Extreme Pollinators

PLUS:
Timber Rattlers
Testing Einstein in Space
Our blue-sky scenario: more U.S. manufacturing jobs, cleaner U.S. manufacturing plants. Since 1986, Toyota has been building vehicles and creating manufacturing jobs in the U.S. Today, with our eight manufacturing plants, sales and marketing operations, research and design facilities, and through our dealers and suppliers, Toyota’s U.S. operations account for more than 200,000 jobs. And with two new state-of-the-art manufacturing facilities being built to strict environmental standards, we’re continuing our commitment to responsible growth as an employer, and a neighbor.

*Toyota components and vehicles are made using many U.S. sourced parts. Direct U.S. employment: 31,040 jobs as of 12/03. ©2005
GOLD DIGGERS WELCOME

the Houston Museum of Natural Science

For more information, visit www.hmns.org or call 713.639.4629.

DIG IN!
FEB. 18 - AUG. 7, 2005

GOLD!
Natural Treasure, Cultural Obsession

FEATURES

36 SOCIAL LIVES OF RATTLESNAKES
Recognizing their relatives is a key advantage, especially for females.
RULON W. CLARK
PHOTOGRAPHS BY JOHN CANCALOSI

52 TESTING EINSTEIN (AGAIN)
Decades of work on a space-based effort to verify the general theory of relativity is about to come to fruition.
ARTHUR FISHER

COVER STORY
58 THE FLOWER AND THE FLY
Extreme pollinators have “coevolved” to favor extreme floral architecture.
LAURA A. SESSIONS AND STEVEN D. JOHNSON

ON THE COVER:
Tangle-veined fly bearing orchid pollen sac
DEPARTMENTS

6 THE NATURAL MOMENT
Spiking the Lunch
Photograph by Carlos Sanz

8 UP FRONT
Editor's Notebook

10 CONTRIBUTORS

12 LETTERS

15 SAMPLINGS
News from Nature

31 UNIVERSE
Living Space
Neil deGrasse Tyson

34 BIOMECHANICS
How Trees Get High
Adam Summers

PICTURE CREDITS: Page 10
Visit our Web site at
www.naturalhistorymag.com
Ed Viesturs was hailed by National Geographic as one of the strongest high-altitude mountaineers on Earth. He's gazed from the summit of Mt. Everest five times. Three of those times he pushed to the top without supplemental oxygen. A feat few people in the world will ever accomplish. In Ed Viesturs' own words: "Getting to the top is optional, but getting down is mandatory." He plans to climb all 14 of the world's highest peaks without oxygen. So far: 13 down, one more to go. There are exceptional explorers on this planet, but there is only one Ed Viesturs.
Spiking the Lunch

Photograph by Carlos Sanz
Milestones

Denis Flanagan, the founding editor of the modern Scientific American, who died this past January on the day the Huygens space probe landed on Titan, never liked anniversaries. They were lame excuses, in his estimation, for the common practice of filling magazines with articles that wouldn't stand up without the crutch of the calendar. Yet I think Flanagan would have enjoyed the coincidence between the imminent results from Gravity Probe B (see Arthur Fisher's article "Testing Einstein (Again)," page 52) and this year's centennial of Einstein's annus mirabilis (see Robert Anderson's column "Einsteiniana," page 72).

To the physicists who designed Gravity Probe B, the coincidence must seem an absurdist joke. The project is a space-based test of Einstein's general theory of relativity, but it was his special theory, not the general theory, that was published in 1905. More to the point, the project was begun in 1959 and, by all original estimates, should have concluded decades ago. Maybe Flanagan's impatience with the counterfeit currency of anniversaries was well founded.

His impatience with cranks certainly was. A crank, according to Flanagan, is anyone who "believes something that on the face of it is unbelievable." Apart from the curved space-time of Einstein's universe, no other scientific principle acts more like flypaper for cranks than does evolutionary biology. The reason, no doubt, is that it makes seemingly remarkable claims about familiar things: flowers, trees, snakes, human beings.

But the evolutionary biology of Darwin and the late Ernst Mayr continues to explain the natural world with such clarity that to deny its insights has become "something that on the face of it is unbelievable." Laura A. Sessions and Steven D. Johnson offer a striking example of the power of evolutionary thinking in their article "The Flower and the Fly" (page 58). For a Natural History forum in which proponents present their case for intelligent design and leading evolutionists respond, see the page www.naturalhistorymag.com/darwinanddesign on our Web site.

Flanagan's version of Scientific American became the very model of the modern science magazine. He created, through his tutelage and example, a generation of science journalists and editors—I'm proud to be one of them—who have carried his legacy to American Scientist, Discover, Muse, National Geographic, Natural History, Science, Technology Review, The Sciences, and many other magazines. When he retired, he remarked—characteristically—that he hoped he had given his colleagues a chance to do intriguing and valuable work. Indeed he had.

Speaking of milestones, with his tour of the island of Saint Lucia ("Peak Experience," page 64), our contributing editor and columnist Robert H. Mohlenbrock has published his 201st "This Land" column. To my knowledge, only Stephen Jay Gould, with his 300 columns, holds a longer record at Natural History. —Peter Brown
“WELCOME ABOARD NATIONAL GEOGRAPHIC.”

Lindblad Expeditions and National Geographic have joined forces to further inspire the world through expedition travel. Our collaboration in exploration, research, technology and conservation will provide extraordinary travel experiences, while disseminating geographic knowledge around the globe.

I have been involved with expedition travel my entire life and National Geographic has always provided constant inspiration, knowledge and guidance. This partnership is really a dream come true, and together we will provide you unprecedented access to the world and all that’s in it.

So, come explore with us on our six expedition ships around the world. Or join the National Geographic Endeavour* on expeditions to Antarctica, Scandinavia, Europe, the Mediterranean, the Arctic and other extraordinary places. With Lindblad Expeditions and National Geographic, you’ll discover the world. And all you have to do is call your travel agent or contact us. Sven-Olof Lindblad

EXPEDITIONS.COM • 800-EXPEDITION

ENTER TO WIN AN EXTRAORDINARY EXPEDITION FOR TWO AT EXPEDITIONS.COM/NHMAR
Biologist CARLOS SANZ ("The Natural Moment," page 6), a native of Spain, specializes in the study of Iberian wolves (Canis lupus signatatus). He recently co-authored a book on the wolves, published under the title Amigo Lobo (Friend Wolf). Sanz has worked extensively as a nature writer and photographer, and has also helped produce nature documentaries. His photographs of a shrike with prey was taken in Spain's central Guadalajara province.

Rattlesnakes have enthralled RULON W. CLARK ("Social Lives of Rattlesnakes," page 36) since childhood. He recalls being particularly drawn to wild animals that didn’t try to fly or run away, because then he could hold them. For the past seven years Clark has been studying timber rattlers in the northeastern United States. He recently completed his Ph.D. at Cornell University in Ithaca, New York, with a dissertation on the group interactions of snakes. He continues to walk the forests near Ithaca, where he is now a postdoctoral associate at Cornell. Photographer JOHN CANCALOSI also lives in Ithaca. He became a teacher after earning a master's degree in zoology, but left the position more than a decade ago to pursue his passion for nature photography full-time.

Back in 1983 ARTHUR FISHER ("Testing Einstein (Again)," page 52) wrote an article for Popular Science about Gravity Probe B, a major experimental test of Einstein’s general theory of relativity. Physicists and engineers had already been working on the project for more than twenty years, when Fisher’s article came to the attention of Stanford University physicist C.W. Francis Everett, the project’s principal investigator. Everett invited Fisher to help write the project’s brochure. With the satellite finally aloft and collecting data, both men look forward to seeing the final results. Fisher, who was the science editor at Popular Science for many years, has been a frequent contributor to many other science publications, and has received numerous awards for his science writing.

With degrees in both ecology and science communication, LAURA A. SESSIONS ("The Flower and the Fly," page 58) is well prepared to write about her interest in plant-animal interactions. A native of Virginia, Sessions has lived in New Zealand for the past eight years. This article is her fourth contribution to Natural History. Botanist STEVEN D. JOHNSON is an associate professor at the University of KwaZulu-Natal in Pietermaritzburg, South Africa. Working in one of the world’s major centers of biodiversity, Johnson says, has heightened his interest in the role of pollinators in the evolution and ecology of plant species. He has co-authored a book about Cape Town’s famous scenic landmark (Table Mountain: A Natural History), and is also a regular contributor to natural history magazines in South Africa.

INTRODUCING OUR EXCLUSIVE NEW PRODUCT LINE OF
PLANT PORTRAITS
FROM ORIGINAL PAINTINGS BY A.R. VALENTIEN

FINE ART PRINTS of CALIFORNIA NATIVE PLANTS
Wolf’s Cholla, Mariposa Lily, Hairy Matilija Poppy, Humboldt Lily,
California Poppy, and Ocotillo. Mix and match beautifully. $80 each

ELEGANT NOTECARDS
In three distinctive assortments: California Poppy/Humbolt Lily/Ocotillo; Matilija Poppy/Washington Lily/California Lilac; Beavertail Cactus/Wolf’s Cholla/Barrel Cactus. Keepsake box of 12 (+ each of 3 designs). $15 each

ORDER online at www.sdnhm.org/store or call the Museum Store 619.255.0239.

SAN DIEGO NATURAL HISTORY MUSEUM | Your Nature Connection
**LETTERS**

**Fruit Cocktail**

In "The Drunken Monkey Hypothesis" (12/04–1/05) Dustin Stephens and Robert Dudley suggest that human alcoholism is rooted in the evolutionary history of primates. They reason that frugivorous primates evolved mechanisms for tolerating dietary ethanol because low levels of alcohol are characteristic of ripe fruits.

It is compelling supporting evidence for the hypothesis that approximately 10 percent of the total solubile protein in the human liver is alcohol dehydrogenase, one of the enzymes that metabolizes alcohol. But it is also important to consider how primates recognize ethanol, if it is a major foraging cue. Matthias Laska of the University of Munich and others report that macaques possess an exquisite olfactory sensitivity to alcohol. Vicktoria Danilova and Göran Hellekant of the University of Wisconsin–Madison have shown that nerves that convey taste and somatic sensations from the mouth respond to ethanol. The responses are far greater in primates than in other mammals. A tendency towards tipsiness, then, could well be an evolutionary hangover.

Nathaniel J. Dominy
University of California
Santa Cruz, California

The key assumption of the argument by Dustin Stephens and Robert Dudley is that contact between prehistoric primates and ethanol is necessary for alcoholism. On closer examination, however, that seems unlikely.

Alcoholism is an addiction; it is characterized by dependence, the development of tolerance, and a loss of control over intake. People become addicted to many different substances that our primate cousins never came in contact with, such as methamphetamines, heroin, and crack cocaine. What appears necessary for addiction is that a substance interacts in specific ways with neural pathways involved in motivation, reward, and reinforcement. Those pathways, of course, also have an evolutionary history, but one that long predated frugivorous primates. A thoughtful critique of the drunken monkey hypothesis was recently published by Katharine Milton ("Ferment in the Family Tree," Integrative and Comparative Biology, 44: 304–314, 2004).

Justin S. Rhodes
and John C. Crabbe
Portland Alcohol Research Center
Portland, Oregon

On our property in the Hudson Valley, my wife and I have several old mulberry trees with berries that ripen in July. As the sun warms the berries, many fruit-eating birds that rarely visit our seed feeders come and feast. It seems as though the berries begin to ferment in the sun. The young robins are particularly affected. They eat their fill and then try to fly, usually flapping and landing close to the tree, seemingly quite drunk. We have not noticed the same phenomenon in more mature birds.

David Ginsberg
New York, New York

**Robert Dudley replies:** Alcohol is unique among the addictive substances in that all fruit-eating animals, including human ancestors, regularly consume low levels of alcohol while feeding on ripe and overripe fruit. Justin S. Rhodes and John C. Crabbe are correct in suggesting that the neural pathways associating alcohol ingestion with reward precede the origin of primates. As Dustin Stephens and I stated in our article, fruit flies track ethanol plumes to find fruit, and the flies’ fecundity and longevity are enhanced at low levels of alcohol exposure.

Recent work by Ulrike Heberlein, an anatomist at the University of California, San Francisco, has demonstrated that fruit flies also have molecular pathways of inebriation similar to those of humans. Her finding shows that fruit flies are good models for studying drug abuse in people. Identifying the evolutionary origins of such physiological and behavioral responses to alcohol is an important goal for basic research in the biology of addiction.

**Good Cause**

I was deeply touched by James A. Zingeser’s article, “Sight for Sore Eyes” (12/04–1/05). Mr. Zingeser's straightforward description of the disease touched my heart, as I imagined how constant the misery of trachoma would be.

I have become sickeningly accustomed to hearing about “solutions” to problems in developing countries that are really political decisions serving the interests of ruling classes and militaries. The epidemiological work and the implementation strategies involved in the trachoma-control effort seemed to me profoundly thoughtful and well grounded in the principle of meeting people where they are.

Keith Thurlow
Tino, Massachusetts

**James A. Zingeser replies:** I thank Mr. Thurlow for his kind and perceptive remarks about the global efforts to control trachoma. He is absolutely correct, we live in a world in which we can either share our enor-
Explore Miracles & Mysteries in the only magazine of its kind—for just $25!

Embark on an adventure you’ll never forget—from phosphorescent fish on the ocean floor to new galaxies being born at the edge of the universe, from ancient civilizations to the future of cyberspace.

All in our unique magazine, world-acclaimed for its award-winning color photographs and reportage by leading scientists, educators and writers.

Yours in Natural History—for $25! You save 37% off the newsstand price.

SUBSCRIBE TODAY & ENJOY THESE YEARLY BENEFITS:

- A free (one-time only) general admission pass to the American Museum of Natural History in New York City
- A discount on a ticket to the Museum’s spectacular IMAX® Theater during your visit
- Discounts on unique items in Museum gift shops, including books, crafts, jewelry and collectibles

THREE EASY WAYS TO ORDER:

Call toll-free: 1-800-234-5252,
(Outside the U.S.: 1-515-247-7631)

Online: www.naturalhistorymag.com

Fax: 1-712-733-1277
mous wealth to end extreme poverty, hunger, and disease, or watch resources waylaid and squandered for war and greed.

Our strategy has always been to "meet people where they are" by listening to them and responding to their needs. In the same way, the Carter Center, the Centers for Disease Control and Prevention, and the World Health Organization, along with dedicated development and health-care workers worldwide, are on the verge of eradicating guinea worm disease and poliomyelitis.

President Jimmy Carter has played another crucial role by using his direct access to heads of state and leaders of industry to speak out for forgotten persons worldwide. A year ago I presented President Carter with compelling data suggesting that providing latrines would reduce trachoma and have a huge impact on other hygiene-related illnesses for extremely impoverished families. He stopped me and asked, "How many latrines are we talking about?" "Hundreds of thousands, perhaps millions," I replied. He didn't flinch, "All right then, who do I need to speak with to get this going? Let's not waste time."

Come Together

As one of the originators of the mission, it was a special pleasure for me to read John C. Zarnecki's account of the Cassini-Huygens mission to Saturn's largest moon, Titan ("Destination: Titan," 12/04-1/05). One of the most satisfying aspects of this project has been its international character. The Cassini-Huygens mission illustrates what can be accomplished when Europe and the United States work closely together as equal partners on a project that is at the cutting edge of technology.

Mr. Zarnecki and I and all the other members of our intrepid crew will still be happily puzzling over the secrets of Titan on the 25th of this month, the 350th anniversary of Christiaan Huygens's discovery of the enigmatic satellite. Huygens would surely be pleased. [For a picture of Titan's surface, see page 15.]

Tobias C. Owen

University of Hawai'i at Manoa
Honolulu, Hawai'i

Naming Rights

In Peter M. Whiteley's article "Ties That Bind" (11/04), the credit given for the portrait of the Hopi Chief Ke wanimpetewa on page 26 was incomplete. The painting is by Eben Cummins; it is part of the collection of the Michael and Margaret B. Harrison Western Research Center at the University of California, Davis.

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

Built one at a time, to match each customer’s home.

Elevette® has more choices in styles, finishes, options and price levels. It also comes with a parts warranty no one can beat. Call us today to learn more. INCLINATOR COMPANY OF AMERICA

www.inclinator.com 800-343-9007

RESIDENTIAL ELEVATORS • WHEELCHAIR LIFTS • DUMBWAITERS

When we fight for the environment, we fight for you. And we win. Take the case that forced the EPA to clean up smog in communities across the country. Join us. Call 1-800-591-6150 or visit earthjustice.org.
**Room to Breathe?**

Sea ice in the Arctic is decreasing, right? That’s certainly true overall: 9 percent of the “perennial” ice and 3 percent of the annually formed ice have been disappearing each decade for the past quarter century. But in some areas the ice has been increasing. One such area is Baffin Bay, between Canada and Greenland. The bay is home to the world’s greatest concentration of narwhals, and for them an increase in ice is a big problem.

Narwhals—small whales that live in the High Arctic—are noted for the males’ long, tusk. Sensibly, they migrate south in winter. “South,” however, is no farther than the middle of Baffin Bay, which is mostly covered in dense pack ice from December through March. At present the ice still has enough leads and cracks so that the narwhals can breathe. But Kristin L. Laidre and Mads Peter Heide-Jørgensen of the Greenland Institute of Natural Resources have found that the winter ice cover in the narwhals’ northernmost wintering grounds in Baffin Bay increased by 0.04 percent a year between 1978 and 2001.

That may not sound like much, but from mid-January until mid-April less than 3 percent of the narwhals’ wintering grounds are open water. The icing trend could become disastrous for the narwhals. Not only will they run the risk of getting trapped in the ice, but there will also be fewer places from which they can dive for one of their main winter foods: the halibut that live at depths of more than 3,000 feet. (“Arctic sea ice trends and narwhal vulnerability,” Biological Conservation 121:509–17, 2005)

—Stéphane Reeb

**Telling Teeth**

That the rich are healthier than the poor is no surprise. But a recent study puts a new face on that dismal truism: centuries ago in Japan, the samurai had healthier teeth than their less affluent neighbors.

Best known as warriors, the samurai became part of Japan’s ruling class during the Edo period (1603–1867). Joichi Oyamada and his colleagues, all dental anthropologists at Nagasaki University, examined the teeth of 357 samurai and 1,211 “commoners” (merchants, farmers, and their families) buried in the city of Kokura between the sixteenth and nineteenth centuries. It turns out that the adult samurai had half as many teeth with decayed roots as adult commoners did. Younger samurai had only an eighth as many as their poorer counterparts.

The reasons? Oral hygiene was key. Tooth powder had long been available, but brushing with an early relative of the toothbrush—the tufted toothpick—began in the Edo period. The teeth of about 20 percent of the samurai, compared with 3 percent of the commoners, were highly polished in precisely those spots that the new device could reach. (“Dental pathology in the samurai and commoners of early modern Japan,” Anthropological Science 112:235–46, 2004)  

—Caitlin E. Cox

**Titan, Ho!**

On January 14 the European Space Agency’s Huygens probe landed on Saturn’s largest moon. From a height of five miles, Huygens photographed what appears to be a ridge with drainage channels that lead to a flat plain.
**Battlefield Protocol**

Social complexity is often cited as the driving force behind the evolution of intelligence. Until recently, animal behaviorists thought only primates displayed the intellectual abilities necessary for complex cooperation or for selfish manipulation of comrades—abilities such as individually recognizing other members of their own group and taking into account both the members’ rank in the group hierarchy and their blood ties. Now a team of behavioral ecologists at Michigan State University in East Lansing has determined that spotted hyenas exhibit that same level of sophistication in their group interactions.

