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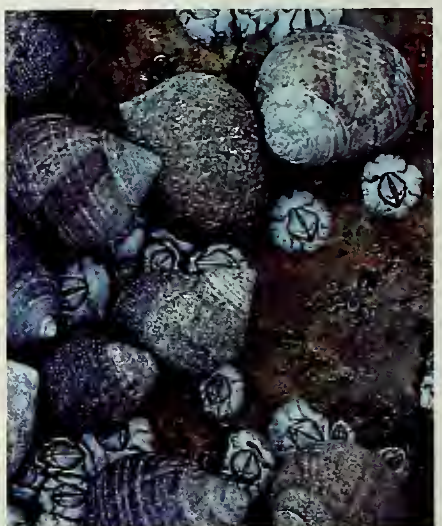
COVER: *A European brown hare in a meadow stays alert to danger. If it sees a dog, it usually crouches; but if it sees a fox, it often stands. Why? Story on page 42. Photograph by E.A. Janes.*

On a misty summer morning, a tidal pool on the coast of Maine may seem timeless and tranquil, but it is neither. Over geologic and historic time, many marine



organisms have gone extinct along the Atlantic coast of North America. New species from around the world have invaded our shores, radically changing the mix of occupants and even the appearance of the seaweed. Humans have caused many changes in recent centuries. To unravel these life-and-death tales, scientists carefully study fossils, the tidal pools' current inhabitants and their relatives, and old shell collections squirreled away in museum drawers.

The fox is a dangerous predator for the brown hare in Europe. So why, wondered a nocturnal naturalist, does a hare stand up conspicuously on its hind legs when a ntents

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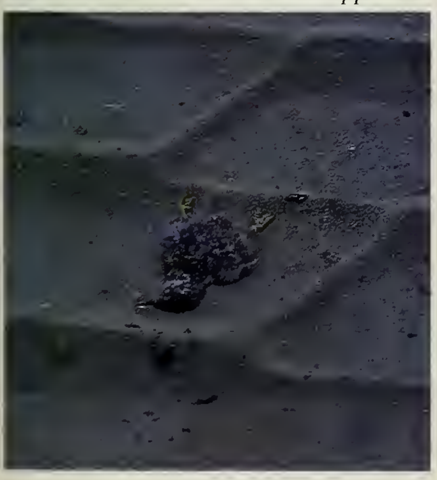
fox approaches? After observing thousands of hours of interactions on the Somerset plains of England, he concludes that the hare is telling the fox, "I see you. Don't waste your energy—or mine—by chasing me, since I can run faster than you can."



God's Own Scientists

A creationist study group grapples with Darwin

by Christopher P. Toumey

On the second Thursday of the month, for nine or ten months each year, a small number of men gather at the comfortable suburban home of a science professor at a major North Carolina public university. The group's object is the serious study of the scientific case for creationism, and its regular members include another science professor from the same university, a computer engineer, an electronics technician, two lab scientists, and two medical doctors. Others who attend occasionally are college students, electrical engineers, and more lab scientists. Preachers come by rarely.

The participants begin to arrive about 7:15 in the evening and proceed to a paneled den at the back of the house. There they chat about jobs and families, trading comments about computer software, laboratory procedures, and their children's schools, or they browse through *National Geographic*, *American Scientist*, or evangelical magazines such as *Christianity Today* and *Moody Monthly*. When all who are expected have arrived, the second science professor begins the meeting with an evangelical prayer, in which he asks God to bless their evening together and enlighten them.

Since many in the group also attend weekly Bible study groups on Wednesday nights at their homes or churches, the lessons from those meetings often influence the Thursday sessions. For example, over many months (while I attended as an anthropologist—and evolutionist—researching creationism in modern America), they kept up an irregular commentary on the meaning of the Hebrew word *yom*, which is the word for *day* in the six days of Creation in Genesis. In modern creationist orthodoxy, as handed down by Henry M. Morris, a former engineering professor in southern California, the days of Creation are literal, twenty-four-hour days. To discourage figure-of-speech interpretations of *yom*, Morris teaches that *yom* has the same meaning in every biblical verse in which it appears. Members of the study group follow Morris's teachings, and some attend conservative Bible study groups that take a similar, literalistic interpretation. Others, who attend less structured Bible study groups, say they have heard that *yom* usually means twenty-four hours, but that it sometimes could be a figure of speech, as in, "In the day of prosperity be joyful" (Eccl. 7:14) or "the day of the Lord" (Isa. 2:12).

Mostly, however, the meetings are technically oriented, as the participants seek to relate scientific evidence to creationism. At the first meeting I attended, the topic was the cosmological theory of the inflationary universe as proposed by physicist Alan Guth. The leader of the discussion, the science professor who hosted the group, began by summarizing several articles he had read recently in *American Scientist*, *Science*, and *Scientific American*. Neither he nor anyone else in the room claimed any special expertise in astrophysics; they behaved like any other curious group of intelligent nonphysicists trying to understand new developments in physics. No one tried to make Guth's model conform to biblical imagery; no one even mentioned the Bible during that evening's discussion.

Henry Morris and his followers believe that the six-day Creation and Noah's Flood were historical events whose authenticity supports a conservative interpretation of Judeo-Christian morality. They also believe, however, that scientific evidence for the Creation and the Flood can be distinguished from the words of Genesis. This data, they argue, can be honestly studied and taught as science in the public schools without violating the constitutional separation of church and state. With this reasoning, the members of the discussion group want their arguments on behalf of creationism to be scientifically credible, and they worry about this very much.

For example, one of the participants became interested in the theories of Barry Setterfield, an Australian creationist who asserts that the speed of light was much greater in the past, but that it has since decreased, leveling off fairly recently at the rate we know today, about 186,000 miles per second. Setterfield's calculations dovetail nicely with certain creationist chronologies that say the universe is less than 10,000 years old. But one of the group leaders cautioned against Setterfield's theory. He had asked Henry Morris about it, he said, and Morris had told him that the staff physicist at Morris's Institute for Creation Research was very skeptical about Setterfield. After that, they did not raise the subject again.

Often the evening emphasizes an educational program, of about an hour's length, produced by Henry Morris's institute—a film, tape, or, most typically, a slide show. These packaged programs tell the group little that they have not already heard, but the members nevertheless study the messages carefully, for they will be expected to bring these programs to their own Bible study groups, Sunday schools, and churches. Five or six of the members

Adapted from *God's Own Scientists: Creationists in a Secular World*, by Christopher P. Toumey (New Brunswick: Rutgers University Press, 1994)

