and ecology of the Canada goose. The sanctuary's eight miles of trails travel through field, forest, and wetland areas and are popular not only for hiking but also for birdwatching.

Natural Beauty
...Comes in many forms

Discover scenic habitats, wildlife exhibits and educational experiences, all just minutes from Washington, DC, Annapolis and Baltimore. Prince George's County offers natural beauty in all its forms.

- Cedarville State Forest
- Merkle Wildlife Sanctuary & Visitor Center
- National Colonial Farm
- National Visitor Center at Agricultural Research Center
- National Wildlife Visitor Center
- Watkins Nature Center
- Patuxent River Park

For additional information, contact:
Prince George's County
Conference & Visitors Bureau
301-925-8300 (or 888-925-8300)



PRINCE GEORGE'S COUNTY MARYLAND WELCOME

Worcester County

The only oceanfront county in Maryland, **Worcester County (800-852-0335; www.visitworcester.org)** was founded in 1742. Active vacationers will want to visit **Ocean City**, a year-round resort that is most popular in the summer. Ocean City has ten miles of white sandy beaches, a famous boardwalk, and an activities line-up that includes golf, tennis, fishing, boating, and water sports.

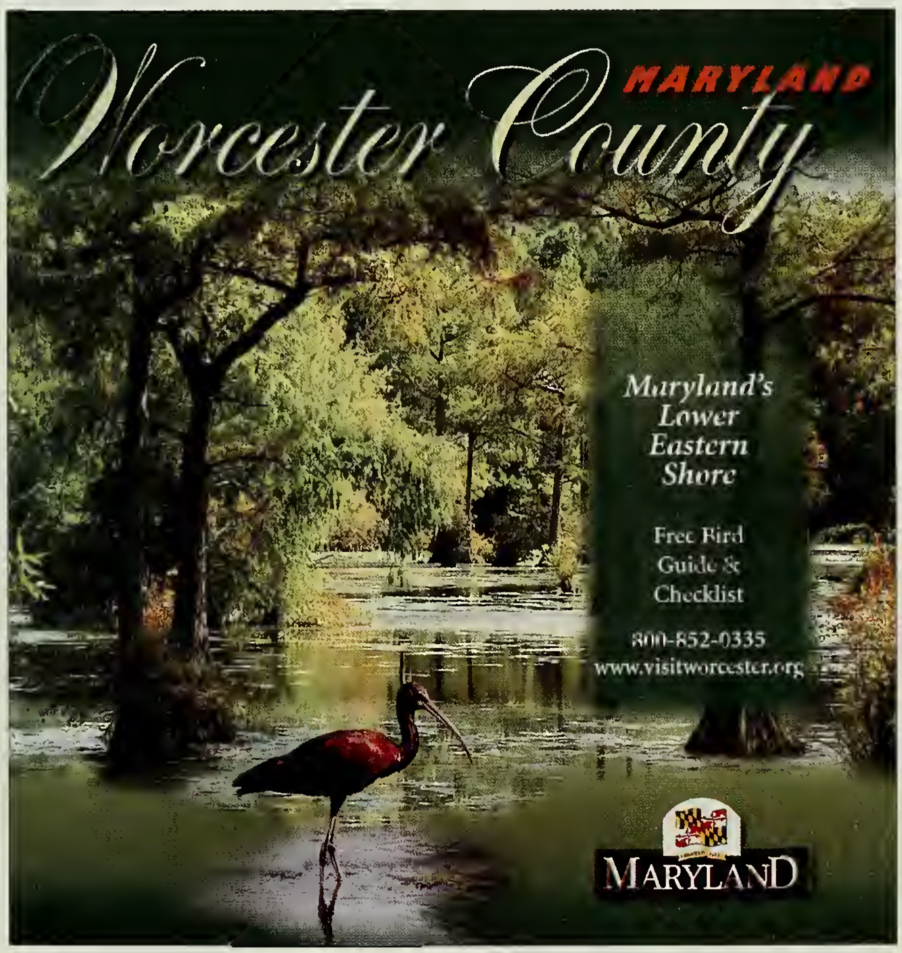
Ocean City is a gateway to **Assateague Island National Seashore**, a 37-mile-long barrier island. You'll want to bring your camera to photograph the wild ponies roaming the beaches and dunes between Ocean City, Maryland, and Chincoteague, Virginia. Legend says the ponies are descendants of horses that survived the shipwreck of a Spanish galleon. Assateague State Park has campsites, bike trails, and rental boats so both residents and visitors can enjoy the shore.

To get away from the hustle and bustle of Ocean City, stay in the Victorian town of **Berlin**, just a short drive from Ocean City. Berlin is peppered with inns and bed-and-breakfasts. Among those are the **Merry Sherwood Plantation (410-641-2112)**, a seventeenth-century plantation home built by a suitor to woo the daughter of a wealthy merchant, and the **Atlantic Hotel (410-641-3589)**, which is more than 100 years old. It offers both fabulous food and accommodations.

Wicomico County

History abounds in **Wicomico County (800-332-TOUR; www.wicomicotourism.org)**. And whether you're interested in a quaint bed-and-breakfast in historic **Whitehaven**, such as the **Whitehaven Bed and Breakfast (888-205-5921)**, or one of Salisbury's modern hotels such as the **Ramada Inn & Conference (888-800-7617)**, the county offers its visitors a wide array of lodging options.

While in **Salisbury**, take a walk in the park along the **Wicomico River** or cruise aboard the *Maryland Lady* and imagine yourself back in the days of the steamboats. Or follow county history through exhibits at the **Wicomico Heritage Center**, a reproduction eighteenth-century Eastern Shore Virginia tobacco barn. The Heritage Center houses the Wicomico County Historical Society's collection and serves as its museum and headquarters. Continue on to nearby **Pemberton Hall**, built in 1741 for Isaac and Ann Handy. This eighteenth-century manor house provides a glimpse into early American life.



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Ann E. Darbin

Photographs by Richard A.K. Darbin

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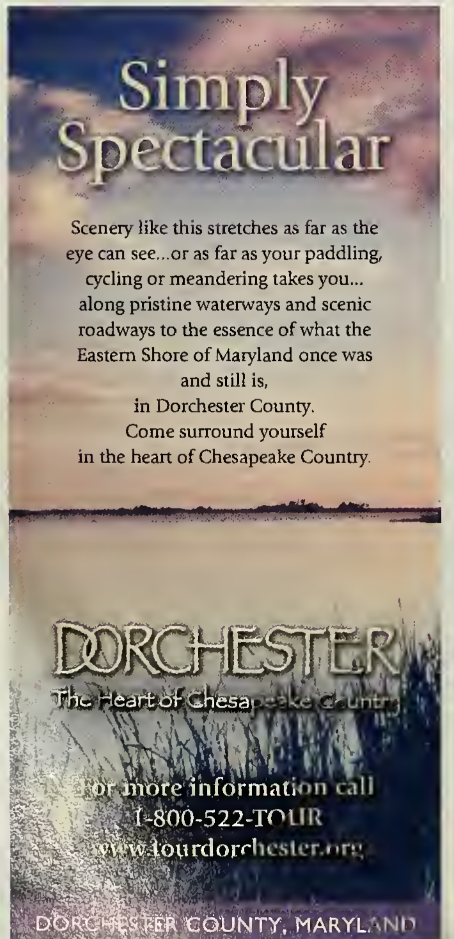
Photo: Middleton Evans

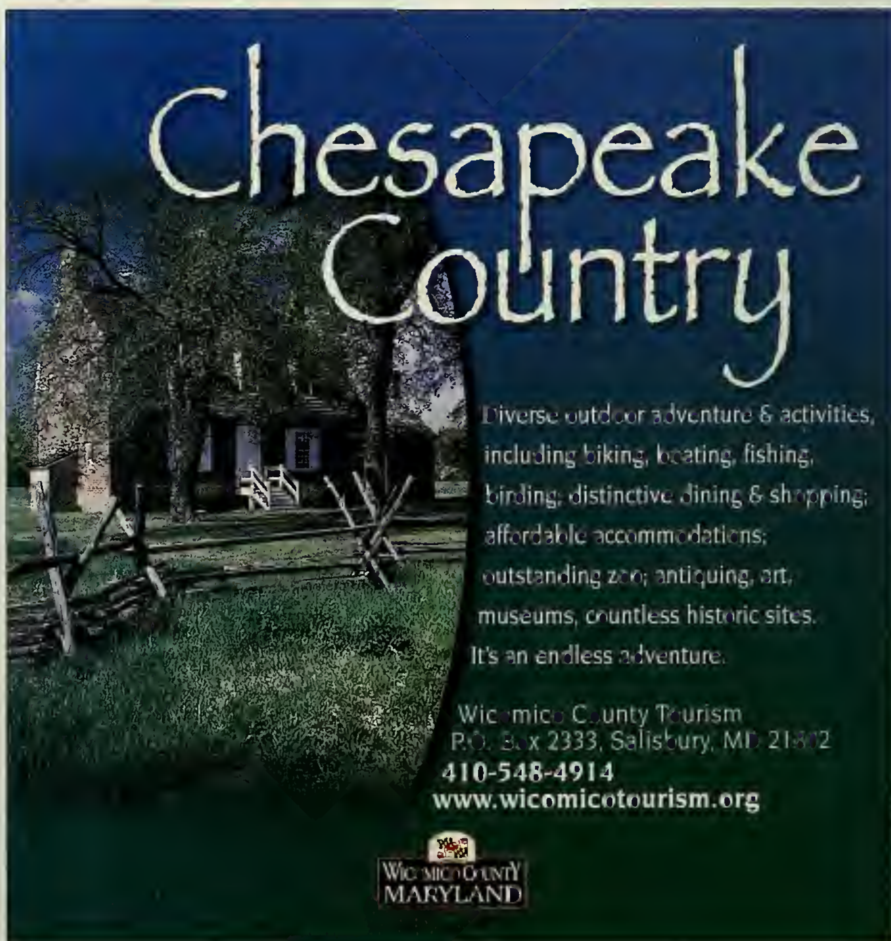
Midshipmen in the U. S. Naval Academy in historic Annapolis

The Johns Hopkins University Press

When looking for information about Maryland, you should first check out **The Johns Hopkins University Press (800-537-5487; www.jhupress.edu)**. The press publishes popular books about the **Chesapeake Bay region**, with titles that cover natural history, photography, history and culture, and fiction and essays on this rich and diverse area. *A Day on the Bay*, *Saving the Bay*, *Journeys to the Heart of Baltimore*, and *Chessie Racing* are all of interest to the Maryland visitor and are currently available through the press. *Chessie Racing* records the history of the racing yacht of the same name, the first ever entry from the Chesapeake Bay in the famous Whitbread Round the World Race. Skippered by Baltimore businessman George Collins and named after the Chesapeake's equivalent to the Loch Ness monster, *Chessie* became a focal point of regional and national pride when she competed in 1997–98.

Chessie Racing is especially timely, as Leg 6 of the **Volvo Ocean Race** will finish at **Fort McHenry** this year. During the stopover, the fourth annual **Baltimore Waterfront Festival** will be held in the city's famed **Inner Harbor**, where the boats will be docked until April 26, 2002, when they move to **Annapolis**. Annapolis will welcome the race fleet at its City Dock, adjacent to the U.S. Naval Academy, prior to the start of Leg 7.





UNIVERSE

Colors of the Cosmos

Red, green, and blue may mean one thing to a scientist and something different to everybody else.

By Neil deGrasse Tyson

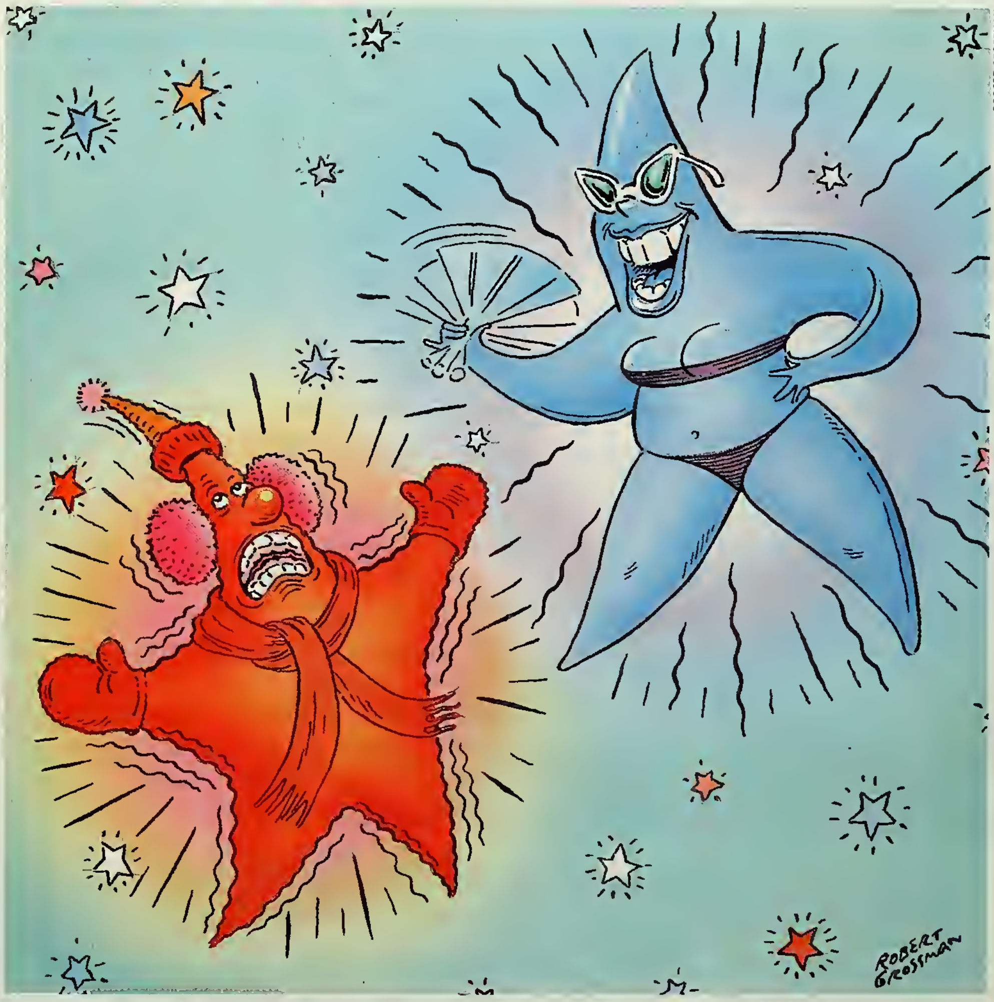
Only a few objects in Earth's nighttime sky emit or reflect enough light to trigger our retinas' color-sensitive cones. The red planet Mars can do it. So can the blue supergiant star Rigel (Orion's left kneecap) and the red supergiant Betelgeuse (Orion's right armpit). But aside from these standouts, the pickings are slim. To the unaided eye, space is a dark and colorless place.

Not until you aim large telescopes at it does the universe show its true colors. Glowing objects such as stars come in shades of red, white, and blue—a cosmic fact that would have pleased the Founding Fathers. Interstellar gas clouds can take on practically any color at all, depending on which chemical elements are present, whereas a star's color follows directly from its surface temperature: Cool stars are red. Tepid stars are white. Hot stars are blue. Very hot stars are . . . still blue. How about very, very hot places, like the 15,000,000° center of the Sun? Blue. To an astrophysicist, red-hot foods and red-hot lovers both leave room for improvement. It's just that simple.

Or is it?

A conspiracy of astrophysical law and human physiology just about rules out the existence of green stars. How about yellow stars? Some astronomy textbooks, many science fiction stories, and nearly every person on the street belong to the Sun-Is-Yellow Movement. Professional photographers, however, would swear the Sun is blue; daylight film is color balanced on the expectation that the light source (presumably the Sun) is strong in the blue part of the spectrum. The old blue-dot flash cubes were just one example of the attempt to simulate the Sun's blue light for indoor shots when using daylight film. On the other hand, painters with loft studios consider sunlight to be pure white, offering them the most accurate possible view of their pigments.

No doubt the Sun acquires a yellow-orange patina near the dusty horizon during sunrise and sunset. But at 12:00 noon, when atmospheric scattering is at a minimum, the color yellow



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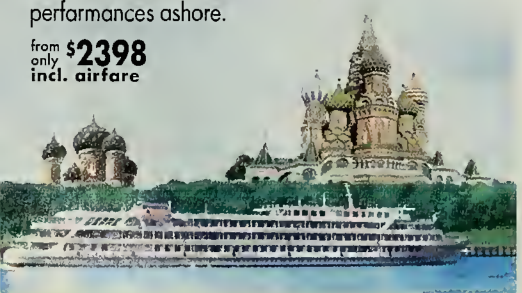

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does not spring to mind. Indeed, light sources that are truly yellow make white things look yellow. So if the Sun were pure yellow, then snow would look yellow—whether or not it had fallen near fire hydrants.

To an astrophysicist, "cool" objects have surface temperatures between 1,000° and 4,000° Kelvin and are generally described as red. Yet the filament of a white incandescent lightbulb cannot exceed 3,000° Kelvin by much—tungsten melts at 3,680°. Below about 1,000°, objects become dramatically less luminous in the visible part of the spectrum. Gaseous orbs with these temperatures happen to be failed stars. We call them brown dwarfs even though they are not brown and they emit hardly any visible light at all.

While we're on the subject, black holes aren't really black. Depending on its mass, a black hole can lose energy across the entire spectrum. In a process that resembles evaporation, black holes emit small quantities of light from their event horizons. Physicist Stephen Hawking was the first to describe this phenomenon, in which the evaporation rate increases as the black hole gets smaller, ending its life in a runaway flash of gamma rays.

Modern scientific images occasionally use a false-color palette. The meteorologists who make TV weather maps might denote heavy rainfall with one color and light rainfall with another. Or better yet, snow with one color, sleet with a second color, and rain with a third. When astrophysicists create false-color images of cosmic objects, they often assign an arbitrary sequence of colors to an image's range of brightness. The brightest parts might be red and the dimmest parts blue. So the colors you see bear no relation to the actual colors of the object. As in meteorology, some of these images have color sequences that relate to other attributes, such as the object's chemical composition or temperature. And it's not uncommon to see an image of a spiral galaxy that has been color coded for its rotation: the parts coming toward you are shades of blue, while the parts moving away are shades of red. In this case, the assigned colors evoke the widely recognized blue and red Doppler shifts that reveal an object's motion.