Anne L. Engh and other students of Kay E. Holekamp’s observed a clan of spotted hyenas for eleven years in the Masai Mara National Reserve in Kenya. The investigators paid particular attention to fighting behavior—an excellent way, they found, to figure out both pecking order and kinship relations. When two hyenas were fighting, a third would sometimes join in. But no matter which animal started the fight or which one was winning at the time, the meddler almost always sided with the combatant having the higher social ranking. Moreover, in the secondary skirmishes that often followed the original fight, the hyena that started the earlier fight was more likely to pick on its opponent’s relatives.

Thus, primates are not the only group-dwelling animals that may have evolved intelligence because of the need to handle social complexity. And in a contest of social acumen between hyenas and monkeys, who knows who would get the last laugh? (“Patterns of alliance formation and postconflict aggression indicate spotted hyenas recognize third-party relationships,” Animal Behaviour 69:209–17, 2005) —S.R.

**Dazzler**

What’s the brightest thing a telescope has ever detected? Answer: a burst of radiation from a small, dense star 12,000 light-years from Earth—a pulsar known as B1937+21.

Pulsars spin much like the searchlight in a lighthouse, except they do it hundreds of times a second. If Earth happens to lie in the path of the pulsar’s beam, we see bright blasts, or pulses, of radiation lasting a few nanoseconds. Sometimes a pulsar puts out an astoundingly powerful “giant pulse” that’s as much as a thousand times more intense than a run-of-the-mill pulse. Vladimir A. Soglasnov of Lebedev Physical Institute in Moscow and a team of astrophysicists caught B1937+21’s fleeting giant outburst through a radio telescope near Canberra, Australia, back in May 1999. It was invisible to the naked eye, but if you’d been talking on your cell phone at the time (and if interstellar space were devoid of matter), you’d have heard a loud click.

At peak intensity, the giant pulse’s brightness indicated a temperature of $10^{10}$ degrees Fahrenheit (the brightness of the hottest areas of the Sun correspond to “only” about $3 \times 10^8$°F). (“Giant pulses from PSR B1937+21 with widths $\leq 15$ nanoseconds and $T \geq 5 \times 10^{10}$ K, the highest brightness temperature observed in the universe,” The Astrophysical Journal 616:439–51, 2004) —Dave Forest
We apologize that it loses 1 second every 20 million years...

The classic watch built with German precision to 1 billionth of a second?

There is a new super-accurate government device that gives you a perfect use for atomic theory. The US government has engineered the most ingenious, most accurate clock in the world, the new F-1 U.S. Atomic Clock in Boulder, Colorado. Our extraordinary new Stauer EMC² watch uses this clock to report the exact time from this remarkable cesium fission clock. So you are on time...all the time. This amazing clock will gain or lose only one second over a twenty million-year period. It is that accurate!

This perfectly tuned technological invention is now available for UNDER $100. And you'll never have to set this watch...the hands set themselves. Just push one of the buttons and you are synchronized with the F-1 and the hands of the watch move to the exact time position. The Stauer EMC² exceeds the accuracy of any Swiss luxury automatic so you can be more accurate and keep most of your money in your wallet...not on your wrist.

There are some unattractive plastic digital atomic watches on the market, but when our German movement maker made it possible for us to break the $100 price barrier with a beautiful, classically styled stainless steel analog watch, we were truly excited.

The EMC² features precise atomic time with an automatic Standard time and Daylight Saving Time adjustment. It will adjust for leap years and even leap seconds! A breakthrough in technology at a breakthrough price.

The large numeric markers are luminescent and extremely easy to read so the watch is perfect for low light situation. The EMC² is water-resistant to 5 atms as well. The small readout shows you the date and has a digital second counter. This watch is rugged enough to take to the gym but handsome enough to wear to the boardroom or out to dinner. The designers built this watch for those who prefer their watches to be practical and sharp-looking rather than overrated and overpriced.

How can it be so accurate? The new F-1 clock uses laser beams to measure the photons emitted from the cesium atom to measure the resonance frequency. This laser-cooling clock makes it about 20 times more accurate than any other clock on earth. This timepiece is a great gift for anyone who values precision and technology. Know precisely when the markets open and close. Know the times for landings and take offs or when the train is leaving the station. If punctuality and accuracy matter, then this watch was built for you.

We're still perfecting atomic theory. We must apologize that our Stauer EMC² Atomic Watch loses 1 second every 20,000,000 years. Our scientists are working diligently to correct this problem; but in the interim if you are not thrilled with the design and the accuracy of the EMC², return it in the next 30 days for a full refund of the purchase price.

This watch is not available in stores and it comes with our 30 day money-back guarantee. If you're not completely satisfied with the accuracy, simply return the watch for the full purchase price.

Not Available in Stores
Call now to take advantage of this limited offer.

Stauer EMC² Analog Atomic Watch
Three EXACT Payments of $33 +S&H
800-482-7995
Promotional Code AAW223-03
Please mention this when you call. To order by mail, please call for details.

For fastest service, call toll-free 24 hours a day 800-482-7995

Visit us online at www.NextTen.com for the complete line of Stauer Watches, Jewelry and Collectibles
Is Mars Alive?

Geologically speaking, most planetary scientists have given up Mars for dead. Although the Red Planet bears the scars of faulting, volcanic eruption, and even glaciation, investigato—s. R. ing have generally concluded that any such activity took place long ago. Álvaro Márquez, a geologist at Rey Juan Carlos University in Spain, and his colleagues disagree.

Satellite images of three Martian volcanoes, all situated on the vast dome known as the Tharsis region, show knobby, ridged piles of rock on the volcanoes’ flanks. According to Márquez and his colleagues, the rock piles look much like the moraines left behind by retreating glaciers on Earth. Not only were the rocks probably left by Martian ice, the investigators say, but they were also deposited less than 10 million years ago—recent by geological standards. The basis for that date is crater counting: Tharsis has far fewer fresh craters caused by asteroid impacts than do regions of the Moon whose rocks are known to be older.

Another sign of geologic activity at Tharsis is a series of ridges and plateaus separated by large fractures. There are conspicuous layers of rock, not obscured by accumulated dust, at the edges of the fractures. Several fissures appear to have spewed lava. All of those features point to active Martian tectonics. Similar patterns occur on Earth where continental plates are being torn apart, such as in East Africa’s Great Rift Valley.

The most intriguing implication of the observations is that, at its heart, Mars may not be dead nor cold. Internal heat energy could be driving the dynamic processes visible on its surface. Such energy, say Márquez and his colleagues, may mean increased chances of finding life on the Red Planet. (“New evidence for a volcanically, tectonically, and climatically active Mars,” Icarus 172:573–81, 2004) —D.F.

Housing Shortage

For many creatures, there’s no cozier shelter from the storm than a hollow in a tree. In Australia, more than 300 species of vertebrates hide or make their nests there, often in one of the continent’s multitudinous species of eucalyptus, and the patches of forest scattered across suburbia offer many species the best chance of finding refuge in urbanized areas. Within those patches, however, trees offering hollows are getting scarce, say Michael J. Harper and two other ecologists from the Australian Research Centre for Urban Ecology in Melbourne.

Aussie vertebrates don’t have the equipment to excavate hollows on their own. So they depend on fire, wind-induced branch breakage, or boring insects to breach the external sapwood; the breach then permits fungi to reach the heartwood and decay it. According to Harper and his colleagues, the entire process usually takes at least 150 years, though it goes faster in dead trees.

In a study of forty-four forest remnants in the suburbs of Melbourne, the investigators found that hollows are most common in eucalypts that are large, more exposed to the wind, or dead. Decades of logging have made large trees a rarity, though, and within city limits, dead trees are often removed. Fire, of course, is suppressed. That leaves only insects and wind as effective initiators of tree hollows. Harper’s team found fewer than two tree hollows, on average, per suburban acre (natural woods have two to four times as many). More than a quarter of the forest remnants had none. (“The abundance of hollow-bearing trees in urban dry sclerophyll forest and the effect of wind on hollow development,” Biological Conservation 122:181–92, 2005) —S.R.

Marriage of Convenience

In the rivers and lagoons of northern Mexico and southern Texas lives a fish called the Amazon molly. Every Amazon molly is a female. Yet unless her eggs meet some sperm, they won’t grow into embryos. Who, then, supplies the sperm? Obviously not an Amazon molly; they’re all females, remember? The sperm comes instead from the males of a closely related species, such as the sailfin molly.

But why should a male waste his sperm on eggs that ignore his DNA? After all, making sperm takes energy. As it turns out, the male isn’t being selfless. Although a male sailfin demonstrably prefers females of his own species, mating with an Amazon is a fine item to add to his reproductive résumé: female sailfins are drawn to males that score with a female molly of any species. Andrea S. Asbury and Caitlin R. Gabor, both biologists at Texas State University in San Marcos, have shown that charity has its limits, however. Male sailfins are not profligate sperm donors: when cooped up with an Amazon molly, they save energy by producing less sperm. (“Discriminating males alter sperm production between species,” Proceedings of the National Academy of Sciences 101:15970–73, 2004) —S.R.
The Great Outdoors

... places to restore the soul
Come to the place where the New World begins. Newfoundland and Labrador. Where the Atlantic Ocean and the dawning sun make their first appearance in North America. Cape Spear, where Newfoundland and Labrador’s oldest surviving lighthouse has stood for 16 decades. And the wind warms your soul as you stand closer to Ireland’s Cape Clear than Ontario’s Thunder Bay.

Come to St. John’s, the oldest settlement in the western world. Built on wooden ships and iron men around a naturally-sheltered harbour. Where 40 vessels lay anchored 40 years before the Mayflower landed. Raise a glass in a place that boasted over 80 pubs before the Americans began their battle for independence. Now that’s history. Stand at the top of Signal Hill where Marconi received the first transatlantic wireless transmission and said “Hello” to the information age.

In these hills, Britain staked its first colony and fought its final battle with France in the Seven Years’ War. Some days you can still hear the muskets echo.

Visit the Cathedral of St. John the Baptist, the oldest parish this side of the ocean, and tread softly around a cemetery that’s been here for close to 300 years. You can even cheer on the longest-running sporting event in North America, the Royal St. John’s Regatta. It takes place the first Wednesday in August on a lake we call Quidi Vidi.
At the edge of the western world, there’s a place where the day dawns first.

Of all the sunrises in North America, this is the first. The yawn and stretch of a new day. Here, you can see the oldest lighthouse in Newfoundland and Labrador live life on the edge, as it has for 160 years. In the far east of the western world.

NEWFOUNDLAND & LABRADOR
CANADA

Discover our true nature

www.gov.nl.ca/tourism or check out our neighbors at www.gov.nl.ca/tourism/neighbors

For more information or to order your free travel guide, call Colleen at 1-800-563-NFLD
Get close to the wildlife in Québec City.

Québec City

QuéBEC CITY IS A CITY WITH A European flair, nestled on the shores of the St. Lawrence River since 1608. Cradle of French civilization in America, Québec City with its historic district is recognized by UNESCO as a World Heritage Site. Narrow winding streets, old stone homes and churches, ramparts and cannons, copper roofs and graceful architectural curves all bring to mind the old continent. It is a lively and dynamic city, with one foot set in the 21st century and the other in history, with its numerous patrimonial sites.

You can stay in a hotel or inn in Old Québec, enjoy a myriad of restaurants, bistros, sidewalk cafes, and yet you are only 40 minutes away from the great outdoors. The best example is Cap Tourmente National Wildlife Area, home to many species of birds and other animals.

Cap Tourmente

Cap Tourmente National Wildlife Area is located on the north shore of the St. Lawrence River about 50 miles downstream from Québec City. The 5,500-acre wildlife area has been the scene of remarkable natural phenomena. A major fault runs across the site from east to west and separates the Laurentian Shield from the St. Lawrence Lowlands. The break is clearly visible in the form of an escarpment rising more than 500 feet above the coastal plain.

The Laurentian Plateau that dominates the site is characterized by well-rounded, forest-covered summits with many streams. A sheer cliff separates it from the lowlands and gives rise to numerous waterfalls.

The convergence of river, plain and mountains makes the Cap Tourmente National Wildlife Area a place of outstanding beauty, rich in opportunities for observing nature. The area is famous for the breathtaking spectacle afforded by the tens of thousands of snow geese that stop over here in spring and fall. The site’s biodiversity is extensive: nearly 305 bird species and many mammal species can be seen here. An interpretation centre, a network of hiking trails and qualified naturalists make Cap Tourmente an ideal natural setting for getting close to wildlife, all this less than an hour’s drive from Québec City.

One astonishing feature of Cap Tourmente is the great variety of vegetation in a relatively limited area: more than 22 forest associations and nearly 700 plant species. Over thirty mammal species visit or live in the wildlife area. Cap Tourmente also provides shelter for a multitude of birds. To date, more than 300 bird species from over 45 families have been identified at the site.

High quality facilities have been built to improve access to the site. The 12 miles of nature trails have encouraged the public to discover the site’s attractions while at the same time reducing impact on the natural environment. Visitor information and documentation are provided to more fully appreciate and support the conservation and protection of the wildlife area’s unique habitats.

Consult www.quebecregion.com for more information.
Migration Time around Québec City

At the heart of the Atlantic Flyway you will find the “Cap Tourmente National Wildlife Area” - one of the best sites for bird watching in North America. This location is one of Québec’s oldest farms established in 1626 by Samuel de Champlain. Located on the north shore of the St. Lawrence River, where great coastal marshes, plains and mountains meet, it is the point of convergence for the St. Lawrence Lowlands and the Canadian Shield.

The region offers over 200 km of hiking trails, 20 of which are located directly on the Cap Tourmente protected area where over 300 species of birds have been observed. After your visit, you will understand why Cap Tourmente is the perfect resting station for migratory birds. From here, they continue to travel East, West and North. Twice a year, bird lovers and enthusiasts can watch thousands of geese on their migration North in Spring or their return South in Autumn. So this spring, follow the geese in one of the most beautiful areas of their migratory route near Québec city. This city offers an immersion in one of North America’s most fascinating colonisation history. It is a region that must be seen, so plan your next migration time around Québec City.

www.cap-tourmente-migrations.com
Prince Edward Island

Above: Orwell Cove - Charming views are found on Prince Edward Island's scenic drives; Paddlers take an excursion to beautiful Hog Island off the coast of Lennox Island, Prince Edward Island

The Island's native peoples, the Mi'kmaq, are credited with the expression "cradled on the waves" which perfectly portrays the way this crescent-shaped slip of red soil and sandy beaches settles into the Gulf of St. Lawrence, on Canada's east coast.

Thousands of years ago, those same Mi'kmaq considered the Island a favorite summering place, rich in fish and wild fruit and gentle of climate. Now, modern-day visitors find much the same attractions. If earlier visitors paddled their way to Prince Edward Island shores, today's visitors can enjoy sea kayaking along the same sandy beaches and red sandstone cliffs, stopping for a snack in a secluded cove.

Probably the delicious shellfish sampled by the Aboriginal visitors has changed little; delicious fresh lobster, mussels and oysters are part of the everyday fare in Prince Edward Island. In fact the Prince Edward Island blue mussel has developed such a reputation that it is seen on all the best menus across North America.

At Greenwich, Prince Edward Island National Park has opened a site that interprets 10,000 years of the Island's history as well as explaining the ecology of a dramatic migrating dune system. Other interpretive centres around the province present intriguing information about potatoes, seaweed, mussels, railways, windmills, shipbuilding or Acadian, Celtic or Mi'kmaq culture!

An important part of the Prince Edward Island identity is entwined with a story about a red-haired orphan called Anne of Green Gables. The novel, published in 1908, is set in Prince Edward Island and readers from around the world visit the storybook island to enjoy the landscapes so lovingly described by local author L. M. Montgomery. That pastoral landscape, a rich quilt of reds and greens, farm fields and woodlots, is greatly admired by all who visit.
These sand dunes move. But we still recommend that you come here to see them.

They move inland at the rate of two to four yards per year. You, on the other hand, could be here in a day or so.

These rare, migrating parabolic sand dunes are moved inland by prevailing winds. They’re home to the piping plover – an internationally endangered shorebird – that nests along our protected coastal dunes. You can explore these natural wonders. Three miles of trails and boardwalk paths surround them to preserve the natural landscape.

Prince Edward Island is host to many more rare and interesting natural attractions, just waiting to be discovered.

We’re just a day’s drive from Boston, yet a million miles from the everyday.

To get your free Visitors Guide, call 1-888-PEI-PLAY and ask for LEONARD or visit www.peiplay.com/leonard

Check out our neighbours at www.peiplay.com/neighbours
Four Parks

Glacier National Park's million acres of untouched wonder serve as a home to countless wildlife including elk, deer, antelope, eagles, hawks, great blue herons, mountain goats, bighorn sheep and grizzly bears. Drive the 50-mile long Going-to-the-Sun Road along the shores of the park's two largest lakes and the cliffs below the Continental Divide, hike over 700 miles of trails or discover secluded areas of the park.

Mount Rushmore lets you look history—and nature—in the eye. Mount Rushmore's 60-foot granite faces gaze out over South Dakota's Black Hills which offer outdoor nature lovers a chance to hike, bike, fish and rock climb.

Hike the Presidential Trail and attend the patriotic Lighting Ceremony, which takes place nightly throughout the summer. Tour Badlands National Park, Crazy Horse Memorial, Wind Cave National Park, Jewel Cave National Monument, and Custer State Park—with its herd of 1,500 bison. See wildlife such as bison, elk, mountain goats and bighorn sheep.

The youngest of the Rocky Mountain system, the Teton Range is the centerpiece of Grand Teton National Park. Rising 13,000 feet above sea level Grand Teton offers magnificent wildlife watching, fishing and birding opportunities. On the Snake River scenic float trips spy bald eagles, beavers and osprey. If you're angling for fishing then try world-class fly fishing on the Snake River or fish for the infamous native cut throat trout on Jackson Lake.

Yellowstone, the world's first national park, offers endless opportunities to experience unique natural phenomena. Guided tours, ranger-led hikes and naturalist-led mini-expeditions will take you to Old Faithful, Mammoth Hot Springs, the famous Lower Falls in the Grand Canyon area, and Yellowstone Lake, as well as into the secret side of Yellowstone. Wildlife species abound, including North America's largest wild bison herd as well as elk, deer, moose, wolves, bears, trumpeter swans, and cut throat trout.

Spanning three states, millions of acres and a billion years, each of the Four Parks is a must-see American icon.
Revisit your childhood through the eyes of your kids—treat them to the magnificent sights of Grand Teton, Yellowstone and Glacier National Parks, along with Mount Rushmore National Memorial. It's the perfect way to reconnect with your youth, and give your kids or grandkids something they'll remember forever. The wondrous beauty and thrilling activities are simply awe-inspiring.

Call 800-225-5996 for a free travel guide or visit www.fourparks.com

montana / wyoming / south dakota
10- to 26-day CruiseTours™
from $999*

Air Available from $199**

In spring and fall, from Barcelona to Istanbul, eight distinct itineraries explore fabulous citadels, fashionable resorts and art-filled cities. Whitewashed Greek isles. Gaudí’s cathedral in Barcelona. Rome’s Colosseum, Croatian antiquity and the mosques and bazaars of Istanbul. Aboard Marco Polo, you’ll enjoy a rare blend of big-ship comfort and small-ship friendliness. Discover for yourself why Orient Lines is known as “The Destination Cruise Specialists.”

For reservations, see your travel agent. For brochures, call 1-800-333-7300.