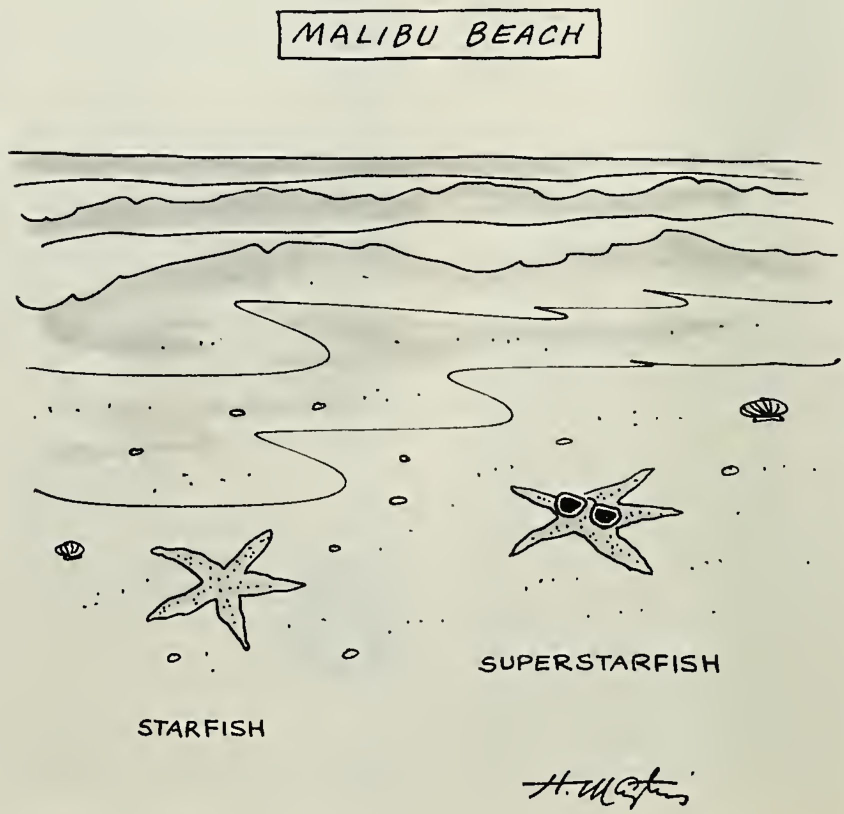
have spoken often in public on behalf of scientific creationism, so they are comfortable rearranging and editing these materials to suit themselves, but otherwise they defer very modestly to Morris's authority, which they never challenge.

The creationists turn to Henry Morris for more than just technical expertise: he is their hero, their inspiration. One of the founders of the group, an electronics engineer, traces his commitment to scientific creationism to the time he met Morris in San Diego. He says he was greatly impressed that Morris, a distinguished fellow engineer, explained creationism and the problems of evolution in terms of their common professional standards; before that, he had thought that creationism was only a religious idea.

These creationists also admire Henry Morris for several biblical commentaries he has written, one on Genesis and another on Revelation. They play no role in the group's scientific discussions because their content is traditional biblical exegesis, not technical information, but these volumes remind the local creationists that Morris is a spiritual leader, as well as a scientific authority. They say to one another that it's amazing that one man can do so much. This kind of comment then leads into folklore about the life of Henry Morris. According to one story I heard several times, Morris is a workaholic who, fortified by strong coffee, often stays up all night writing. Another tells of Morris's anguish over a son who was dissolute and disrespectful, but who, because of Morris's perseverance in his ministry, had a change of heart and became a reputable Christian.

One memorable evening, in place of the usual format, the group arranged for space at a church and invited the public to a special presentation by a man they had heard was a good creationist speaker. About fifty people came to hear Arleton C. Murray, a short, pudgy man with receding gray hair, who called himself Mr. Fossil. He appeared wearing a khaki bush jacket with a *Tyrannosaurus rex* embroidered on the left breast, a small badge reading "Creation scientist" on the right lapel, and a Gideon's badge on the left lapel (the Gideons are Christian businessmen best known for distributing Bibles to the public).

After the opening prayer and a vague introduction, Mr. Fossil explained that many years earlier he had been a fossil preparator in the Department of Vertebrate Paleontology at the Smithsonian Institu-



tion. He had been very interested in nature ever since childhood, he said, but he was told that "it never had God behind it." While at the Smithsonian, "I didn't know about Jesus Christ as my savior. I used to annoy prayer meetings; I was interested in drinking liquor and smoking cigars." One night, he continued, he went to an evangelical revival in Greenbelt, Maryland, intending to scoff at the preacher. Instead, he told us, he was moved by the things the preacher said and became a Christian that night. Soon afterward, he started speaking out against evolution.

He went on to say that the Smithsonian paleontologists heard about an antievolutionary talk he gave at Washington Bible College. His boss confronted him the next day, demanding that he cease such activities. "He said I had to, but I said I didn't have to, and I just walked out and never went back."

From this point on, Mr. Fossil illustrated his talk with exciting slides of his finding dinosaur fossils, excavating them, and reassembling them at the museum. As he related his fossil-finding experiences in Nebraska and Panama, he easily won the respect of the audience: here was a creationist who undoubtedly was a scientist.

Next he launched a venomous attack on evolution. "All museums teach the doctrine of evolution," he said. "They're all Karl Marx." He declared that "Fossils are the Waterloo of evolution," that the fossil rooms of the museums are "taboo to the public; they might find out something.... Evolution is a fake and a lie of the Devil.... Evolutionists actually believe a watch would evolve from a hairspring and filings."

This was fundamentalist preaching at its finest, faithfully following the classic pattern of first confessing a sinful life, then describing the personal conversion, and finally atoning by exposing the lurid secrets of the evildoers. But Mr. Fossil was not through yet. After dismissing evolution, he led the audience through his own scientific case for creationism. Fossils, he said, are evidence of the Flood. For example, the deposits at Agate Springs, near Carnegie Hill, in Nebraska contain numerous species together. "Only a great catastrophe like a flood could mix them all together like this." Furthermore, the fossil forms of leaves, shrimps, tapirs, and starfish are just like today's forms, showing no sign of change.

By this point, the members of the local creationist group were beaming, enjoying every minute of this presentation. But as he neared the end of his talk, Mr. Fossil declared that dinosaurs and men had never lived together. Dinosaurs did not become extinct in Noah's Flood, he explained; they perished in a previous catastrophe he called Lucifer's Flood. After that, the world became "without form, and void" (Gen. 1:2). The six-day Creation, according to Mr. Fossil, was consequently a re-creation of the earth and its creatures, now including man.

I don't think many in the audience noticed anything amiss in this explanation, but I saw that the local creationist leaders were aghast. In terms of Henry Morris's creationist orthodoxy, Mr. Fossil was presenting the heresy called Gap Theory, meaning there was a long period of time, a gap, between the events of the first and second verses of Genesis. Thus many geological changes could have happened before the six-day Creation. Still worse, Mr. Fossil then attacked Henry Morris personally, saying, "Morris and his friends know nothing about fossils; Morris is an engineer, not a paleontologist."

Mr. Fossil justified his own theory of Lucifer's Flood by saying it came to him "as the spirit moved me." This was a perfectly credible explanation to most in the fundamentalist audience, but wholly out of place to those sensitive to issues of scientific evidence. After a very brief question-and-answer session, the moderator, who was plainly rattled by Mr. Fossil's comments, abruptly ended the evening's program by saying meekly, "Well, uh, this shows you that not all creationists agree on everything."

At the group's next meeting, the previous month's debacle was the first item of discussion. One of the leaders said he had asked some people about Mr. Fossil and had a story to tell. It seemed that Henry Morris had once been on the verge of having Mr. Fossil run the Institute for Creation Research's Museum of Creation, which at that time consisted of four small rooms at the back of the institute's headquarters. Morris apparently did not anticipate Mr. Fossil's views on biblical floods, and Mr. Fossil had not yet seen the museum displays, which categorically excluded Gap Theory and Lucifer's Flood. At first the two men hit it off well, but when Mr. Fossil saw the exhibits, he sized up the situation and left quickly, never to return. At this, the local creationists listening to the story laughed. The tension had been broken. True, they had let themselves be hoodwinked by Mr. Fossil, but so had Henry Morris. With this perspective, their embarrassment wasn't so bad after all.

The same evening, they turned to a slide show that discussed adaptation in the natural world. The show had two things to say about adaptation. First, adaptation is evidence of God's design. When a creature's behavior and anatomy are intimately related to the environmental conditions around it, this can be interpreted to mean that God has planned the natural world very carefully. Second, the slide show distinguished adaptation from speciation, calling the first "microevolution" and the second "macroevolution." It accepted that adaptation occurs, and that it is observable, giving the classic example of the English peppered moths, wherein scientists documented a dramatic change in the proportion of darker colored moths in the population. The creationist position was that this was only microevolution, and provided no support for the view that new species evolve.