In the cosmic microwave background (the energetic remnants of the big bang), some areas are hotter than average. And, of course, some are cooler than average. The range spans a mere 0.00001°. How do you display this fact on a map? Make the hot spots blue and the cold spots red or cold spots blue and hot spots red. In either case, a teeny fluctuation in temperature shows up as an obvious difference on the picture.

Brown dwarfs are gaseous orbs that aren't brown and emit hardly any visible light.

In other cases, we create a full-color image of a cosmic object by using invisible light, such as infrared or radio waves. What we do is assign the three colors to which the human retina is sensitive (red, green, and blue, or RGB for short) to three different parts of the spectrum. This way, we construct the full-color image we would see if we were born with the capacity to see colors in otherwise invisible bands.

So, presented with images created by scientists, you do not always know what they are selling you. Common colors mean very different things to scientists than they do to everybody else. On the occasions when astrophysicists choose to speak unambiguously, we use tools and methods that precisely quantify the color emitted or reflected by an object, allowing us to avoid the personal preferences of the image makers or the messy business of human color perception. But the approach is not public friendly—it involves the logarithm to the base of the fifth root of 100 of the ratio of the flux from an object as measured through pairs of filters in a well-defined system corrected for the detector's sensitivity profile. When that ratio decreases, for example, we say the object is turning blue—no matter what color it appears to be.

The vagaries of human color perception took their toll on the wealthy American astronomer and Mars fanatic Percival Lowell. During the late 1800s and early 1900s, he made quite detailed drawings of the Martian surface. To make such observations, you need dry and steady air, which reduces the smearing of the planet's light en route to your eyeball. In the clear air of Arizona, atop Mars Hill, Lowell founded the Lowell Observatory in 1894. The rust-rich surface of Mars looks reddish at any magnification, but Lowell also recorded patches of green at the intersections of what he described and illustrated as canals—artificial waterways, presumably made by real live Martians who were eager to save their dying species by redistributing precious water from the polar ice caps to their cities, hamlets, and surrounding farmlands.

Let's not worry here about Lowell's alien voyeurism. Instead, let's just focus on his canals and vegetation. Poor Percival was the unwitting victim of two well-known optical illusions: First, in almost all circumstances, the brain attempts to create visual order where there is no order at all. The constellations in the sky are prime examples—the result of imaginative, sleepy people imposing order on a random assortment of stars. Likewise, Lowell's brain interpreted uncorrelated surface and atmospheric features on Mars as large-scale patterns.

The second illusion, first pointed out by French chemist Michel-Eugène Chevreul in 1839, arises from a physiological effect in which a color-neutral area surrounded by yellow-orange appears bluish green to the eye. Mars displays a dull orange on its surface with spots of grayish brown—green, in Lowell's mind's eye.

In another peculiar but less embarrassing physiological effect, your brain tends to color-balance the environment in which you are immersed. Under the canopy of a rainforest, for example, where nearly all the light that reaches the jungle floor has been filtered green (by having passed through leaves), a milk-white sheet of paper ought to look green. But it doesn't. Your brain makes it white in spite of the lighting conditions.

For a more homey example, walk past a window at night while the people inside are watching television. If the TV is the only light in the room, the walls reflect a soft blue. But the brains of the people immersed in the light of the television actively color-balance their walls and see no such bluishness around them. This bit of mental compensation may prevent

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residents of our first Martian colony from taking notice of the prevailing red of their landscape and their rusty, dusty sky.

During the mid-twentieth century, most of Earth's night sky was systematically photographed from a mountaintop outside San Diego, California. This seminal database, known as the Palomar Observatory Sky Survey, served as the foundation for targeted follow-up observations of the cosmos for an entire generation. The sky was photographed twice, using two different kinds of black-and-white Kodak film—one ultrasensitive to blue light, the other ultrasensitive to red. (Indeed, the Eastman Kodak Corporation had an entire division devoted to serving astronomers, whose photographic needs helped push the limits of the company's R&D efforts.) If a celestial object piqued your interest, you'd be sure to look at both the red- and the blue-sensitive images as a first indication of the character of light it emitted. For example, extremely red objects would be bright in the red-sensitive image but might be barely visible in the blue. These sorts of useful facts informed subsequent observing programs intended to target these objects.

Although modest in size compared with the largest ground-based observatories, the 94-inch Hubble Space Telescope can take spectacular color images of the cosmos. The most memorable ones are part of the Hubble Heritage portfolio, which will doubtless secure the telescope's legacy in the hearts and minds of the public. For an ordinary color photograph, astrophysicists start with the same digital (CCD) technology found in household camcorders, except that we were using it a decade before you did, and our detectors are much, much higher quality. Our CCDs are so sensitive that we must cryogenically cool them lest they detect themselves. Next, we obtain three successive images of the object, seen through broadband red, green, and blue filters (despite their names, these filters, taken together, span the entire visible spectrum). Next, we combine the three images in software the way the wetware of your brain combines the signals from the red-, green-, and blue-sensitive cones in your retinas. This generates a color picture that greatly resembles what you would see if your eyeballs' pupils were 94 inches in diameter.

Suppose, however, that the object emits light strongly at specific wavelengths due to the quantum properties of its atoms and molecules. If we know this in advance and use filters tuned to these emissions, we can narrow our image sensitivity to just these wavelengths, instead of using broadband RGB. The result? Sharp features pop out of the picture, revealing structure and texture that would otherwise go unnoticed. A good example lives in our cosmic backyard. I confess that for all the times I've looked at Jupiter in a telescope, I've never actually seen its Great Red Spot. Sometimes this atmospheric storm turns pale, but in any case the best way to see it is through a filter that isolates red light selectively reflected by molecules prevalent in the spot itself.

> The vivid greens that jump out of many Hubble Space Telescope images come directly from oxygen's rarefied emissions.

When found near regions of star formation, as part of the rarefied gas of the interstellar medium, oxygen can emit a pure green color. Filter for it, and oxygen's signature arrives at the detector undiluted by broadband green light that may also occupy the scene. The vivid colors that jump out of many Hubble images come directly from oxygen's emissions. Filter for other atomic or molecular species, and the color images become chemical probes of the cosmos. Hubble has done this so well and so often that its most famous color images bear little resemblance to classical RGB images of the same objects taken by others who have tried to simulate the natural color response of the human eye.

The debate rages over whether or not these Hubble images contain "true" colors. One thing is certain: they do not contain "false" colors. The Hubble hues derive from the actual colors emitted by actual astrophysical objects and phenomena. Purists insist that we are doing a disservice to the public by not showing cosmic colors as the human eye would perceive them. I maintain, however, that if your retina were tunable to narrowband light, you would see just what the Hubble sees. I further maintain that my "if" in the previous sentence is no more contrived than the "if" in the phrase "if your eyes were the size of large telescopes."

The eternal question remains, If you added together the visible light from all objects in the universe, what color would you see? Phrased more simply, What color is the universe? Fortunately, some people with nothing better to do have actually calculated the answer to this question: *The universe is a cross between medium aquamarine and pale turquoise*. Karl Glazebrook and Ivan Baldry, of the Johns Hopkins University, the two astrophysicists responsible for this chromatic revelation, used a survey of visible light from more than 200,000 galaxies occupying a large and representative volume of the universe.

The nineteenth-century English astronomer John Herschel made the first color photograph in 1842. To the frequent confusion but occasional delight of the public, we astrophysicists have been messing with the process ever since.

Astrophysicist Neil deGrasse Tyson is the Frederick P. Rose Director of New York City's Hayden Planetarium and a visiting research scientist at Princeton University.

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THIS LAND

Interleavings

Hardwood and coniferous forests rub shoulders in Michigan's Lower Peninsula.

By Robert H. Mohlenbrock

While driving north from Lansing in Michigan's Lower Peninsula, my wife, Beverly, and I passed the town of Clare, which a billboard proclaimed to be the "Gateway to the North." As if to confirm this, after a few miles the vegetation suddenly began to change. The woods to our south had consisted of broad-leaved hardwood trees—sugar maple, black oak, red oak, white ash—beneath which grew shrubs and wildflowers that required mild summers and moderate rainfall. Now the slender spires of tamarack and balsam fir dominated a scraggly forest, while impenetrable-looking layers of hardy shrubs filled the understory. Flashes of sunlight bounced off pools of water as we passed by, revealing the soggy nature of the forest interior.

In fact, broad-leaved hardwood forests also exist in the north of Michigan's Lower Peninsula, but there they are confined to drier, upland areas. The coniferous forests appear in the lowlands, which are filled with lakes, bogs, and fens. In many places,

Birch trees in the upland woods

both of these northern forest habitats can be observed close together. One place where this is evident is the seven-square-mile Rifle River Recreation Area, administered by the Michigan Department of Natural Resources, Division of State Parks and Recreation. There, at the lower elevations but away from boggy depressions, you will also find a moist forest with red maple, American elm, and green ash.

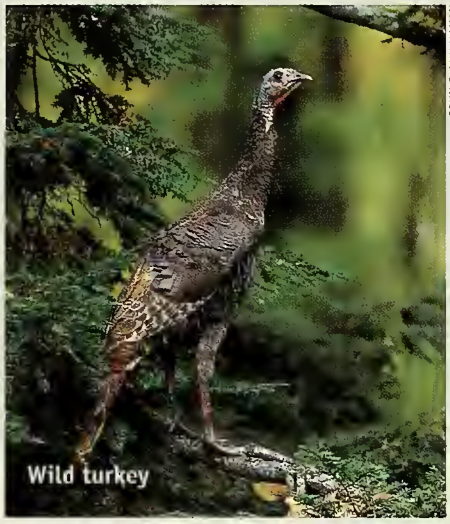
A loop road that begins at the park entrance provides a broad overview of the forests and passes by several of the numerous lakes. Wild turkeys and white-tailed deer may be seen on almost every drive around the park. Waterfowl abound, including herons, egrets, and loons.


LARRY DECH

For a more intimate experience, hike one of the trails. Pintail Pond Trail will take you from an upland woods to a moist woods to a white cedar swamp and finally to a tamarack bog. Be on the lookout for woodcocks, rabbits, squirrels, raccoons, foxes, beavers, otters, ruffed grouse, and muskrat. And if you go to the park in the first half of June, be sure to visit Grouse Haven Lake, reached by a quarter-mile-long side road off the loop road. In a sandy zone that begins about ten feet back from the shore, colonies of pink lady's-slipper orchids will be showing off their pale, delicate blooms.

HABITATS

Upland woods. Color and texture variations are provided by the soft, bright green needles of white pine, the broad leaves of red oak and black oak, the stark white trunks of paper birch, and the gray trunks of quaking aspen and big-tooth aspen. The leaves of balsam poplar are particularly showy when the wind blows, exposing their rust-colored lower surface. Shrubs and small trees: round-leaved dogwood, hazelnut, bush honeysuckle. Wildflowers: several species of asters and goldenrods.


Wild turkey

JOHN & ANN MAHAN

Moist forest. Red maple, American elm, and green ash provide dense shade, fostering a lush, junglelike growth of mosses and other plants. Wildflowers: false lily-of-the-valley, bluebead lily, cucumber-root, star-flower, goldthread (named for its roots), partridge berry.

White cedar woods. White cedar (sometimes known as arbor vitae) grows in fairly flat areas, but within this forest are numerous shallow depressions where water stands for much or all of the year. Other trees are black ash, green ash, and red maple. Mosses and extensive patches of sedges carpet much of the forest floor. Shrubs: shrubby cinquefoil, sweet gale, several species of willows. Wildflowers: false Solomon's-seal, starry Solomon's-seal, pink bog avens, recurved buttercup, one-flowered shinleaf, pink pyrola, grass-of-Parnassus, wild cranberry, creeping wintergreen, twinflower.

Tamarack bog. Tamarack (larch) grows where the ground becomes more saturated and the water in depressions is a little more acidic. This conifer, like the bald cypress and pond cypress of the southeastern United States, is deciduous, losing all of its short, soft needles in the autumn. Smaller trees are bog birch and bog willow. Two species of sedges that form cottony seed masses are called cotton grass. Wildflowers: pitcher plant, rose pogonia orchid, yellow lady's-slipper orchids, Labrador bedstraw.

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.

JOE LEMONNIER

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AT THE MUSEUM

Baseball's Reliquary

The oddly possible hybrid of shrine and university

By Stephen Jay Gould

Baseball did not win its central place in America's heart and culture because the sport, in a silliness of common parlance, "imitates life" or stands as a symbol for larger truths and trends of human existence. Rather, baseball became America's defining sport for the far more ordinary and concrete reasons of simple persistence and pervasiveness. (And one would have to inhabit a particularly tall ivory tower, or a particularly deep cave, to deny the status of sport as a central institution of human culture.)

Baseball As America, an exhibition that explores the impact of baseball on American culture, will be in Gallery 3 from March 16 through August 18, 2002. Organized by the National Baseball Hall of Fame and Museum, the exhibition will travel to nine other cities. The national tour is sponsored by Ernst & Young LLP.

Baseball (as the codified form of a large variety of basically similar stick-and-ball games) has, like the poor, always been with us. Teams, leagues, and various lists of "official" rules had coalesced by the mid-nineteenth century, but Jane Austen refers to something called "base ball" in her 1797 novel *Northanger Abbey*, and various contests based on hitting a ball with a stick and scoring by running around bases came to America in the early days of European colonization and then grew and diversified as the nation expanded and knit together.

One might assume, given the current popularity of football and basketball among Americans of all social classes, that these sports, rather than baseball, should carry (or at least share) the status of "national pastime." But these games are neophytes in popular acclaim, as anyone of my generation will remember. They do boast a reasonably long following—but they emerged mainly as college sports, at a time when only a few percent of Americans (not including anyone in my family) enjoyed access to higher education. During my childhood, professional basketball and football were distinctly minor enterprises, with short seasons and limited followings. But baseball, known to every sentient citizen and played with enthusiasm by farmers, street urchins, and swells (or whatever prosperous young men have been called at various times), has been keeping us together from our beginnings.

Stuff of legend: The Doubleday baseball

MILO STEWART JR./NATIONAL BASEBALL HALL OF FAME AND MUSEUM

Home-run bats of (left to right) Ruth, McGwire, Sosa, Maris, and Mantle

MILO STEWART JR.; NATIONAL BASEBALL HALL OF FAME AND MUSEUM

If I may offer just one person's testimony, I am enmeshed in four generations of serious fandom. My immigrant grandfather arrived in 1901 and acclimatized to America, or so he told me, by watching Jack Chesbro win forty-one games (still a record, and not likely to be broken) for the New York Highlanders (now the Yankees) in 1904. My father regaled me with tales of Ruth and Gehrig, the ultimate secular gods of his world. I have been a passionate Yankee fan for five decades, from tears of joy at age eight for victory over the Brooklyn Dodgers in the 1949 World Series to bitter tears in November 2001 at a gruesomely painful ending in Phoenix—that is, from DiMaggio to Jeter. My son, a native of Boston, has switched to the Red Sox; he rises by the bashed dreams and plunges into the despairs of that particularly painful form of rooting. (I was especially touched when he interviewed me last year for a paper in his college sociology course on baseball as a mode of bonding between fathers and sons—though daughters will now be commonly included as well—especially in past generations when fathers, culturally constrained to assume far greater emotional distance, could use this opportunity for forging ties otherwise hard to establish.)

Baseball's status as both a secular religion and an embodiment of important themes in American history imposes a common, yet fascinatingly paradoxical, problem for any exhibition dedicated to conveying the essence and vitality of the enterprise. How can a museum present two such apparently different, even contradictory, aspects of a single subject at the same time, especially when both embody primary responsibilities of museums in general: the role of the reliquary (reverent display of sacred objects, whose importance lies in their very being) and the role of the teacher (instructive display of informative objects, whose importance lies in their ability to inspire questions)? How can the awe of reverence mix with the skepticism of learning?

In my observations, only two museums have ever managed to solve this common dilemma in a consistent, even triumphant, way: the Ellis Island Immigration Museum (where I can pay homage to my grandfather's courage, as embodied in whole walls devoted to respectful display of such humble but noble items as battered traveling bags and lockets of loved ones left behind, and also study the history of American immigration in any desired degree of detail) and the National Baseball Hall of Fame and Museum in Cooperstown, New York (where I can immerse myself among the actual relics of our primary secular religion and also trace nearly any desired detail or generality about the history of baseball and its linkages to American life).

The wonderful selection from Cooperstown, on temporary display at the American Museum of Natural History starting this month, epitomizes this duality to near perfection and therefore gives us an object lesson in how to hybridize these two greatest potential excellences of museums, despite their apparently irreconcilable disparity. In other (and more specific) words, we can learn a ton about baseball while feeling both the spine shivers of contact with "holy" items and the touch of *genius loci,* the magic of real and special places.

Baseball, known to every sentient citizen and played by farmers, street urchins, and swells, has been keeping us together from our beginnings.

To cash out my claims by examples on display, consider just five categories where the object as both relic and item for instruction forges potential synergy rather than frustrating contradiction:

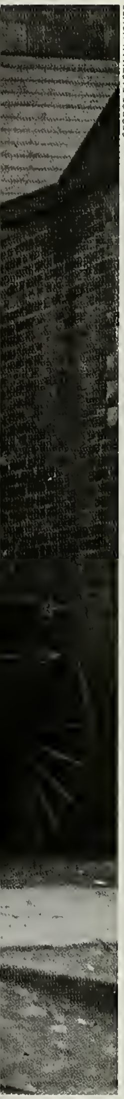
1. *The embodiment of mythology.* As a supreme irony, the Cooperstown museum, as argued above, has covered itself in deserved glory but still occupies an utterly inappropriate turf for the weirdest of perfectly reasonable circumstances—as the very antithesis of *genius loci*. I say this not primarily for the practical reason that this tiny and isolated town in central New York State cannot offer enough hotel rooms within fifty miles to house the crowds of people wishing to attend the annual induction ceremonies for the Hall of Fame, but simply because Cooperstown can stake no legitimate claim as a shrine for baseball. As argued above, baseball experienced no eureka of origin but just grew, evolved, and eventually coagulated from a host of precursors. But humans need origin myths, so when baseball became enshrined as a national pastime, an official commission, established early in the twentieth century, was charged with the task of


Baseball in a tenement alley, 1909

discovering baseball's origins. For a set of complex reasons, the members of the commission allowed themselves to be persuaded that Abner Doubleday had effectively invented the game in Cooperstown in 1839. No even remotely plausible evidence links Doubleday to baseball (one commentator pungently remarked that the man probably couldn't tell a baseball from a kumquat). But Doubleday was certainly a sufficiently adequate American hero to embody an origin myth, for he had fired the first Union shots of the Civil War, as artillery officer at Fort Sumter, and he later served as one of the generals at Gettysburg.