*Rate is shown in U.S. dollars for one cabin suite per person, based on double occupancy for a minimum category inside stateroom and applicable on other itineraries. **Rate is shown in U.S. dollars. Rates vary based on cabin size and availability. All offers are based on a first come, first served basis and are subject to change. Rate per person is based on double occupancy per stateroom for one cabin suite per person. Rate per person includes all taxes, gratuities, meals, entertainment and shore excursions. Offer not combinable with any other offer and is not available on Brochure EC2003. Open only to new bookings. Offer expires December 31, 2003.
native wildlife. If sea life is your interest, stop by the Bon Secour National Wildlife Refuge and the Estuarium Sea Lab marine education and research center.

For a dose of history, don’t miss Fort Morgan, situated on a beautiful beach and the site of the Civil War Battle of Mobile Bay. Then tour Bellingrath Gardens and Home, 65 lushly landscaped acres in semi-tropical rain forest that resonates with Old World charm.

Located off the coast of Georgia, Little St. Simons Island is a privately owned 10,000-acre barrier island accessible only by boat and shared with no more than 30 overnight guests.

Recognized as one of the premier birding areas on the east coast, Little St. Simons Island is located in the path of the Atlantic Migratory Flyway. Each spring, waves of warblers, sparrows and a variety of shorebirds settle on the barrier island’s seven miles of deserted beach and vast maritime forests. Over 280 species of birds, some of which are threatened or endangered, have been recorded on Little St. Simons Island.

Besides birding, activities include strolling secluded, shell-strewn beaches, boating, kayaking, canoeing horseback riding, bicycling, hiking and naturalist programs. Delicious regional cuisine, gracious accommodations and a knowledgeable staff make a trip to St. Simons Island even more enjoyable.

Bayou, Alabama Gulf Coast

Head to Alabama’s beautiful Gulf Coast, where you’ll not only find sugar-white beaches but hundreds of species of indigenous birds and neo-tropical migrants among some of the world’s most glorious preserves, forests, and saltwater marshes. It’s a nature lover’s paradise, calling to be explored.

toll-free 1-866-324-7776
closer by the minute

www.alabamasnaturalcoast.org
Our native cultures invite your discovery

In the heart of Arizona's cool pine country

Study the origins and admire the art of regional Native American peoples at the Museum of Northern Arizona.

On the same day walk among 800-year-old ruins at Wupatki National Monument. Climb to equally ancient cliff dwellings. Then view traditional ceremonial dances amidst today's sights and sounds at a living pueblo.

You'll find so much more to discover here as well — The Grand Canyon and other nearby natural wonders, Famous Lowell Observatory, Hiking, Mountain biking. And our historic 1890s streets filled with unique shops, great restaurant choices and evening entertainment.

Flagstaff
They don't make towns like this anymore.
www.visitflagstaff.us 888-788-FLAG

Mountain High
At an elevation of 7,000 feet, Flagstaff offers exceptional opportunities to not only experience the spectacular natural beauty of the high country, but also to enjoy historic downtown area shops, galleries and world-class restaurants. Plus, Flagstaff is just a short drive to Sunset Crater, Walnut Canyon, Oak Creek Canyon and Sedona, many Native American Reservations and of course, the Grand Canyon.

When in Flagstaff, don't miss the Arboretum, presenting the nation's primary collection of Southwestern high country wildflowers and a mile-long nature trail through Coconino National Forest, the world's largest contiguous Ponderosa Pine Forest. Step back in time at the Riordan Mansion State Historic Park, a turn-of-the-century mansion highlighting arts and crafts style architecture filled with original Stickley furniture.

This spring, come discover what the winged world has always known.

From the moment you step ashore, you will sense the magic of this extraordinary sanctuary. Unhurried. Unbothered. Unrivaled for birding.

Join us this Spring on Little St. Simons Island—a very private, barrier island off the Georgia coast along the migratory flyway. 10,000 acres of wilderness, seven miles of perfect beach. Gracious accommodations; sensational cuisine.
A place that welcomes hundreds of species, yet just 30 guests.
Visit soon.

For information on Spring Birding Events call 888.733.5774.
www.LittleStSimonsIsland.com
If you ask people where they’re from, they will typically say the name of the city where they were born, or perhaps the place on Earth’s surface where they spent their formative years. Nothing wrong with that. But an astrochemically richer answer might be, “I hail from the explosive jetsam of a multitude of high-mass stars that died more than 5 billion years ago.”

Outer space is the ultimate chemical factory. The big bang started it all, endowing the universe with hydrogen, helium, and a smattering of lithium: the three lightest elements. Stars forged all the rest of the ninety-two naturally occurring elements, including every bit of carbon, calcium, and phosphorus in everything on Earth, human or otherwise. How useless this rich assortment of raw materials would be had it stayed locked up in the stars. But when stars die, they return much of their mass to the cosmos, sprinkling nearby gas clouds with a portfolio of atoms that enrich the next generation of stars.

Under the right conditions of temperature and pressure, many of the atoms join up to form simple molecules. Then, through routes both intricate and inventive, many molecules grow larger and more complex. Eventually, in what must surely be countless billions of places in the universe, complex molecules assemble themselves into some kind of life. In at least one cosmic corner, the molecules have become so complex that they have achieved consciousness and attained the ability to formulate and communicate the ideas conveyed by the marks on this page.

Yes, not only humans but also every other organism in the cosmos, as well as the planets or moons on which they thrive, would not exist but for the wreckage of spent stars. So you’re made of detritus. Get over it. Or better yet, celebrate it. After all, what nobler thought can one cherish than that the universe lives within us all?

Molecules made of just two atoms form early: carbon monoxide and the hydrogen molecule (hydrogen atoms bound together in pairs). Drop the temperature some more, and you get stable three- to four-atom molecules such as water (H₂O), carbon dioxide (CO₂), and ammonia (NH₃)—simple but top-shelf ingredients in the kitchen of life. Drop the temperature even more, and hordes of five- and six-atom molecules form. And because carbon is both abundant and chemically enterprising, most of the molecules include it; indeed, three-quarters of the nearly 130 molecular “species” sighted in interstellar space have at least one carbon atom.

Sounds promising. But space can be a dangerous place for molecules. If the energy from stellar explosions doesn’t destroy them, ultraviolet light from nearby ultraluminous stars will. The bigger the molecule, the less stable it is against assault. Molecules lucky enough to inhabit uneventful or shielded neighborhoods may endure long enough to be incorporated into grains of cosmic dust, and ultimately into asteroids, comets, planets, and people. Yet even if none of the original molecules survive the stellar violence, plenty of atoms and time remain available to make complex molecules—not only during the formation of a particular planet, but also on and within the planet’s nubile surface. No—
tables on the short list of complex molecules include adenine (one of the nucleotides, or “bases,” that make up DNA), glycine (a protein precursor), and glycoaldehyde (a carbohydrate). Such ingredients, and others of their caliber, are essential for life as we know it—and are decidedly not unique to Earth.

But orgies of organic molecules are not life, just as flour, water, yeast, and salt are not bread. Although the leap from raw ingredients to living individual remains mysterious, several prerequisites are clear. The environment must encourage molecules to experiment with one another, and must shelter them from excessive harm as they do so. Liquids offer a particularly encouraging environment, because they enable both close contact and great mobility. The more chemical opportunities an environment affords, the more imaginative its resident experiments can be. Another essential factor, brought to you by the laws of physics, is a generous supply of energy to drive chemical reactions.

Given the wide range of temperatures, pressures, acidity, and radiation flux at which life thrives on Earth, and knowing that one microbe’s cozy nook can be another’s house of torture, scientists cannot at present stipulate additional requirements for life elsewhere. Demonstrating the limits of this exercise is the charming little book Cosmotheros, by the seventeenth-century Dutch astronomer Christiaan Huygens, wherein the author speculates that life forms on other planets must grow hemp, for how else would they weave ropes to steer their ships and sail the open seas?

Three centuries later, we’re content with just a pile of molecules. Shake ‘em and bake ‘em, and within a few hundred million years you might have thriving colonies of organisms.

Life on Earth is astonishingly fertile, that’s for sure. But what about the rest of the universe? If somewhere there’s another celestial body that bears any resemblance to our own planet, it may have run similar experiments with its similar chemical ingredients, and those experiments would have been choreographed by the physical laws that hold sway throughout the universe.

Consider carbon. Its capacity to bind in multiple ways, both to itself and to other elements, gives it a chemical exuberance unequalled in the periodic table. Carbon makes more kinds of molecules (how does 10 million grab you?) than all other elements combined. A common way for atoms to make molecules is to share one or more of their outermost electrons, creating a mutual grip analogous to the fist-shaped coupler between freight cars. Each carbon atom can bind with one, two, three, or four other atoms in this way, whereas a hydrogen atom binds with only one, oxygen with one or two, and nitrogen with three.

By binding to itself, carbon can generate myriad combinations of long-chain, highly branched, or closed-ring molecules. Such complex organic molecules are ripe for doing things that small molecules can only dream about. They can, for example, perform one kind of task at one end and another kind at the other; they can coil and curl and intertwine with other molecules, creating no end of features and properties. Perhaps the ultimate carbon-based molecule is DNA: a double-stranded chain that encodes the identity of all life as we know it.

What about water? When it comes to fostering life, water has the highly useful property of staying liquid across what most biologists regard as a fairly wide range of temperatures. Trouble is, most biologists look to Earth, where water stays liquid across 100 degrees of
the Celsius scale. But on some parts of Mars, atmospheric pressure is so low that water is never liquid: a freshly poured cup of H₂O boils and freezes at the same time! Yet in spite of Mars’s current sorry state, its atmosphere once supported liquid water in abundance. If ever the Red Planet harbored life on its surface, it would have been then.

Water has another useful, though eccentric, property: when it freezes, it expands, becoming slightly less dense than when it’s liquid. That’s why pipes break when the water in them freezes. It’s also why, when a pond freezes, the ice floats and the pond’s inhabitants can endure the winter in liquid safety.

Liquid water can occur far beneath a surface, too. Vast quantities can be locked up inside the rocky interior of a planet, or sloshing away under the permanently icebound exterior of a world orbiting far from an external source of heat. Evidence suggests the latter condition may prevail on Jupiter’s moon Europa.

Earth, of course, happens to have a goodly—and occasionally deadly—amount of water on its surface. Where did it come from? Comets are a logical source: they’re chock full of (frozen) water, the solar system holds countless billions of them, some are quite large, and they would regularly have been slamming into the early Earth back when the solar system was forming. Another source of water could have been volcanic outgassing—a frequent phenomenon on the young Earth. Volcanoes erupt not simply because magma is hot, but because hot, rising magma turns underground water to steam, which then expands explosively. The steam no longer fits in its subterranean chamber, and so the volcano blows its lid, bringing H₂O to Earth’s surface from below. All things considered, then, the presence of water on our planet’s surface is hardly surprising.

Although Earth-life takes multifarious forms, all of it shares common stretches of DNA. The biologist who has Earth on the brain may revel in life’s diversity, but the astrobiologist dreams of diversity on a grander scale: life based on alien DNA, or on something else entirely. Sadly, our planet is a biological sample of one. Nevertheless, the astrobiologist may glean insights about life-forms that dwell elsewhere in the cosmos by studying organisms that thrive in “extreme” environments here on Earth.

Once you look for them, you find these “extremophiles” practically everywhere: nuclear dump sites, acid-laden geysers, iron-saturated acidic rivers, chemical-belching vents on the ocean floor, submarine volcanoes, permafrost, slag heaps, commercial salt-evaporation ponds, and a host of other places you would not elect to spend your honey-moon but that may be more typical of the rest of the planets and moons out there. Biologists once presumed that life began in “some warm little pond,” to quote Darwin; in recent years, though, the weight of evidence has tilted in favor of the view that extremophiles were the earliest earthly life-forms.

For its first half-billion years, the in–

(Continued on page 73)
How Trees Get High

And the limit on their height is set by the force that holds water together.

By Adam Summers – Illustrations by Tom Moore

On a hike recently in the Montgomery Woods State Reserve, near Ukiah, California, I wandered among the area's massive coast redwoods with my friend Al Richmond. We were looking for the Mendocino Tree, which, although it rises 367 feet above the forest floor, can still be hard to pick out from the ground. The surrounding trees are nearly that tall.

As we stood dwarfed by the grove of towering trees, I pondered a biomechanical question that might occur to anyone who comes face to face with a life-form as majestic as the Mendocino Tree: how do trees grow so tall, and what, if anything, keeps them from growing even taller? The leading hypothesis has been that trees are limited only by their ability to get water from the ground to their highest leaves. To get to the bottom of the mystery, a group of plant physiologists went to the top: they scaled the redwoods in a grove a few miles to our north.

Water does not ordinarily run uphill. And, as Aristotle knew, it's impossible to pull water higher than about thirty feet by suction. Trees, however, can lift water well past the xylem is surprisingly high: for every thirty feet of tree height, the tension increases by roughly fifteen pounds per square inch. For a xylem tube 360 feet high, the tension at the top is enough to break the water column, though, to cause problems for a tree. Photosynthesis, which takes place in leaf cells, converts carbon dioxide and water to carbohydrates and oxygen. To get the water into the cells, plants rely on osmosis, the movement of water from dilute to concentrated solutions. Such a flow can be reduced and even halted by applying a countervailing pressure. That's precisely what the tension in the water column does. With the osmotic flow reduced by the great tension in tree's lofty heights, leaf cells take up less water, which limits the amount of water available for photosynthesis.

Indeed, photosynthesis in the topmost leaves, at about 360 feet, scarcely occurs at all. By extrapolation, the investigators determined that photosynthesis would cease just above 420 feet. The finding dovetails nicely with the height of the tallest tree ever measured—a Douglas fir that towered 415 feet.

The cohesiveness of water makes it act like a string.
Coast redwood tree relies on evaporation to raise an unbroken column of water from the soil up to its leaves, where some of it is used in photosynthesis. The water diffuses from the soil through root hairs and into xylem tubes running upward within the sapwood. The electrostatic attraction of water molecules for one another can sustain sufficient tension to support a continuous, cohesive column of water as high as 420 feet. Much of the water at the top of the column evaporates into empty space within a leaf, then diffuses into the air through pores on the underside of each leaf. The evaporation opens up space near the top of the column for more water to move upward through capillary action. That motion, transmitted through the unbroken column of water, ultimately draws more water from the ground into the root hairs.

Tension in the water column does not vary only with height, though. The environment at large affects it, too. At dawn, when the air is foggy and moist, little water evaporates from the leaves, and tension in the xylem is just what is predicted by gravity: about 180 pounds per square inch. But at noon, dry air and sunlight conspire to increase evaporation from the leaves, and the tension in the water column increases to some 260 pounds per square inch. Koch performed laboratory tests on the same plant tissue he had measured in the field, and the tests showed that the measured tension on the water column in the dry, sunlit air at noon is right at the limit of its cohesive strength.

The tension doesn’t have to be great thirty feet, so what gives? Well, for one thing, they don’t suck. Thanks to a phenomenon known as capillary action, water, even if it can’t climb hills, can climb walls. Look at the surface of water in a clear vessel, and you will see at the edges that water does indeed move up the sides of the vessel. That property of water is crucial to the life of the tree.

The wooden core of a tree trunk is largely a dense array of narrow tubes, called xylem, that carry water from the roots up to the leaves. The water moves up the xylem via an entirely passive process known as transpiration, which is driven by a combination of capillary rise and evaporation through the leaves. At the tops of the open xylem tubes, the water evaporates into spaces within the tree’s leaves, then exits to the atmosphere through pores in the leaves. As the water evaporates, capillary action—the electrostatic attraction between the water and the leaf cells and the inner surface of the xylem tubes—moves more water up the xylem and into the leaves. At the same time, the electrostatic attraction of the water molecules for one another provides enough cohesive force on the entire top is 180 pounds per square inch.

But water is only so cohesive; if the tension is great enough, the column will break. An air bubble at the break would obstruct the xylem. Theoretical calculations led plant physiologists in the 1990s to surmise that water transport, rather than the strength of wood or some other constraint, limits the height of a tree.

George Koch, a plant physiologist at Northern Arizona University in Flagstaff, and his colleagues tested the theory in the most direct way possible: they dragged measuring equipment to the tops of five of the tallest trees on Earth. Gauging pressure in the xylem as well as the rate of photosynthesis as they climbed, Koch and his colleagues established how those two measures vary with height. And sure enough, tension in the water column is highest, and the rate of photosynthesis lowest, nearest the top.

It was still possible that the anemic oxygen production was the result of low light levels or some other characteristic of leaves that grow at such lofty heights. But two other lines of evidence made a strong case for water pressure. First, when leafy twigs from the tops of trees were placed in water, the leaves acted just like less lofty leaves. The finding suggested that nothing about the leaves themselves was restricting photosynthesis. Second, the tree climbers discovered an important “natural experiment”: they found a seedling that had germinated in a crotch near the top of one of the trees and had grown as tall as a person. Its leaves were carrying out photosynthesis as fast as if they were only six feet off the ground.

There is one final bit of evidence suggesting that the giant redwoods are as tall as water will let them be: the tops of the tallest trees have died back a number of times. In the trees’ 2,000-year life span, there must have been many times of drought, when a strong capillary force would have pulled water both out of the leaves, as well as out of the roots and into the dry soil. The tension in the column would have become high enough to break the column at lower heights, killing the topmost branches. Then, when water became plentiful again, and xylem tensions were lower, new shoots would have reached skyward. Only a few places on Earth, though, enable the giant redwoods to reach their full potential.

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

Because the snakes bask, breed, and hibernate together, recognizing their relatives is a key advantage, especially for females.
Rattlesnakes

By Kulan W. Clark
Photographs by John Cancalosi

Timber rattlesnakes (Crotalus horridus) cluster near a communal den in the Pennsylvania woods. Group congregation sites such as this one are becoming rare, as are the snakes themselves, in part because they are often prime targets for hunters.
So, what good are they anyway?

I sigh as I hear this question, yet again, about the animals I study: rattlesnakes. I suppose anyone who spends taxpayer dollars studying animal behavior has to deal with that kind of skepticism at some point along the way. Answering such a question gets even trickier if what you study is small and seemingly insignificant, like a cricket. And getting a sympathetic ear for such a feared, hated, misunderstood, and potentially dangerous species as a rattlesnake is nearly impossible.

On this occasion, a retired truck driver has quizzed me over breakfast at the counter of a rural Pennsylvania diner. As it happens—though he doesn’t know it—we are just a few miles from one of the largest concentrations of timber rattlesnake dens in the country. Rattles, usually thought of as solitary tailshakers, actually breed in groups, making them an easy, albeit elusive, target for hunters—not to mention the people who take part in the dreadful “rattlesnake roundups,” in the mistaken belief that killing snakes improves the woods. The group behavior of rattlesnakes is the focus of my research. Yet it is becoming increasingly difficult to study large groups of the snakes, because their numbers are dwindling. Pennsylvania continues to be one of the few places in the United States where timber rattlesnakes (Crotalus horridus) are still common.

Immediately I’m on the defensive—cautious about revealing too much about where I’m going to study the snakes, yet eager to respond. Being flip, I nearly say, “Well, what good are you?” Instead, I settle on an easy, utilitarian answer: they help control rodents.

But the timber rattlesnake is more than a simple rodent-eater. As top-level predators, rattlesnakes are an integral part of the ecosystem, contributing to the overall health of the forests. The snakes influence prey populations and perform vital ecosystem functions through their natural effect on the dynamics of the food web, helping to maintain balances between herbivore populations, plants, and predators. The loss of any one species from a community may not be catastrophic, but the ongoing decline of many populations in an ecosystem erodes the balances that make natural systems persist.