In the group's discussion following the slide show, one of the creationists surprised me by saying very emphatically that the case of the peppered moths proves what the evolutionists allege about adaptation; he went on to say that he believed in *some* evolution, that *some* evolution does occur. Another then chimed in to say that natural selection occurs regularly in nature, just as the evolutionists claim it does. From this exchange and others, I saw that the members of the creationist study group could be flexible in their beliefs when gathering privately, although in public appearances and public statements they tended to close ranks in defending their orthodoxy.

One evening we viewed a creationist film about hominid fossils. Its narrator discussed the Piltdown Man and Nebraska Man hoaxes to make the point that evolutionary assumptions lead to foolish mistakes. He also compared the teeth and jaws of a young girl with those of a chimpanzee to suggest that it was easy to overemphasize superficial similarities and overlook important differences. The movie concluded with the idea that anatomical similarities between species should be interpreted as functional similarities designed by God, not as evolutionary links from common ancestry.

After the film, one of the leaders turned to me, saying, "Chris, you're an anthropologist. You probably know these fossils better than we do. Maybe you can tell us what weaknesses the film had that we didn't notice because we're creationists." As tactfully as I could, I replied that this film, like much creationists literature, described differences between hominid fossils in terms of two extreme polarities, labeling them either as obvious apes or as modern humans, with nothing transitional in between. However, I went on, there is a credible continuum of fossil features between the apelike early australopithecines and the recent Cro-Magnons.

One of the creationists responded that he'd heard that Neanderthal skulls fit within the range of modern human variation, and asked if this were true. "The largest and most rugged modern human skulls," I replied, "are probably Eskimo skulls. Neanderthal skulls are probably more rugged than those." At that point another of the creationists, a veterinarian, commented that if Neanderthals were within the modern human range, as creationists say, even if at the end of the range adjacent to Eskimos, the creationist scientists ought to be able to find some Neanderthals in the world's population today. None of us knew what to say to that.

Next, I was asked my opinion about studies of chimpanzee communication. "They show chimps are very clever," I responded, "but they don't prove chimps have human language capacities or that chimp communication is a prototype of human language." I added that many anthropologists are less skeptical than I am about this. The veterinarian observed that many animals are clever, but that this does not prove evolution. He then went on to emphasize how intelligent some animals are, telling us of his familiarity with animals and his concerns about animal welfare in research labs. He almost seemed on the brink of acknowledging a continuum between humans and animals. Suddenly, however, he switched to a rambling tirade about how evolutionists do not want to admit that they're living in sin.

Now the discussion had come full circle, back to hearty denunciations of evolution. A doctor remarked, "I've studied Darwin and the other evolutionists carefully, and I've found that there's nothing in it worth believing. Sure, the peppered moths changed, but that's just genetic variation, not evolution."

At this point, the meeting came to its logical end. To my surprise, I was invited to lead the closing prayer. I thought to say no. I'm the anthropologist, the observer, the evolutionist, the guy you don't really want to lead you in prayer. But I saw that they were showing appreciation for my words about fossils and chimps, or at least their honesty, if not their substance. This meant that the creationists' discussions in response to my comments had been good, that I hadn't derailed the meeting.

I stifled my instinct, as a Catholic, to blurt out a Hail Mary—not the kind of prayer I had been invited to lead. In my mind I reviewed the common pattern of evangelical prayer—I had heard many hundreds over the previous years—and began in a calm, clear voice:

God our Father, as we gather here tonight in your heavenly presence, we're really glad to be able to come together again to study the wonders of your Creation, and to share fellowship with each other for this purpose. We're happy that these folks have been able to be here tonight. We don't always understand what you mean in the Creation you've given us, and we don't always agree about it. But we're thankful for this wonderful gift you've given us. We say this in Jesus' name. Amen.

When I got home that night, I wondered whether by leading the prayer I had in some way deceived these creationists about my work or my beliefs. I had told them many times that I was not a creationist and was not trying to pose as one. When pressed about my personal views on evolution and science, I'd say that I was a Catholic, that I got my faith and morals from revelation and inspiration, not from biology or geology or anthropology. To me, I would explain, evolution is an empirical fact, not a spiritual truth; I do not search it for God or godliness.

But since I seldom volunteered my own views at the group's meetings, and did not argue against creationism, they might have thought I agreed with their creationist beliefs, or was drifting toward them. With this in mind, I was concerned that saying the prayer could have added to that impression. But I needn't have worried. Following that evening, they took to introducing me to other creationists by saying, "This is Chris Toumey. He's an evolutionist, but he's our friend." □

The Struggle for the Schools

Despite a 1987 rebuff from the Supreme Court, creationists are still pushing for equal time in science classes

by Eugenie C. Scott

Late last year, a letter received at the National Center for Science Education from one of our Alaskan members reminded me that even though some things change in the creation–evolution conflict, old battles continue. My job is to help teachers teach evolution when they are pressured not to, and to help people cope with attempts to insert the biblical story of the Creation into science classes. The letter alerted me that the Alaska State Board of Education was debating a requirement that teachers give creationism equal status alongside evolution in science classes, even though the Supreme Court outlawed such "equal time" provisions in 1987. In Alaska, as usually happens when such attempts are made to legally enforce creationism, cooler heads prevailed and the requirement was not added to the guidelines. But more frequently, I am confronted by evolved forms of creationism designed to sidestep the legal prohibitions.

By the turn of the twentieth century, evolutionary theory had captivated the world of science and had even begun to take hold in American textbooks. Some citizens, distressed at these developments, lobbied for legislation against the teaching of evolution in the public schools. John Scopes was convicted under Tennessee's antievolution law in 1925, in the so-called Monkey Trial. Although the Supreme Court struck down such laws in 1968, antievolutionists have never given up the struggle.

Antievolutionism in America is largely the creature of a Christian fundamentalist theology that was built upon five core beliefs, called "the Fundamentals," which had crystallized by about 1915. The first of these argued that the Bible should be read literally, not interpreted. The Bible said not only that God created the universe, but also how—all at one time, over six 24-hour days, and only a few thousand years ago. Evolution contradicted the biblical account of the Creation by proposing that the universe came into being over a vast period of time, and that living forms descended with modification from earlier ones. Most Catholic and Protestant clergy, while stressing the ultimate creative role of the Deity, were willing to leave the details to science, but fundamentalists rejected any such compromise.

Fundamentalists did not oppose evolution just because they believed it contradicted God's Word. After all, so did spherical-earth geology and heliocentrism; but by the early twentieth century, few Christians interpreted the Bible literally on those issues. The evidence of science on the shape and location of the earth is also accepted by most creationists today, although some still argue that the earth is the center of the solar system.

But turn-of-the-century fundamentalists were convinced, as are their modern descendants, that acceptance of evolution breeds not only theological problems but also moral ones. The most influential creationist of this century, Henry M. Morris, has blamed evolutionary theory for "communism, fascism, Freudianism, social Darwinism, behaviorism, Kinseyism, materialism, atheism, and, in the religious world, modernism and neo-orthodoxy." The worry is that if children learn evolution they will reject God. Lacking faith, children may accept "nature red in tooth and claw" as the only morality and fall into evil ways. Believers in evolution, according to Morris, will be lost to salvation and face eternal damnation.