In any case, myths require relics, so you may see on display the famous Doubleday ball—submitted as corroboration for the founding legend, perhaps discovered in Cooperstown, probably a bit younger than 1839, and surely possessing no plausible tie to Doubleday himself. I have also been told that enough nails from the true cross exist in European cathedral reliquaries to affix a hundred of Spartacus's soldiers to their crosses on the Appian Way. Thank God that the human mind can embrace contradiction by acknowledging reality in the head yet respectfully allowing an imposter to stand for a symbol in the heart. (In a funny and recursive sense, moreover, once frauds achieve sufficient fame, they become legitimate objects of history in their own right!)

2. *Relics and icons.* If a reliquary really preserved a nail of the true cross, any Christian (I am not one) would bow in reverent awe, and any decent person (as I am) would stand respectfully before such an important item of history and symbol of human cruelty and hope. Well, this exhibition includes many true relics of a secular church that admittedly cannot claim similar importance but that does mean one helluva lot to many quite sane and even reasonably perceptive people. Hey folks, I mean you're really going to see the Babe's bat from 1927 (the year he hit those sixty dingers for an "unbeatable" record), Roger Maris's bat from 1961 when he broke the record, and Mark McGwire's bat from when the record fell again in



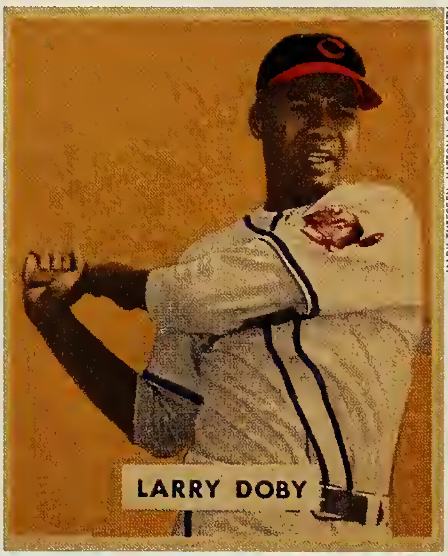
GEORGE EASTMAN HOUSE

1998. And because failure can be as sublime as hope (the raised Lazarus versus that nail of the true cross, although I know that Christian theology does not regard the Crucifixion as a dud), you will also see Michael Jordan's bat from the year he tried baseball, discovered he really couldn't hit a curveball despite being the world's greatest athlete, batted about .225 in a year of minor league play, but stayed the course (and played the full season) with honor.

3. *Records of sacred events.* Churches and shrines not only boast general heroes, they also feature parables and stories of canonical import. Baseball revels in poignant, heroic, and defining stories by the dozen, and many items in this exhibition embody such crucial moments. But just as you need a scorecard to tell the players (an adage with baseball origins), so too do you need a tale to explain each of these items. So let me tell you just two stories of ultimate pain from two generations of Yankee worship in my family. (I suspect that cleansing drafts of pain match ecstatic quaffs of joy in any religion.) First, the 1926 World Series ring of Grover Cleveland Alexander. So what? Well (and you can see the scene yourself in an old film, with none other than Ronald Reagan playing the inebriated pitcher), here's the setting: October 10, the deciding seventh game of the World Series, Cardinals against Yankees. The Yanks, just slightly behind in the score, load the bases in the seventh, and the Cardinals' manager brings in his aged hero, the dipsomaniacal Alexander, who had pitched a full game (and won) the day before and then got stinking drunk, never expecting a call for the final contest. Tony Lazzeri at the plate, and my Dad (age eleven) at the radio. Lazzeri hits one headed for the seats, a homer, and a Yankee victory,

No even remotely plausible evidence links Doubleday to baseball, but he was enough of an American hero to embody an origin myth.

but the ball goes foul by a few feet. Alexander then strikes Lazzeri out and later wins the game. My father thought he would never again be happy but recovered two days later. Second, a ball used by Johnny Podres in the 1955 World Series. Well, I was walking home from school with my friend (and Dodger fan) Steve Cole, listening to the seventh and last game of the World Series. Podres won for the Dodgers, the only time (in their Brooklyn incarnation) that the Bums ever beat the Yanks in the World Series. I'm not sure I've ever been truly happy since then. But wiser—and that's more important, I suppose.



MARK THIESSEN; NATIONAL GEOGRAPHIC SOCIETY

4. *Linkage to general culture.* Religion wouldn't do much for us as a sanitized shrine, fully divorced from the spaces and realities of surrounding life. And as I noted to open this piece, baseball does not "stand for" America because the sport imitates life in some metaphorical way; rather, baseball illustrates nearly all aspects of America because the institution has been so central and important in our life and culture (and also because the basic rules of play have not changed for more than a century, so we can truly understand and feel the import of old happenings). Consider just two cardinal (if tragic) realities of our lives. First, war. The exhibition includes the most famous icon of all, the ultimate sign of baseball's importance to the fabric of America: President Franklin D. Roosevelt's 1942 letter to the baseball commissioner, urging that baseball continue during World War II so that symbols of normalcy might boost our morale. For other items, one needs a bit more explanation. I love the pairing of Moe Berg's ID card for the Office of Strategic Services with Bob Feller's military goggles, both from World War II. Berg, baseball's great raconteur and quite mediocre catcher, always claimed that he spoke at least half a dozen languages and had worked as a spy, tracking Werner Heisenberg and the German nuclear program during the war. His tales were widely disbelieved, but several recent studies have confirmed the basic story after all. Feller, the fastest pitcher of his generation, a rootin' tootin' midwestern conservative and a fighting man from day one, was a genuine military hero—never doubted for a moment, always honored, and God bless. Another item needs no explanation for its searing into recent memory: a baseball found in the rubble of the World Trade Center.

Second, the sad history of racism, where baseball has ever so much to answer for but finally responded well, albeit so belatedly. Again, humble items, easily bypassed, tell deep tales once one knows the context. Consider, for ex-

DAILY NEWS PHOTO (1952)

ample, the baseball cards for Pumpsie Green and Larry Doby: Green, a utility infielder of no special merit as a player, wins his poignant role in this sad history as the first black player on the last team to integrate—shameful to say, the Boston Red Sox, from New England's bastion of liberty. Doby, a truly great player for the Cleveland Indians, has never received his proper due because he came second, and our culture remembers only front runners: Jackie Robinson, as everyone knows, integrated baseball with the Brooklyn Dodgers of the National League in 1947; Doby entered just after Robinson, as the first black player in the American League.

5. *Social spreadings and meanings.* Baseball has become so enmeshed with our general culture that I can only feel sorry for Europeans who, in watching American movies, have to be mystified by the young stud's lament, "I didn't even get to first base with her," or who cannot appreciate the poignancy of a great moment in the history of tear-jerkery—when Gary Cooper, playing Lou Gehrig in *The Pride of the Yankees,* asks a physician who has just diagnosed the fatal illness that now bears his name. "Doc, is this strike three?"

Yes, you can use baseball to understand more general culture. But the process can also work in the less-appreciated reverse direction by citing cultural norms to understand baseball's peculiarities. To choose two examples, both auditory rather than visual this time: Everyone knows the ritual of singing "Take Me Out to the Ball Game" during the seventh-inning stretch, but where did this ditty—second in inanity and frequency only to "Happy Birthday" as an American universal—come from? The piece sounds like a pop song from the Gay Nineties or the early twentieth century—an entirely correct inference, by the way. But as the Edison cylinder in the Museum's exhibition shows, the words that we know and sing comprise only the chorus for a standard pop tune that has several verses as well. And the verses record the pleas of a woman trying to convince her boyfriend to "take me out . . ."!

As a second example, I could never understand why such abominable and silly doggerel as "Casey at the Bat" ever became the canonical poem of both American baseball and the normalcy of failure in general. That is, until I *heard* the poem in an ancient film of a vaudeville performer (as the Victor disc also in this exhibition illustrates). Then I understood. The poem was written to be declaimed, not to be read silently. Declamation of poetry in the nineteenth century represented a standard social recreation in American life, a fixture of nearly every party, and the doggerel succeeds marvelously in this intended aural context.

Finally, if we need any more proof of the vitality of baseball and the power of *genius loci,* just stare in reverence at the centerpiece of this exhibition: a pile of dirt from Ebbets Field, home of the Brooklyn Dodgers (and the greatest ballpark I ever knew—an admission, remember, that comes from a Yankee fan!). I mean, folks, it's just a pile of dirt. And dirt is dirt. Yeah, and nails are nails. But a nail from the true cross and dirt from Ebbets Field—need I say more? We cannot dedicate, we cannot consecrate, we cannot hallow such ground. Robbie did, and

> The most famous icon of all is the 1942 letter from FDR to the baseball commissioner, urging that the sport continue during World War II.

Campy, and Duke, and Pee Wee, and also the Preacher—and what poor power do *we* have to add or detract? So of course I don't care if I ever get back, because I'm there already, and there's no other place to go. Truly we are all in this particular game together, and if we play our collective cards right (after all, my family's going on four generations and still counting), we may ward off strike three for the evolutionary equivalent of forever.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University. He is also the Frederick P. Rose Honorary Curator in Invertebrates at the American Museum of Natural History.

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Looking back on his career as an executive at Simon and Schuster, Jason Berger says, "One of my proudest achievements was the distribution of Little Golden Books to supermarkets and pharmacies across the country, where they found their way into the hands of millions of young children who otherwise might have had little exposure to children's literature."

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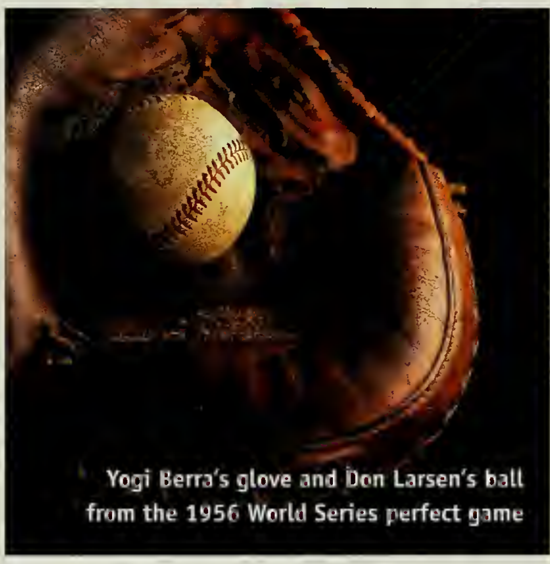
3/02

MUSEUM EVENTS IN MARCH

"BASEBALL AS AMERICA"

Exhibition opens 3/16 in Gallery 3 and continues through 8/18/02.



Yogi Berra's glove and Don Larsen's ball from the 1956 World Series perfect game

MILO STEWART JR.; NATIONAL BASEBALL HALL OF FAME AND MUSEUM

Screenings 3/16, 3/31: Program of baseball shorts, including *Mickey's Nine* (1927), *Boulevardier From the Bronx* (1936), and *Oompahs* (1951). Presented by film historian Karl Cohen, San Francisco State University. Kaufmann and Linder Theaters, 1:00–2:00 P.M.

"PEARLS"

Exhibition in Gallery 4 through 4/14/02.

Lecture 3/2, 3/3: "Carib Pearls: The Impact of the Spanish-Caribbean Pearl Trade on the Indigenous People of the Caribbean." A. Michael Auld, Bell Multicultural School. Linder Theater, 1:00 P.M.

Performance 3/2, 3/3: *Kinding Sindaw* ("Dance of Light"). Linder Theater, 2:00 P.M.

Lecture 3/2, 3/3: "Powhatan's Pearls: Freshwater Wealth During the European Contact Period of Early America." Native American historian and artist Rose Powhatan. Linder Theater, 2:45 P.M.

Workshops 3/10, 3/17: "Pearl Needle Art." Artist Ita Aber. Room 319, 10:00 A.M. and 12:00 P.M.

Screening 3/15: *Pearl of the South Seas* (1926). Silent feature film by Shackleton expedition photographer Frank Hurley, with piano improvisation by Ben Model. Kaufmann Theater, 7:00 P.M.

Screenings 3/17, 3/30: Program of short films that feature pearls, including *Sultan Pepper* (1934) and *Ali Baba Bunny* (1957). Presented by Karl Cohen. Kaufmann Theater, 1:00–2:00 P.M.

MARINE CONSERVATION

Film and panel 3/5: "Empty Oceans, Empty Nets." Carl Safina, National Audubon Society's Living Oceans Program. Linder Theater, 7:00 P.M.

Symposium 3/7–3/8: "Sustaining Seascapes: The Science and Policy of Marine Resource Management." Kaufmann and Linder Theaters, 9:00 A.M.–5:00 P.M. Information at (212) 769-5200 or at research.amnh.org/biodiversity/.

SCIENCE MEETS MUSIC

Discussion and concert 3/14: "An Evening of Theremin" (a musical instrument, invented by a physicist, that is played without being touched). AMNH senior preparator David McCornack and musician Pamelia Kurstin. Rose Center, 7:30 P.M.

"FORCED OUT! SEEKING REFUGE"

Roundtable 3/9: "The Reality of Refugee Women." Presented by Art for Change. Linder Theater, 4:30 P.M.

Performance 3/9: *Displaced.* Stephanie Barton-Farcas, Natily Blair, Julie Campbell, Gina Daniels, and Jo Yang. Kaufmann Theater, 6:00 P.M.

Workshop for teens 3/10: "On Refugees." Leonhardt People Center, 1:00–4:00 P.M.

"PAPER TRAILS . . . IN REAL TIME!"

Art installation 3/9–4/21 (weekends): "The Path of Paper." Sculptor Helen Evans Ramsaran. Leonhardt People Center, 1:00–5:00 P.M.

Lecture 3/9: "Global Paper." Mina Takahashi, Gail Deery, Lynn Sures. Leonhardt People Center, 1:00 P.M.

Field trip 3/9: Dieu Donné Papermill, 4:00–6:00 P.M.

Walking tour 3/9, 3/10: "Paper Objects in the Halls of Asian and African Peoples." 2:00 P.M.

Workshop 3/10: "Accordion-Fold Books." Calder Lab, 3:00–4:00 P.M.

Workshop 3/23: "Objects of Power for Mothers, Daughters, and Others." Calder Lab, 3:00–4:30 P.M.

Gallery talk 3/23, 3/24: "Images and Symbols of the Power of Women in Sub-Saharan Africa." AMNH Hall of African Peoples, 2:00 P.M.

Slide lecture 3/24: "Dwellings: Real and Imagined." Leonhardt People Center, 3:00 P.M.

AMNH BOOK CLUB

Monthly meeting 3/10: *Women of Discovery: A Celebration of Intrepid Women Who Explored the World,* by Milbry Polk and Mary Tiegreen. Portrait Room, 3:00–4:30 P.M.

GARDENING

Composting course 3/26–4/23 (five Tuesdays): Scott Kaufmann, Manhattan Compost Project and New York Botanical Garden. Information at (718) 817-8024. Rose Center Classroom, 6:00 P.M.

ASTRONOMY & COSMOLOGY

Lecture 3/4: "When the Universe Was Young: The Most Distant Objects in the Universe." Astrophysicist Michael Strauss, Princeton University. Space Theater, Hayden Planetarium, 7:30 P.M.

Lecture 3/18: "First Light: The End of the Cosmic Dark Ages and the Formation of Stars." Michael Norman, Center for Astrophysics and Space Sciences, University of California, San Diego. Space Theater, Hayden Planetarium, 7:30 P.M.

Upcoming sky events 3/26: "Celestial Highlights." Joe Rao, meteorologist and *Natural History* columnist. Space Theater, Hayden Planetarium, 6:30 P.M.

"CREATING ETHNICITY"

Photographic self-portraits 3/22–4/21: Artist Margaret Francis. Charles A. Dana Education Wing.

JAMES ARTHUR LECTURE

Lecture 3/5: "Emotion and the Human Brain." Neurologist Antonio Damasio, Iowa College of Medicine and the Salk Institute. Kaufmann Theater, 6:00 P.M.

ALSO IN MARCH

Tours: "Many Religions: One City." Visit centers of worship around New York City and pertinent AMNH galleries. Karen Kane, AMNH. 9:30 A.M.–2:00 P.M., beginning 3/16. For information about this and other tours, workshops, and field trips, call (212) 769-5200.

Planetarium courses: "How To Choose a Telescope," "The Planets: A Historical Perspective," and others. Complete schedule at (212) 769-5200 or at www.amnh.org/hayden/.

The American Museum of Natural History is located at Central Park West and 79th Street in New York City. For listings of exhibitions, public programs, 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.

THE SECRET LIFE OF THE BRAIN

Richard Restak, M.D.