I was in Pennsylvania to observe the spring emergence of the timber rattlesnakes. Several years ago an expert on local rattler populations, Curt E. Brennan, who works for the Pennsylvania Department of Conservation and Natural Resources, first showed me the populous rattler den to me. My return trek in the spring took me to the secluded site up along a steep, forested bluff. At the summit of the bluff is a small clearing with exposed slate bedrock, fractured by cracks and crevices. Such exposed openings are few and far between in northeastern forests; whenever possible, the snakes use them as dens. Timber rattlesnakes are ectothermic, or cold-blooded, animals; come winter, they take refuge in the cracks beneath the frost line. By early May, though, temperatures become warm enough for the rattlers to move safely out into the woods. They don’t return to their dens for hibernation until mid-October, just before the nighttime frosts begin.

I had arrived in the middle of May, the peak of the spring emergence period. The day was cool and slightly overcast—perfect for viewing snakes. They would be out in the open, trying to soak up what little warmth penetrated the haze. It took a moment of scanning to see them. A dozen or so large, thick-bodied, velvety timber rattlesnakes lay loosely piled and wrapped around each other just under the edge of a large stone slab. They basked contentedly in the sun, gently shifting their muscular coils every so often. If they were aware of my presence, they seemed unconcerned about it. I felt I was looking through a small window onto an alien world.

Everyone I have ever taken into the field—my mother, a businessman, a local redneck, a college student, a six-year-old child—has been equally moved by the sight of timber rattlesnakes in the wild. After such an experience, no one seems to have any further doubts about the value of these animals. Perhaps the overhyped fear and loathing whipped up about animals such as rattlesnakes arises from surprise encounters that people have with snakes, in which the snakes are perceived as intruders. Yet a visit to the same animal in its natural environment can have the opposite effect, fostering a sense of value and appreciation.

Timber rattles are striking in such large aggregations. They come in two colors: some are almost solid black, whereas others are bright yellow, marked with splotches of brown. These two “color morphs” can even occur in the same litter. As I watched the jumble of snakes in May, I noticed one large, yellowish-brown male start to make his way slowly but steadily up the slope and into the woods. He was probably beginning his yearly migration through the forests in search of food. Males, juveniles, and non-

Timber rattlesnakes are unfazed by the stray garter snake (left foreground in the photograph at right) that is sharing their basking area amidst rocky crevices and boulders. Within a few weeks of emerging from winter hibernation, male snakes, like the one pictured at the top of this page, and non-pregnant females slip into the woods in search of prey.
pregnant females all leave the denning areas over the course of a few weeks. After a winter without food, the animals need to seek out the small mammals that constitute their diet.

Rattlesnakes are not fast animals, and they certainly lack endurance. Instead, they rely on patience, camouflage, keen senses, and a lightning-quick strike to capture their prey by ambush. After several months of such hunting and feeding, males become restless and start dispersing more widely through the woods—fifteen to twenty times farther than normal—to pick up the scent of receptive females.

Adult females become receptive to male advances only in years when they have stored enough body fat to bear a litter. The storage process usually takes no less than three years following a season of pregnancy and sometimes as long as six, depending on hunting conditions—leaving only a fraction of the female population available for breeding each year. Mating season is in late summer. Females hold sperm in their reproductive tract during winter hibernation and fertilize their eggs at the beginning of the following spring. During pregnancy, females forgo foraging. Incredibly, even after a winter without food, the expectant mothers spend almost the entire summer without hunting. Instead, they stay at exposed, south-facing basking areas near their winter den, allowing their hard-earned fat reserves alone to support the growth and development of their embryos [see photograph on pages 36 and 37].

In a good year, the females give birth to live young in late August. But the mothers, typically emaciated
by this point, still aren’t quite ready to abandon their newborns. Even though a baby rattlesnake is venomous from birth, it is a somewhat helpless creature, susceptible to attack from a wide range of predators that have no problem dispatching tiny reptiles. The babies need to spend the first week of life basking in the open until they shed their natal skin and can disperse into the relative safety of the woods. During that natal basking period, the mothers stay near their young, defending them from potential predators. Although this form of parental care is common among rattlesnakes and other vipers, herpetologists have been slow to appreciate the sacrifices it entails. Imagine what it would be like to carry eggs around in your body all year and forgo your own chance to eat until your young have fed off your fat and can survive on their own! Small wonder that female timber rattlesnakes in northern climates can afford such an ordeal only once every three to six years. Such a slow reproductive rate, combined with a maturation period as long as ten years for the young snakes, leads to a slow rate of population growth and—if a population endures a crash—to a slow recovery.

Perhaps the most impressive aspect of the reproductive cycle, however, is its communal nature. Like the denning areas, a good basking area is a prize find. In spring and summer, piles of gravid females can be found lounging in the sun together, black and yellow coils piled up in intricate mounds. These females give birth together at sites that biologists have termed “birthing rookeries.” The rudimentary protective crèche they form with their entwined bodies probably makes a basking area the safest place for newborn snakes.

Are such groupings merely chance meetings at an ideal locale, or do they constitute gatherings of more subtle and sophisticated social groups? Vertebrate biologists have long taken it almost for granted that snakes in general are asocial animals, leading simplistic lives of solitude filled only with basic instinctual drives toward food and sex. My research, in which, among other techniques, I radio-tag individual snakes and follow them around in the field, has led me to think otherwise.

Timber rattlesnakes live as long as thirty years in the wild, and they seem to live as stable, cooperative community members. They appear to form lasting relationships with other individuals, follow similar paths through the woods, bask together before shedding their skins under the same fallen log, and sometimes follow each other from one den to another. Young timber snakes have demonstrated a tendency to trail older ones. A recent genetic study has demonstrated that snakes sharing a den are closely related. Other research on a similar species, the prairie rattlesnake (Crotalus viridis), has shown that the species can mobilize a

**Biologists have long taken it almost for granted that snakes lead simplistic lives of solitude; in fact, they are highly social animals.**
group defense, mediated, in part, by alarm pheromones. Add to those findings the clear concern of mother snakes for their young [see photograph on preceding page], and you have to wonder whether the social lives of rattlesnakes are really so simplistic after all.

Those and similar observations sent me to the laboratory, to see whether snakes raised in captivity could recognize their relatives. Kin recognition serves as the foundation of advanced social systems in a wide variety of other animal societies. No one, though, had ever demonstrated that ability among snakes. Yet if snakes did work collectively, they could enjoy several important benefits in the wild. A group of snakes could retain their combined heat longer than an individual could, making thermoregulation more efficient. And a group of snakes could make a far more convincing display against predators, and mount a much fiercer defense, than could a lone snake on its own.

Because relatives share genetic material, the benefits of group membership would be enhanced if the group were made up of kin—from an evolutionary perspective, raising offspring is just one way of passing your genes on to the next generation. The same genes could be passed on if they helped non-descendant kin, such as siblings, survive and reproduce. Working in the laboratory, I raised litters of timber rattlesnake siblings in isolation from one another, and then placed the snakes one by one at random in an enclosure with a nonsibling snake. The snakes—at least the females—associated more closely with littermates than with unrelated females. In other words, the female snakes seemed to recognize their sisters.

That intriguing result has led me to investigations that are still ongoing: with genetic techniques I am testing the kin relationships among females in the wild that spend time basking together at communal rookeries. Perhaps it will turn out that timber rattlesnakes organize themselves matrilineally—in other words, that social groups form along the maternal line, with extensive contact among related individuals across generations. Such a finding could go a long way toward changing people’s negative perceptions about snakes. The stereotype—that they are emotionless predators leading solitary and uninteresting lives devoid of social contact—is certainly untrue.

To collect tissue samples for the genetic project, I return to the Pennsylvania woods in late summer with John Cancalosi, a nature photographer who has decided that snakes are, photogenically, “the new birds.” As we approach the boulder-strewn clearing, dozens of females and their babies are lying in huge piles at the base of a large rock. As many as thirty females have given birth here. Each litter includes, on average, seven or eight young, putting the number of babies in the hundreds. The sight is awesome. How many people realize that one can view hundreds of venomous snakes in their natural habitat without seeming to create much of a disturbance? Even the busy whirring of Cancalosi’s camera makes no notable impression on the snakes.

In the middle of a pile, we notice a garter snake [see photograph on page 39]. The garter has apparently decided that even in the presence of its venomous, mammal-eating cousins, the slab isn’t such a bad place to get a little sun of its own. Since natural breaks in the woods are so important for ectotherms, it is not uncommon to find several different snake species sharing basking and denning sites.

The annual aggregation of rattlesnakes is a natural spectacle that remains underappreciated by naturalists and the public alike, and it underscores the importance of these vital habitat sites to the local reptile population. The once-abundant timber rattlesnake is quickly succumbing to the twin pressures of habitat loss and overhunting. Its plight is worsened by its public-relations problem: lots of people don’t care if the species is actively protected or not. The problem is not insurmountable, though. In my experience, people in general have an innate fascination with snakes. That fascination can be the hook that fosters an appreciation for unusual and interesting wildlife of all kinds.

The next time you see a snake in the woods, you will be startled and probably a little frightened. But think of the myths and fables that once portrayed the woods as a magic, mysterious place—a place where the senses quickened to catch any whiff of danger that might be lurking beyond the next tree. Would a domesticated forest, without that spice of risk, the unpredictable wild, really be a better place? The loss of the rattlesnake—a very real possibility—would change our forests irrevocably, making them a kind of stage set, rather than a portal to nature.
THIS SPRING, EXPLORE THE STATE THAT HAS IT ALL

Maryland has it all: mountains and forests, Atlantic and Chesapeake Bay shorelines, the Potomac and Patuxent rivers and more. With such a diversity of ecosystems, it’s no wonder that this state draws nature lovers from near and far. And best of all, every single one of these attractions is easy to get to—within three hours from Maryland’s major city, Baltimore, close to the state capital, Annapolis, or near Washington, D.C.
The state has so many different geographical regions that it was once nicknamed "America in Miniature." Visit Maryland, and you'll feel you've visited many states, but all are within easy driving distance of one another.

Outdoors fans prize Western Maryland for its hiking and picturesque mountains. This is where you'll find the best white-water rafting in the state, with all levels of technical difficulty. Here, Deep Creek Lake, which is man made, is a haven for boaters and fishermen.

In Central Maryland, you'll find Annapolis, Maryland's capital—as well as America's sailing capital. This beautiful center of naval history has rows of pristine eighteenth-century houses, more than any other city in the country. In Baltimore, don't miss

*Annapolis, America’s sailing capital*

the attractions of the famed Inner Harbor, a model urban preservation and renewal project that been imitated throughout the country. After a day at the harbor's world-known National Aquarium in Baltimore or exploring the shops, enjoy a harbor-side meal of oysters, fish, or Maryland's beloved blue crabs.

The Capital Region, just outside of Washington, D.C., is where you'll find Bethesda and Glen Echo. The region combines all the sophisticated attractions of an urban environment with abundant recreational and rural opportunities. Spend the day fishing for bass, then head to the Olney Theatre for a well-staged play.

Southern Maryland is on the western side of the Chesapeake Bay and also distinguished by two powerful rivers, the Potomac and the Patuxent. The state was first settled here, and you'll find many quaint and historic waterfront towns, all offering some of the best seafood you're likely to ever have. Visit ponds, swamps, fragile marshes, and pretty beaches along the Chesapeake, or fish the area's many streams and rivers.

The state's beautiful Eastern Shore, part of the Delmarva Peninsula, is surrounded by the Chesapeake Bay, and its southern tip fronts the Atlantic Ocean. Explore the Eastern Shore by biking its country roads, boating along meandering inlets and Chesapeake kayaking trails, or lazing on the beach at Ocean City.

With so many places to choose from, plan your trip to Maryland ahead of time. Read ahead for a guide to some of the state's most rewarding counties.
MARYLAND'S GOVERNOR EHRLICH SAYS:

PUT THE HONEY-DO LIST DOWN AND BRING YOUR HONEY TO MARYLAND.

To make the most of your precious time off, call for your free Maryland travel guide. 1-800-984-9502. Or visit www.VisitMaryland.org.
A Guide to Maryland’s Counties

CAPITAL REGION

An hour away from Baltimore, and just outside of Washington, D.C., you’ll find Maryland’s Capital Region. Sophisticated Montgomery County, just outside D.C., offers several museums, public galleries, theaters, and historic sites. But it is also a place to explore the outdoors. Hike along the historic C&O Canal, or rent a canoe and spend a day on Seneca Lake at Black Hills Regional Park. Located in Boyds, Black Hills has excellent fishing, especially for largemouth bass. Purchase a Maryland state fishing license at the park’s Visitor Center. Black Hills also boasts miles of forest trails, horseback riding, mountain biking, and camping. Reserve a naturalist-led trip on the pontoon boat Kingfisher, which carries up to thirty people, by calling ahead at 301-916-0220.

Prince George’s County, adjacent to Montgomery and Washington, D.C., is a magnet for aerospace fans. College Park Airport, founded by the Wright Brothers in 1909, is the world’s oldest airport in continuous operation. It’s also home to the College Park Aviation Museum, which houses historic flying machines, including a 1911 Wright B and a 1918 Charles County buck.

STAY WITH US

AND SEE THE BEST OF THE NATIONAL CAPITAL REGION

Make the most of your trip by staying with us in Montgomery County, Maryland. Here, you’ll enjoy value and quality in our wide selection of lodgings and restaurants as well as the opportunity to visit our many historic sites and national parks. Our 13 METRORail stations will transport you to Washington, DC’s many attractions. Call for our Visitor Guide at 800-925-0880 or by visiting www.visitmapongomery.com

Montgomery County
MARYLAND
WELCOME

CONFERENCE AND VISITOR BUREAU OF MONTGOMERY COUNTY, MD, INC.
1820 PARKLAWN DRIVE, SUITE 380 • ROCKVILLE, MARYLAND 20852
Fishing for largemouth bass

Curtis Jenny. Nearby, in Suitland, the Airmen Memorial Museum profiles pioneering aviators. NASA’s Goddard Space Flight Center, in Greenbelt, is responsible for the development of unmanned sounding rockets and research in space and earth sciences. Visitors can explore interactive educational exhibits, which focus on the center’s contributions from 1958 to present. Current exhibits include “Hubble Space Telescope: New Views of the Universe,” which presents spectacular backlit color images, taken from the Hubble, of planets, galaxies, and black holes.

Once at the crossroads of the Civil War, Frederick County attracts history buffs with its many battlefields sites and monuments. Frederick also is home to the Catoctin Mountains and the Potomac River, and has ninety parks offering swimming, boating, camping, skating, horseback riding, and nature programs. You might hike part of the Appalachian Trail along the county’s western border, or try your hand at fly fishing in Catoctin Mountain Park, located in Thurmont. Full of wildlife and wildflowers, the park offers hiking trails and historic buildings. West of Thurmont, in Cunningham Falls State Park, hike a trail to a cascading waterfall almost eighty feet tall.

SOUTHERN MARYLAND

South of the Capital Region, explore Charles, St. Mary’s, and Calvert counties in Southern Maryland. These three counties are located in the Atlantic Coastal Plain peninsula and are easy to reach by water, whether the Chesapeake Bay or the Potomac and Patuxent rivers. Because they lie along the Atlantic Flyway, the counties are great places to spot waterfowl in the winter and a host of migrants in the spring and fall.

Just 30 miles from Washington, D.C., on the western border of Charles County, you’ll find one of the most unusual nature areas in Maryland: Mallows Bay. Near Sandy Point, and just ten minutes from Sweden Point Marina, Mallows is a
Located along the Atlantic Flyway, Southern Maryland is a great place to spot migrating birds.

Located along the Atlantic Flyway, Southern Maryland is a great place to spot migrating birds.

One-mile-long Natural Embayment of the Potomac River. It is also one of the largest graveyards of ships in North America, with vessels dating from as far back as the Revolutionary War. Among the ships are a fleet of wooden steamships, built to serve in World War I but then abandoned and brought here to be salvaged. The task was never completed, and many of these hulks have become islands filled with trees and bushes. The mini-ecosystems have converted the bay into a refuge for wildlife. Mallows Bay now harbors herons, snowy egrets, and American bald eagles. Incidentally, the bay also has some of the best inland largemouth bass fishing on the eastern seaboard.

St. Mary’s County is the birthplace of Maryland, and not surprisingly, there is a lot of history in this county. It is home to the first permanent settlement in Maryland, St. Mary’s City, which was the state’s first capital. Historic St. Mary’s City, an 800-acre living history museum with interpreters in authentic 17th-century dress, has replicas of the first statehouse, a tobacco barn, and many other colonial buildings. There is also a renowned archeological dig...
farm, and an inn. Combine history with the outdoors at Point Lookout State Park. Once the site of a Civil War prison housing more than 50,000 Confederate soldiers, the park now has a museum that recounts this part of its history. It's also a good place to swim, fish, and boat in a beautiful bay setting.

Would-be archeologists can hunt for fossils of prehistoric shark teeth and more along the shores of Calvert Cliffs in Calvert County. Don't miss the county courthouse in Prince Frederick, the seat of the county, or the waterside town of Solomons, an island community known for boating and fishing. Battle Creek Cypress Swamp, a nature center that is home to the northernmost naturally occurring stand of bald cypress trees in America, has a self-guided boardwalk trail. These towering subtropical trees, once widespread in the region, fell victim to logging and are now only found in scattered sites. In early spring, the park isblanketed with wildflowers, including violets, may apples, spring beauties, and lady's slipper orchids. While you're in Battle Creek, keep an eye out for warblers: Kentucky, worm-eating, prothonotary, parula, and hooded warblers migrate to the swamp each spring to breed.

**EASTERN SHORE**

Don't leave Maryland without exploring its beautiful Eastern Shore, the peninsula directly opposite of Southern Maryland. Spend a day sailing the...

---

**Natural Beauty**

...Comes in many forms

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

- Calvert Cliffs State Park
- 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
301-925-4500 (or 1-800-925-6300)
www.princegeorges.org
On the Eastern Shore, watch watermen reap a hard day's harvest and sample some of the best crabs, oysters, and fish in the state.

Chesapeake Bay Maritime Museum, Talbot County

Chesapeake Bay or drive from one waterfront village to the next.

Start in Dorchester County, perhaps with a stay in a quiet inn in historic Cambridge. The town boasts many stately eighteenth- and nineteenth-century homes, especially along brick-paved, tree-lined High Street. Sign up for a historic tour or a ghost walk to learn about the prosperous era in which these homes were built. Outside Cambridge, visit the Blackwater National Wildlife Refuge, home to many endangered species and a haven for waterfowl. More than 85 species of birds, including the American bald eagle and more than 20 species of ducks, make their home in Blackwater. After a day of birdwatching, catch one of Dorchester County's spectacular sunsets along its 1,700 miles of shoreline.

From Dorchester, you might head to Worcester County. Worcester is known for the sandy beaches of
Ocean City and the exotic ponies at Assateague. But its many different habitats—barrier islands, coastal bays, tidal wetlands, cypress swamps, upland fields, and primeval forests—have made it the county in Maryland with the most recorded bird sightings. Plan to attend the Dehnarva Binding Weekend, from April 22–24, and witness the migration of hundreds of warblers, shorebirds, and waterfowl as well as many nesting birds and raptors. The weekend will include boat and canoe trips as well as walking expeditions.

In charming Talbot County, explore the lovely small towns of St. Michaels, Easton, Oxford, Wye Mills, and Tilghman Island. All are full of history, heritage, culture, and architecture, as well as natural beauty and serenity. Their historic downtowns are now filled with fine art galleries, antiques stores, museums, theaters, and boutiques, as well as fine restaurants. In St. Michaels, don’t miss the Chesapeake Bay Maritime Museum, located on the waterfront. The museum brings together the most complete collection in the nation of Chesapeake Bay artifacts, visual arts, and indigenous water craft.