After 1968, when the attempt to exclude evolutionary teaching from the public schools was outlawed by a decision of the Supreme Court (*Epperson* v. *Arkansas*), creationists sought equal time for their own views. Since the teaching of religious beliefs would violate the constitutional separation of church and state, creationists repackaged the Bible as science to give it a legitimate position in the curriculum. The result was the birth of "scientific creationism," the idea that scientific data exist to document the sudden creation of the universe in the not-too-distant past.

Overwhelmingly, scientists who have analyzed these arguments have concluded that creation science misstates evolutionary theory, presents erroneous data, and reveals a gross misunderstanding of the nature of science (*see* "The Flood of Antievolutionism," by Laurie R. Godfrey, *Natural History*, June 1981). But during the 1970s, several organizations, the largest being Morris's Institute for Creation Research, in California, and the Bible-Science Association, in Minnesota, successfully promoted the idea that creationism and evolution should be taught side by side in science classes as "two models" or "two theories." Their appeal for fairness won creation scientists more support than their science.

By the late 1970s, at least twenty-six state legislatures were considering "equal time" laws. Two states, Arkansas and Louisiana, passed such legislation, and both laws were immediately challenged in the courts and struck down. In 1987, the Louisiana case reached the Supreme Court, which proclaimed in *Edwards* v. *Aguillard* that creationism is inherently a religious idea. Its teaching thus represents a state advocacy of religion, violating the establishment clause of the first amendment to the Constitution.

Since 1987, the attempts to give equal time to creation science have dwindled, al-

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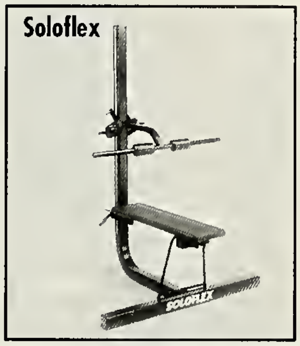

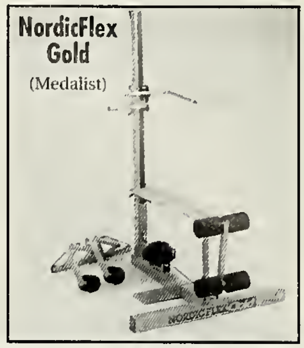

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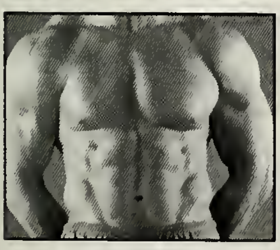

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though they still occur. For example, a school district in Vermont passed a resolution in late 1992 that "creation be presented as a viable theory on an equal status with the various theories of evolution." Once shown to school district lawyers, such resolutions are usually rescinded.

But the Supreme Court decision left a loophole that encouraged creationists to persevere. In *Edwards,* the court recognized that teachers are free to teach "all scientific theories about the origins of humankind." Justice Brennan wrote that "teaching a variety of scientific theories about the origins of humankind to schoolchildren might validly be done with the clear secular intent of enhancing the effectiveness of science instruction." This suggested that alternative theories could be taught, but it ignored that there are no reputable alternatives to evolution as a *scientific* explanation. Antievolutionists were further encouraged by Justice Antonin Scalia's dissenting opinion, when he stated that residents of Louisiana had a right "as a secular matter, to have whatever scientific evidence there may be against evolution presented in their schools."

Antievolutionists thus adopted a new strategy: avoiding Creation, Creator, or any term that implied creationism, they called for equal time to teach that evolution did not occur. This new language appeared quite soon after the *Edwards* decision, in the Texas textbook guidelines for 1990. The Texas Educational Agency told publishers that books submitted for adoption should discuss "scientific evidence of evolution and reliable scientific theories to the contrary." This language also cropped up in August 1991 in Louisville, Ohio, where a school board's science curriculum stated that teachers should "develop an appreciation of theories on evolution and its alternatives." Teachers were supposed to "contrast, compare and discuss alternatives to evolutionary theory."

In May of 1993, the school board in Vista, California, presented a resolution stating that "weaknesses that substantially challenge theories in evolution should be presented." And in December, the Tangipahoa Parish (Louisiana) school board, quoting from the *Edwards* decision itself, drafted a policy that would allow the teaching of "other theories of the origin of man" besides evolution "if done with the clear secular intent of enhancing the effectiveness of science instruction."

The "weaknesses in evolution" and "evidence against evolution" that have been put forward include such arguments as: there are no transitional forms; life is so improbable that it could not have originated "randomly"; the second law of thermodynamics (which refers to a tendency toward increased disorder) disproves evolution; radiometric dating is invalid and the earth is young. On examination these views turn out to be identical to what in pre-*Edwards* days was called scientific creationism. But the lack of obvious religious content and purpose may help insulate these antievolution arguments from legal challenge. A judge might decide that regardless of scholarly merit, these teachings did not obviously promote religion. Just because the first amendment protects against the government establishment of religion doesn't mean it will be a protection against bad science.

So far this strategy seems to have failed, at least in the cases that have been brought to the attention of the National Center for Science Education. This is partly because we are often able to offer information or other assistance to the local opposition, including finding scientists to testify on behalf of evolution and against creationism. For example, in the Vista, California, case, members of a citizens' group testified vociferously at several school board meetings that they wanted evolution, not creationism, taught and threatened to sue if the board pushed the issue. Similarly, in Tangipahoa Parish, Louisiana, scientists from the local state university and others protested at school board meetings, as well as in such public forums as "letters to the editor" columns and radio talk shows, against the teaching of "other theories" besides evolution. In March 1994 the board gave up its plan.

Students in Texas and elsewhere are not now reading science textbooks that present "scientific" theories that contradict evolution because members of our organization and others, such as People for the American Way, helped promote a change in the final wording of Texas's very influential guidelines. The curriculum now calls for adopting textbooks that provide "scientific evidence of evolution and reliable scientific theories to the contrary, if any." The "if any" allows the textbook publishers some wiggle room—they can argue that they cannot find any such theories. And the Louisville, Ohio, situation is currently on hold while the district awaits the release of a state curriculum. Protest from community members and a threatened lawsuit by the Ohio chapter of the American Civil Liberties Union probably encouraged this delay.

The evolution of creationism has taken another turn, however. In 1989, the Foundation for Thought and Ethics, a Texas-based creationist organization, published *Of Pandas and People* as a supplement to high-school biology texts. *Pandas* claims to be a balanced treatment of evolution and "intelligent design theory." In familiar creationist fashion, it presents evolution as a largely chance process that cannot account for the impressive complexity of such intricate structures as the vertebrate eye. The alternative to this allegedly random process is "intelligent design," a term that obviously suggests divine creation, although the authors deny that the intelligence is necessarily supernatural. All in all, the text parades the usual creationist arguments, only without identifying them as such.

The publisher promotes *Pandas* through a grass-roots campaign, encouraging parents to approach school curriculum committees to adopt the book. According to the publisher, *Pandas* is being used in more than forty states, although in which states and in which districts is not made clear. The book was submitted for state adoption in Idaho and Alabama and rejected in both places. A creationist school board member in Vista, California, asked teachers there to consider it as a supplementary textbook. Armed with reviews prepared by our scientists and educators, they, too, soundly rejected it. Despite these successes, however, individual teachers may be using the book. In a case in northern California, the colleagues of one teacher directed him to return the classroom copies he had ordered for his students, on the grounds that the book had not passed normal district review.

Compared with those of other industrialized nations, the American public school system is very decentralized. Local school districts make the majority of curriculum decisions, sometimes guided by state curricula but not always bound by law to obey them. State agencies may influence school districts by requiring them to spend state funds only on approved books, but what is taught in the classroom will vary locally. Not only the local school board but also the individual teacher has considerable leeway. Unless students report on what happens when the door is closed, no one else may know.