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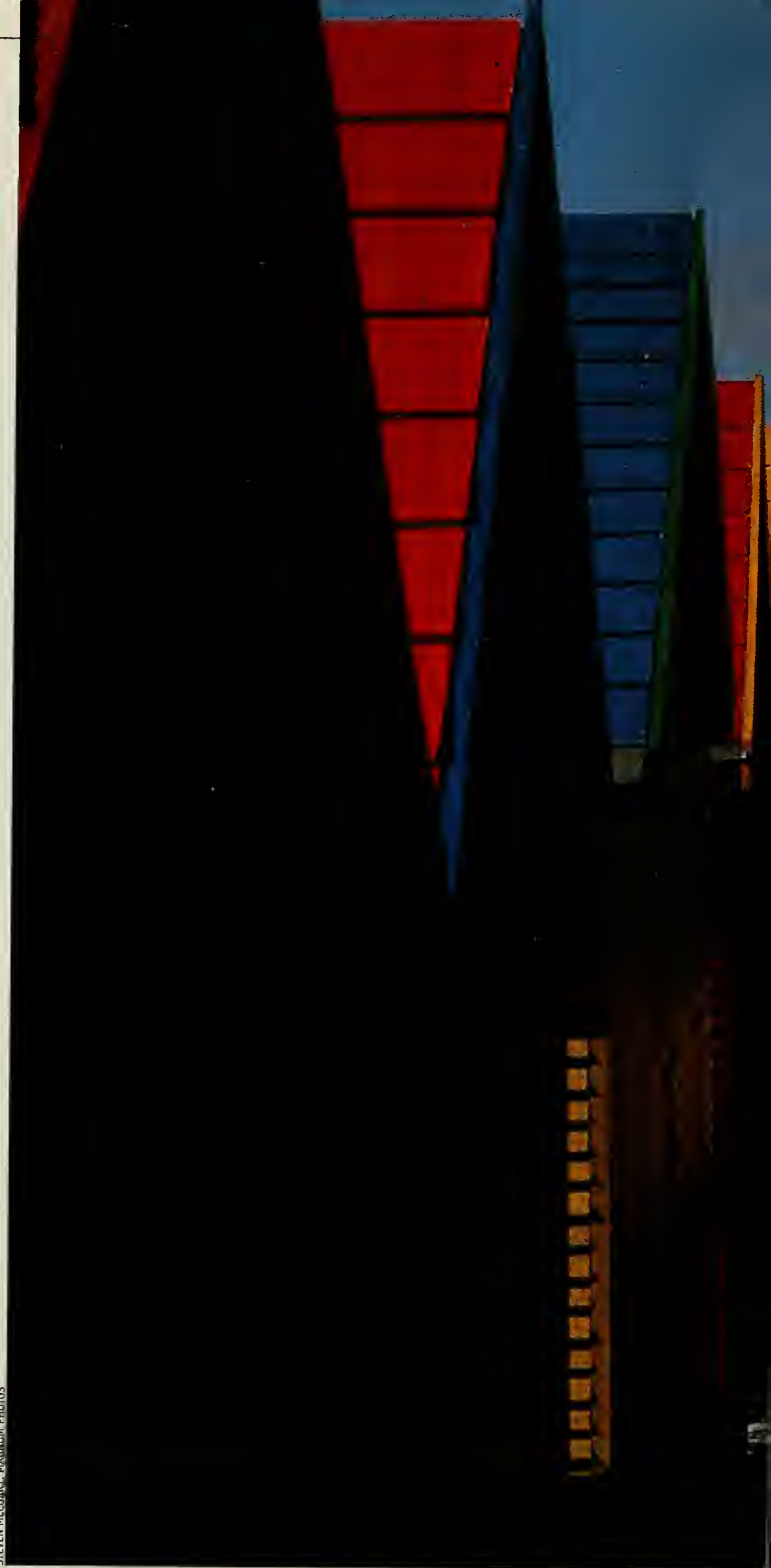
We owe our appreciation of color—what it is and how we perceive it—to scientists and artists. Do we also have some hungry primate ancestors to thank for the great pleasure it brings us?

By Philip Ball

When the sun shines through a rain-darkened sky, one of nature's most celebrated wonders is revealed. In the arch that curves from the earth to the heavens, we can read the origin of colors. Sunlight seems to take on the color of anything it bounces off—a red rose or a green leaf—because all these colors lie within the light, waiting to be sifted out by an encounter with the tangible world. In the rainbow, raindrops do the sifting systematically; each band is part of a progression through the visible spectrum, from red to violet.

In the seventeenth century, when Isaac Newton showed how this happened, he seemed at last to have answered the question that had frustrated philosophers for centuries: What exactly is color? Yet Newton's was not the last word. Indeed, for some people it simply raised more questions. Painters struggled to understand how Newton's theory of light and color applied to pigments. The German Romantic literary figure Johann Wolfgang von Goethe decided that Newton's ideas about color were nonsense, and some scientists were ready to agree with him. Even today it would be unwise to conclude that we fully understand color.

What did Newton say that created so much confusion and controversy? And why didn't his theory, brilliant though it was, tell the whole story? Why is color so hard to pin down?



STEVEN MCCURRY; MAGNUM PHOTOS

Seeing Red...and

Beach huts, Saint James, South Africa

Yellow...and Green...and

BLUE

Julius Caesar's legions were awed by the fierce blue warriors who resisted the Roman conquest of Britain. "All Britons dye themselves with woad which makes them blue," Caesar recorded, "so that in battle their appearance is more terrible."

Woad was extracted from the plant *Isatis tinctoria,* which grew throughout Europe and Asia. Its blue colorant is chemically identical to the indigo dye made from plants of the genus *Indigofera,* cultivated in Asia. The Romans themselves imported the dye from the East and used it to paint their armies' parade shields.

PICTISH MAN, WATERCOLOR BY JOHN WHITE (CA. 1585); THE GRANGER COLLECTION

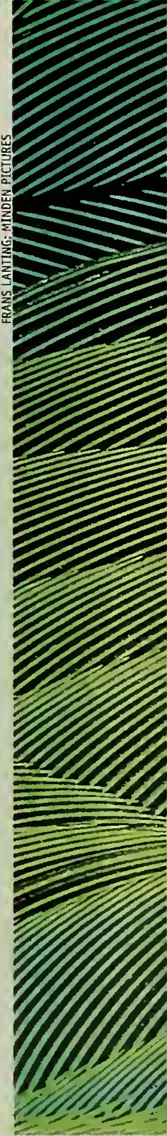
Dried indigo was traded in bricklike lumps. Unaware that it came from a plant, the first-century Roman writer Pliny the Elder called indigo a "silt that forms in frothy water and attaches itself to reeds."

Manufacturing indigo and woad could indeed be a frothy business. Woad plants were dried and ground, then fermented in a vat and beaten, whereupon a blue-colored froth rose to the surface. It was not a nice process: an ancient recipe directs that the plants be soaked in urine under the heat of the sun and trampled daily. Fermenting urine gives off ammonia gas, so production of these dyes may have been responsible for one of the first noxious industrial emissions. Dye makers were often shunned and banished to the outer reaches of town.

The plants themselves are scarcely more benign. Woad robs the soil of nutrients, forcing medieval woad growers in Europe to move frequently in search of uncultivated land. They left so much wasteland in their wake that laws were passed to curb the planting of woad.

Newton is often credited with explaining (or, in English poet John Keats's derogatory phrase, "unweaving") the rainbow. But that is not quite what he did. The ancient Greeks speculated that rainbows are caused by sunbeams falling onto clouds, and philosophers had known for centuries that light passing through glass, transparent minerals, or water can generate a multitude of colors. Then, in 1637, French philosopher René Descartes showed that sunlight becomes focused into a circular arc when it bounces off raindrops.

What Newton did was to bring color to Descartes's rainbow. In 1665 he split a sunbeam into a many-hued spectrum by passing it through a prism in a darkened room. And he found that if all the spectral colors were brought back together with a lens, they merged into a beam of white light. (By definition, white light is composed of rays of all the wavelengths from red to violet.) Newton deduced that the prism caused rays of different colors to bend through different angles and that the same thing happens in rainbows, wherein each raindrop acts like a tiny prism. More than three centuries later, schoolchildren are still taught that the spectrum's "bow," as Newton declared, has seven strands: red, orange, yellow, green, blue, indigo, and violet. In fact, this list of colors is rather arbitrary. A man of his time, Newton saw concordances throughout nature, leading him to imagine that the colors of the rainbow must mirror the seven notes of the heptatonic scale, the dominant scale used in Western music. Later color theorists generally replaced indigo and violet with just a single hue: purple or violet.



FRANS LANTING/MINDEN PICTURES

Newton had discovered that color comes from plucking this rainbow of light. But what is light? The modern answer to that question came two centuries after Newton, when Scottish physicist James Clerk Maxwell declared that light is a vibrating field of electrical and magnetic energy: an electromagnetic field passing through empty space like a wave traveling across the sea. The frequency of the vibrations increases from the red to the violet end of the spectrum, thus determining the perceived color of the light. The wavelength of these light waves gets shorter as the frequency gets higher.

Most objects acquire their color by absorbing rays of certain frequencies and reflecting the rest. A substance absorbs light of a particular frequency because the vibrations of its cloud of electrons—negatively charged subatomic particles that bind one atom to another—resonate at that same frequency, like a guitar string humming in sympathy with a loudly sung note. These resonant frequencies depend on the chemical composition of the substance: which atoms it contains and how they are joined together.

We don't see absorbed rays, only reflected ones.

So we ascribe to an object the color of the very rays it rejects. A red berry soaks up green and blue from white sunlight; a yellow flower pulls in blue and red. The pigments on the painter's palette also derive their color by absorbing light.

JEFF LEPORE; PHOTO RESEARCHERS, INC.

Above: Detail of feathers on the wing of a military macaw. Left: Eye of a tree frog from Central America.

But not all color is generated this way. The rainbow's variegated arc results from refraction, the bending of lights rays as they pass from one medium to another (in this case, from air to the water in raindrops). Another physical color-producing process is scattering: the dispersal of light in all directions by particles in the atmosphere that are about as big as a single wavelength. Light scattering is what makes the sky blue. Rays from the sun are scattered by atmospheric dust, sending the light bouncing in all directions. These dust particles scatter more high-frequency light than low-frequency light, so blue light bounces around in the atmosphere and reaches our eyes from all parts of the sky. Distant hills have a bluish tint because the light reflected from the hills is mixed with blue light from the atmosphere.

A different physical mechanism is responsible for the colors of certain plants and animals: interference.

Above: Textile dyeing factory in Rajasthan, India. Right: Slices of watermelon.

LAROYE 084, BY MARIO CRAVO NETO (1978); COURTESY YANCEY RICHARDSON GALLERY

This happens when light is reflected from a gridlike arrangement of very small objects. The reflected rays interfere with one another; those at some wavelengths are canceled out (destructive interference), and those at others are enhanced (constructive interference). Some of the tiny scales on butterfly wings, for example, are covered with a grid of microscopic ridges. The spacing between the ridges determines which wavelengths of light interfere destructively and which survive. If the ridges are close enough together, the scales reflect the short wavelengths of visible light, and the wing looks blue. But the

XAVIER ZIMBARDO

precise color also depends on the angle at which the wing is viewed, since the wavelength of the constructively interfering rays varies with the angle of reflection. This explains the iridescence—the shimmering changes of color—of many butterfly wings as well as the iridescent cuticle of some insects and the shifting colors of the peacock's tail.

Artists and technologists interested in making colors have long recognized two basic types of colored materials: inorganic (derived from minerals) and organic (derived from living organisms). When modern-day chemists speak of organic substances, however, they don't necessarily mean ones taken directly from living organisms; rather, they mean materials whose building blocks are carbon-based molecules, present in crude oil and alcohol, for example. Many of today's organic materials (polyester, vinyl, acrylics) are synthetic, produced by industrial processes. Traditionally, organic materials provided dyes (which would usually fade when exposed to sunlight, because light breaks down the light-absorbing carbon molecules), and inorganic materials furnished pigments. Bright-colored inorganic substances usually contain atoms of the elements known as transition metals: Copper minerals are often green or blue; iron minerals are typically red or yellow or brown, and cobalt minerals deep blue. Chromium is something of a chameleon, offering colors ranging from bright yellow to deep green and rich red. Its very name comes from the Greek word for color.

Many minerals are, of course, simply a drab shade of gray. These typically lack transition metals, being instead composed of other metals (sodium, calcium, magnesium, aluminum) plus silicon and oxygen. They generally absorb light strongly only outside the visible range, so they have little to offer by way of chromatic beauty. Certain colorless minerals—corundum (aluminum oxide) and beryl (beryllium aluminum silicates), for example—are transformed into gorgeous gems such as sapphires, rubies, and emeralds by the presence of a sprinkling of transition-metal impurities.

While rose quartz acquires its color from impurities of titanium or manganese, no such metals tint the rose itself: the coloring agents in flowers and other living organisms are organic compounds. Tyrian purple, the imperial dye of ancient Rome, was squeezed from shellfish; natural indigo was the precipitate of a frothy extract of several species of plants.

Nature owes its verdancy to chlorophyll, an organic pigment molecule with a magnesium atom at its heart that imbibes the red and blue of the sun's

RED

The philosopher's stone is red, or so the alchemists believed: "Red is last in the work of Alkimy," said Norton of Bristol in the fifteenth century. To make the stone, which was thought to transform base metals such as lead into gold (and also to prolong and sustain life), one had to guide the raw ingredients through a series of color changes ending in red.

But what was this mythical substance, sometimes called the Red King? Medieval alchemists experimented with a range of red-colored materials, among them the precious pigment known as vermilion, a synthetic compound of sulfur and mercury that was probably first made by ancient Chinese alchemists. Cinnabar, a natural mineral form of mercury sulfide, is included in some Chinese recipes for making the stone.

Islamic alchemists of the eighth and ninth centuries had the notion that all metals were mixtures of especially pure forms of sulfur and mercury. Making gold from lead, they thought, was simply a matter of adjusting the balance. It would have been natural for them to suspect that vermilion might play a role in this.

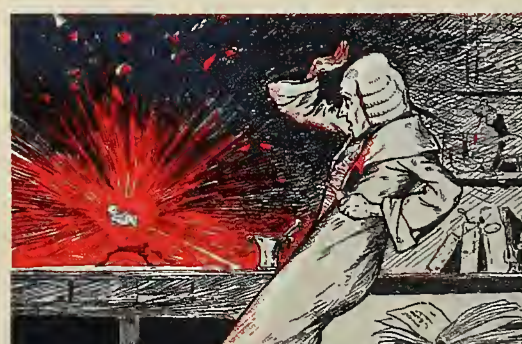
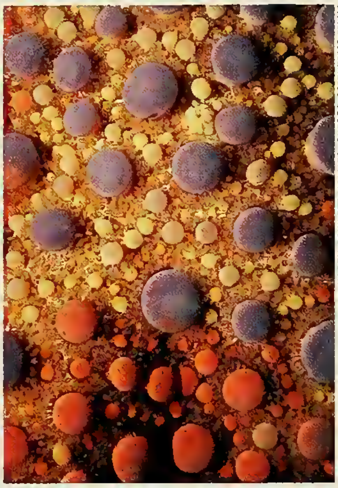


IMAGE OF ALCHEMIST (1911). JEAN-LOUP CHARMET; SPL/PHOTO RESEARCHERS, INC.

The Anglo-Irish chemist Robert Boyle was an avid alchemist who, shortly before his death, found a way to produce what he believed was a rudimentary form of the stone; this "red earth" probably contained mercury. Isaac Newton obtained some of Boyle's mysterious red powder and experimented on it. Shortly afterward, Newton had some kind of mental breakdown. His sickness may have been caused by mercury poisoning: high levels of this toxic metal were found in preserved samples of Newton's hair.


KAREN GOWLETT-HOLMES; OXFORD SCIENTIFIC FILMS

Close-up of a sea star

rays. Chlorophyll channels this solar energy into the metabolic processes of plant cells. And within the hemoglobin in our blood are light-absorbing groups of atoms whose structures are similar to that of chlorophyll, except that iron, in all its ruddiness, substitutes for magnesium. The yellows, oranges, and reds of many flowers, as well as the hues of carrots, tomatoes, and sweet corn, are produced by carotenoids. These pigments are also present in many leaves, though their presence there is usually masked by the stronger absorption powers of chlorophyll. When chlorophyll decays in autumn, the carotenoids shine through.

In Newton's 1704 book *Opticks,* in which he set out his theory of color, the physicist did a curious thing: he bent the spectrum into a circle, marrying red to violet so that the progression of colors would be continuous. This is how the familiar image of the color wheel came into being. Subsequent color theorists made the wheel even tidier by cutting it up into six equal slices: red, orange, yellow, green, blue, and violet. The modern incarnation of the color wheel is neither symmetrical nor egalitarian but is more accurate (breaking up the misleadingly smooth marriage of red and violet, for instance) and a lot more informative. Drawn up in 1931 by the Commission Internationale de l'Éclairage (CIE), it is known as the CIE chromaticity diagram. The colors of Newton's spectrum correspond to points along a tongue-shaped curve, while the colors inside (or beneath) the curve are made by mixing these spectral rays.

Yet even the CIE diagram doesn't encompass all colors; no single flat diagram could. The CIE diagram doesn't show colors produced by variations in brightness: gray is a dim white, while brown is a dim yellow or orange. To map out every possible color, we would need a whole stack of CIE diagrams in which the white center got progressively grayer.

One of the first cartographers of color space was the American artist and teacher Albert Munsell. In 1913 he introduced a system in which colors were plotted as a series of discrete steps, or "chips." Schemes like Munsell's provided us with the charts that are now available from paint manufacturers. In truth, of course, colors merge smoothly in color space, much as the evening sky may shift from fire orange to cobalt blue. All the same, we tend to pick out "color kingdoms" and label them "red," "blue," and so forth. How many kingdoms exist? Newton, as we have seen, claimed there were seven, from which all other colors were made. But by the seventeenth century, painters had decided they could manage with just three: red, yellow, and blue (plus black and white to lighten and darken them). These three were considered the primary colors. Mixtures of each pair (red and yellow, yellow and blue, blue and red) produced the three secondaries—orange, green, and violet—that filled in the rest of the spectrum.

Painters' experience with color mixing seemed at odds with Newton's claims. When mixed in equal parts, red, yellow, and blue paints yield a murky brown, not the white


BRUNO BARBEY; MAGNUM PHOTOS

BROWN

Brown may be the least glamorous of all colors. It is the hue of mud and grime, and the murky result we get from mixing all the colors on the palette. It is also the color of decay—for what is soil, after all, but rotted vegetable matter? Fall leaves are considered beautiful when red and golden, but most of us lose interest when they become brown.

RENÉ MAGRITTE; ART RESOURCE, NY; 2002 C. HERSCOVICI, BRUSSELS/ARS, NY

Some languages don't even deign to give brown an unambiguous name. Translated into French, it is usually rendered as *brun*. But *brun* can also imply simply "dark" (when referring to a hair color, for instance), while the French would always prefer to designate individual brown objects as *marron* or *beige,* never *brun*.

And you can scan the visible spectrum in vain for brown: it is not there. The Impressionist painters decided that brown was antithetical to their prismatic technique, and several of them banished the color from their palettes. When Claude Monet wanted a brown, he typically mixed it from primary colors rather than using traditional earth pigments such as sienna and umber.

that Newton said would result from combining all the colors of the rainbow. This apparent inconsistency offered plentiful ammunition to Newton's detractors, Goethe among them. Any fool could see that no mixture of pigments produced pure white or anything like it.

James Clerk Maxwell dispelled the confusion in 1855 when he explained that mixing light rays of different wavelengths produces color in a different way than mixing pigments does: the former works by a kind of addition, the latter by subtraction. Maxwell showed that three kinds of light—orange-red, blue-violet, and green (a triad usually denoted simply as red, blue, and green)—suffice to generate almost any color. This additive method is how television screens, for instance, make color. On the other hand, making colors by mixing pigments is a form of subtractive mixing. A red pigment absorbs—that is, subtracts—the blue and green rays of light, and much of the yellow; only red light is reflected. A yellow pigment would remove the blue, violet, and some of the red and green. So mixing red and yellow narrows the range of unabsorbed rays, leaving just those in the orange part of the spectrum. Each time a pigment is added to a mixture, another chunk of the spectrum is subtracted from the reflected light, and the color gets muddier.