Kent County, a scenic peninsula on the Chesapeake Bay, claims a portion of the only National Scenic Byway in Maryland. It is a destination of historic waterfront towns dating back to the 1600s; stretches of low, rolling farmlands; dramatic sunsets; scenic beauty; and rich heritage, with some of the United States’ most quaint and beautiful towns. Stroll tree-lined, red brick sidewalks lined with art galleries and specialty and antique shops. Enjoy the county’s five museums, terrific restaurants, farmer’s markets, and beaches. Catch a performance at the Prince Theatre in Chestertown or the Mainstay in Rock Hall, which feature local and internationally acclaimed performers.

Maryland is a great place to explore—naturally.

---

The schooner Sultana 1768 may be found in her home port of Chestertown when she’s not sailing the Chesapeake Bay.
Testing Einstein (Again)

In 1959, just two years after the launch of Sputnik I, investigators began work on a space-based experiment to verify the general theory of relativity. Their efforts are about to come to fruition.

By Arthur Fisher

Prolonged hard work, which has lasted fourteen hundred years. Newton also made a universe, which has lasted three hundred years. Einstein has made a universe, and I can't tell you how long that will last.

—George Bernard Shaw (1939)

On April 24, 2004, at 9:57:24 a.m. local time—meeting a one-second launch window—a Delta II rocket rose from Vandenberg Air Force Base in California, bearing a payload with the less-than-evocative name Gravity Probe B, or GP-B.

Launched into a 97.5-minute, pole-crossing orbit 1,015 miles above the Earth was a three-ton satellite designed to accomplish one of the most technologically challenging experiments in the history of physics. The launch, which proceeded flawlessly, was the culmination of forty-five years of effort by hundreds of physicists and engineers from Stanford University, Lockheed Martin in Sunnyvale, California, and NASA's Marshall Space Flight Center in Huntsville, Alabama. Its purpose: to perform two new tests of Einstein's general theory of relativity.

Publicly presented in 1915, the general theory of relativity was a spectacular intellectual feat. It interprets gravity not as a force but as a field distorting space and time. It holds that massive objects such as planets follow geodesics—paths that act as straight lines, or shortest "distances"—through a curved, four-dimensional generalization of geometry called space-time, which encompasses both space and time. As the physicist John Archibald Wheeler of Princeton University once wrote: "Spacetime grips mass, telling it how to move... Mass grips spacetime, telling it how to curve."

"I do not consider the main significance of the general theory of relativity be the prediction of some tiny observable effect," Einstein remarked in 1924, "but rather the simplicity of its foundations and its consistency." One reason the theory gained rapid acceptance, however, is that it passed a couple of experimental tests with flying colors, proving itself superior to existing theories of the universe. No one doubts, by now, that it is a powerful theory. But undertaking new tests of its predictions is no idle exercise. Even if all they do is confirm Einstein's views, they could save physicists from exploring some theoretical blind alleys.

Long before Gravity Probe B bounced into orbit, the idea behind it...
was bounced around in a conversation among three naked professors sunbathing at a male-only Stanford University swimming pool. Leonard I. Schiff, executive head of the physics department, had been working out a way to use gyroscopes to test two obscure, minute effects predicted by the general theory of relativity. The experiment he had in mind would have to be performed in space because there the gyroscopes are weightless and better isolated from extraneous disturbances. He and his companions, William M. Fairbank, an authority on superconductivity, and Robert H. Cannon, an expert in gyroscopes, met at the pool in December 1959, to talk about the idea and its engineering difficulties. The three later learned that George E. Pugh, a Department of Defense scientist, had articulated the same idea independently in a November 1959 memo.

Nursed along for four decades, the project has cost nearly $700 million and has followed a turbulent path, suffering technical setbacks, suspensions, threatened cancellations, and intense political and academic criticism. In the intervening years, both Schiff and Fairbank have died, and Cannon is only indirectly involved. The principal investigator is C.W. Francis Everitt, who signed on in 1962, when he was just a twenty-eight-year-old postdoc from England. Now seventy, with a cascade of long gray locks, Everitt says, “I would never have joined GP-B if I’d had any idea of how long it would take.”

The eminent English physicist Patrick M. S. Blackett, with whom Everitt had studied in London, once told him, “If you don’t know what kind of physics you want to do, invent some new technology. It will always lead to new physics.” Inventing the technology required for Gravity Probe B has turned out to be a supreme test for the ingenuity of the project’s scientists and engineers. Happily, the technology is now doing its job, collecting data methodically and with exquisite sensitivity. Will it lead to new physics? If the experiment reveals that Einstein’s calculations were even slightly off, the quest for a more exact theory could transform human understanding of the physical universe.

Einstein formulated two theories that interweave space and time. His special theory of relativity, published a hundred years ago this year, describes the behavior of objects moving close to the velocity of light; it also predicts the equivalence of mass and energy, according to the famous equation $E=mc^2$. The special theory has been confirmed repeatedly, in the innards of particle accelerators, in nuclear power plants, and, of course, in atomic weapons. But it was Einstein’s second theory, the 1915 general theory of relativity, that was first put to a public test, making the name “Einstein” a household word.

In spite of Einstein’s insistence that the importance of his theory was its conceptual simplicity, he was keenly aware that every scientific theory must make observable predictions. In 1915, however, most conceivable tests of general relativity were too subtle to be practical. One experiment was technically feasible. The theory predicted that starlight would be deflected when it passed close to the Sun on its way to Earth. Isaac Newton’s classical theory of gravity, together with his particle theory of light, also predicted a deflection, but the magnitude of the effect Einstein calculated was readily distinguishable from Newton’s.

How could star positions be measured accurately, however, when the stars appeared close to the Sun? Answer: observe them during a total solar eclipse. Astronomers knew an eclipse would take place in 1919, presenting a golden opportunity for a test. Photographs of stars near the edge of the Sun, made during the eclipse, could be compared with photographs of the same stars made when the Sun was absent from that region of the sky.

The eminent English astronomer Arthur Eddington led an expedition to an island off the west coast of equatorial Africa, where the eclipse viewing was predicted to be excellent. On the day of the eclipse, May 29, there was a tremendous rainstorm, and Eddington was in despair. But the storm lifted before totality, and the pinpoints of five stars were photographed. When the eclipse photographs were compared with a photographic plate taken at the University of Oxford before the expedition, Einstein’s ideas were confirmed, at least as well as they could be at the time. On November 7 the London Times headlined: “Revolution in
Even before Eddington's dramatic announcement, Einstein himself had pointed out that his theory could solve a longstanding problem in astronomy. Like the other planets in the solar system, Mercury moves in an elliptical orbit around the Sun. Along with that primary motion, Mercury's perihelion, its closest approach to the Sun along the orbit, gradually migrates as well, drifting around the Sun in the same direction as its primary motion. This wobble, comparable to that of a toy top, is called precession, and is caused by external forces—in the case of Mercury's orbit, by the gravity of the other planets orbiting the Sun.

In 1859 Urbain-Jean-Joseph Le Verrier, the director of the Paris Observatory, published his observations of an anomaly in Mercury's orbit. Le Verrier had found that Mercury's precession is 574 arc seconds per century (an arc second is 1/3,600th of a degree). In other words, the precession would complete a full 360-degree cycle around the Sun in some 2,260 centuries. When Le Verrier applied Newton's theory to calculate the gravitational effects of the other planets on Mercury, however, he arrived at a precession rate of only 531 arc seconds per century. The discrepancy perplexed astronomers for more than fifty years.

Relief came in 1915, when Einstein was working out ways to test his own theory of gravity. The theory maintained that space-time near the massive Sun would be distorted in previously unforeseen ways. Taking that distortion into account in calculating Mercury's precession, lo and behold, the results matched the observed amount. "I was beside myself with joyous excitement," Einstein wrote later.

There things stood, notwithstanding numerous technical advances, until June 18, 1976. On that day, NASA and the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, confirmed, with high accuracy, Einstein's equivalence principle—one of the fundamental assumptions of the general theory of relativity. The experiment, known as Gravity Probe A, confirmed that clocks in gravitational fields of differing strengths do not keep the same time. The investigators compared the frequency of an atomic clock that stayed on the ground with that of an identical clock that was lofted 6,200 miles above the Earth, atop a rocket. Consistent with Einstein's theory, the clock aboard the spacecraft, in the weaker gravitational field, ran slightly faster.

Later in 1976, another space-age test became feasible, when two Viking landers arrived on Mars. As
Earth and Mars traced their orbits around the Sun, signals from Earth were bounced off the landers and back to Earth, and each signal’s round trip was precisely timed. When Earth and Mars were on nearly opposite sides of the Sun, the signals were slightly delayed, by an amount predicted by Einstein’s theory. Known as the Shapiro time delay (after the physicist Irvin I. Shapiro of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts), the effect is related to the bending of light by the Sun.

Gravity Probe B seeks to test, with very high accuracy, two further, very small effects predicted by the general theory of relativity. The first, known as the geodetic effect, is a consequence of the calculated curvature of space-time near a massive object such as Earth. The Dutch astronomer Willem de Sitter first derived the effect mathematically from Einstein’s theory in 1916, but it was Schiff who extended the theory to the case of a spinning gyroscope. Translated into the behavior of a gyroscope aboard Gravity Probe B, the geodetic effect should be detectable as a rotation of a gyroscope in the plane of its orbit—or to use a nautical term, a deviation in its pitch. Given Earth’s mass and the height of the satellite’s orbit, the gyroscope should rotate slightly more than 6.6 arc seconds per year. [To visualize how the warping of four-dimensional space-time is predicted to change the orientation of a gyroscope, see the illustration on preceding page.]

The second effect GP-B is looking for, known as frame-dragging, is an even smaller one. According to Einstein’s theory, a massive rotating body such as the Earth should drag nearby space-time around itself. Imagine a soccer ball spinning in a viscous fluid such as honey. As it spins, the ball pulls the honey around as well, creating a vortex. Similarly, the Earth’s rotation exerts a pull on space-time, which in turn affects any orbiting satellites.

Frame-dragging was derived in one form from the general theory of relativity in 1918 by two Austrian physicists, Joesf Lense and Hans Thirring, and thus is also known as the Lense-Thirring effect. Their calculations concerned the effect of frame-dragging on a moon’s orbit. Schiff, instead, calculated the effect of frame-dragging on the axis of a gyroscope. To return to the analogy of the soccer ball spinning in honey, the effect would show up as a gradual change in direction of a pointer immersed in the honey [see illustration at left].

In both cases the effect of frame-dragging is very small. For a gyroscope in polar orbit, it works out to be about 0.041 arc second per year. If you walked “up” a slope at that angle, you would have to walk nearly eighty miles to climb an inch. But in 1959 Schiff calculated that an ideally constructed gyroscope would be able to detect not only the geodetic effect but also frame-dragging. Aboard Gravity Probe B frame-dragging should cause a gyroscope to turn, or yaw, in the same direction as Earth’s rotation.

Conducting the experiment, however, requires much more than a near-perfect, drift-free gyroscope. Every force that might affect the gyroscope, except gravity, must be understood and excluded. Minute changes in the gyroscope’s spin angle have to be measured without disturbing the gyroscope. A point of reference is needed, in the form of a bright, nearby star whose motion is known, and an onboard telescope is needed to keep track of the star. Each of those challenges at first seemed insurmountable.

The heart of GP-B is a twenty-one-inch-long block of fused quartz bonded to a quartz telescope [see illustration on pages 52 and 53]. For redundancy, the block of quartz houses four gyroscopes, each a gemlike sphere the size of a Ping-Pong ball, also made of fused quartz. The four gyroscopes are the most perfectly round objects ever manufactured, honed to within forty atomic layers, or 0.6 millionth of an inch from the highest “peak” to the deepest “valley.” Each sphere is coated with a uniform layer of niobium, a metallic element that becomes a superconductor at 9.3 degrees Kelvin (−442.9 degrees Fahrenheit).

To reduce friction on the spheres, they are levitated by voltages applied to saucer-shaped electrodes. Jets of helium gas spin the gyroscopes up to a speed of 5,000 revolutions per minute. Then, to further minimize friction, the gas is evacuated from around the spheres. The gyroscopes are isolated from external magnetic fields by a succession of magnetic shields.
The telescope itself is kept rigorously aimed at the guide star, I\textit{M} Pegasi, in the constellation Pegasus. Because the satellite loses sight of the star when it passes behind the Earth, the telescope must be able to reliably reacquire, or locate, the star after every orbit.

The entire gyroscope-telescope assembly is maintained at high vacuum within a nine-foot-long chamber, known as the “probe.” The probe in turn is enclosed within a kind of large thermos bottle known as a Dewar. Filled with 645 gallons of liquid helium, the Dewar maintains the probe at a temperature of only 1.8 degrees Kelvin (−456.4 degrees Fahrenheit). The temperature is kept from rising by gradually venting helium from the Dewar.

The problem of measuring changes in the gyroscope’s spin axis without disturbing the gyroscope has a particularly clever solution. Attaching a pointer to it is not feasible. Enter the spherical coating of niobium: when niobium becomes superconducting, and the spherical superconductor spins, it does something very handy. It generates a small magnetic field that is proportional to the rate of spin and precisely aligned with the spin axis. Hence every tiny shift in the gyroscope’s spin axis can be measured by an exquisitely sensitive magnetometer.

Originally, Everitt explains, the gyroscopes were to be arranged so that one pair would detect frame-dragging, and a second pair, whose spin axes would be perpendicular to those of the first pair, would measure the geodetic effect. For technical reasons, that approach was abandoned, and all four gyroscopes were set spinning along the telescope’s line of sight to the reference star. Each gyroscope senses both axis-shifting effects. Clever mathematics then enables the Gravity Probe B team to sift them apart.

For all the advanced technology aboard Gravity Probe B, frame-dragging may have already been observed. Two NASA satellites, LAGEOS (Laser Geodynamics Satellite) I and LAGEOS II, each studied with 426 minute reflectors, have been tracked for years with laser range-finding equipment. In 1998 Ignazio Ciufolini of the University of Lecce, Italy, and Erricos Pavlis of the University of Maryland, in Baltimore, reported an analysis of the satellite orbits over a period of eleven years. The data suggested the orbits had shifted as a result of frame-dragging, though the measurements had a large margin of error. More recently, Ciufolini and Pavlis have refined their calculations, based on new data on Earth’s gravitational field. They maintain that frame-dragging has wrenched the LAGEOS satellites out of their expected orbital positions by two meters a year. There have also been hints of frame-dragging in observations of neutron stars and black holes.

Does that finding mean NASA wasted $700 million on Gravity Probe B? Hardly. The mission is expected to measure frame-dragging directly with an accuracy of 1 percent—good enough, for many experts, to prove the physical reality of Einstein’s prediction. For LAGEOS the displacement of two meters per year, expressed as an angle, is just 0.03 arc second (1/120,000th of a degree). It seems at least questionable whether such a vanishingly small signal can be isolated from the overwhelming noise of the panoply of ordinary Newtonian effects, which amount to 120 degrees a year. In addition to measuring frame-dragging, of course, Gravity Probe B is also investigating the geodetic effect.

What about the possibility that Gravity Probe B will show the way to new physics? According to one Nobel laureate, the physicist Chen Ning Yang of Stony Brook University in New York, Einstein’s general theory of relativity is likely to be amended in a way that somehow entangles spin and rotation. “The Stanford experiment is especially interesting in that it focuses on the spin,” he writes. “I would not be surprised at all if it gives a result in disagreement with Einstein’s theory.”

Given such high stakes, Everitt is on guard against any premature release of his own data. The Gravity Probe B team expects the helium on board to be exhausted by the end of July. “Then,” he says, “it will be four to six months after that before we publish any results.” After forty-five years, that might almost seem like rushing into print.
The Flower and the Fly

Long insect mouthparts and deep floral tubes have become so specialized that each organism has become dependent on the other.

By Laura A. Sessions and Steven D. Johnson

The meganosed fly (Moegistorhynchus longirostris) of southern Africa, like its literary counterpart, Pinocchio, has a bizarre appearance that reveals an underlying truth. Its proboscis, which looks like a nose but is actually the longest mouthpart of any known fly, protrudes as much as four inches from its head—five times the length of its bee-size body. In flight the ungainly appendage dangles between the insect’s legs and trails far behind its body.

To an airborne fly, an elongated proboscis might seem a severe handicap (imagine walking down the street with a twenty-seven-foot straw dangling from your mouth). Apparently, though, the handicap can be well worth its aerodynamic cost. The outlandish proboscis gives the meganosed fly access to nectar pools in long, deep flowers that are simply out of reach to insects with shorter mouthparts.

But that poses a conundrum: why would natural selection favor such a deep tube in a flower? After all, nectar itself has evolved because it attracts animals that carry pollen, the sperm of the floral world, from one plant to another. And since pollinators perform such an essential service for the flower, shouldn’t evolution have favored floral geometries that make nectar readily accessible to the pollinators?

Yet the story of the long proboscis of the meganosed fly and the long, deep tubes of the flowers on which it feeds is not quite so straightforward. There are subtle advantages, it turns out, to mak-
Meganosed fly, an insect native to southern Africa, visits a Pelargonium suburbanum flower, a member of the geranium family. Dangling from its proboscis (the lengthy mouthpart that gives the insect its somewhat misleading name) are yellow pollinaria, or sacs of pollen, from an earlier visit to an orchid.

ing nectar accessible to only a few pollinators, and nature factors those advantages into the evolutionary equation as well. In fact, the evolution of those two kinds of organisms, pollinator and pollinated, presents an outstanding example of an important evolutionary phenomenon known as coevolution. Coevolution can explain the emergence of bizarre or unusual anatomies when no simple evolutionary response to natural selection is really adequate. It can help conservationists identify species that could be vital in maintaining a given habitat. And it can help naturalists investigating novel plants predict what kinds of animals might pollinate their flowers.

The coevolution of the meganosed fly and the plants it pollinates is a tale of extreme specialization. Each species has adapted to changes in the other in ways that have left each of them, to some degree, reliant on the other. The idea that a plant species might become dependent for pollination on a single species of animal goes back to the writings of Charles Darwin. For example, Darwin noted, the flower spur of the Malagasy orchid (Angraecum sesquipedale) contains a pool of nectar that is almost a foot inside the opening of the flower. (A flower spur is a hollow, hornlike extension of a flower that holds nectar in its base.) In pondering the evolutionary significance of those unusual flowers, Darwin predicted that the orchid must be adapted to a moth pollinator with a long proboscis.

Critical to Darwin’s prediction was his suspicion that pollination could take place only if the depth of a plant’s flowers matched or exceeded the length of a pollinator’s tongue. Only then would the body of the pollinator be pressed firmly enough against the reproductive parts of the flower to transfer pollen effectively as the pollinator fed. Thus, as ever deeper flowers evolved through enhanced reproductive success, moths with ever longer proboscises would also, preferentially, live long enough to reproduce, because they would most readily reach the available supplies of nourishing nectar. Longer proboscises would lead
yet again to selection for deeper flower tubes. The result would be the reciprocal evolution of flowers and pollinator mouthparts. That coevolutionary process would cease only when the disadvantages of an exaggerated trait balanced or outweighed its benefits. Given enough time, the process might even produce new species: an insect that specializes in feeding on nectar from deep flowers, and a deep-flowered plant specialized for being pollinated by insects with long mouthparts.