In Stanwood, Washington, for example, local residents didn't know, until a student mentioned it to a parent, that a creation scientist had been invited to lecture on the "latest scientific findings" about how humans and dinosaurs lived at the same time. In another Washington community, a teacher who was teamed up with another for a high-school science class was astounded to hear his colleague advocating the creationist view that the earth was very young. Until the two shared the same classroom, no one had known that this teacher presented creation science.

From kindergarten through high school, public school teachers face pressure to teach creation science or "evidence against evolution," or at least to downplay evolution. Our caseload at the National Center for Science Education has been steadily increasing over the last six years. Part of this increase has been brought about by a shift in American politics. The religious right, disappointed by its lack of success on the national level, has focused on winning local elective offices, including representation on school boards and curriculum committees.

When the religious right wins a majority of seats on a school board, as in Vista, California, the teaching of evolution becomes a contentious issue. Even if not forced to do so, some teachers just quietly stop teaching it. Others feel a chilling effect. One teacher wrote me that he makes sure to collect all the handouts when he teaches evolution so that parents won't know what he is teaching. That teachers have to sneak good science into the classroom is regrettable. Unfortunately, in the face of parental pressure, principals and superintendents frequently fail to support teachers, even when the curriculum mandates the teaching of evolution.

If public school teachers shrink from teaching evolution, many students will not learn about it unless they go to college—if then. Others will be deprived of one of the great enriching ideas of science. If, as the geneticist Theodosius Dobzhansky said, "Nothing in biology makes sense except in the light of evolution," these students will learn nonsensical biology, a "pile of sundry facts" unconnected by an organizing theory. □

The Monster's Human Nature

When filmmakers adapt books for the screen, they often dumb down the subtle themes

by Stephen Jay Gould

An old Latin proverb tells us to "beware the man of one book"—*cave ab homine unius libri.* Yet Hollywood knows only one theme in making monster movies, from the archetypal *Frankenstein* of 1931 to last summer's megahit, *Jurassic Park.* Human technology must not go beyond an intended order decreed by God or set by nature's laws. No matter how benevolent the purposes of the transgressor, such cosmic arrogance can only lead to killer tomatoes, very large rabbits with sharp teeth, giant ants in the Los Angeles sewers, or even larger blobs that swallow entire cities. Yet these films often use far more subtle books as their sources and, in so doing, distort the originals beyond all thematic recognition.

The trend began in 1931 with *Frankenstein,* Hollywood's first great monster "talkie" (although Boris Karloff only grunted, while Colin Clive, as Henry Frankenstein, emoted). Hollywood decreed its chosen theme by the most "upfront" of all conceivable strategies. The film begins with a prologue (even before the titles roll), featuring a well-dressed man standing on stage before a curtain, to issue both a warning about potential fright and to announce the film's deeper theme as the story of "a man of science who sought to create a man after his own image without reckoning upon God."

In the movie, Dr. Waldman, Henry's old medical school professor, speaks of his pupil's "insane ambition to create life," a diagnosis supported by Frankenstein's own feverish words of enthusiasm: "I created it. I made it with my own hands from the bodies I took from graves, from the gallows, from anywhere."

The best of a cartload of sequels, *The Bride of Frankenstein* (1935) makes the favored theme even more explicit in a prologue featuring Mary Wollstonecraft Shelley (who wrote *Frankenstein* when she was only nineteen years old and published the story two years later in 1818). In conversation with her husband, Percy, and their buddy Lord Byron, she states: "My purpose was to write a moral lesson of the punishment that befell a mortal man who dared to emulate God."

Shelley's *Frankenstein* is a rich book of many themes, but I can find little therein to support the Hollywood reading. The text is neither a diatribe on the dangers of technology nor a warning about overextended ambition against a natural order. We find no passages about disobeying God—an unlikely subject for Mary Shelley and her free-thinking friends (Percy had been expelled from Oxford in 1811 for publishing a defense of atheism). Victor Frankenstein (I do not know why Hollywood changed him to Henry) is guilty of a great moral failing, as we shall see later, but his crime is not technological transgression against a natural or divine order.

We can find a few passages about the awesome power of science, but these words are not negative. Professor Waldman, a sympathetic character in the book, states, for example:

> They [scientists] penetrate into the recesses of nature, and show how she works in her hiding places. They ascend into the heavens; they have discovered how the blood circulates, and the nature of the air we breathe. They have acquired new and almost unlimited powers.

We do learn that ardor without compassion or moral consideration can lead to trouble, but Shelley applies this argument to any endeavor, not especially to scientific discovery (her examples are, in fact, all political). Victor Frankenstein says:

> A human being in perfection ought always to preserve a calm and peaceful mind, and never to allow passion or a transitory desire to disturb his tranquillity. I do not think that the pursuit of knowledge is an exception to this rule. If the study to which you apply yourself has a tendency to weaken your affections...then that study is certainly unlawful, that is to say, not befitting the human mind. If this rule were always observed...Greece had not been enslaved; Caesar would have spared his country; America would have been discovered more gradually, and the empires of Mexico and Peru had not been destroyed.

Victor's own motivations are entirely idealistic: "I thought, that if I could bestow animation upon lifeless matter, I might in process of time (although I now found it impossible) renew life where death had apparently devoted the body to corruption." Finally, as Victor expires in the Arctic, he makes his most forceful statement on the dangers of scientific ambition, but he only berates himself and his own failures, while stating that others might well succeed. Victor says his dying words to the ship's captain who found him on the polar ice:

> Farewell, Walton! Seek happiness in tranquillity, and avoid ambition, even if it be only the apparently innocent one of distinguishing yourself in science and discoveries. Yet why do I say this? I have myself been blasted in these hopes, yet another may succeed.

But Hollywood dumbed these subtleties down to the easy formula—"man must not go beyond what God and nature intended" (you almost have to use the old gender-biased language for such a simplistic archaicism)—and has been treading in its own footsteps ever since. The latest incarnation, *Jurassic Park,* substitutes a *Velociraptor,* re-created from old DNA, for Karloff, cobbled together from bits and pieces of corpses, but hardly alters the argument an iota. Spielberg's *Jurassic Park* also dumbs down Michael Crichton's

book version, just as James Whale demoted Shelley.

Ian Malcolm, a mathematical specialist in chaos theory, acts as the key moral critic in both book and film. In the book, he makes an intellectually interesting argument fully consistent with his specialty: visitors to the park must be protected from rapacious dinosaurs, but a safety system, so complex and so dependent upon hundreds of integrated parts and procedures, all working exactly as anticipated every single time, must eventually fail—and the collapse must be both unpredictable and spectacular.

I do not find this argument too complex for popular culture. Moreover, the genre of science fiction maintains a tradition for playing with intellectual themes not often treated elsewhere—and this practice has been extended to films of great commercial success, as in the truly challenging *2001* and even in the mass marketed *Star Trek* or *Star Wars* series. Why couldn't Spielberg and company (including Crichton, who participated in the dumbdowning of his own book for the screen) have maintained Malcolm's character and argument in the film of *Jurassic Park*?