Goethe may have been unfair to Newton, but he was right to stress that color is not about light alone. There is also the matter of how we perceive it—and this is the trickiest business of all. Maxwell agreed, averring that "the science of colour must be regarded as essentially a mental science."

Perception is what happens when the eye and brain meet color and form. In 1802, English scientist Thomas Young proposed a theory of color

Street scene in Jodhpur, India

vision based on the primaries red, blue, and green. He postulated that the retina of the eye contains "particles" that respond to rays of light by vibrating in resonance with them and that these vibrations create a signal that is dispatched along the optic nerve to the brain. Young suggested that three types of particles, each sensitive to one of the three primaries, are enough to enable us to perceive a full range of colors. People who are color-blind, he proposed, lack one type of light receptor. Later in the nineteenth century, German scientist Hermann von Helmholtz developed Young's ideas further, and the resulting trichromatic (three-color) theory of vision bears both their names.

We now know that Young's particles are light-sensitive cells in the retina, of either a rodlike or a conelike shape. Each human retina contains about 120 million rods and 5 million cones.

Experiments in the 1960s con-

RANDI HIRSCHMANN

Right: Chugach Mountains reflected in Reedy Lake, Matanuska Valley, Alaska. Below: Mexican tulip poppies.

firmed Young's 1802 hypothesis of trichromaticity by showing that cone cells come in three varieties, each with a different color sensitivity. Some respond most strongly to yellow light (as reflected from, say, a yellow flower), some to green, others to violet. The three types of cones are often, and somewhat misleadingly, equated with Maxwell's additive primaries of red, blue, and green. They are more accurately denoted as responsive to (that is, most strongly absorbing of), respectively, long (L), medium (M), and short (S) wavelengths of visible light. Together these three types of cone cells allow us to perceive all colors. A mixture of red and green rays, for example, can stimulate the L and M cone cells in the same ratio (about 70 L to 30 M) as does pure yellow light—and so the color sensation is identical in both cases. This is why the additive mixing of red and green produces yellow. The overall sensitivity of the eye to any particular color is the sum of the responses for all three types of cones. The neural signal increases steadily from red to yellow and then declines from yellow to violet, so yellow is perceived as the brightest color. The S (blue-violet) cones are the least sensitive of the three, which is why fully saturated blue looks relatively dark.

TIM FITZHARRIS; MINDEN PICTURES

Rod cells, by contrast, send out an identical neural response regardless of the wavelength of light they absorb. They are extremely sensitive and are the main light receptors we use in very dim illumination, such as starlight, but because they don't encode any information about wavelength, rods are of little help in identifying colors. Rods do respond to blue-green light more strongly than they respond to light of other colors, however, so objects that reflect these colors (such as leaves) appear brighter at night than red objects do.

Many animals have better color vision than we do. Several types of birds and fish have four types of color-sensitive cone cells, making them more "sophisticated" at distinguishing colors. Like us, bees have three color sensors in their eyes, but because their sensitivities are shifted to shorter wavelengths than ours, bees can see in the ultraviolet (UV) range. They use their color vision to search for nectar and can distinguish flower "colors" that are invisible to us. Many birds, too, see in the ultraviolet range. Some may use this ability to find a mate or fruits that reflect UV light. Some researchers have suggested that kestrels may track voles by homing in on trails that the little rodents have scent-marked with urine. These urine trails strongly absorb UV light and thus are visible to the birds as dark streaks. And the night vision of owls may extend into the infrared region.

Color vision helps animals find their way in the world. Objects of different colors but similar brightness can't be easily distinguished without color clues: it would be hard to make sense of a sports event watched on an old black-and-white television if one team wore red and the other wore green. To tell colors apart, we need at least two different types

YELLOW

In the West, yellow is often associated with cowardice and treachery, which is why Judas wears a yellow cloak in Giotto's *Kiss of Judas.* But in China yellow is a noble color; from the seventeenth to the twentieth century, only the Ch'ing emperors could wear it.

Traditionally—again in the West—yellow has been the least popular of colors. Fashion designers tend to avoid yellow, since few people think they look good in it. Yellow eyes or a yellow complexion can be signs of illness (as in jaundice) or of devilry, or both: Frankenstein's monster had yellow, watery eyes.

PORTRAIT OF YINXIANG (1905), ARTHUR M. SACKLER GALLERY; SMITHSONIAN INSTITUTION

But as the brightest, and thus most visible, of all colors, yellow is valued as a danger signal or simply an attention-getter. Think of school buses or of New York City taxicabs. Horse-drawn coaches for hire in nineteenth-century Paris were also painted yellow. Flying a yellow naval flag once signaled sickness on board ship—linking the color's visibility to its frequent association with ill health. The yellow markings of many poisonous insects warn larger predators not to try eating them; yellow signs warn us of toxic or radioactive hazards.

In the Middle Ages, painters had good reason to be wary of glorious yellow orpiment, for it contained deadly arsenic. "Beware of soiling your mouth with it," advised late medieval craftsman Cennino Cennini. Vincent van Gogh used safer yellows, but he made from them sickly, incandescent suns that seem to promise no warmth.

WHITE

White sometimes seems like a color for people who don't like color. The sculpture and architecture of the ancient Greeks were once considered noble and pure because of their whiteness (we now know that all the bright paint has simply come off). The Swiss modernist architect Le Corbusier crusaded for whiteness to suppress "the distracting din of colors." By applying a coat of whitewash, he said, "we would perform a moral act: to love purity! We would improve our condition."

FEMALE TORSO II, BY KASIMIR MALEVICH (1878–1935): AKG PHOTO

Le Corbusier was not alone. Many a minimalist modern interior radiates the order and control that white is deemed to produce. Dutch painter Theo van Doesburg celebrated white as "the color of modern times, the color which dissipates a whole era." Russian painter Kasimir Malevich went further, painting white squares on white backgrounds. White, he said, is the ultimate color, the "true, real conception of infinity."

And many of us seem to agree, at least on some level, with the supremacy of white. The pigment produced commercially in the greatest quantities by far is titanium white, which we apply to everything from window frames and office interiors to automobiles.

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of cone cells. Indeed, most mammals are capable of only this minimal kind of color discrimination.

Between 30 million and 35 million years ago, however, our primate ancestors began to develop the trichromatic color sensitivity that humans, apes, and Old World monkeys possess today. Our M and L cones differ only slightly in their wavelength sensitivity, leading scientists to conclude that they arose when one gene—the one encoding the light-sensitive protein, or photopigment, of the primitive yellow-green cone cell—mutated into two forms. The first monkeys to reach South America did not experience a similar mutation, and the history of color vision in New World primates is thus different. Most New World monkeys have two-color (dichromatic) vision, although the existence of two different forms of the gene for the medium wavelength photopigment—a gene that sits on the X chromosome—renders a high proportion of females trichromatic. (Because they have two X chromosomes, females are likely to acquire both forms of this gene.) Meanwhile, the nocturnal New World owl monkey gets by with just a single kind of photopigment. This is not a disadvantage, though, because the ability to distinguish colors is not especially useful at night.

Iridescent wing of a *Morpho* butterfly, opposite page

The difference between two- and three-color vision is significant. In the dappled light of a rainforest, primates with dichromatic vision may fail to distinguish between mature green leaves (which are rarely eaten) and ripe, pulpy orange and yellow fruits such as bananas. By contrast, the peak sensitivities of the three cones in the trichromatic system are well placed to provide good visual discrimination between these colors and therefore to help monkeys find their food. If our color sensitivity were spread more evenly across the spectrum, we would have smoother color vision but would have a harder time distinguishing colors in the orange-yellow-green range—distinctions crucial to our hungry tree-dwelling ancestors. So it can be argued that we visit art galleries with a visual apparatus that's fine-tuned to locating bananas. Perhaps Andy Warhol was on to something.

Some researchers think that linking primate color vision to fruit eating doesn't explain everything, however. Besides eating fruit, primates consume leaves, nuts, insects, and other prey. Since young, succulent leaves in rainforests are often reddish, folivory may have provided another impetus for color vision to evolve as it did, providing us with a firm red-green distinction. The New World howler monkey, which has a notably folivorous diet, evolved full trichromaticity independently of Old World primates.

Dichromatic humans—who lack either L or M cones—are unable to experience the lush diversity of hues in fall leaves. But dichromaticity has advantages, too. It appears to confer an improved ability to distinguish textures and to spot camouflage. Dichromatic monkeys are therefore good at detecting insects—or predators, for that matter—that try to blend with their surroundings. And some important fruits, such as figs, are colored like the surrounding foliage but are distinguishable by their texture. Social animals such as monkeys may thus benefit from foraging in groups that contain both dichromats (the males) and trichromats (some females). Humans have discovered the same thing in adverse circumstances: during the Second World War, the British Royal Air Force used color-blind dichromats to spot camouflaged camps and vehicles in reconnaissance flights over enemy lines. Paradoxically, nowadays colorblindness can rule out a career in the RAF. A good eye for color may be invaluable in the gallery, but in the wild it may be a mixed blessing. ☐

GEORGE BERNARD: ANIMALS ANIMALS

Say It With Bowers

If male bowerbirds build it, females will come. But in the mountains of New Guinea, one species is sending mixed messages. By J. Albert C. Uy

The first Westerners to penetrate the rugged interior of New Guinea encountered a world of plants and animals new to them. One of the earliest European naturalists to explore the inland mountains was Odoardo Beccari, who set out in 1872 to climb the Arfak range in a northwestern peninsula of the island. Before his ascent, Beccari had heard stories of a small mountain bird with prodigious architectural talents, and in the Arfaks he found both the bird and its structures. They proved to live up to the rumors.

Now known as the Vogelkop bowerbird, this uniformly brown creature was scientifically christened *Amblyornis inornatus,* its species name taken from the Latin for "unadorned." Its behavior, however, is reflected in the name used by local New Guineans: *burung pintar,* or "clever bird." It was this reputation that first led me to New Guinea to study the Vogelkops. In 1994, along with my then doctoral advisor, Gerald Borgia, a biologist who had already spent more than twenty years studying various bowerbirds, I climbed up the Arfak slopes.

Arfak style: A male Vogelkop bowerbird's "hut" is walled, spacious, and ornamented. At the bower on the opposite page, decor includes a pathway of brown acorns.

Found only on the large island of New Guinea and in Australia, bowerbirds comprise nineteen species. Males of all but three species are polygynous, meaning that they try to mate with as many females as possible. In some species, one male can mate with as many as twenty females in a single season, while the majority fail to mate at all. Of the polygynous species, fourteen have the peculiar habit of building ground-based structures, called bowers, solely to attract the opposite sex. Bower design and decoration are specific to each kind of bowerbird. For example, the satin bowerbird, which inhabits the dry woodlands of eastern Australia, erects two parallel walls of sticks on top of a circular platform, also made of sticks. The walls flank a path that visiting females step onto. Adorning the platform in front of the path are objects such as assorted blue parrot feathers, white snail shells, and yellow and purple blossoms from wild tobacco. Other species of bowerbirds build towers; some simply clear leaf litter from the ground to form a court where the male dances for visiting females. In their own way, most bowerbirds are skilled architects, but none can rival the plain brown Vogelkop.

A male Vogelkop selects a forest sapling and tightly weaves sticks around it, shaping a conical hut that can reach six feet in width and four feet in height. Huts typically have a single doorway, neatly trimmed to form a perfect arch, which opens out onto a thick carpet of moss up to six feet square, also laid by the industrious male. On this mossy stage, the male displays thousands of objects he has collected from the surrounding forest, including orange rhododendron flowers, yellow leaves, blue fruits, red ginger berries, iridescent blue beetle carapaces, shiny fungi, and feathers from other birds, such as birds of paradise. (At one site we studied, a male pilfered a strip of blue tarp from our camp and laid it under his doorway; another stole a pair of knee-high green socks with bright yellow stripes.) Males arrange these objects according to color and size and promptly remove any that decay. In fact, the best way to coerce a male to come down from the forest canopy and onto his bower is

RICHARD KIRBY; BBC NATURAL HISTORY UNIT

The Vogelkops of the Fakfak Mountains are minimalists. Although tall, their spire bowers are wall-less and spare, the decorations dark and subdued.

to mix up his decorations. He quickly returns and puts everything back in order, sometimes in the presence of a surprised spectator.

The dimensions of a Vogelkop bower are even more impressive given the size of the builder. Weighing less than five and a half ounces, a Vogelkop male is not much bigger than an American robin. Great time and energy are thus invested in constructing and maintaining the relatively colossal bowers, illustrating the lengths to which the birds go to attract females. The bower is not used as a roost or a nest site. Females, which usually mate with only one male in a season, rear their young on their own, building simple bowl-shaped nests six inches in diameter and six to ten feet up in a tree.

Hut-building Vogelkops inhabit New Guinea's Tamrau and Wandammen Mountains as well as the Arfak range. In 1981 physiologist Jared Diamond, of the University of California, Los Angeles, found an isolated population of Vogelkop bowerbirds in the Kumawa Mountains, about 100 miles south of the Arfaks. The Vogelkops of Kumawa (and the adjacent

Vogelkops build the most elaborate structures of all nineteen species of bowerbirds.

J. ALBERT C. UY

KONRAD WOTHE: MINDEN PICTURES

Fakfak range) construct strikingly different bowers. Instead of elaborate huts, these birds erect five-foot-high, spindly spires. Made of sticks loosely interwoven around a sapling, the spire resembles a dry Christmas tree. At the base of the spire, the male neatly lays a circular carpet, usually of black moss. The decorations are spartan, consisting exclusively of drab objects such as brown bamboo bark, black seedpods, and brown snail shells, all arranged by color and type near the carpet's perimeter. Given their distinct bower styles and color preferences, and the species-specific character of most bowers, one might guess that spire builders and hut builders are two kinds of bowerbirds. Yet they are physically identical and are classified as the same species.

Because Vogelkops build the most elaborate structures of all bowerbirds, they were an important element in Borgia's and my study, which was aimed at understanding how bower building evolved. We decided to focus on the Arfak hut builders and the Fakfak spire builders. But these two populations also presented another opportunity. We realized that they could be used to test an idea first posited by Charles Darwin more than a century ago and still being debated.

Today one of the hottest topics in the field of evolutionary biology is how species originate. Researchers agree that new species arise when one

An Arfak male, left, puts some finishing touches on the arch of his bower. Below: Hut bowers are an engineering feat for birds weighing less than five and a half ounces.

J. ALBERT C. UY

KONRAD WOTHE; MINDEN PICTURES

Vogelkop habitat: At the end of New Guinea's far northwestern peninsula, the Arfak range is cloaked with vegetation. Now known as Irian Jaya, the western half of the island is part of Indonesia.

MYRA KLOCKENBRINK

population of a species splits off from the rest. Just how these changes occur remains a contentious issue. Darwin championed the idea that new species often evolve when populations of one species become geographically isolated—by mountain formation, by changes in the course of rivers, or by emigration to an island, for instance. Gradually, a population may change in order to make the most of any new resources, such as food, in the environment. In the case of birds, a larger bill, for example, may enable some individuals to take advantage of particular seeds. Over time, bigger-billed members of that population may thrive, while those not as well equipped will be weeded out. This phenomenon, known as natural selection, can lead to the evolution of a new species when the changes in an isolated population become so great that its members no longer recognize individuals of the original population as potential mates. Studies by several biologists, including the long-term work of Rosemary and Peter Grant on Galápagos finches, provide solid support for this theory.

Darwin also alluded to another process by which new species could form, in this case in the absence of adaptations to new resources. Creatures use various signals to find and recognize others of the same species. For instance, in several species of freshwater cichlid fish in African lakes, distinct color patterns and courtship dances allow individuals to recognize conspecifics. If such traits should begin to diverge between populations, then the criteria for choosing a mate would change, and some populations that once mated freely would become reproductively isolated. During the early and mid twentieth century, this idea was overshadowed by Darwin's theory of speciation by natural selection. Recently, biologists are showing renewed interest in the alternate or additional possibility of speciation by sexual selection, wherein changes in mating signals drive the formation of species. Studies of certain Hawaiian fruit flies and of Hawaiian and North American crickets, as well as African cichlids, are beginning to provide support for this phenomenon, but hard evidence remains rare, especially in birds, which inspired much of Darwin's thought on the matter.

The hut-building and spire-building populations of Vogelkop bowerbirds show no signs of changes in bill structure, plumage, wing shape, or other features that would indicate they are adapting to new conditions in their mountain habitats. But their mating signals—bowers—vary dramatically. Could these birds and their bowers be an example of sexual selection leading to the formation of new species? We began field studies to test whether this could be the case.

Could these birds and bowers be an example of sexual selection leading to a new species?

Scientists have found that in most bowerbird species, the colors of the bower decorations are those that both males and females prefer. But what if spire-building Vogelkop males also prefer colorful decorations but are forced by a lack of these ornaments in their immediate habitat to make do with brown or black bower accents? Jared Diamond first tested this idea in the hut builders of the Wandammens and the spire builders of the Kumawas by offering males poker chips of six different colors. He found that the hut builders strongly preferred bright colors, while the spire builders typically ignored them. To determine if Diamond's results held in our own populations, we undertook similar experiments with the Vogelkop populations of Arfak and Fakfak, using a wider array of colors. We offered males from each population a set of tiles of sixteen different colors. Our results were almost identical to Diamond's: The hut builders of the Arfak Mountains typically ignored drab-colored tiles but were drawn to blue and red ones and were quick to harvest them for placement on their bowers. (The males often began the experiment even before we had a chance to get back to our blinds.) In contrast, the spire builders of Fakfak paid no attention to any of the tiles we placed near their bowers, even when we left them there overnight. The two populations seemed to differ not only in which colors they liked but also in the basic propensity to decorate.

To find out how closely related the hut builders and spire builders are, we turned to genetics. If only distantly related, then they have been distinct species for a long time. In the case of the Vogelkops, this would mean that changes in bower display may not have been involved in the speciation process itself. Our collaborators Ross Crozier and Rab Kusmierski, of La Trobe University in Bundoora, Aus-

JEAN-PAUL FERRERO; ARDEA

Left: A great bowerbird in Australia sorts his metal, plastic, and glass ornaments. Below: A male satin bowerbird, also in Australia, displays to a female appraising his bower.

DAVE WATTS: NHPA

tralia, sequenced a portion of mitochondrial DNA from both populations. The DNA showed only slight genetic differences. The hut- and spire-building populations are closely related, and bower displays may be working as a reproductive wedge. One population may be on the verge of becoming a separate species.