In the early twentieth century it seemed that Darwin’s prediction had been borne out. A giant hawk moth from Madagascar, *Xanithopan morganii praedicata*, was captured, with a proboscis that measured more than nine inches long. Although no one has actually seen the insect feeding on the flower, the discovery is still remarkable, and strongly suggestive of the coevolution of the orchid and moth. Other insects that have relationships with highly specific plants, such as the meganosed fly and other, related long-nosed fly species of southern Africa, provide even better evidence of the reciprocal links between plants and their pollinators.

Darwin would have been amazed that some flies in southern Africa have longer tongues than most hawk moths do. After all, the flies’ bodies are several times smaller than the hawk moths’ are. Flies are described as long-nosed if their mouthparts are longer than three quarters of an inch. By that criterion, more than a dozen long-nosed fly species are native to southern Africa. They belong to two families. The nemestrinids, or tangle-veined flies (which include the meganosed fly), feed solely on nectar, whereas the tabanids, or horseflies, feed mostly on drome of the long-nosed fly (and indeed, in all pollination syndromes of long-nosed insects) is a deep, tubular flower or floral spur. One of us (Johnson) and Kim E. Steiner of the Compton Herbarium in Claremont, South Africa, studied the orchid *Disa draconis*, a southern African plant with a deep, tubu-

---

**Plant tactic to minimize the possibility that the pollen of one species will be wasted by ending up on the female reproductive parts of another species is shown in the diagram. Plant species belonging to the “pollination guild” of the meganosed fly all risk distribution of their pollen by the fly to plants of different species. The members of the guild have evolved to deposit their pollen on differing parts of the nectar-seeking fly, each part characteristic of the plant species.**
Orchid Disa draconis is a member of the pollination guild of the megaranosed fly, and so the orchid depends on the fly for pollination. Like other, similarly adapted flower species, it has a long tube, but unlike the others, it provides no nectar to the fly; the fly is simply fooled into visiting the flower. As the drawing shows, the pollen of the orchid, enclosed in sacs, is deposited uniquely along its proboscis.

And the plants pollinated by long-nosed flies benefit from a near-exclusive pollen courier service—or at least one that minimizes the risk of delivery to the wrong address. But specializing can also be a risky strategy for the plants if the pollinators are less interested in fidelity than the plants are. Long-nosed flies could not survive on the nectar they could get by visiting just one plant species; the flies must visit several plant species to gather the energy they need. Johnson and Steiner observed megaranosed flies visiting at least four species with deep flowers.

There are advantages for the specialists on both sides of this relationship. The long-nosed flies obviously get privileged access to pools of nectar.
mutualistic partner it seems. The flower attracts the meganosed fly because it looks like other members of the fly’s guild. But, whereas the fly carries the orchid’s pollen, the orchid offers no nectar in return.

The risk of falling for such a trick seems a small price for the flies to pay for the benefits of specialization. But specialization also carries a much graver risk—in fact the ultimate risk—for both members of the partnership because the disappearance of either partner is likely to doom the other one, as well. Some plant species have mechanisms, such as vegetative reproduction or self-pollination, that may help sustain their populations in the short run. But in the long run, without their pollinators, the species will slowly and irrevocably decline. Pollinating insects may be more flexible in some cases, but are still vulnerable if a key food source disappears.

Unfortunately, in southern Africa that is just what is happening to many plants and their long-nosed fly partners. Often not even closely related insect species can help in pollination. For affected plants, the loss of a single fly species means extinction. And examples of that gloomy cascade have already been observed. Peter Goldblatt of the Missouri Botanical Garden in St. Louis and John C. Manning of the Compton Herbarium have reported that many populations of long-nosed flies are threatened by the loss of their wetland breeding habitat, and also, possibly, by the loss of other insects they parasitize during their larval stages. In some habitats, flowers in the long-nosed fly guild already produce no seeds, because their pollinator is locally extinct.

Naturalists have accepted the concepts of guilds and pollinator syndromes for many years, and predicting which pollinators regularly visit which plants has become something of a cottage industry. But just how common is pollinator specialization in southern Africa? Promiscuity could turn out to be a more successful—and more widespread—strategy than specialization, even among plants that seem to fit into identifiable guilds.

In recent years ecologists have discovered that just because plants and insects appear to form a pollination guild does not guarantee they never venture outside it. For example, ecologists have noted that in years when hummingbird populations are low, flowers ordinarily pollinated by hummingbirds can fill up with nectar and become pollinated effectively by bees. Likewise, bees once thought to specialize in only one or two plant species turn out to forage on a variety of plants.

The take-home lesson has been that the syndrome concept is no substitute for careful field observation. Some investigators even think that the concept has caused botanists to overlook generalists. In the Northern Hemisphere, for instance, studies suggest that generalization is the norm, not the exception. Johnson and Steiner recently completed a study showing that members of the orchid and asclepiad families in the Northern Hemisphere tend to rely on between three and five pollinators each. In contrast, plants from the same families in the Southern Hemisphere rely on just one pollinator each.

So why might generalization be more common in the Northern Hemisphere than it is in the South-
Peak Experience

The Caribbean island of Saint Lucia harbors rainforest reserves and a drive-in volcano.

By Robert H. Mohlenbrock

Beginning in my high school days, whenever I happily browsed through books on geography and travel, I was fascinated by pictures of the Pitons, two pyramidal volcanic peaks that rise along the coast of the Caribbean island of Saint Lucia. My chance to see them "in the flesh" finally came in January of last year, when my wife Beverly and I traveled to the island. We flew to the capital city, Castries, on the island’s western coast, and headed south in our rental car toward Soufrière, Saint Lucia’s third largest city. The journey along the narrow, crooked, but well-paved road took about an hour. Although our route never strayed far from the coast, it passed almost entirely through mountainous terrain, only occasionally dipping down to a picturesque fishing village.

The final leg of our drive took us through rainforest, virtually announced by tree ferns as high as forty feet. As we rounded one sharp curve, I could not contain my own excited announcement, as the mighty Pitons came into view through a forest opening: "There they are!" I exclaimed. The two peaks, Gros Piton (French for "large peg") and Petit Piton ("small peg") made a striking couple. They also recall Saint Lucia’s checkered colonial past, reminding the visitor that many locals still speak a French patois, even though English is the island’s official language.

We continued through the rainforest, then descended to the sea and the city of Soufrière, on the west coast of the island. The two Pitons lay to our south, though from some vantage points we could not see Gros Piton, taller than its 2,461-foot sibling by 158 feet but often concealed behind it. The Pitons are probably what is left of a complex of volcanoes. Their steep slopes extend 250 feet below sea level.

In Soufrière we visited the Diamond Botanical Gardens, where trails offer close-up views of vegetation, including many native species, along with mineral springs and a waterfall. Saint Lucia is a popular destination for divers and snorkelers, who report seeing lots of sponges, including the large barrel sponge, on the Pitons’ underwater slopes. Caves, reefs, and peaks, all abounding with colorful fish, also lure the underwater visitor.

Above the water line, coconut palms ring the base of the Pitons, and a little higher up the dominant flora change to dry-loving species, including a number of euphorbias and other semisucculent plants. On their eastern side the Pitons are cloaked in the middle with deciduous tropical dry forest; nearer the summit is a rainforest of mostly evergreen species. At the summits and on the western side, where high winds and cooler temperatures make growing conditions most severe, is a so-called elfin forest comprising dwarf, gnarly trees draped with epiphytes, or air plants, including orchids.

Climbing the Pitons, though, is not the most straightforward way to see Saint Lucia’s rainforests. The summit trails are hazardous and difficult—and sometimes closed because of the danger of rockfall. Fortunately, other zones of rainforest are accessible to hikers and drivers within
the island’s forest reserves, which cover nearly thirty square miles of the island’s interior. Mount Gimie, at 3,117 feet Saint Lucia’s highest point, lies within the reserves [see map at right]. Permission to enter the reserves must be obtained from Saint Lucia’s Forest and Lands Department.

The rainforests get more than 150 inches of rain a year, on average, mostly from June through November. The trees forming the upper canopy grow as tall as 180 feet, and many have large girths. The most common species is gommier, a member of the Burseraceae family. Temperate North America has no bursieraceous representatives, but two Old World species are familiar, at least in name: frankincense and myrrh. Another tree species on Saint Lucia is bois canan, or cerapia, whose large, palm-like leaves decay very slowly when they fall to the ground. The hiker is apt to spot the leaves on the forest floor before noticing the tree itself, towering overhead.

Beneath these and other large trees is a dense mid-canopy of trees and tall shrubs, ranging from twenty to sixty feet high. Among them is dede-fouden, or bead tree, whose shiny red-—and—black seeds are gathered to make necklaces, earrings, and eyes for teddy bears. Tree ferns (known locally as firije) and bamboo grasses also inhabit the midcanopy layer. Epiphytes cling to the branches of many trees, and vines seeking sunlight climb their trunks.

Hard to spot but at the top of many visitors’ watch lists is the Saint Lucia parrot, a green—, red—, and blue—feathered endemic species that lays its eggs in hollows in the tops of the gommier trees. The numbers of the birds in the wild have fallen to critical levels, because of loss of habitat and because they are taken locally for food or captured for the pet industry. Thanks to a conservation effort, however, the population has increased to 800 from a low of about 100 in 1979.

The snake most apt to be seen in the rainforest is the boa constrictor. Two of the island’s other snakes are of special interest to herpetologists—though they do not occur in the rainforest. One is the Saint Lucia racer, perhaps the rarest snake in the world, and the other is the worm snake, one of the smallest, measuring less than six inches long.

When Beverly and I drove south on the main road from Soufrière, we passed near the inland side of Petit Piton. The coastal area between that peak and Gros Piton, farther south, was once the site of the Jalousie sugar plantation; now it is occupied by a resort. Beyond the resort turnoff we came to a rough road that led inland through the remains of a volcanic crater (it is touted as the world’s only drive—’in’ volcano). In fact, on our initial descent into Soufrière, we had noticed steam rising in the distance from this valley. The sulfurous fumes we now breathed up close gave the city its name (souf is French for “sulfur”).

Robert H. Mohlenbrock is professor emeritus of plant biology at Southern Illinois University in Carbondale.

### Rainforest Plants

In addition to cercropia and gommier, tall native trees include bois de masse (a relative of Florida’s gopher apple tree), chataignier, and incense tree (the last, like gommier, in the Burseraceae family). A nonnative tree is blue mahoe, a kind of hibiscus. A beautiful evergreen tree with red, orange, or yellow flowers, blue mahoe is native to Jamaica. Like so many other plants in the tropics, it has escaped from cultivation and gone wild.

Species that make up the midcanopy layer in the forest, along with the bead tree, bamboo grasses, and tree ferns, include the common palms gwi gwi and palmite, mahot cochin (a tree in the same family as the chocolate tree), and paletuvier (this last species is also called mountain mangrove, and the stilt roots it forms at the base of its trunk resemble those of the red mangrove, though it is not actually a mangrove). The epiphytes hanging from the tree branches are either bromeliads or orchids. One of the common vines, known as the climbing palm, is not a true palm, but is a member of the closely related Cyclanthaceae family.

The forest floor is a jumble of coarse and delicate herbs, many of them escapes from cultivation. Commonly encountered are lang poul (a kind of gentian), several species of lobster claw, tet neg (a plant in the same genus as the elephant’s—foot of the eastern United States), venvern lache wat (a member of the verbena family), and various species of wild ginger.
Sable Island: The Strange Origins and Curious History of a Dune Adrift in the Atlantic
by Marq de Villiers and Sheila Hirtle
Walker & Company, 2004; $24.00

Battered remains of the trawler Gale, shipwrecked off Sable Island in 1945

Before I picked up this book, I’d never heard of Sable Island. But the seafaring communities of New England and Canada’s Maritime Provinces know it all too well. One hundred and seventy-nine miles southeast of Halifax, Nova Scotia, Sable Island is a treeless, crescent-shaped sliver of sand stretching some twenty-five miles from west to east, near the edge of the continental shelf. It has never sustained a resident population of more than a few dozen souls, but this mere spit of land and its surrounding sea has become the final resting place for thousands of unfortunate sailors and fishermen—a veritable graveyard of the Atlantic.

Sable is a perilous place, and not only because it is barely visible above the swells of the sea. Situated along the principal trade route between Europe and North America, and in near proximity to the fishing grounds and oil-rich drilling sites of the Grand Banks, the island is literally in the way of much of the passing maritime traffic. To compound the danger, the island is surrounded by miles of offshore sandbars, whose extent and shape constantly shift under the battering of storms and currents. Even experienced sailors have concluded that the best way to survive Sable is to give it a wide berth.

Yet over the centuries, hundreds of ships, lost or driven by high seas, have gone aground off its coast—an estimated seven wrecks for every mile of coastline. Sable Island has also attracted its fair share of writers over the years.

Like Cape Cod, Sable is both a remnant of the last ice age—a dollop of sand and gravel left behind as the great glaciers retreated—and an environment surprisingly well-suited for human habitation (albeit only the minimally invasive type). A large though fragile freshwater aquifer underlies its dunes, and plenty of grasses and lowly shrubs manage to hang on, despite nearly constant winds. A variety of nesting birds, different species of seal, and a resident herd of several hundred feral horses reside within its approximately thirteen square miles.

That’s not to say Sable is an easy place to live. As early as the 1600s, French merchants tried to establish settlements on the island, but a chain of supply with the mainland proved hard to maintain. Once you read de Villiers and Hirtle’s accounts of winter storms, as recorded by later residents, it’s easy to understand why. In the 1860s, one of them told a Halifax newspaper that during one rather strong gale, the only way to move around at all was to crawl on all fours. “When the seas hit Sable,” another resident recalled, “you could see the oil in the lamps just quivering from the vibrations of a thousand tons of water hitting the south beach.”

By the beginning of the twenty-first century, Sable was home to just two people: a Canadian-government meteorologist and a freelance environmentalist. The island’s lighthouses and its various weather and ocean sensors have all been automated, and such modern navigational aids have vastly reduced the incidence of shipwrecks. A preservation trust oversees its management from mainland Canada. Yet the island remains a remote and exotic outpost, its only visitors the occasional naturalist.

If you’re fascinated by islands, dipping into this lively book is a great way to visit Sable without getting wet. Then, with your appetite whetted, visit the Web site museum.gov.ns.ca/mnh/nature/sableisland/index.htm for some personal accounts and wonderful old photographs of the island as it was in Victorian days.

Beast of Never, Cat of God: The Search for the Eastern Puma
by Bob Bultz
The Lyons Press, 2005; $22.95

There are wild things among us. Who would have thought, just a few decades ago, that suburbanites would come to view the white-tailed deer as a major nuisance to their lawns and gardens? Who would have imagined that peregrine falcons would nest in city high-rises and terrorize squirrels in city parks? The heightened environmental sensitivity of the past century, along with a drastic reduction in the number of rifle-toting frontiersmen, has rescued a host of creatures from the brink of extinction in the eastern United States.

So why not the mountain lion (Puma concolor)? Known by many names—puma, cougar, catamount, panther—this large feline predator was once wide-
spread throughout much of North America. A full-grown cougar can weigh more than 150 pounds and can measure seven feet from the tip of its nose to the end of its tail. It stalks everything from rabbits to elk, but its preference is deer—nowadays in plentiful supply. Estimates of the present-day cougar population in North America range between 30,000 and 50,000, but most experts think virtually all of them inhabit the western mountain or Pacific Coast states. A vestigial population of a hundred or so live deep in the Florida Everglades. But except for the Florida felines, as far as one can tell, wild cougars no longer live east of the Mississippi.

At least that’s the official version. Bob Butz, a nature writer who lives near Traverse City, Michigan, at the far northern edge of the lower peninsula, has a different story. Butz has spent the past few years among a strange subculture of hunters and outdoorsmen who truly believe, contrary to the stance of state and federal wildlife managers, that cougars have begun to recolonize the East. Butz’s principal informant is Patrick Rusz, who has both a Ph.D. in wildlife ecology and a bee in his bonnet about the big cats. Rusz seems to spend most of his weekends in the woods, following up reports of sightings and collecting piles of suspicious scat, which he stores in an ice chest in the back of his pickup to save for DNA analysis.

By immersing himself in the cat-chasers’ culture, Butz has put together plenty of evidence pointing to the presence of wild cougars in the eastern woods. Many candid snapshots of purported cougars are no clearer than fuzzy pictures of Bigfoot, but some are sharp and unambiguous. A lot of the tracks seem genuine, and laboratory tests of scat samples often come back positive for puma.

But caution is in order. Wildlife officials seem willing to grant the occasional sighting, but they are reluctant to conclude that such cougars represent a native wild population, as many of the “cat people” believe. One or two strays may have wandered east; an occasional pet puma may have escaped from a zoo or a private preserve. That’s a bit different from claiming that dozens of pumas are breeding in the woods.

In the absence of incontrovertible evidence (there’s been a notable lack of pumas shot during hunting season), game wardens seem inclined to regard the cougar issue as something of a nuisance. With plenty of well-documented species that need conserving, the official position is that the cougar lobbyists should “get a life.” After reading Butz’s reportage, I tend to agree. But, recalling the occasional sightings of pumas my local newspaper has reported, I’m going to keep a sharper eye out for the big cats the next time I’m out on the trail.

Mendel in the Kitchen: A Scientist’s View of Genetically Modified Foods
by Nina Fedoroff and Nancy Marie Brown
Joseph Henry Press, 2004; $24.95

It is marvelous how submicroscopic strands of DNA, through their many permutations, can influence the structure, development, and functioning of (Continued on page 70)
1. ADVENTURE LIFE JOURNEYS
Small group travel in the Andes, Amazon, Galapagos, Patagonia, Antarctica, and Central America. Expert local guides lead our cultural and ecological explorations and naturalist cruises.

2. ADVENTURES ABROAD
Adventures Abroad offers small group tours to 110 countries. Our tours are part education, part exploration and a complete holiday.

3. ADVENTURESOUTH EXPLORATIONS
Uncommon adventures for naturally active travelers. Explore nature and wildlife up close and in style. Hike and kayak with engaging naturalist guides from upscale wilderness lodges and adventure vessels. Alaska, Costa Rica, Galapagos and more.

4. ALABAMA GULF COAST
Spectacular beaches. Outstanding accommodations. And warmed by sunshine, history, culture and unspoiled natural beauty.

5. AMAZONIA EXPEDITIONS
Award-winning Jungle Lodge in the Tamshiyacu-Tahuayo Reserve, known to have the greatest diversity of mammals in all of the Amazon.

6. AMERICAN CRUISE LINES
Enjoy scenic and culturally enriching 7 night cruises through the smooth waters of the inland passages along the eastern U.S. seaboard.

7. ARCTIC WILD
Inquire to learn more about natural history expeditions throughout Alaska’s Brooks Range, and select destinations elsewhere in Alaska and the Canadian Arctic.

8. BERMUDA TOURISM
Bermuda. It’s not just a pretty island. It’s a paradise served on fine bone china.

9. CALVERT COUNTY, MARYLAND
Discover a place where there are still places to discover...just an hour from Washington, DC. Catch a glimpse of Southern Maryland’s heritage and history and experience fabulous festivals and extraordinary events.

10. CHARLES COUNTY, MARYLAND
It's for the birds! Take a hike! Hunt for fossils, golf, fish, shop. Experience the wild side of the Potomac where eagles soar.

11. CROW CANYON ARCHAEOLOGICAL CENTER
Small-group cultural adventures led by world-renowned scholars explore some of the world’s most interesting locations; programs also include Southwest archaeological explorations that focus on ancient Pueblo Indian culture.

12. DORCHESTER COUNTY, MARYLAND
Destination Dorchester - Home to world-renowned Blackwater National Wildlife Refuge, excellent paddling, cycling, fishing and hunting; explore the heart of Chesapeake Country on Maryland’s Eastern Shore.