But Jeff Goldblum, as the movie's Ian Malcolm, completely perverts and overturns his own proclaimed status as a "chaotician" by invoking the tired old cliché of monster films: "man must not go beyond...." He states to John Hammond, the park's creator: "Your lack of humility before nature staggers me." Hammond then counters Malcolm's opposition to bringing back extinct species from their preserved DNA by asking whether the mathematician would object to such a reconstitution of the California condor, should the last few individuals of the magnificent bird die. Malcolm replies that he would not protest such a project because the extinction would have occurred "unnaturally" as a result of human malfeasance. Why, then, object to dinosaurs? Hammond asks. Malcolm now cites the catechistic cliché: "Dinosaurs had their shot and nature selected them for extinction." In other words, the death of dinosaurs, as an event of nature's broad and intended order, as part of life's predictable and sensible development, must be honored and left untroubled, while a technologically imposed blip upon nature's pattern, like the extinction of condors, must be undone.

But such an argument emasculates chaos theory, Malcolm's stated guide to every interpretation. Chaos theory tells us that we cannot predict a sensible unrolling of life's history or state that any given event, like the extinction of dinosaurs, possessed an inevitability beyond alternative construction or present challenge. (I would also like to know why Spielberg's dinosaurs, as intended rulers of a former world less advanced than our own, can beat any mammal in Jurassic Park, including *Homo sapiens*.)

This fatal inconsistency destroys Malcolm's intellectual character. In the film's silliest and most embarrassing scene, chaos theory has no remaining clout beyond a crude invocation during a bumbling and unsuccessful seduction scene—as Goldblum's Malcolm drips water on Laura Dern's knuckles and tells her that chaos theory permits no prediction about the direction of roll, down to the fingertips or toward the wrist (of course, you have to hold your subject's hand as you illustrate this point). I suspect that Spielberg recognized the impotence thus imposed upon Malcolm, for he breaks the mathematician's leg and mercifully puts him out of further action soon thereafter.

But Karloff's *Frankenstein* contains an

even more serious and equally prominent distortion of a theme that I regard as the primary lesson of Mary Shelley's book—another lamentable example of Hollywood's sense that the American public cannot tolerate even the slightest exercise in intellectual complexity. Why is the monster evil? Shelley provides a nuanced and subtle answer that, to me, sets the central theme of her book. But Hollywood opted for a simplistic solution, so precisely opposite to Shelley's intent that the movie can no longer claim to be telling a moral fable (despite the protestations of the man in front of the curtain, or of Mary Shelley herself in the sequel) and becomes instead, as I suppose the maker intended all along, a pure horror film.

James Whale, director of the 1931 *Frankenstein,* devoted the movie's long and striking opening scenes to this inversion of Shelley's intent—so the filmmakers obviously viewed this alteration as crucial. The movie opens with a burial at a graveyard. After the mourners depart, Henry and his obedient servant, the evil, hunchbacked Fritz, dig up the body and cart it away. Then they cut down another dead man from the gallows, but Henry exclaims, "The neck's broken. The brain is useless; we must find another brain."

The scene switches to Goldstadt Medical College. Professor Waldman is lecturing on cranial anatomy and comparing "one of the most perfect specimens of the normal brain" with "the abnormal brain of a typical criminal." Waldman firmly locates the criminal's depravity in the inherited malformations of his brain; anatomy is destiny. Note, Waldman says,

> the scarcity of convolutions on the frontal lobes and the distinct degeneration of the middle frontal lobes. All of these degenerate characteristics check amazingly with the case history of the dead man before us, whose life was one of brutality, of violence, and of murder.

Fritz breaks in after the students leave and steals the normal brain, but the sound of a gong startles him and he drops the precious object, shattering its container. Fritz then has to take the criminal brain instead, but he never tells Henry. The monster is evil because Henry unwittingly makes him of evil stuff. Later in the film, Henry expresses his puzzlement at the monster's nasty temperament, for he made his creature of the best materials. But Waldman, finally realizing the source of the monster's behavior, tells Henry: "The brain that was stolen from my laboratory was a criminal brain." Henry then counters with one of the cinema's greatest double takes, and finally manages a feeble retort, "Oh well, after all, it's only a piece of dead tissue." "Only evil will come from it," Waldman replies, "you have created a monster and it will destroy you"—true enough, at least until the next sequel.

Karloff's intrinsically evil monster stands condemned by the same biological determinism that has so tragically and falsely restricted the lives of millions who committed no transgression besides membership in a despised race, sex, or social class. Karloff's actions record his internal state. He manages a few grunts and, in one of the sequels, even learns some words from a blind man who cannot perceive his ugliness, although the monster never gets much beyond "eat," "smoke," and "good." Shelley's monster, by contrast, is a most remarkably literate fellow. He learns French by assimilation after hiding for several months in the hovel of a noble family temporarily in straitened circumstances. His three favorite books would bring joy to the heart of any college English professor who could persuade students to read and enjoy even one: Plutarch's *Lives,* Goethe's *Sorrows of Young Werther,* and Milton's *Paradise Lost* (of which Shelley's novel is an evident parody). The original monster's thundering threat certainly packs more oomph than Karloff's pitiable grunts: "I will glut the maw of death, until it be satiated with the blood of your remaining friends."

Shelley's monster is not evil by inherent constitution. He is born unformed—carrying the predispositions of human nature, but without the specific manifestations that can only be set by upbringing and education. He is the Enlightenment's man of hope, whom learning and compassion might mold to goodness and wisdom. But he is also a victim of post-Enlightenment pessimism as the cruel rejection of his natural fellows drives him to fury and revenge. (Even as a murderer, the monster remains fastidious and purposive. Victor Frankenstein is the source of his anger, and he only kills the friends and lovers whose deaths will bring Victor the most grief; he does not, like Godzilla or the Blob, rampage through cities.)

Mary Shelley chose her words carefully to take a properly nuanced position at a fruitfully intermediate point between nature and nurture—whereas Hollywood opted for nature alone to explain the monster's evil deeds. Frankenstein's creature is not inherently good by internal construction—a benevolent theory of "nature alone," but no different in mode of explanation from Hollywood's opposite version. He is, rather, born *capable* of goodness, even with an *inclination* toward kindness, should circumstances of his upbringing call forth this favored response. In his final confession to Captain Walton, before heading north to immolate himself at the Pole, the monster says:

> My heart was fashioned to be *susceptible of love and sympathy;* and, when wrenched by misery to vice and hatred, it did not endure the violence of the change without torture, such as you cannot even imagine [my italics to note Shelley's careful phrasing in terms of potentiality or inclination, rather than determinism].

He then adds:

> Once my fancy was soothed with dreams of virtue, of fame, and of enjoyment. Once I falsely hoped to meet with beings who, pardoning my outward form, would love me for the excellent qualities which I was *capable of bringing forth* [again, my italics]. I was nourished with high thoughts of honor and devotion. But now vice has degraded me beneath the meanest animal.... When I call over the frightful catalogue of my deeds, I cannot believe that I am he whose thoughts were once filled with sublime and transcendent visions of the beauty and the majesty of goodness. But it is even so; the fallen angel becomes a malignant devil.

Why, then does the monster turn to evil against an inherent inclination to goodness? Shelley gives us an interesting answer that seems almost trivial in invoking such a superficial reason, but that emerges as profound when we grasp her general theory of human nature. He becomes evil, of course, because humans reject him so violently and so unjustly. His resulting loneliness becomes unbearable. He states:

> And what was I? Of my creation and creator I was absolutely ignorant; but I knew that I possessed no money, no friends, no kind of property. I was, besides, endowed with a figure hideously deformed and loathsome.... When I looked around, I saw and heard none like me. Was I then a monster, a blot upon the earth, from which all men fled, and whom all men disowned?