Next we went about setting up experiments to determine if bowers do indeed function as a means of recognizing potential mates. Our ultimate aim was to answer several questions: Does the difference in bower styles act as a reproductive barrier? Would Arfak females recognize Fakfak spires as mating signals, and thus Fakfak males as potential mates? We first set up video cameras at Arfak hut bowers. The cameras were triggered automatically by any movement in the vicinity of the bower, where all courtship and mating take place. This technique allowed us to get continuous and simultaneous video recordings of behavior at sixteen bowers for more than six weeks. From the hundreds of hours of video footage, we were able to determine how successful each Arfak male was in attracting females, and then to relate his success to specific components of his bower display. The video cameras captured a total of thirteen matings. Only half of the sixteen videotaped males mated, with the three most successful males taking part in fully 60 percent of the observed matings. Why the lopsided numbers? Males with the biggest bowers and the most blue decorations were the ones that mated the most. We found that both bower size and abundance of colorful ornaments influenced the mating behavior of females. They appear to use both criteria when choosing a male.

Colors are a staple of Arfak bowers, even when the actual structure is less than classical, below. If bower size and color serve as mate magnets, a Fakfak bower, opposite, might not hold much appeal for an Arfak female.

KONRAD WOTHE; MINDEN PICTURES

Arfak males with the biggest bowers and the most blue decorations mated with the most females.

To balance the equation, we will need to compile similar records of mating activity among the spire builders. But Vogelkop bowerbirds are restricted to mountains in western New Guinea, which is now known as Irian Jaya and is administered by Indonesia. Proving more difficult to surmount than any mountain range, political instability and the recent restriction on visits to this region by scientists have prevented us from carrying out these observations. The data we have gathered so far, however, do allow us to make inferences: Spire bowers are substantially smaller than huts and are never decorated with blue or any other colorful ornaments. Because Arfak females prefer showy bowers, they might find these spire bowers unattractive or inadequate, and so might fail to see the architects as potential mates. This suggests the possible presence of reproductive barriers, but only information from the spire-building population will provide direct support for this argument. Given the political situation in Irian Jaya, testing the preferences of Fakfak females and gauging the responses of Arfak females to a Fakfak male and his spire bower may have to wait a few years.

In the meantime, the role of sexual selection in generating biodiversity is gaining attention and stimulating discussion. Current research, including my own, is now exploring *why* mating signals change in the first place. Do visual conditions, such as the play of light and shadow on foliage, select for certain signals that are most effective in those particular environments? Or are these changes arbitrary relative to the habitat, analogous to fads we see in our own society? In the search for answers to how species are generated, creatures as varied as fish, flies, crickets, and bowerbirds are leading the way. □

A Short History of Mu

scle-Powered Machines

THE QUEEN'S EMPIRE; MARY EVANS PICTURE LIBRARY

What goes around comes around—and does useful work.

By Steven Vogel

Today we have machines for making people move in place: run, walk uphill, push pedals back and forth or up and down, row, ski, or even climb a never-ending staircase. Machines that are designed to waste energy and that usually rely on still more energy, in the form of electricity, to run—who would have anticipated their popularity? Thanks to the ingenuity of these contraptions' designers and purveyors (people who, one might say, live off the fat of the land), the toils of Sisyphus have been transformed into a healthful pastime.

Such machines mirror the ancient technology of animal-powered engines. Millennia ago, humans discovered that wheels could do something other than turn tables for shaping pottery or underpin a vehicle and that a domesticated animal could do something other than carry a load or pull a wagon. We figured out that animals could do lots of useful tasks by turning wheels that were fixed in place. In an era when the nonmuscular power sources included only a few types of sails and waterwheels, such a realization was no small matter. The diverse devices that followed had in common a fixed position, rotational motion, and whole-animal muscle power. Few looked much like today's fancy exercise machines. Some were designed to be powered by humans, others by (usually) domesticated animals, and a few by either (depending on availability)—showing, perhaps, how little the inventors distinguished a serf, a slave, or a convict from other sources of involuntary labor.

We can recognize three major designs. In the oldest, a horizontal bar jutted from a vertical shaft. An animal attached to the bar turned the shaft by circling. Because the animal itself rotated, the ma-

From Prime Mover: A Natural History of Muscle, *by Steven Vogel. Copyright © 2002 by Steven Vogel. Reprinted with permission of the publishers, W. W. Norton & Company, Inc.*

The treadmill—this one and its human motors were photographed in the Rangoon, Burma, jail in 1900—was a staple of the British penitentiary system in the nineteenth century.

THE GRANGER COLLECTION

A Roman relief shows a donkey grinding grain, observed by a dog that is no doubt thankful that the machine was called the asinine—and not the canine—mill.

chine needed no true crank, such as the kind we use to pedal bicycles. Sometimes the vertical shaft was itself part of the business end of the machine, as in systems that ground grain between stones. Sometimes a pair of gears connected the vertical shaft to a horizontal one, often to run a chain of buckets descending into a well.

In a second type, a human or a domestic animal worked within a huge hollow wheel, like a hamster in an exercise wheel. The motor thus climbed rather than pulled. A greater load on the wheel meant a greater resistance to its being turned, and this meant that the living motor had to climb farther up the inside of the wheel to keep it going. The increasing slope gave the wheel a neatly self-regulating character: the motor's output was automatically matched with the load. Bipeds such as humans made particularly good motors, but these cage wheels didn't require domesticated creatures—even bears, contend historians, could be pressed into service.

The third design also made an animal climb, but it used a moving sloped platform instead. This ancestor of our fitness treadmills presented severe mechanical challenges: its sliding platform had to support both an animal's weight and the impact of its feet, as well as be durable and sufficiently flexible to go around revolving drums fore and aft. But the challenges were worth overcoming: its slope could be adjusted to match the motor with the load, and the variable slope made the machine less finicky about what sort of animal powered it. However, the engineering feats required to build such true treadmills meant that they were uncommon before the nineteenth century.

Not that the three basic designs exhausted the possibilities for muscle-powered engines: A person could sit on a plank and rotate an inclined disk by pushing the edge with his feet, or an animal could walk in place uphill on top of the disk. A person could pull downward on crossbars on the outside of a revolving vertical wheel (essentially replacing water on a waterwheel) or pull on a slack chain hung over such a wheel. Indeed, the makers of modern exercise equipment might profitably peruse the works of great Renaissance engineers such as Georgius Agricola, Agostino Ramelli, and

Fausto Veranzio when deciding what new kinds of devices to unleash on the public.

Although muscle-powered engines are ancient, they originated long after chariots, carts, and potters' wheels—probably about 4,000 years ago, in the Middle East or India. Their main use in that part of the world was (and remains) lifting water with a bucket chain, a task that demanded a reliable way to turn horizontal into vertical motion. The problem's solution—putting a pair of gears at right angles to each other—was far from obvious, and this may have delayed its invention or adoption. Rotary grain mills needed no such gears, but these mills came into use later, perhaps initially invented by the Greeks about 400 B.C. By the first century A.D., the Romans used slaves and donkeys to power a highly effective version—their *mola asinaria* (asinine, or donkey, mill).

The machines' designs perhaps showed how little the inventors distinguished human motors from other sources of involuntary labor.

Revolving cage wheels may have been a Roman innovation. Unambiguous images of them occur on bas-reliefs, and remnants of the actual wheels have been found at Pompeii. As with rotary grain mills, humans and donkeys provided the energy. Such wheels powered cranes that lifted blocks into place during the building of tall structures. Centuries later, similar cranes helped a more technologically savvy culture erect the great medieval cathedrals.

Because wells and irrigation systems were widespread and the hulls of wooden ships usually leaked, pumping water was a common use of stationary muscle-driven engines. Sometimes these engines were used to lift water to heroic heights. In one Roman mine, a cascade of eight pairs of scoop wheels raised water almost a hundred feet. Grinding grain and lifting stonework were not these engines' only other tasks; in medieval Europe they also ran sawmills, pile drivers, dough-kneading machines, dockside cranes, bellows, and even one wheel (powered by a dog) that turned a roasting spit.

Muscle-powered mechanical engines also provided an alternative to sails and oars for the propelling of boats. On China's rivers, human-powered cage wheels drove paddle wheelers as long ago as the eighth century A.D., though this mating of two relatively efficient devices never caught on in the West. Here shipbuilders stuck with oars, but building large oar-powered ships proved difficult: no matter how many were added to power a bigger ship, the oars couldn't keep pace with the increased drag of the vessel. Also, larger oars were heavy and clumsy to maneuver and required multiple oarsmen. By contrast, paddle wheelers lose nothing by being big, and it's easy to link the paddle wheel to the cage wheel amidships.

One form of animal-powered boat did appear in the West, mainly in eastern North America, during the first half of the nineteenth century. Shortly after steamboats came into use, horse-powered "teamboats" began serving as ferries across waterways such as New York's Hudson

The work of horses, sheep, and other animals promised to free at least some humans for more ennobling endeavors.

W. H. HOPKINS: MARY EVANS PICTURE LIBRARY

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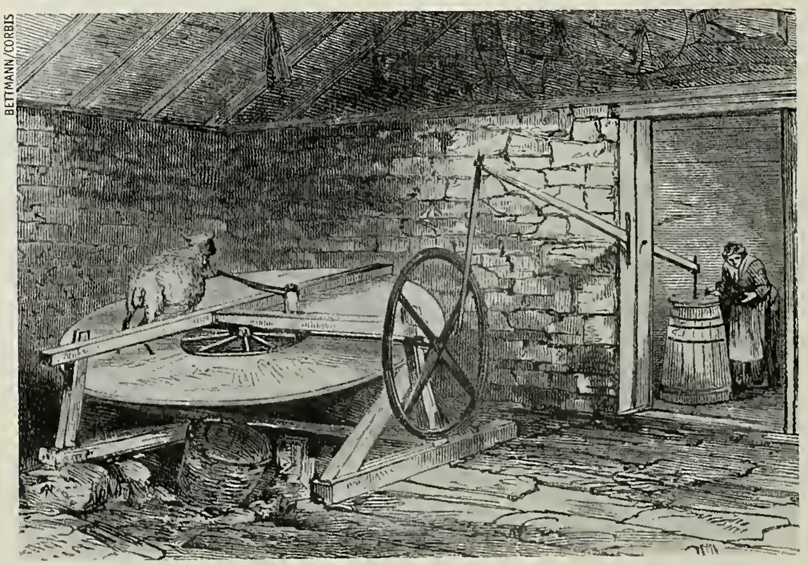


C. OSBORNE; PHOTO RESEARCHERS, INC.

MICHAEL ANDREWS; EARTH SCENES

Muscle-powered machines are still in wide use today. Top: Pumping water at the Fayoum Oasis in Egypt. Above: Grinding corn in the village of Mizhi in Shaanxi, China.

River. They were less expensive than steam, more reliable than sail, and required none of the human labor—more scarce in the New World than in the Old—demanded by oars. In one design, two or more horses walked in a circle on deck, turning a capstan amidships that was geared to a paddle wheel set between a pair of catamaran-like hulls. Another version had a turntable below deck, with horses in fixed stalls and two paddle wheels, one on each side of a single hull.

Usually, however, the nineteenth century's many muscle-powered engines operated away from water: in prisons and on the prairie. Penal versions abounded. In its entry for "treadmill," the great *Oxford English Dictionary,* compiled at the century's end, recognized only a penal application for the machines. Punishment and useful work—what a nice combination. British parliamentary commissions repeatedly examined and endorsed the treadmill's safety and beneficial effects on the health of inmates.

Great Britain was not alone in using these mills as a correctional device. New York City began using one in Bellevue Penitentiary in about 1820. Eight prisoners climbed the wide rows of steps that formed a revolving drum, while four sat in reserve. Each team member (some were women) therefore worked two-thirds of the time. Still, treadmills remained relatively uncommon in America; the shortage of labor meant that humans were rarely employed as motors when other animals would do.

Used judiciously, however, a muscle-powered engine provided aerobic exercise to incarcerated people who otherwise would have lacked it. Furthermore, the engines supplied necessities, such as ground grain for prison bakeries. An 1824 report ("The History of the Treadmill," by James Hardie) makes much of the safety of the New York wheel, and its assertions about the health of inmates using

By any technological yardstick, we animals, whether horses or humans, are strange engines.

it don't seem unreasonable. Inmates apparently received sufficient food for the work. But its punitive character is evident: the jailers claimed rapid attitude adjustments in formerly obstreperous prisoners. As Thomas Henry Huxley, famous defender of Charles Darwin, put it when complaining about an adversary, "I would willingly agree to any law which would send him to the treadmill."

For size and technological audacity, nothing has ever come close to the agricultural machines used during the nineteenth century on the North American prairie. After about 1880, large "combines," pulled by up to forty horses, reaped and threshed wheat as they moved through the fields. But in the preceding decades, the threshing of grain depended on stationary machines called sweeps, powered by as many as twenty horses pulling radial bars as they circled. The machine's parts were brought to a threshing location the evening before the scheduled work was begun, and the thresher was assembled before dawn; after being run all day, it was dismantled and moved (by its own horses) to the next farm. While these big and otherwise sophisticated machines incorporated a novel level of portability, they also relied on the oldest of designs for muscle-powered engines.

Unlike the combines, most nineteenth-century American devices were relatively small, general-purpose machines powered by one to four horses or oxen. These often used the third basic design, a suspended treadmill of two rollers and an inclined "belt." The belt consisted of wooden boards, laid perpendicularly to the animals' path and hinged side-to-side, forming an endless moving platform that slid on greased tracks or small rollers positioned between the big front and rear rollers. A one- or two-animal model looked like an open horse trailer. This machine worked much like a modern tractor motor; it could be connected to various machines and could be pulled out of the barn and positioned wherever it was needed for chores such as sawing logs. These multipurpose units appeared in farm catalogs as late as 1890.

Smaller versions of the giant threshing sweeps also appeared as late as 1890. For some tasks, either a treadmill or a sweep was suitable. Sweeps, which were simpler and lighter relative to their potential power, demanded more goading of the driving animals, and many designs required that the animals step over a horizontal driveshaft once during every revolution. Treadmills, which were more compact and easier to move and put to work than the sweeps, were harder on the animals' hooves. But treadmills were advertised as being twice as effective, which was not an unreasonable claim: on an inclined belt, an animal works by lifting itself; attached to a sweep, a harnessed animal pulls—a less natural activity, severely constrained by the effectiveness of the harness.

You Expect Me to Do Watt?

A worker doing hard physical labor all day long—or a felon turning a treadmill—can put out about 100 watts of power. That's the output, in the form of a little light and a lot of heat, of the familiar lightbulb. It's a little more than the rate at which an inactive human heats a room. But to understand 100 watts of muscle power, one needs to turn to a quantifiable everyday task that humans do with reasonable efficiency. Climbing stairs fits that bill.

When you climb a flight of stairs, what's your power output? Just multiply your weight in pounds by the height of each step in inches and by your climbing rate in steps per second, and then divide by 9. The last number takes care of gravity and converts the figure into watts. I weigh 140 pounds. When climbing seven-inch steps at two per second, I put out about 220 watts—a rate that I, an age-challenged man, can sustain only briefly. Ascending a down escalator, I work at 140 watts.

JIMMY HOLMES; PANOS PICTURES

Working a waterwheel in Cambodia

But what climbing rate corresponds to an output of 100 watts? Divide 900 by your weight in pounds and by the step height in inches; the resulting figure is how many steps per second you would have to climb. On seven-inch stairs, I'd have to ascend them at a little less than one step per second—trivial for the first couple of flights but a tiring regimen to keep up for even an hour.

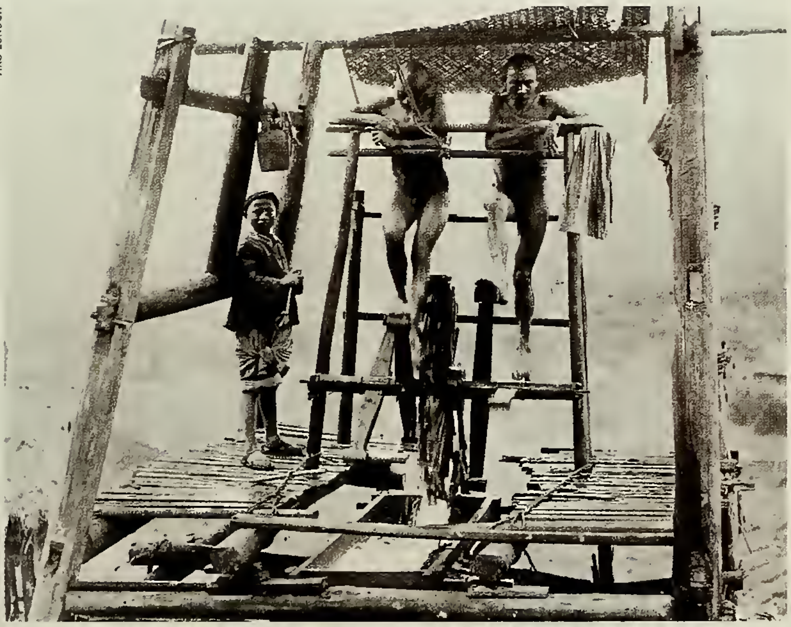
What about fuel? We're at best only about 25 percent efficient, so an output of 100 watts requires a minimum input of 400 watts, which translates (when we multiply by 0.86) into about 350 Calories per hour. Burning a tenth of a pound of good fuel—fat—yields 350 Calories, so working at 100 watts for eight hours costs less than a pound of body fat—still nearly double a human male's normal energy use.

By any technological yardstick, we animals, whether horses or humans, are strange engines. For a difficult task of only a few seconds' duration, a person can put out thousands of watts—many times the 746 watts in one official horsepower. For tasks lasting a few minutes, a fit human can generate perhaps 1,000 watts. For an activity that must be sustained for an hour, output drops to around 300; for an activity kept up all day, 150 watts is about the maximum. But by physiological standards, horses and humans (and dogs but not cats) sustain especially high power outputs. Fleet-footed ancestors bequeathed us the lungs and hearts that let us work long and hard.

Like other muscle-powered machinery, treadmill devices were not designed only for horses or oxen. Household (or dooryard) models even included a butter churn; the manufacturer asserted that dogs, goats, sheep, or children could power it.