13. EARTHJUSTICE
Earthjustice is a nonprofit law firm dedicated to protecting the magnificent places, natural resources, and wildlife of this earth by enforcing and strengthening environmental laws.

14. FLAGSTAFF ARIZONA
Culture and clean air, festivals and forest paths - Flagstaff, Arizona is a place packed with energy, surrounded by natural wonders and unique attractions.

15. FREDERICK COUNTY, MARYLAND
Maryland’s Crossroads of History. Antiques, Battlefields, Covered Bridges, Parks, Wineries and more close to Gettysburg and DC.

16. GALAPAGOS TRAVEL
Specializing in comprehensive, educationally-oriented, professionally-led natural history tours of the Galapagos Islands. Spend 11 or 15 days touring all the significant outer islands.

17. INCLINATOR COMPANY OF AMERICA
Inclinator’s Elevette® residential elevators provide convenience for people and add value to homes. They can be designed into new construction or added to existing homes.

18. INDIA
From the snow covered Himalayas to the tropical rain forests, India offers incredible experiences and adventures. Come visit India for an experience that is truly incredible!

19. JOHNS HOPKINS UNIVERSITY PRESS
Celebrating 150 years of publishing for the world. Books about nature and science.

20. KENT COUNTY, MARYLAND
The County of Kent is a scenic peninsula on the Chesapeake Bay, offering fishing, boating, kayaking, small beaches, awesome sunsets, museums, the “Arts,” farmers’ markets, and great shopping.

21. LINDBLAD EXPEDITIONS
Expedition travel by the family that pioneered expedition travel.

22. LITTLE ST. SIMONS ISLAND
Exclusive 10,000-acre Georgia island paradise, private 7-mile pristine beach, natural history tours, birding and recreational activities galore, gourmet regional cuisine and gracious accommodations await just 30 guests.

23. MARYLAND VACATIONS
Beaches, mountains, big cities, small towns. Maryland has so many things to do, so close together.
24. MONTANA/WYOMING/SOUTH DAKOTA

25. MONTANA'S MISSOURI RIVER COUNTRY
Explore Dinosaur digs and museums, the Lewis & Clark trail, Native American cultures, pioneer history and more. Free Travel Planner available.

26. MONTGOMERY COUNTY, MARYLAND
Experience transportation history along the C & O Canal and the National Capital Trolley Museum. So many things to do with easy access to the nation's capital.

27. NEW BRUNSWICK, CANADA
Walk on the ocean floor along the Bay of Fundy, home of the World’s Highest Tides!

28. NEWFOUNDLAND & LABRADOR
Newfoundland and Labrador. We offer our visitors the natural wonders of whales, icebergs and seabirds framed by our dramatic seascape and landscape and unique culture.

29. NORTH CAROLINA OUTER BANKS
Pristine Beaches, Fishing, History. For FREE Travel Guide & Getaway Card good for seasonal values.

30. NORWAY
Norway is nature at its most spectacular. A land of cosmopolitan cities, charming towns, ancient Viking ships, and breathtaking coastal voyages.

31. NOVA SCOTIA
Yes, please send me my FREE 400 page Nova Scotia Doer's & Dreamer's Travel Guide - packed with everything I need to plan and book my vacation.

32. ORIENT LINES
Explore Scandinavia and Russia. Cruise to the Mediterranean's most glamorous playgrounds. Enjoy luxury at sea, aboard the elegant mid-sized ships sophisticated travelers prefer.

33. PRINCE EDWARD ISLAND, CANADA
Come experience our unique red cliffs and parabolic sand dunes and hike or bike the Confederation Trail across our Island.

34. PRINCE GEORGE'S COUNTY, MARYLAND
Wonderful museums and historic sites, the National Wildlife Sanctuary, affordable accommodations and much more. All just minutes from Washington, DC.

35. QUEBEC CITY
Discover the magic of North America's most European City! Only 40 minutes from the Old City, go birdwatching, hiking and enjoy yourself.

36. SCOTLAND
Scotland's rich cultured heritage is celebrated in museums, galleries, theaters, concert halls, vibrant festivals, pubs and street corners.

37. ST. LAWRENCE CRUISE LINES
Canadian River Cruise Vacations. Spend 5 or 6 nights aboard a classically designed riverboat cruising the calm waters of the St. Lawrence and Ottawa rivers.

38. ST. MARY'S COUNTY, MARYLAND
A Maryland original! Visit Maryland's first colony...historical sites and outdoor adventure await. 400 miles of Chesapeake shoreline and 3 1/2 centuries of history.

39. SWAN HELLENIC CRUISES
Ocean and sea cruises, expedition and river cruises all with the accent on discovery. Exotic destinations and distinguished guest speakers.

40. TALBOT COUNTY, MARYLAND
Talbot County's five beautiful rivers, 602 miles of shoreline, unique charming hamlets St. Michaels, Oxford, Tilghman Island and Historic Easton offer a timeless treasury of natural beauty and history.

41. TARA TOURS
Tara Tours specialize in travel to Central and South America since 1980. Free brochures and quotes.

42. TOYOTA
In the U.S., Toyota is more than the cars we sell here. Together with our dealers and suppliers, Toyota is responsible for creating over 190,000 good jobs across the U.S. Learn more about our eight manufacturing plants, design, and R&D facilities, and how we invest in local communities.

43. VICTOR EMANUEL NATURE TOURS
Over 140 tours annually worldwide, including special cruises, and introductory tours for new birders.

44. WORCESTER COUNTY, MARYLAND
Maryland's only seaside county. Visit Assatogue Island National Seashore. Kayak, canoe, bird watch or golf. Stay in one of our many Bed & Breakfast Inns.

45. ZEGRAHM EXPEDITIONS
Offers small-group expeditions to remote locations around the world. Expertly led and staffed, our programs provide the finest adventure travel experience imaginable.
every living species on the planet. Yet to Nina Fedoroff, a molecular biologist at Pennsylvania State University in University Park, it also seems ironic that the same molecules have played such a powerful role in the recent political life of our species.

Here in the United States, the methods of genetically modified (GM) agriculture have been applied nationwide. Outside the U.S., however, genetic modification is regarded as a horrific form of tinkering with nature—so much so that the chromosomal makeup of fruits and vegetables has been a major bone of contention in agreements between the European Union and its trading partners.

Fedoroff grants that ecological and ethical issues abound. But she still believes that GM foods are no more dangerous than foods were before this particular round of technology became available. A little more understanding of the science behind GM food production and consumption, she seems to think, might cool down the doomsday rhetoric. So with the able assistance of science writer Nancy Marie Brown, she has produced not only an authoritative primer on the science and ecology of agricultural genetics, but a much-needed guide for the perplexed.

The main point Fedoroff makes is that plant manipulation is nothing new to the farmer. Agriculture, from the beginning, has been all about fooling Mother Nature. Millennia before Mendel, the first farmers to domesticate wheat and corn bred their stock selectively to tilt the balance of the gene pool toward features they favored—harvestability, size, flavor, and the like. For centuries, orchard managers have cloned their favorite fruit stocks by grafting branches of a desirable plant onto the trunks or branches of other trees. Intriguingly, that practice, accepted today even by organic farmers, drew its share of opposition in the late 1700s, when it was first introduced in America by John Chapman, aka Johnny Appleseed.

By the twentieth century, agricultural scientists were crossbreeding plants extensively, according to the trial-and-error method pioneered by Luther Burbank: selecting desirable variants and frequently accelerating variability by dosing the plants with radiation or chemicals.

What is different about modern genetic manipulation, of course, is that it can be accomplished at the molecular level. The outcome is usually predictable and often quite precise, dispensing as it does with so much of the trial and error of earlier techniques. The methods of recombinant DNA make it possible to select desirable genes from widely divergent species, and even to add or delete genes at will. In the 1990s, for instance, workers inserted a gene from the bacterium Bacillus thuringiensis into corn and potato chromosomes, creating plants that produce their own insecticides. The new varieties have reduced the need for chemical insecticides. Who knows what new and ingenious organisms may yet be produced?

It’s that “who knows?” that will no doubt keep the opposition going. Yet to all but the harshest critics of GM, Fedoroff and Brown certainly seem to have made their case: genetic modification, deployed with the same wisdom as any other agricultural innovation, is more of a boon than a hazard.

Laurence A. Marschall, author of The Supernova Story, is W.K.T. Salth Professor of Physics at Gettysburg College in Pennsylvania. He is the 2005 winner of the Education Prize of the American Astronomical Society.
The Trip of a Lifetime
Specializing in comprehensive, professionally-led, natural history and photo tours of the Galapagos Islands. Monthly departures on 11-16 passenger yachts.

Amazon, Galapagos, Machu Picchu
For brochures a custom made tours Tara Tours 1-800-327-0080
Since 1980, ...www.taratours.com

ARCTIC WILD
Natural history expeditions in Alaska’s arctic wilderness.
www.arcticwild.com 888-577-8203

AMAZON
Award winning lodge in Peru’s Tamshiyacu-Tahuayo Reserve, shown to have the greatest mammal diversity in the Amazon. Customized itinerary, from soft family to wilderness camping. Featuring the Amazon’s longest zipline canopy access. In business since 1981. References available. Customized economical tours to Cusco and other sites in Peru as well.
AMAZONIA EXPEDITIONS
800-262-9669 www.peruandes.com

MIDDLE EARTH to DOWN UNDER
Experience native wildlife on the other side of the world: wallabies, Hooker’s sea lions, quolls, and rare penguins. Explore Tasmania, New Zealand, and the remote, protected Sub-Antarctic Islands on board the 110-passenger Clipper Odyssey. 14 NOV - 02 DEC 2005
ZEGRAHM EXPEDITIONS
(800) 628-8747 www.zeco.com

CULTURAL, WILDLIFE & NATURAL HISTORY TOURS
OVER 100 COUNTRIES WORLDWIDE
In-depth escorted tours since 1987
Call for free 136-page color catalog
adventuresabroad.com
1.800.665.3998
sales@adventures-abroad.com

BEFORE A RIVER RAN THROUGH IT, SOMETHING ELSE ROAMED THE LAND.
CALL FOR A FREE TRAVEL PLANNER.
Montana's Missouri River Country
1-800-653-1319
www.missouririver.visitmt.com/dine.html

ADVENTURE SMITH EXPEDITIONS
Alaska
Wild Alaska up close and in style. Distinctive small group expeditionary travel since 1978.
AdventureSmithExplorations.com 800-726-2875

ALASKA

Touch the Past...
Archaeology Learning Adventures!

THE EXCAVATED PAST
August 21-27, 2005
LIFE & DEATH IN ANCIENT PERU
September 8-22, 2005
MICHOCAN, MEXICO:
Archaeology, Cultures & Arts
December 2-11, 2005

CROW CANYON ARCHAEOLOGICAL CENTER
Near Mesa Verde in Southwest CO
800-422-8975 / www.crowcanyon.org
Einsteiniana

By Robert Anderson

This year marks the centennial of Einstein’s *annus mirabilis*, a commemoration that, to my mind, is far more significant than the centennial of the great physicist’s birth. In 1905 the young Einstein published a remarkable series of four scientific papers, culminating with his special theory of relativity in June and, in September, a report on the consequences of the theory, his formulation for the equivalence of mass and energy, \( E=mc^2 \). In one year, Einstein produced an outpouring of insights so profound that they set the stage for all of modern physics.

You’ll find a good summary of the papers on a Web page of the American Institute of Physics (AIP): go to www.aip.org/history/einstein and click on “The Great Works—1905.” To listen to Einstein himself explaining his famous formula in English, go to another page of the AIP site (www.aip.org/history/einstein/voice1.html).

Where did Einstein’s great burst of creativity come from? For one kind of answer, have a look at the research conducted by Sandra F. Witelson, a neuroscientist at McMaster University in Hamilton, Ontario, and her colleagues. Working on sections from Einstein’s brain, the team found unusual development in areas of his “gray matter” having to do with visual imagery and mathematical thinking. The Web site www.bioquant.com/gallery/einstein.html includes an image of the famous brain, as part of an excerpt from Witelson’s 1999 paper in the journal *The Lancet*.

The citizens of the Swiss capital, Bern, are interested in preserving the apartment at number forty-nine Kramgasse, where Einstein lived between 1903 and 1905. You can find photographs and other information about his years in Bern at their Web site (www.einstein-bern.ch). Still another source of Einsteiniana is the Einstein Papers Project (www.einstein.caltech.edu). Filed away in the project’s archives are copies of more than 40,000 documents from Einstein’s estate (the originals were bequeathed to the Hebrew University of Jerusalem). At the site you can browse through the papers that the project has already translated by clicking on “Albert Einstein Archives Online.”

If you care less about the facts and events of the man’s life and more about his discoveries, you can access the online site (www.amnh.org/exhibitions/einstein) of an exhibition that originated at the American Museum of Natural History in New York City (a special Einstein—for-kids page is at www.ology.amnh.org/einstein/index.html). Another source of facts can be found at the Web site of the PBS NOVA TV series, on a page called “Think Like Einstein” (www.pbs.org/wgbh/nova/time/think.html). And if you’re looking for Einstein in the here—and-now, you can tune in (einstein.stanford.edu) and follow the week-by-week results of experiments devised to test two yet-unverified predictions from Einstein’s general theory of relativity [see “Testing Einstein (Again),” by Arthur Fisher, page 52].

One of the most fitting tributes to Einstein’s “miraculous year” can be found at the site of the “World Year of Physics 2005: Einstein in the 21st Century” (www.physics2005.org). As part of the worldwide celebration, amateur enthusiasts are invited to participate in the “Einstein@Home” project (www.physics2005.org/events/einsteinathom), which aims to find evidence for another of Einstein’s predictions: gravitational waves. The idea is to sift through data from observatories for signals emitted by extremely dense, rapidly rotating stars. Physicists are hoping to enlist the help of a million or more volunteers with personal computers that are “idle” much of the time—such as yours, perhaps. Who knows? Your desktop PC might help confirm one of Einstein’s predictions.

ROBERT ANDERSON is a freelance science writer living in Los Angeles.
The solar system resembled a shooting gallery. Earth’s surface was continually pulverized by crater-forming boulders large and small. Any attempt to jump-start life would have been swiftly aborted. By about 4 billion years ago, though, the impact rate slowed and Earth’s surface temperature began to drop, permitting experiments in complex chemistry to survive and thrive.

Older textbooks start their clocks at the birth of the solar system, and typically declare that life on Earth needed 700 million or 800 million years to form. But that’s not fair: the planet’s chem-lab experiments couldn’t even have begun until the aerial bombardment lightened up. Subtract 600 million years’ worth of impacts right off the top, and you’ve got single-celled organisms emerging from the primordial ooze within a mere 200 million years. Even though scientists continue to be stumped about how life began, nature clearly had no trouble creating the stuff.

In just a few dozen years, astrochemists have gone from knowing nothing of molecules in space, to finding a plethora of them practically everywhere. Moreover, in the past decade astrophysicists have confirmed that planets orbit other stars, and that every exosolar star system is laden with the same top four ingredients of life as our own cosmic home is. Although no one expects to find life on a star, even a thousand-degree “cool” one, Earth has plenty of life in places that register several hundred degrees. Taken together, these discoveries suggest it’s reasonable to think of the universe as fundamentally familiar rather than as utterly alien.

But how familiar? Are all life-forms likely to be like Earth’s—carbon-based and committed to water as their favorite fluid?

Take silicon, one of the top ten elements in the universe. In the periodic table, silicon sits directly below carbon, indicating that they have an identical configuration of electrons in their outer shells. Like carbon, silicon can bind with one, two, three, or four other atoms. Under the right conditions, it can also make long-chain molecules. Since silicon offers chemical opportunities similar to those of carbon, why couldn’t life be based on silicon?

One problem with silicon—is apart from its being a tenth as abundant as carbon—is the strong bonds it creates. When you link silicon and oxygen, for instance, you don’t get the seeds of organic chemistry; you get rocks. On Earth, that’s chemistry with a long shelf life. To have chemistry that’s friendly to organisms, you need bonds that are strong enough to survive mild assaults on the local environment but not so strong that they don’t allow further experiments to take place.

And how important is liquid water? Is it the only medium suitable for chemistry experiments, the only medium that can shuttle nutrients from one part of an organism to another? Maybe life just needs a liquid. Ammonia is common. So is ethanol. Both are drawn from the most abundant ingredients in the universe. Ammonia mixed with water has a vastly lower freezing point (around -100 degrees Fahrenheit) than does water by itself (32 degrees), broadening the conditions under which you might find liquid-loving life. Or here’s another possibility: on a world that lacks an internal heat source, orbits far from its host star, and is altogether bone-cold, normally gaseous methane might become the liquid of choice.

This past January 14, the European Space Agency’s Huygens probe (named after you-know-who) landed on Saturn’s largest moon, Titan, which hosts lots of organic chemistry and supports an atmosphere ten times thicker than Earth’s. Setting aside the planets Jupiter, Saturn, Uranus, and Neptune, each made entirely of gas and having no rigid surface, only four objects in our solar system have an atmosphere of any significance: Venus, Earth, Mars, and Titan.

Titan was not an accidental target of exploration. Its impressive résumé of molecules includes water, ammonia, methane, and ethane, as well as the multi-ringed compounds known as polycyclic aromatic hydrocarbons. The water ice is so cold it’s as hard as concrete. But the combination of temperature and air pressure has liquefied the methane, and the first images sent back from Huygens seem to show streams, rivers, and lakes of the stuff [see photograph on page 15]. In some ways Titan’s surface chemistry resembles that of the young Earth, which accounts for why so many astrobiologists view Titan as a “living” laboratory for studying Earth’s distant past. Indeed, experiments conducted two decades ago show that adding water and a bit of acid to the organic ooze produced by irradiating the gases that make up Titan’s hazy atmosphere yields sixteen amino acids.

Recently, biologists have learned that planet Earth may harbor a greater biomass belowground than on its surface. Ongoing investigations about the hardy habits of life demonstrate time and again that it recognizes few boundaries. Once stereotyped as kooky scientists in search of little green men on nearby planets, investigators who ponder the limits of life are now sophisticated hybrids, exploiting the tools of not only astrophysics, biology, and chemistry but also geology and paleontology as they pursue life—here, there, and everywhere.

Many astrobiologists view Titan as a “living” laboratory for studying the young Earth.

Seeing Red

In distant galaxies that shine with a ruddy glow are stars that look older than the universe that begat them.

By Charles Liu

T
to an astronomer, color is just as important as it is to an interior designer—though in quite a different way. To both, what the eye perceives as red is light of relatively long wavelength; the wavelength of the light the eye perceives as blue is relatively short. The designer, however, seeks the complex balance of wavelengths that, like the notes in a musical chord, gives a unified color tone to create a mood—a crimson, say, a scarlet, or a cardinal. The astronomer’s colors are equally complex, but here it is the parts that are important, the individual, single-wavelength colors into which the spectrum of a distant star or galaxy can be analyzed.

The many colors of starlight, it turns out, can reveal a great deal about a star—including its age. Statistically speaking, long-lived stars emit more long-wavelength light than short-lived stars do. The most massive stars in the cosmos are also the bluest and brightest, and they tend to explode, as supernovae, after at most a few million years. Stars of lower mass and luminosity, however, glow dimly with red light for billions of years: the redder the star is, the older it is. So if, for instance, a large population of stars forms in a relatively short time, with a broad mix of stellar masses and luminosities, the combined light from those stars is relatively blue at first and then reddens gradually with age.