But why is the monster so rejected if his feelings incline toward benevolence, and his acts to evident goodness? He certainly tries to act kindly, in helping (albeit secretly) the family in the hovel that forms his hiding place:

> I had been accustomed, during the night, to steal a part of their store for my own consumption; but when I found that in doing this I inflicted pain on the cottagers, I abstained, and satisfied myself with berries, nuts, and roots, which I gathered from a neighboring wood. I discovered also another means through which I was enabled to assist their labors. I found that the youth spent a great part of each day in collecting wood for the family fire; and, during the night, I often took his tools, the use of which I quickly discovered, and brought home firing sufficient for the consumption of several days.

Shelley tells us that all humans reject and even loathe the monster for a visceral reason of literal superficiality: his truly terrifying ugliness—a reason heartrending in its deep injustice and profound in its biological accuracy and philosophical insight about the meaning of human nature.

The monster, by Shelley's description, could scarcely have been less attractive in appearance. Victor Frankenstein describes the first sight of his creature alive:

> How can I describe my emotions at this catastrophe, or how delineate the wretch whom with such infinite pains and care I had endeavored to form? His limbs were in proportion, and I had selected his features as beautiful. Beautiful!—Great God! His yellow skin scarcely covered the work of muscles and arteries beneath; his hair was a lus-

"I find I can think better when I stand upright."

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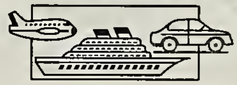

trous black, and flowing; his teeth of a pearly whiteness; but these luxuriances only formed a more horrid contrast with his watery eyes, that seemed almost of the same color as the dun white sockets in which they were set, his shriveled complexion, and straight black lips.

At the hyper-NBA height of eight feet, the monster scares the bejeezus out of all who cast eyes upon him.

The monster quickly grasps this unfair source of human fear and plans a strategy to overcome initial reactions and prevail by goodness of soul. He presents himself first to the blind old father in the hovel above his hiding place and makes a good impression. He hopes to win the man's confidence, and thus gain a favorable introduction to the world of sighted people. But in his joy at acceptance, he stays too long. The man's son returns and drives the monster away—as fear and loathing overwhelm any inclination to hear about inner decency.

The monster finally acknowledges his inability to overcome visceral fear at his ugliness; his resulting despair and loneliness drive him to evil deeds:

I am malicious because I am miserable; am I not shunned and hated by all mankind?... Shall I respect man when he contemns me? Let him live with me in the interchange of kindness, and, instead of injury, I would bestow every benefit upon him with tears of gratitude at his acceptance. But that cannot be; the human senses are insurmountable barriers to our union.

Our struggle to formulate a humane and accurate idea of human nature focuses on proper positions between the false and sterile poles of nature and nurture. Pure nativism—as in the Hollywood version of the monster's depravity—leads to a cruel and inaccurate theory of biological determinism, the source of so much misery and such pervasive suppression of hope in millions belonging to unfavored races, sexes, or social classes. But pure nurturism can be just as cruel and just as wrong—as in the blame once heaped upon loving parents, in bygone days of rampant Freudianism, for failures in rearing as putative sources of mental illness or retardation that we can now identify as genetically based, for all organs, including brains, may be subject to inborn illness.

The solution, as all thoughtful people recognize, must lie in properly melding the themes of inborn predisposition and shaping through life's experiences. This fruitful joining cannot take the false form of percentages adding up to 100—as in "intelligence is 80 percent nature and 20 percent nurture," or "homosexuality is 50 percent inborn and 50 percent learned," and a hundred other harmful statements in this foolish format. When two ends of such a spectrum are commingled, the result is not a separable amalgam (like shuffling two decks of cards with different backs), but an entirely new entity that cannot be decomposed (as adults cannot be separated into maternal and paternal contributions to their totality).

The best guide to a proper integration lies in recognizing that nature supplies general ordering rules and predispositions—often strong ones to be sure—while nurture shapes specific manifestations over a wide range of potential outcomes. We make classical "category mistakes" when we attribute too much specificity to nature—as in the pop sociobiology of supposed genes for such complexly social phenomena as rape and racism; or when we view deep structures as purely social constructs—as in earlier claims that even the most general rules of grammar must be learned contingencies without any universality across cultures. Noam Chomsky's linguistic theories represent the paradigm for modern concepts of proper integration between nature and nurture—principles of universal grammar as inborn learning rules, with peculiarities of any particular language as a product of cultural circumstance and place of upbringing.

Frankenstein's creature becomes a monster because he is cruelly ensnared by one of the deepest predispositions of our biological inheritance—our aversion toward seriously malformed individuals. (Konrad Lorenz, the most famous ethologist of the last generation, based much of his theory on the primacy of this inborn rule.) We are now appalled by the injustice of such a predisposition, but this proper moral feeling is an evolutionary latecomer, imposed by human consciousness upon a much older mammalian pattern.

We almost surely inherit such an instinctive aversion to serious malformation, but remember that nature can only supply a predisposition, while culture shapes specific results. And now we can grasp—for Mary Shelley presented the issue to us so wisely—the true tragedy of Frankenstein's monster and the moral dereliction of Victor himself. The predisposition for aversion toward ugliness can be overcome by learning and understanding. I trust that we have all trained ourselves in this essential form of compassion; that we all work hard to suppress that *frisson* of revulsion (which in honest moments we all admit we feel) and to judge people by their qualities of soul, not by their external appearances.

Frankenstein's monster was a good man in an appallingly ugly body. His countrymen could have been educated to accept him, but the person responsible for that instruction—his creator, Victor Frankenstein—ran away from his foremost duty, and abandoned his creation at first sight. Victor's sin does not lie in misuse of technology or hubris in emulating God; we cannot find these themes in Mary Shelley's account. Victor failed because he followed a predisposition of human nature—visceral disgust at the monster's appearance—and did not undertake the duty of any creator or parent: to teach his own charge and to educate others in acceptance.

He could have schooled his creature (and not left the monster to learn language by eavesdropping and by scrounging for books in a hiding place under a hovel). He could have told the world what he had done. He could have introduced his benevolent and educated monster to people prepared to judge him on merit. But he took one look at his handiwork and ran away forever. In other words, he bowed to a base aspect of our common nature and did not accept the particular moral duty of our potential nurture:

> I had worked hard for nearly two years, for the sole purpose of infusing life into an inanimate body. For this I had deprived myself of rest and health. I had desired it with an ardor that far exceeded moderation; but now that I had finished, the beauty of the dream vanished, and breathless horror and disgust filled my heart. Unable to endure the aspect of the being I had created, I rushed out of the room.... A mummy again endued with animation could not be so hideous as that wretch. I had gazed on him while unfinished; he was ugly then; but when those muscles and joints were rendered capable of motion, it became a thing such as even Dante could not have conceived.

The very first line of the preface to *Frankenstein* has often been misinterpreted: "The event on which this fiction is founded has been supposed, by Dr. Darwin, and some of the physiological writers of Germany, as not of impossible occurrence." People suppose that "Dr. Darwin" must be Charles of evolutionary fame. But Charles Darwin was born on Lincoln's birthday in 1809 and wasn't even ten years old when Mary Shelley wrote her novel. "Dr. Darwin" is Charles's grandfather Erasmus, one of England's most famous physicians and an atheist who believed in the material basis of life. (Shelley is referring to his idea that such physical forces as electricity might be harnessed to quicken inanimate matter—for life has no inherently spiritual component and might therefore emerge from nonliving substances infused with enough energy.)

I will, however, close with my favorite moral statement from Charles Darwin, who, like Mary Shelley, also emphasized our duty to foster the favorable specificities that nurture and education can control. Mary Shelley wrote a moral tale, not about hubris or technology, but about responsibility to all creatures of feeling and to the products of one's own hand. The monster's misery arose from the moral failure of other humans, not from his own inherent and unchangeable constitution. Charles Darwin then invoked the same theory of human nature to remind us of duties to all people in universal bonds of brotherhood: "If the misery of our poor be caused not by the laws of nature, but by our institutions, great is our sin."