Such devices demonstrate that mechanization needn't involve muscle-displacing motorization. Nonetheless, by the end of the century, steam power had largely replaced muscle power. The small steam engines of the nineteenth century may have been less fuel- and weight-efficient than gasoline-powered engines, but in low-population areas they were a good solution. Engines in which steam pushed pistons operated at relatively low pressures and temperatures, so they could be built simply, of common metals, and were easy to repair. Furthermore, they could burn anything combustible. Farm museums across North America still display such steam engines—self-propelled tractors that could also work as stationary power sources, powering all the same accessories as the treadmills that preceded them.

AKG LONDON



Workers at a Chinese salt mine in the 1920s. Decades after the advent of horse- and sheep-powered engines, humans still labored in obviously miserable conditions.

How good were these ingenious animal-powered machines at making muscle do useful work?

Where humans worked against gravity, as they did inside cage wheels and upon treadmills, we can calculate the power outputs. As a benchmark, we might use data, first obtained in the eighteenth century by British scientists Jean Desaguliers and John Smeaton, of the power a human laborer could produce if working steadily all day: 90 to 100 watts. In contemporary terms, this means that if you attach a generator to an exercise machine, you can watch TV as long as you climb, pedal, or row.

By the same token, a Roman cage wheel sixteen feet in diameter and eight feet across accommodated six to eight men, who could, forty times per hour, jointly lift one ton a distance of twenty-seven feet—which equals a power output of 600 foot-pounds per second. Dividing that among eight workers, we calculate a power output per person of just over 100 watts. That figure attests both to respectable efficiency for the machine and to considerable effort for the workers (who may have worked in relays).

In the lab, flying insects such as fruit flies and migratory locusts have powered engines with their beating wings.

On the Bellevue Penitentiary treadmill, prisoners climbed on treads protruding from a wheel that was slightly over five feet in diameter and turned three times each minute. If one assumes that a typical prisoner weighed 132 pounds, then the prisoner must have worked at a power of almost 140 watts. Since the normal duty cycle allowed each prisoner to rest one-third of the time, the sustained output would have been a little over 90 watts—sustained, according to the report, for up to ten hours a day. That figure of 90 watts confirms the reported unpleasantness of the task. A similar output was demanded of nineteenth-century Australian convicts, who worked up to twelve hours per day; some said they'd rather hang than work their mill.

We can view that 90 watts in yet another context. At best, only about one-fourth of the energy in food emerges as useful mechanical work. Thus, laboring on the treadmill—sustaining 90 watts for ten hours—itself requires more than 3,000 Calories. So Bellevue's inmates worked hard enough and long enough to require double the food intake of a normally active adult male.

Although nonhuman animals don't complain and can be fed cheaper food, attaching them to machines greatly lessens their efficiency. Which animals give the best service? Biology tells us that bigger is better. The strength and power of muscle tissue vary little from animal to animal, and mammals all have about the same amount of muscle: about 40 percent of body weight. But larger creatures spend relatively less energy on basic body functions, and this increases the fraction of their food that can be appropriated for labor—so forget battalions of wheel-turning rodents. Insects put out lots of power for long periods while spending less on personal maintenance than even big mammals do; in particular, they don't insist on staying warm when idle. Under laboratory conditions, flying insects such as fruit flies and migratory locusts have powered stationary engines with their beating wings. But even large insects remain impractically small for our purposes.

Nor can practicality be ignored at the other end of the scale. Elephants, whatever their potential efficiency, are awkwardly large. Oxen have given excellent service for millennia, and horses for a little more than a thousand years—since the invention of the horse collar, which enabled them to pull effectively—but only on sweeps and treadmills. Few if any tractable animals come close to the mechanical versatility of agile humans.

Today, only a few types of muscle-powered stationary engines remain in use. A "treadle pump" first disseminated in Bangladesh during the 1980s (and now used by many farmers in Asia and sub-Saharan Africa) pumps water for irrigation; it's run by a person who climbs what looks like a StairMaster stair climber. More sophisticated and convenient means of generating energy have largely taken the place of muscle-powered machinery. Engines powered by fossil fuels require far less infrastructure than do working animals and come in a much wider range of sizes and models. Still, why not take instruction from history and hook a generator to your exercise bike or rowing machine? That power source could run some entertainment device that performs only when you do likewise. □

In the West, the energy wasted running on exercise machines could be put to better use—even powering the TVs and lights in the gym.

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BIOMECHANICS

One Giant Leap for Wormkind

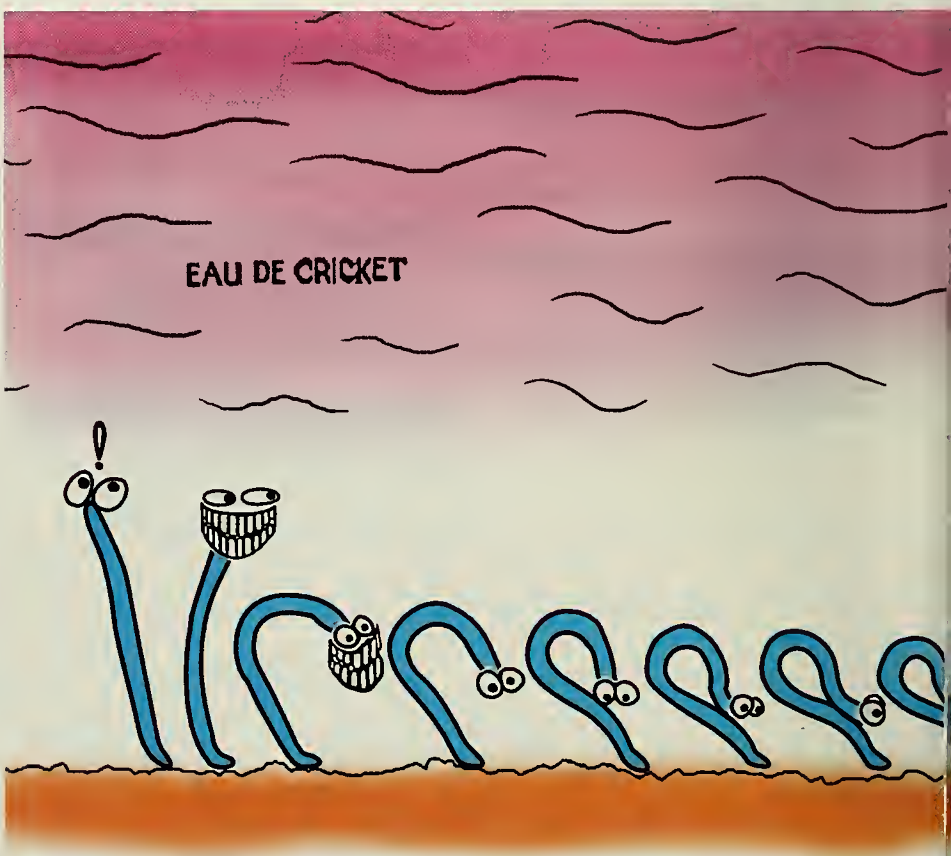
Some microscopic nematodes jump for their supper.

Many creatures—snakes, most fishes, some lizards, and all worms—have mastered the neat trick of getting around without benefit of appendages. Not even the aerial realm is free of the limbless: there are jumping vipers in South America, flying (or, more accurately, gliding) snakes in Southeast Asia, and even worms that fling themselves into the air on occasion. Especially intriguing to Jim Campbell, of the USDA's Agricultural Research Service, and Harry Kaya, of the University of California, Davis, are microscopic (ten laid end to end would just about fit across the top of a pencil eraser) parasitic nematodes. These worms can propel themselves through the air to infect their hosts—sometimes leaping nine times their own body length in the process.

Most nematodes, also called roundworms, are small, simple worms lacking the segmentation of the more familiar earthworms. Many are parasitic, living in the gut, the muscles, and even the circulatory and respiratory systems of vertebrates and invertebrates. Lawn doctors are particularly fond of a couple of species in the genus *Steinernema* that infect adult mole crickets (bullet-headed cousins of the house cricket). Mole crickets can wreak havoc on lawns and golf courses: the adults dig burrows as big across as your thumb, and the larvae eat grass roots. The native species of mole crickets are relatively benign, but the introduced species (most of which entered North America from South America, Europe, and Southeast Asia in the late 1700s and the 1800s) are real pests, right up there with leaf spot and necrotic ring spot on the list of things you don't want on your lawn.

When a free-living juvenile nematode lands on a cricket, it makes its way inside through the digestive or respiratory system and penetrates the body cavity, where it matures into an adult. Bacteria inside the roundworm go along for the ride. These microbes produce a toxin that is beneficial to the worm but poisonous to the cricket. Several generations of nematodes can live and reproduce happily inside the cricket, but eventually the bacterial toxins overwhelm the cricket, and it dies. With the death of their host, the current cohort of juvenile nematodes (together with their bacterial companions) burrow out of the corpse and lie in wait for new victims. When a cricket happens by, any juvenile worms it touches will try to latch onto it; roundworms that are too far away to climb on board but are within striking distance will hurl themselves into the air and, with any luck, land on the hapless arthropod.

To take to the air, a nematode must leave the peculiar watery realm it inhabits in its free-living stage. Nearly every surface in our environment is coated with a thin film of water. Even seemingly dry surfaces may be covered with a water



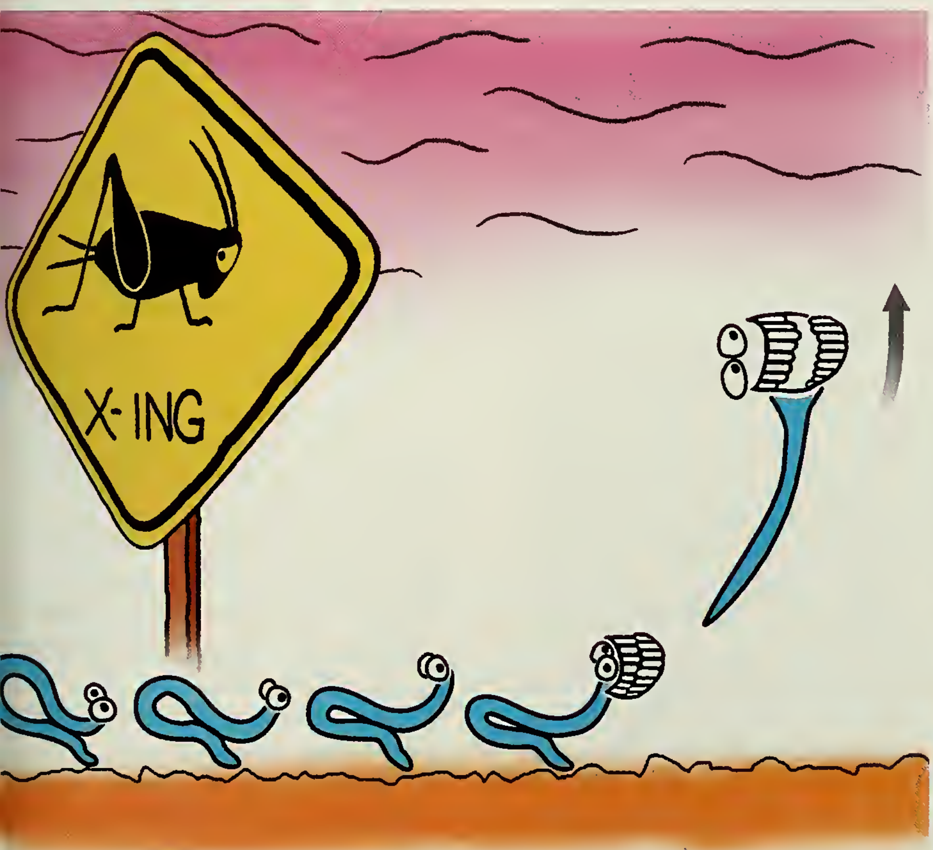
Story by Adam Summers ~ Illustration by Sally J. Bensusen

layer several molecules thick. Jumping nematodes are so tiny that they can live within this filmy world. They pass their youth squirming through it, flopping and writhing across soil particles and blades of grass to get from one place to another. When ready to hitch a ride with an insect, however, a nematode rises up on the tip of its tail with its mouth in the air. "Standing up" decreases the adhesive force of the water surrounding the worm's body, making the worm easier for a passing cricket to pick up. It also, as Campbell and Kaya found, puts the tiny creature in position to execute its aerial acrobatics.

Hit by a puff of cricket-scented air, a nematode rapidly bends over, touching its head to its body about where its knees would be—if it had any. The cohesiveness of the thin film of water covering the worm holds it in this bent posture. Imagine taking a long, thin balloon (the worm) and bending it into an 0 with a little tail left over. Now, move the balloon so that the point of contact slides "back" toward the bend and away from the tail. This will tighten and close the loop, stretching the surface along its outer edge and causing pressure inside the balloon to rise. As a result, the forces working to straighten the balloon become stronger and stronger. So it is with a nematode that bends and then slides its head back along its body. Eventually the straightening force exceeds the cohesive force of the water holding the worm in its contorted pose, and it suddenly flings itself off into space. In this impressive maneuver, the nematodes jump primarily in the direction of the triggering odor, though they often fall short or miss the target.

Current pest-control practices on golf courses include spraying bucketfuls of live parasitic nematodes onto areas of cricket infestation in the evening, when the grass and soil are moister. Unfortunately, grass suffers from species of nematodes that are not parasitic and that eat plants. The treatment for these undesirable roundworms also kills the useful ones, so some golf-course superintendents are faced with a tough choice: protect their precious turf from the ravages of burrowing crickets or lose some of the course to plant-eating nematodes.

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



When a parasitic nematode detects the scent of a cricket, it bends over. As it bends, pressure and tension build up inside the worm. Eventually these forces become overwhelming, and the worm is flung into the air—toward, if all goes well, its next meal.

CELESTIAL EVENTS

Rhymes With June and Spoon

By Richard Panek

How well do you really know the Moon?

"There's a moon in the sky / It's called the moon." These lyrics from a late 1970s song by the B-52s might have been deliberately dopey, but they happen to capture a couple of truths about Earth's only natural satellite (aside from the fact that it's in the sky and it's called the Moon). First, they correctly summarize the total knowledge about all matters lunar that many people have. Second, they accurately reflect the total knowledge about all matters lunar that even many amateur and professional astronomers *care* to have.


The Moon recedes.

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After the Sun, the Moon is probably the celestial object that's easiest to take for granted. Novice observers testing a first piece of equipment might take a moment to point their new binoculars or telescope at the brightest object in the night sky, to marvel at the mountainous terrain and shadow play that originally fascinated Galileo in the autumn of 1609. But then they turn to more distant, and more exotic, targets, as if the Moon has nothing to show us but phenomena we've known about for millennia (such as phases) or at least for centuries (such as craters). For many astronomers, familiarity with the Moon has bred not contempt but indifference.

Still, a sky watcher can continue to find in the Moon the twin rewards of observational astronomy: challenge and discovery. The challenge in the case of the Moon can be to actually *find* it. Not when it's full and overhead and the sunlight reflecting off its surface is flooding night on Earth, but when it's new—when the Moon is lying between the Sun and you, when the disk is fully *un*illuminated. At such times, moonrise and moonset almost exactly coincide with sunrise and sunset, in which case you can forget about seeing the Moon.

But what about a day later? How soon can you spot the fresh crescent? For observers who look forward to this particular challenge, March offers one of the two best opportunities of the year to see a Moon that's less than a day old (the other comes in early September). The Moon turns new at 9:03 P.M. EST on March 13. The next evening, for the first half hour or so after the 6:00 P.M. sunset (or twenty-one hours after the new Moon on the East Coast, twenty-two hours in the Midwest, and so on), the slenderest of crescents will still be above the horizon—just high enough to see it if your western horizon is absolutely without obstacles, the weather is cooperating, and your eyesight is keen.

But don't stop there. On March 15 the crescent will be just wide enough to be easily evident to the naked eye and will be hovering above the horizon until 7:30 P.M., a good ninety minutes or so after sunset. Shining nearby will be a breathtakingly brilliant, nearly -4.0 magnitude Venus, which itself will set about an hour after sunset. The sight should be sufficiently spectacular to make even the most Moon-fatigued observer look twice.

But don't stop there, either. Continue to follow the Moon through its phases until the end of the month, and perhaps you'll make the same discovery I once did: the Moon isn't a circle; it's a sphere. I claim no originality for this observation, but it sure shook my world.

Two or three years ago, I looked out my living room window one morning and saw, hanging above the Manhattan horizon, a waning gibbous—or just past full—Moon. It would soon be setting, past the skyscrapers to the west, but at the moment it was catching the rising Sun's rays behind me, somewhere beyond the East River and Queens. The Moon looked so big, so luminous against the purple sky, that I reached for a telescope I keep in my desk drawer.

When I looked through it, I found

craters, which I expected. I found shadows, which I expected. What I didn't expect, however, was the third dimension.

I didn't expect it even though I knew it was there. We all know it's there. We all know when we look at the night sky that it's not the flat surface it appears to be, that it has depth. But the difference between knowing and *knowing*—between accepting a fact intellectually and experiencing it for oneself on a deep emotional level—can be more profound in astronomy than in many other human endeavors.

Through the telescope that morning, I could see the surface of the Moon receding, curving back, angling away from the Sun and around the lunar horizon and out of sight. Here, unmistakably, was a sphere, and this sphere, equally unmistakably, was just hanging there. By itself. In space. Untethered, unsupported, unbound. Loose in the universe.

Just like Earth.

Just like me.

I had to sit down. Fortunately, a chair was there when I did. Which is why I recommend that anyone hoping to make impromptu astronomical observations should consider keeping handy three indispensable tools: a telescope or binoculars; a chair; and the knowledge that there's a planet in space, and it's called the Earth.

Richard Panek's next book, The Invisible Century: Einstein, Freud, and Our Search for Hidden Universes, *will be published next year by Viking.*

THE SKY IN MARCH

By Joe Rao

Mercury is approaching the Sun and is increasingly difficult to see. By the end of the first week of March, the -0.1 magnitude planet rises less than an hour before dawn; thereafter it is hidden in the Sun's glare.

Venus hovers nearly due west on the horizon after sunset at the beginning of March, setting only about fifty minutes after the Sun. Although the planet is very bright (magnitude -3.9), you need to look carefully because it's so low in the sky. By month's end it stays above the horizon for ninety minutes after sunset (as seen from midnorthern latitudes) and is twice as high in the sky. At midtwilight on March 1 (forty-five minutes after sunset), Venus is a mere 1° above the horizon, but by the 31st it is 8° above. On the evening of March 15, the delicate sliver of a two-day-old crescent Moon is about 6° above and to the left of Venus. For the rest of the spring, Venus grows more and more prominent as it climbs higher in the western evening sky.