Astronomers have long exploited this correlation between age and color to study the ages of stellar populations in star clusters and galaxies. Time and again, such study has led to new and fascinating scientific puzzles. In the past few years, for instance, observations of numerous distant galaxies whose light dates to the earliest years of the universe have posed a bewildering paradox: some of these galaxies appear to be older than the universe that begat them. Yet there’s no way these child galaxies can be older than their parent universe.

One possible resolution of the deep-red paradox is as clear as a city sunset.

So why do we astronomers think these galaxies are so old? For one thing, their starlight is very, very red.

If the light emitted from a galaxy looks red, it’s a safe bet that most of its stars are long-lived—and at least some of them are billions of years old. Moreover, if such a galaxy is also billions of light-years from Earth, the effects of cosmological redshift make the galaxy look redder still [see “A Desert No More,” by Charles Liu, June 2004]. Such doubly red galaxies are known as “extremely red objects,” or EROs.

Imagine observing extremely red objects between 9 billion and 12 billion light-years away. Among the nearer EROs, based on their redshift, are stars at least 4 billion years old, as indicated by their starlight colors. Among the farther EROs are stars at least 2 billion years old. Now do the math: stars in the closer EROs must have started forming 9 billion plus 4 billion, or 13 billion, years ago; the more distant EROs must have formed 12 billion plus 2 billion, or 14 billion, years ago.

That’s the problem. The universe is about 13.7 billion years old, according to the best current measurements. How can distant EROs include stars that were born before the cosmos itself?

Well, of course, they can’t. There must be another explanation. One possibility is as clear as a city sunset. Particles in dust in Earth’s atmosphere along the line of sight tend to absorb blue light more effectively than red light. That’s why the setting sun looks redder over a polluted urban skyline than it does over a pristine seascape. For the same reason, EROs might be made up simply of younger stars, heavily enshrouded by dusty gas. The dust would redden their outgoing starlight, thereby making them look like an older stellar population.

In some cases, at least, dust may be the solution. A recent study of 275 EROs between 6 billion and 10 billion light-years away, led by Leonidas A. Moustakas of the Space Telescope Science Institute in Baltimore, showed that there’s no way to distinguish “dust-free old-star” EROs from “dusty young-star” EROs by looking at galaxy colors alone. Dust, the investigators report, could be causing the EROs’ extremely red colors. Furthermore, their study demonstrated that EROs can take any shape, from the ellipsoid traditionally associated with old-star galaxies to the disk or irregular shapes typical of young-star galaxies.

Another recent study, however, led by Natascha M. Förster Schreiber of the Max Planck Institute for Extraterrestrial Physics in Garching, Germany, reached a different conclusion. Schreiber’s group examined thirty-four EROs between 10 billion and 12 billion light-years away, comparing ERO colors with color models of starlight and dust reddening. They determined that dust alone cannot account for the extreme redness of many of the EROs.
in their sample. These galaxies, they report, really do include old stars, and the measured ages of the stars, though imprecise, are still high enough to make cosmologists sweat just a little.

Extremely red objects in the distant universe are reminders of how much astronomers still don’t understand about the birth and aging of stars and galaxies. Everyone agrees that EROs probably play a big part in that story. The study by Moustakas and his colleagues, for instance, noted that the number of ellipsoidal EROs in the distant universe is about the same as the number of giant elliptical galaxies in the nearby universe. Are many EROs, then, juvenile ellipticals, destined to grow bigger? Just as children seem ruddier than their parents, some galaxies may show the same tendency until they, too, grow old.

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

By Joe Rao

THE SKY IN MARCH

Mercury is the first planet to look for as the twilight fades in early and mid-March. The little planet is highest and brightest from about March 1 through the 10th. Look low in the west about forty-five minutes after sunset; Mercury is the only bright “star” in the otherwise barren constellation Pisces, the fish.

On the evening of the 1st Mercury shines at magnitude –1.2 and sets more than an hour after the Sun. After the 12th, the planet appears to drop toward the sunset horizon as it moves between the Sun and Earth.

Venus, obscured by the glare of the Sun all month, reaches superior conjunction on the 31st.

Mars, which rises about two-and-a-half hours before sunup, brightens ever so gradually throughout the month from magnitude 1.2 to 0.9. Even at its brightest this month, it still appears as a small, shimming disk. On the morning of the 6th, about an hour before sunrise, you’ll see Mars shining well above the crescent Moon.

Jupiter, in the constellation Virgo, the virgin, rises an hour after dark at the beginning of March and a few minutes earlier every night thereafter. By month’s end, the planet is rising almost at sunset, and becomes as big, bright, and close to Earth as it will be all year.

Saturn is in excellent position for evening viewing: near the top of its daily arc across the sky as twilight ends. Shining at magnitude 0.2, the planet appears with Castor and Pollux, the two brightest stars in the constellation Gemini, the twins. The rings of Saturn are tilted to their maximum extent, twenty-five degrees, for 2005. With a high-power telescope and good atmospheric conditions, you may see the shadow of Saturn on the rings just to the east of the planet’s limb.

The Moon wanes to last quarter on the 3rd at 12:36 P.M. and to new on the 10th at 4:10 A.M. Our satellite waxes to first quarter on the 17th at 2:19 P.M. and to full on the 25th at 3:58 P.M. Early on the morning of the 3rd the Moon appears to occult, or hide, the bright ruddy star Antares above North America. For Easterners the event takes place during bright twilight or after sunrise, but the sight could be spectacular over central and western regions.

The vernal equinox takes place at 7:33 A.M. on the 20th. Spring begins in the Northern Hemisphere; autumn begins in the Southern.

All times are eastern standard times.

Smart Mower for Small Lawns!
The NEUTON® Cordless Electric Mower uses no gas or oil, so it’s quiet, clean, and starts instantly — every time! It is lightweight, so it’s easy for anyone to use. So economical! It costs just 10¢ to mow your lawn and never needs a tune-up. It’s the only lawn mower that will also TRIM around trees and EDGE along your walk or driveway.

You can try a NEUTON® Mower for 6 Months RISK-FREE!

TOLL-FREE 1-800-592-4488

YES! Please rush my FREE Catalog and Video all about the amazing NEUTON® Cordless Electric Mower, and details of your optional Trimmer/Edger Attachment.

Name ____________________________
Address ____________________________
City ____________________________ State __________ ZIP
E-mail ____________________________

Country Home Products®, Dept. 50555X
Melv' Road, P.O. Box 25, Vergennes, Vermont 05491
Freshwater systems—lakes and ponds, rivers and streams, reservoirs, wetlands, and groundwater—are essential for our survival. In addition to providing goods and services such as drinking water, energy, recreation, food, and nutrient cycling, freshwater systems support an immense variety of life. Despite their importance and decades of protection efforts, freshwater species and habitats are being lost or degraded at an alarming rate. Increased demand from industry and agriculture, introduced species (for example, the now-ubiquitous zebra mussel), and ongoing alteration in the form of dams and canals are primary causes. There is an urgent need for the development and application of innovative approaches to freshwater conservation and for the sharing of success stories.

On April 7 and 8, 2005, the Museum’s Center for Biodiversity and Conservation will host a forum for scientists and conservation practitioners to showcase recent successful initiatives in freshwater conservation and to discuss how and where cutting-edge ideas and tools can be implemented. The symposium will examine projects that not only integrate scientific fields, but also link science with other disciplines. Talks will highlight innovative methods used by local communities to manage their freshwater resources, the use of economic valuation to support conservation efforts, and the importance of science-based policy and trade initiatives. This cross-disciplinary integration will generate a fertile environment for discussing the future of freshwater conservation. Promising new tools and approaches will be explored, including advances in remote sensing, the application of molecular research, the use of underwater videography, alternative futures analyses, and environmental flow methods.

International participation is expected, with speakers from Asia, Australia, Africa, Europe, and North and South America presenting their work on rivers, lakes, wetlands, and subterranean systems. Each expert will highlight lessons learned from their projects, emphasizing those findings that can transfer to different regions and habitats. Among the three hundred or more speakers, poster presenters, and attendees will be representatives from nonprofit, government, development, and research sectors, among others.

The two-day symposium will be divided into four main sessions, beginning with a focus on innovations in understanding freshwater systems—their species, habitats, and processes, as well as what threatens them. The symposium’s two keynote addresses, scheduled during the first day’s presentations, will be delivered by the U.S. Fish and Wildlife Service’s Assistant Director for Fisheries and Habitat Conservation, Dr. Marnie Parker, and the Museum’s Axelrod Research Curator of Ichthyology, Dr. Melanie Stiassny. The second session will highlight new methods of planning for conservation. This will be followed by a discussion of effective ways of putting conservation plans into practice. The closing session will explore innovations in evaluating and monitoring outcomes. The symposium will conclude with a synthesis, identifying important commonalities among the case studies and lessons that might be applied broadly.

New Currents is geared toward a professional audience, and interested members of the public are encouraged to attend. For more information and to register please go to http://cbc.amnh.org/symposia/freshwater/index.html.

New Currents in Conserving Freshwater Systems is sponsored by the Center for Biodiversity and Conservation in collaboration with the World Wildlife Fund, the U.S. Fish and Wildlife Service, and the National Park Service. Funding is provided by Daniel and Sheryl Tishman and by the National Oceanic and Atmospheric Administration; Additional support is provided by The Conservation Trust of the National Geographic Society, the American Society of Ichthyologists and Herpetologists, The Nature Conservancy, and the American Fisheries Society.
Before planets around stars other than our Sun were first discovered nearly a decade ago, many scientists expected alien solar systems to resemble our own, with small rocky planets close to their stars and large gaseous planets farther away. But what we've found instead are predominately Jupiter-sized or larger planets as close to their host stars, or closer, as tiny Mercury is from our Sun. These systems force us to question whether our own solar system is the rule or the exception.

Join Neil deGrasse Tyson, Frederick P. Rose Director of the Hayden Planetarium, and this panel of experts in planetary science as they discuss why our solar system looks the way it does and why others we've detected look so different.

Fritz Benedict, University of Texas, longtime observer of planetary systems
Paul Butler, Carnegie Institution of Washington, codiscoverer of more than two-thirds all known exoplanets
Peter Goldreich, California Institute of Technology, theorist with expertise on the formation of planets, asteroids, and comets
Scott Tremaine, Princeton University, expert on the gravitational interactions between a star and its planets
Margaret Turnbull, Carnegie Institution of Washington, planet hunter and expert on habitable zones around stars

The first direct evidence that some primitive mammals fed on dinosaurs is shown here. The fossil of a 130-million-year-old opossum-sized mammal, Repenomamus robustus, with a juvenile psittacosaur preserved in its stomach area was unveiled at the American Museum of Natural History on January 12, 2005. The remarkable finding was described in the journal Nature by Meng Jin, Associate Curator, Division of Paleontology; his graduate student Hu Yoming; and colleagues at the Institute of Vertebrate Paleontology and Paleoanthropology in Beijing. Exciting new findings such as this are among the topics of the upcoming exhibition, Dinosaurs: Ancient Fossils, New Discoveries, opening May 14, 2005. Also, visit www.amnh.org to learn about the public display of R. robustus.

Living in America, the Museum's annual series of weekend programs that focuses each January on a different cultural group in the U.S., this year highlighted Native Americans of the Northeast. Here, the Mohawk Singers and Dancers perform in their colorful traditional regalia.
Museum Events
AMERICAN MUSEUM OF NATURAL HISTORY

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

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

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

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

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

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

GLOBAL WEEKENDS
SPRING EQUINOX FESTIVAL
Sunday, March 20
Science of the Sun
11:00 a.m.—1:30 p.m.
Explore the Sun’s energy on the Ross Terrace.

Paper from Scratch
12:00 noon—1:30 p.m. (Ages 4–6, each child with one adult)
1:30—2:30 p.m. (Ages 6–8)
3:00—4:00 p.m. (Ages 8–10)
Learn how to make beautiful recycled paper.

Eggceptional Art
12:00 noon—1:30 p.m. (Ages 6–8, each child with one adult)
2:30—4:00 p.m. (Ages 8–10)
Learn about the mythology of spring eggs across cultures, and decorate your own delicate creations.

City That Drinks the Mountain Sky
2:30—3:30 p.m.
Arm-of-the-Sea Theater tells the epic story of NYC’s water supply through poetry, puppetry, and music.

Global Weekends are made possible, in part, by The Coca-Cola Company, the City of New York, and the New York City Council. Additional support has been provided by the May and Samuel Rudin Family Foundation, Inc., the Tolman Family, and the family of Frederick H. Leonhardt.

LECTURES
400 Million Years on Six Legs
Tuesday, 3/1, 7:00—8:30 p.m.
David A. Grimaldi, Division of Invertebrate Zoology, on major events in insect evolution.

An Evening with Roger Rosenblatt: “The Narrative Species”
Thursday, 3/10, 7:00–8:30 p.m.
One of America’s finest writers discusses the power, sanctity, and mystery of writing and storytelling in human experience.

Diamond Discoveries in Canada: New Frontiers in the Arctic
Thursday, 3/24, 7:00–9:00 p.m.
This panel discussion will explore the geology and human impact of recent diamond discoveries in Canada. Moderated by George Harlow, Division of Physical Sciences. Cosponsored by the Canadian Consulate General.

Obsessive Genius: The Inner World of Marie Curie
Thursday, 3/24, 7:00 p.m.
Barbara Goldsmith offers a fresh look at the life of this famous woman, a scientist, wife, and mother.
FAMILY AND CHILDREN'S PROGRAMS

Space Explorers: Myths and Constellations of the Spring Sky
Tuesday, 3/8, 4:30 p.m.
(Ages 8 and up)
On the second Tuesday of each month, kids (and their parents) can learn under the stars of the Hayden Planetarium.

ID Day
Saturday, 3/12, 1:00–4:00 p.m.
Museum scientists will attempt to identify treasured items and mysterious finds you bring from home.

Southwest Jewelry Arts
Sunday, 3/13, 11:00 a.m.–12:00 noon (Ages 6 and 7, each child with one adult)
Use traditional Native American techniques and materials to create your own jewelry.

Wild, Wild World: Predators
Saturday, 3/26, 12:00 noon–1:00 p.m. and 2:00–3:00 p.m.
Live-animal presentation with a golden eagle, alligator, python, and cougar cub.

Dr. Nebula's Laboratory: Light and Optics
Saturday, 3/12, 2:00–3:00 p.m.
(For families with children ages 4 and up)
Dr. Nebula's apprentice Scooter exposes the mystery of light and its colors.

HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME

Virtual Universe
Messier Tour
Tuesday, 3/1, 6:30–7:30 p.m.

This Just In...
March's Hot Topics
Tuesday, 3/15, 6:30–7:30 p.m.

Celestial Highlights
The Lion King of the Sky
Tuesday, 3/22, 6:30–7:30 p.m.

END OF THE WORLD AND... CHILDREN'S PROGRAM

Five Wednesdays, 3/2–3/29
3:00–4:30 p.m.
Lecture
Parallel Worlds
Monday, 3/7, 7:30 p.m.

PLANETARIUM SHOWS

SonicVision
Fridays and Saturdays, 7:30, 8:30, and 9:30 p.m.

Hypnotic visuals and rhythms take viewers on a ride through fantastical dreamspace.

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

The Search for Life: Are We Alone?
Narrated by Harrison Ford
Made possible through the generous support of Swiss Re.

Passport to the Universe
Narrated by Tom Hanks
Tuesday, 3/2, 6:00–7:00 p.m.

STARry NIGHTS

Live Jazz

ROSe CENTER FOR EaRTH AND SPACE

Friday, March 4
6:00 and 7:30 p.m.

Starry Nights is made possible by Lead Sponsor Verizon and Associate Sponsor NewEnergy.

Spend $10 or more at the Planetarium Shop and get a free Rose Center pennant.

INFORMATION

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

TICKETS AND REGISTRATION

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

AMNH eNotes delivers the latest information on Museum programs and events to you monthly via email. Visit www.amnh.org to sign up today!

LARGE-FORMAT FILMS

LeFrak Theater
Vikings
Discover the historical and technological achievements of this legendary society of seafaring explorers.

Jane Goodall's
Wild Chimpanzees
This breathtaking film takes visitors into the realm of our closest animal relatives.

The contents of these pages are provided by Natural History by the American Museum of Natural History.
Drama at My Feet

By Don Dailey

On a backpacking trip in the Sierra Nevada some years ago, I was sitting in quiet contemplation at my campsite beside a small alpine lake, when I became aware of a flurry of activity going on around me. Narrowing my senses to ground level, I was drawn into a bustling world of miniature creatures. As I watched, several kinds of ants crossed my view, followed by a tiny red mite, a sizable wolf spider, and two colorful jumping spiders. At least three species of fly landed in plain sight, "tasting" the landscape with their feet. A grasshopper materialized, then several hornets, two shiny black wasps, a drab brown damselfly, and a large azure-blue dragonfly.

Already engrossed in the passing scene, I saw something that was to capture my rapt attention for hours to come. In a shallow depression of granite, I noticed what appeared to be a large black insect. Moving closer, I saw the "insect" was really two large carpenter ants. These giants of the ant family, each at least three-quarters of an inch long, were tightly locked together, jaw-to-jaw, and fiercely immobile except for an occasional twitching leg. Apparently of different species—one was totally black and the other had a black body but maroon legs—the two had been left behind, I surmised, from a major military engagement somewhere close by, an operation probably involving entire tribes of their kind. Once joined in mortal struggle, were they unable, or unwilling, to disengage?

Then I made a grisly discovery: neither ant possessed a complete set of legs. Even more appalling, the severed head of another ant was clamped, by its jaws, in a death-grip to one antenna of the all-black ant. I imagined the epic battle that must have taken place, fought with a ferocity I had only read about as a boy. The two ants remained locked together for nearly two hours, and though I was tempted to poke the gladiators into a more animated contest, I decided not to interfere. I felt privileged to be witnessing such an awesome display of resolve. It seemed that fighting, even to the death, was what eons of evolution had programmed them to do.

Suddenly a much smaller ant appeared. The intruder took a few moments to size up the situation before approaching the all-black ant, grabbing it by the antenna to which the severed head was attached, and dragging it into a nearby bush. Resistance proved futile. The hapless, nearly legless victim was unable to get a firm grip on the rock, and the smaller ant had no trouble hauling the larger ant away.

I returned my attention to the remaining combatant. It had taken a terrible beating. Only one of its antennae was complete, and of its former complement of six legs, only two remained fully intact—one leg was missing, two had been reduced to short stubs, and the last was bent ninety degrees at the terminal joint. Reduced to a crawl, it wandered in circles, unable to set a straight course. Occasionally it threw back its head, jaws agape, possibly in a gesture of frustration, or perhaps in reaction to the torment it must surely have been suffering.

I watched the ant for two hours more, spellbound by its heroic struggle. Eventually the sky began to darken, and I had to leave the scene to prepare my evening meal. When I came back to my spot a short time later, the ant was gone. The finale of another of life's countless dramas had been enacted, and my miniscule warrior had blended back into its world, one small dimension of this beautiful and peaceful place in the mountains.

Don Dailey is a retired science teacher living in Quincy, California.
Because I can read,
I can understand. I can write a letter.
I can fill out a job application.
I can finally get off welfare.

Because I can read,
I can learn. I can help my daughter
with her homework.
I can inspire her to be better.
I can be a role model.

Because I can read,
I can succeed, I can
contribute. I can live
my life without fear,
without shame.
I can be whatever
I want to be.

Because I can read.

National Center for Family Literacy

Literacy can make the difference between poverty and progress. Visit www.famlit.org to help us write more success stories.

©2005  Photographer: Marvin Young
a monument to love, an ode in white.
a caravan of colours, bathed in light.
a river of passion, a timeless tide.
the colours of india, an incredible sight.