Mars, in Aries, shines at magnitude +1.4. This month it sets three and a half to four hours after the Sun. On the 17th, the four-day-old Moon is less than 5° below and to the left of Mars.

Jupiter, in Gemini, is situated high toward the south at dusk. It sets just after 3:00 A.M. local time at the start of the month and shortly before 1:30 A.M. local time by month's end. At a dazzling -2.3 magnitude, it reigns as the brightest planet, once Venus has set. Jupiter stands well above and to the left of the Moon on the night of March 21–22.

Saturn is high in the southwestern sky at dusk, setting soon after 1:00 A.M. local time on March 1. It sets about three minutes earlier each night thereafter. In Taurus, the +0.1 magnitude planet passes 4° north of the star Aldebaran on the 31st. The planet's rings are now tilted some 26° toward Earth. With the aid of a moderate-sized telescope, the shadow that the planet's sphere casts on its rings is especially noticeable this month. Observers with telescopes also have an excellent opportunity to identify one of the solar system's largest asteroids. On the evening of March 19, Vesta (334 miles in diameter; the fourth asteroid to be discovered) appears to pass within about three arc minutes of Saturn for viewers across North America—looking like a tiny "star" of magnitude +8.3, just southeast of the planet. Make sure not to confuse Vesta with Saturn's brightest satellites (Titan, Rhea, Dione, Tethys, Iapetus, and Enceladus), all of which will be noticeably fainter and closer to the planet. According to Jean Meeus, a specialist in spherical and mathematical astronomy, Vesta makes its closest approach to Saturn at 10:48 A.M. (during daylight across North America). At that point, Vesta is 253 million miles from Earth and Saturn is 867 million miles away. Yet by sheer coincidence, from our perspective both objects appear to line up almost exactly in space.

The Moon is at last quarter on March 5 at 8:25 P.M. The new Moon falls on the 13th at 9:03 P.M., and first quarter on March 21 at 9:28 P.M. The Moon is full on the 28th at 1:25 P.M.

The vernal equinox occurs at 2:16 P.M. on March 20. Spring begins in the Northern Hemisphere; fall begins in the Southern Hemisphere.

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

REVIEW

The Spice of Life

Mining history for the source of an essential mineral

By Raymond Sokolov

Salt is a pillar of nature; without it, life is impossible. We may think of salt primarily as a minor and optional condiment, something so trivial that many restaurants keep it off the table, along with pepper (a truly nonessential spice with a short history in the West and no biochemical role to match, even remotely, that of salt). But salt really matters, and Mark Kurlansky wants to make sure you never forget this.

By "salt," I refer to the naturally occurring mineral sodium chloride, the defining constituent of seawater, the stuff that makes you float so high in the brackish waters of the Dead Sea. In pure form, the way we mostly see it, salt is white and crystalline. It improves the taste of food and has, over the years, played a crucial part in the survival of the human race, because it offered a means of preserving foodstuffs in a world without refrigerators.

This is Kurlansky's main subject in *Salt: A World History.* If you want to know a lot about the biochemistry of salt or its use in the kitchens of the world, this is not the book for you. Kurlansky is primarily a social historian. Or perhaps he should be called an economic mineralogist, since his focus is on the intersection of salt with civilization. His approach will be familiar to people who read his earlier work *Cod: A Biography of the Fish That Changed the World,* a study that must have led him logically to this one, since salt cod really did change the world.

Here was a food with a remarkable shelf life that made it possible to feed Christendom despite the menu-challenging insistence by Rome that dozens and dozens of days be officially meager, which is to say meatless. Salt cod was not the only response to the need for fishy protein. Indeed, Catholics in this country have in some times and places chosen to deem that muskrat was fish. But cod, salted down, dehydrated and cured stiff as boards, was a meal for the pious—seemingly infinite in its availability and lightweight, therefore easily shipped. This is why conquistadores from the landlocked Spanish region of Extremadura spread salt cod to the New World, where it is a staple of Latino cookery today.

Salt: A World History, *by Mark Kurlansky (Walker and Company, 2002; $28)*

The fish came from northern waters, but the salt—well, that is Kurlansky's subject this time: where it came from, how it was gathered, the economic and political ramifications of the salt trade, and the infamous salt taxes. And, gosh, he is thorough. Could there possibly be a salt mine or salt marsh anywhere on earth, operating at any point in history, that Kurlansky does not describe?

He quotes Cassiodorus on the Venetian salt industry in the sixth century A.D. He waxes lyrical about Brittany's *paludiers,* the marshlanders of Guérande, who rake salt from evaporation lagoons—an ancient technology that gives gourmets the pricey *fleur de sel* they treasure. He is knowledgeable

THE METROPOLITAN MUSEUM OF ART

Curing fish in ancient Egypt

about the salt mines way below the city of Detroit. And he is eloquent about the deep mine at Avery Island, Louisiana, where Tabasco sauce comes from:

> *The mine is dug in rooms called benches that are 60 feet by 100 feet with 28-foot ceilings. Once a bench is mined, a road is dug through the floor down to another level and another bench. The salt dome that is being mined is a column of solid sodium chloride, crystal clear, thought to be 40,000 feet deep—almost eight miles. . . . The vehicles are all four-wheel drive, because the salt floor is as slippery as ice. . . . The mine is currently operating at a depth of 1,600 feet, and with 38,400 feet to go, it might seem that this salt dome is an inexhaustible resource. But as the miners dig, to withstand added stress from the weight above them, the benches must be made smaller.*

In another fifty years, the mine will cease to be worth the trouble.

Was this book worth the trouble? Kurlansky's enthusiasm never seems to flag. He sees the quest for salt as a key motive in human history, and he is sometimes unquestionably right. A salt dome in Texas turned into the Spindletop oil bonanza, a serendipity of far-reaching import. But much of what he mines from many other people's books (relegated to a bibliography but rarely cited in the text, which has no footnotes) is curiously repetitious. Marvelous nuggets do, however, reinvigorate the text with regularity: Who wouldn't be charmed to learn that in 1350 one Wilhelm Beuckelzon, a fish merchant in Flanders, found a new way to pickle herring: he eliminated the traditional drying stage and just salted the fish directly as they came out of the nets, greatly reducing the danger of spoilage from exposure to the air. Beuckelzon was honored by great monarchs, but the story, Kurlansky reveals, is "bogus," a sort of red herring. Pickling in brine had already been done for centuries.

Even with these lighter moments, Kurlansky's relentless march from one salt operation to another, from a description of salt curing here to salt curing there, will try the patience of even the most halophilic reader. The sheer accumulation of detail does not, somehow, add up to a coherent argument about salt in human affairs. It certainly does not, despite its length, begin to cover all that could be said or thought about salt. Salt in medicine and nutrition, salt in chemistry, even salt in cooking are given short shrift. And considering the amount of attention paid to the preservation of food by salt, the book never comes to grips more than superficially with the complex process that makes it work. Perhaps Kurlansky would argue that he has written a work of history and that hard science has no central place in it. And yet, wouldn't this have been a stronger book if it had included basic information about salt as a mineral and as an agent of beneficial change in meat, fish, and vegetables—information to be easily found in many encyclopedias?

Raymond Sokolov, the Wall Street Journal*'s arts editor, is a biographer of A. J. Liebling and a veteran food writer. From 1974–94 he wrote the* Natural History *column "A Matter of Taste."*

nature.net

Drought Watch

By Robert Anderson

Our attention in Afghanistan has been focused on the war and the removal of the terrorists harbored there. But some of the suffering in that distant country comes from an entirely different kind of threat: persistent drought. As one starving Afghan refugee explained, "We had a good life, but then four years ago the rains stopped and our crops could not grow."

What are the chances that nature could do the same in the United States? To give us some appreciation for the threat, the National Oceanic and Atmospheric Administration has created a Web site entitled "North American Drought: A Paleo Perspective" (www.ngdc.noaa.gov/paleo/drought/drght_home.html). I was surprised to learn that a recent drought, not an earthquake or a hurricane, was the costliest natural disaster in U.S. history. It began in 1987 along the West Coast and spread across 36 percent of the country, lasting into 1989 and causing some $39 billion worth of damage, mostly in the northern Great Plains and in the East. Other prolonged droughts in the 1930s (responsible for the dust bowl) and 1950s were more severe, but because of our population growth in semiarid areas and our overtaxing of water supplies, we are now more vulnerable to drought's effects.

The site does a remarkable job of presenting the data on past droughts, going back several thousand years. Perhaps the best example is the animated map of the United States—in the section called "The Last 500 Years"—showing drought severity for every summer from 1700 to 1978. Elsewhere in this section, two particularly bad droughts that affected the early colonists are examined. The first, in 1587–89 (the worst three-year dry spell in 800 years), is thought to have doomed the settlers on Roanoke Island, North Carolina; the second, two decades later, decimated but did not destroy the Jamestown, Virginia, colony.

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

BOOKSHELF

Among the Bears: Raising Orphan Cubs in the Wild, *by Benjamin Kilham and Ed Gray (Henry Holt, 2002; $26)*
Kilham's account of orphaned black bear cubs, raised by him in New Hampshire's woodlands, overturns some of our long-held assumptions about bear behavior and captures his affection for North America's intelligent and (except for us) dominant omnivore.

Submerged: Adventures of America's Most Elite Underwater Archeology Team, *by Daniel Lenihan (Newmarket Press, 2002; $25.95)*
An archaeologist and National Park Service ranger, the author has undertaken a variety of underwater jobs during his quarter-century career—from surveying shipwrecks in Lake Superior's frigid waters to recovering bodies of drowned divers in Florida's water-filled underground caves.

Small Deaths, *photographs by Kate Breakey (University of Texas Press, 2001; $65)*
"Making photographic images of small deaths is, in a sense, my own version of natural history museum dioramas," writes Breakey, "a place where I can come to know my subjects in all their exquisite detail: the iridescence of their feathers, the patterns of their scales, the texture of their bones."

World Atlas of the Oceans, *edited by Manfred Leier (Firefly Books, 2001; $50)*
A wide-ranging and accessible compendium brimming with photographs, maps, and charts, this atlas covers marine exploration and oceanography and provides detailed data on topographical features of the ocean floor.

Lichens of North America, *by Irwin M. Brodo, Sylvia Duran Sharnoff, and Stephen Sharnoff (Yale University Press, 2001; $69.95)*
This tome includes detailed entries on more than 800 foliose, fruticose, and crustose lichens; essays on the biology, structure, uses, and ecological significance of these plants; and hundreds of color photographs.

HENRY HORENSTEIN

Aquatics, *by Henry Horenstein (Stewart, Tabori & Chang, 2001; $35)*

The Origins of Fruit and Vegetables, *by Jonathan Roberts (Universe/Rizzoli, 2001; $22.50)*
The first references to rhubarb date to a Chinese herbal of 2,700 B.C.—a tidbit that is part of the wealth of information filling this beautiful volume.

Eco-Economy: Building an Economy for the Earth, *by Lester R. Brown (W. W. Norton, 2001; $27.95)*
Brown, founder of the Worldwatch Institute, provides a road map for making economic progress compatible with preservation of the environment.

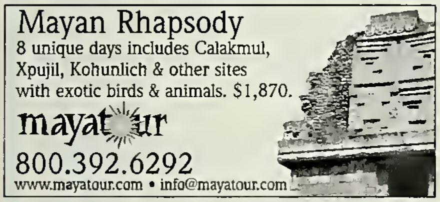
Nature's Robots: A History of Proteins, *by Charles Tanford and Jacqueline Reynolds (Oxford University Press, 2001; $27.50)*
Ranging from the earliest research in the nineteenth century to recent efforts to find the three-dimensional structure of individual proteins, this book portrays the "uniquely versatile macromolecules at the heart of all living processes."

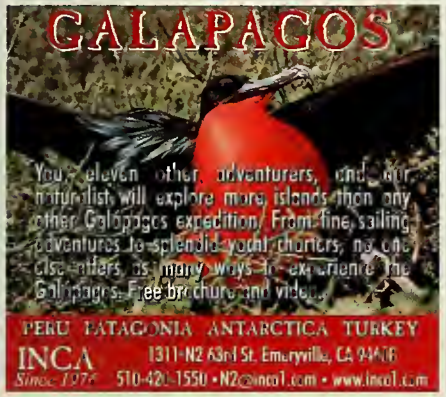
The Hidden Powers of Animals: Uncovering the Secrets of Nature, *by Karl P. N. Shuker (Reader's Digest, 2001; $30)*
Abundant photographs accompany fascinating tales of creatures' specialized senses, including the ultraviolet vision of some insects, spiders, and birds; the sensory powers of sharks; and the infrasonic hearing that allows elephants, ground-dwelling rodents, and various insects to detect the approach of a storm.

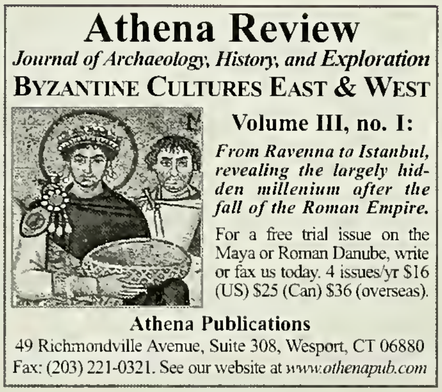
Flora: An Illustrated History of the Garden Flower, *by Brent Elliott (Firefly Books, 2001; $60)*
Garden Eden: Masterpieces of Botanical Illustration, *by H. Walter Lack (Taschen, 2001; $39.95)*
Splendid botanical illustrations from the Royal Horticultural Society in London *(Flora)* and from the Austrian National Library in Vienna *(Garden Eden)*.

The books mentioned are usually available in the Museum Shop, (212) 769-5150, or via the Museum's Web site, www.amnh.org.

EXPLORER GUIDE







THE NATURAL MOMENT

Head Start

The lowland rainforests of the Indonesian island of Java are perfect places for an arboreal, leaf-green snake to ply its predatory trade. Silently gliding through the trees or swimming in forest streams, it hunts for birds, frogs, lizards, and rodents. This snake, a member of a species given various names (*Elaphe oxycephala, Gonyosoma oxycephalum,* alias red-tailed ratsnake, green racer), is taking time out to attend to the hygienic chore of sloughing its skin. Photographer Nicole Viloteau notes that snakes have "a skin language." This benign individual, in Ujung Kulon National Conservation Park in western Java, accepted a back scratch after Viloteau rubbed her hands together to create a "warm perfume." The snake may indeed be smelling her; the extended tongue probes the air and gathers scent, which is carried to the odor-sensitive Jacobson's organ inside the mouth.

In snakes, the cyclic molt, or ecdysis, starts at the front end. To begin the process, the animal may scrape its nose or chin against a branch. It then moves forward to peel the skin inside out. Viloteau compares it to "pulling off an old sock." This four-foot-long snake took only about fifteen minutes to emerge completely from its ghostly and minutely detailed sheath.—*Judy Rice*

Photograph by **Nicole Viloteau**

ENDPAPER

Beastly Fun

By Philippe Germond

Of all the civilizations of the ancient world, none seems to have enjoyed such a close and significant relationship with the animal realm as that of the ancient Egyptians. The vivid scenes that decorate the mastabas, or funerary chapels, of the Old Kingdom, and the delicate paintings on the walls of the rock-cut Theban tombs of the New Kingdom underline repeatedly the essentially pastoral nature of ancient Egyptian life. Animals are everywhere here, faithful allies doggedly helping humans in the accomplishment of their everyday tasks. Oxen are yoked to the plough, donkeys carry the harvest from field to village, and cows and sheep trample the grain on the threshing floor. Some scenes depicting the rearing of livestock indicate that the inhabitants of the Nile Valley were still attempting to domesticate semidesert species such as the oryx, while poultry yards and aviaries were home to a great variety of bird life that included geese, ducks, pelicans, cranes, and pigeons.

RÉUNION DES MUSÉES NATIONAUX/ART RESOURCE, NY

Crown from a figurine of the Egyptian god Bes, decorated with a cat herding geese, ca. 600 B.C.

Depictions of this rich fauna—wild or domesticated; useful or dangerous; native to the semidesert regions, the damp river margins, or the cultivated areas—offer evidence of the way in which the inhabitants of the Nile Valley gradually adapted to their environment. For the ancient Egyptians, animals had a significance that went far beyond the purely utilitarian. They were among the fundamental elements of creation—and were the visible signs of primeval forces that had to be both recognized and propitiated. The realm of beasts was simultaneously the expression and the justification of a magico-religious approach to the world. Moreover, whether the artist in question was a scribe, a painter, or a sculptor, his work was judged solely according to the criteria of the divine, religious, or funerary worlds.

Some works, however, fall outside these realms, and their glorification of eternal life is all the more precious for revealing an unfamiliar side of Egyptian artists. To poke fun at established institutions and distinguished figures, or to convey the notion of political or social instability, what more effective conceit could there be than to use a cast of animals in place of humans? Anticipating the Greek fabulist Aesop, the animal morality tales of medieval Europe, and the fables of La Fontaine, the Egyptians created works that were both unexpected and humorous, neatly mocking the weaknesses of a rigidly hierarchical society.

Although surviving literary documents are rare, numerous ostraca (inscribed potsherds or limestone flakes) and a few papyri are illustrated with parodic and satirical scenes in which the human roles are played by animals: a cat guards a flock of geese, or cradles a mouse like a loving nursemaid; a lion dexterously plucks the strings of a lute; a monkey plays a double flute. Occasionally, these unexpected images seem to convey a social situation turned on its head for the sake of making a humorous point, such as a rich man suddenly made penniless and a poor man who finds himself wealthy. These topsy-turvy—and, it would have been hoped, temporary—states of affairs gave artists the opportunity to create, outside the confines of officialdom, remarkable cameos featuring animal characters in surprising attitudes, such as foxes leading ducks to water or a lion playing the board game senet (a sort of draughts) with a wildebeest.

Whether they set out to illustrate fables, to offer an ironic critique of the establishment, or simply to make people laugh, Egyptian artists were skilled at using humor in a spontaneous and refreshing fashion, far removed from the solemn and rather stiff approach that we generally associate with ancient Egyptian art.

Philippe Germond is an Egyptologist at the University of Geneva and has written widely on ancient Egypt and its art.

From An Egyptian Bestiary: Animals in Life and Religion in the Land of the Pharaohs, *by Philippe Germond, photographs by Jacques Livet, translated from the French by Barbara Mellor. Copyright © 2001 by Thames & Hudson, Inc. Reprinted by permission of the publisher.*

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