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Trigg Sandstone Pavement, Illinois

by Robert H. Mohlenbrock

Below: Weathered sandstone in the Shawnee Ridge. Right: A prickly pear in bloom.
Todd Fink; Daybreak Imagery

While most of Illinois is flat—a one-time prairieland now mostly devoted to corn and soybean fields—the southern eighth of the state is much more varied. Three-hundred-foot limestone bluffs line the Mississippi River to the west and the Ohio River to the east as they roll toward their confluence at the southern tip of the state. In between is a more or less continuous outcropping of sandstone, known as the Shawnee Ridge, much of which is managed by the Shawnee National Forest. Within it are exposed sandstone surfaces up to several acres in size. I sometimes have referred to them as glades or barrens, but a better name for them is sandstone pavements.

In the Shawnee Ridge zone are 200- to 300-foot-deep ravines, locally referred to as canyons, filled with large American beeches, sugar maples, shagbark hickories, and tulip poplars. On the midslopes above the shaded canyon floors, a rather dry forest is dominated by several kinds of oaks, while the driest ridgetops support a forest of stunted, gnarly post oaks, blackjack oaks, winged elms, black hickories, and red cedars. The patches of exposed sandstone, often no more than a few feet wide, lie mainly on west- or southwest-facing ridgetops, where the full heat of the afternoon sun bears down on the rock surface. Trees have not been able to encroach on these spots because conditions are so hot and dry during the growing season.

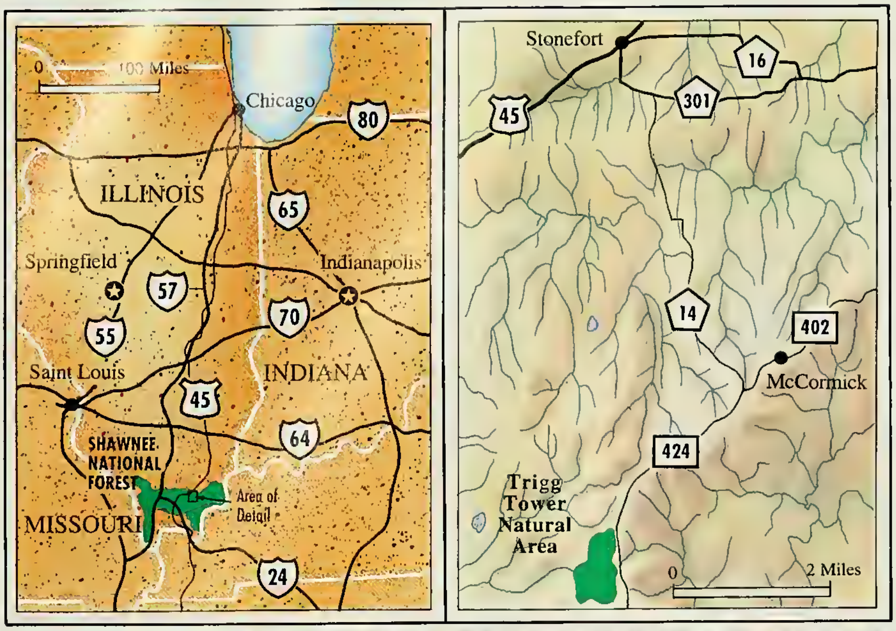
One of the most extensive and pristine bare areas is Trigg Sandstone Pavement, accessible only by a network of one-lane gravel roads. From a distance, it appears bare of vegetation, but a closer look reveals a variety of colorful lichens cemented to the rock surface, as well as mats of black moss. The lichens, and to a lesser extent the mosses, anchor themselves on the pavement by secreting an acid that etches the rock surface just enough for them to become established. After hundreds or even thousands of years, the lichens and mosses, along with the weather, have gradually eroded the sandstone, creating pockets and crevices filled with thin soil. This soil provides tiny footholds for some flowering plants and ferns that can tolerate the harsh habitat.

One afternoon last summer, when the air temperature had soared into the mid-90s, I recorded the temperature at the exposed pavement surface at 120°F (in comparison, the soil of the nearest canyon floor was only 76°F). Among the plants I found surviving this desertlike heat was a prickly pear with waxy, yellow flowers. This cactus stores lots of water in its flat, thick stems, while its leaves, reduced to hard spines, offer no surface for water loss.

Other succulent plants on the pavement have fleshy, water-storing leaves. Among them are a six-inch-tall, pink-flowered sedum known locally as widow's-cross, a small agave related to the century plants of the western United States, and a delicate plant related to portulacas called flower-of-an-hour (this plant is unrelated to the flower-of-an-hour in the hibiscus family). The three-quarter-inch-wide, pink flowers of flower-of-an-hour open about ten o'clock in the morning and begin to wither an hour later. Beginning in mid-July, one or two flowers open on the plant each day until all the flower buds have opened, usually by late August. The timing is almost accurate enough to set your watch by.

A dense covering of hairs or scales on the leaves of other plants insulates them from the direct rays of the sun and pre-

Joe LeMonnier



Trigg Sandstone Pavement
For visitor information write:
Forest Supervisor
Shawnee National Forest
901 S. Commercial Street
Harrisburg, Illinois 62946
(618) 253-7114

Nearly bare of soil, Trigg Sandstone pavement supports the growth of some lichens, cactuses, and other plants that can tolerate the desertlike heat.
Kenneth Murray

vents moisture from escaping. Lip fern, a six-inch fern with a purplish black leaf stalk, has fronds so densely covered with hairs that they hide the surface of the leaves. Another six-inch plant with hairy leaves is small croton, while an equally diminutive one whose protection consists of flat, silvery scales is rushfoil.

Several species on the sandstone pavement have tiny leaves, sometimes so reduced that they scarcely resemble leaves. These provide less surface for evaporation. Among them are a tiny evening primrose known as thread-leaved sundrop, a dwarf Saint Johnswort called pinweed, and rock club moss, which is a dwarf evergreen plant closely related to ferns.

Some of the plants send down unusually long taproots through the rocky crevices, where they may reach additional moisture. One of the most striking is pencil flower, a yellow-flowering member of the pea family. While its aboveground stem may be only six to eight inches tall, its taproot may penetrate two to four feet.

But some plants avoid the hottest, driest days on Trigg Sandstone Pavement by simply making their exit before midsummer. These are annual plants, which sprout early in the year, usually in March, and produce their full set of leaves, flowers, and fruits during April, May, and early June. They then wither away by July, relying on their seeds to repeat the cycle the following year.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U.S. national forests.

Charting the Actual and Imagined

by Yi-Fu Tuan

In May of 1977, geographers Brian Harley and David Woodward were strolling through the English countryside, discussing a collaboration on the mapping of North America. But as they walked and talked, they began to plan a work of even greater scope—a comprehensive history of worldwide mapping from prehistoric times to our century.

Under their joint editorship, two volumes of *The History of Cartography* are now in print, with at least four more to come. Their international team of scholars has already appraised for us an extraordinary range of cartographic artifacts, from Neolithic wall paintings to the globes, maps, and diagrams of the ancient Mediterranean and medieval European worlds to the dazzling variety of cartographic accomplishments in Islamic and Asian societies. Future volumes will include the brilliant works of the Renaissance and the Enlightenment; cartographic enterprise in the age of expansion and the nineteenth century; and the technological innovations of our time, including, no doubt, satellite and GIS (Geographical Information Systems) imagery.

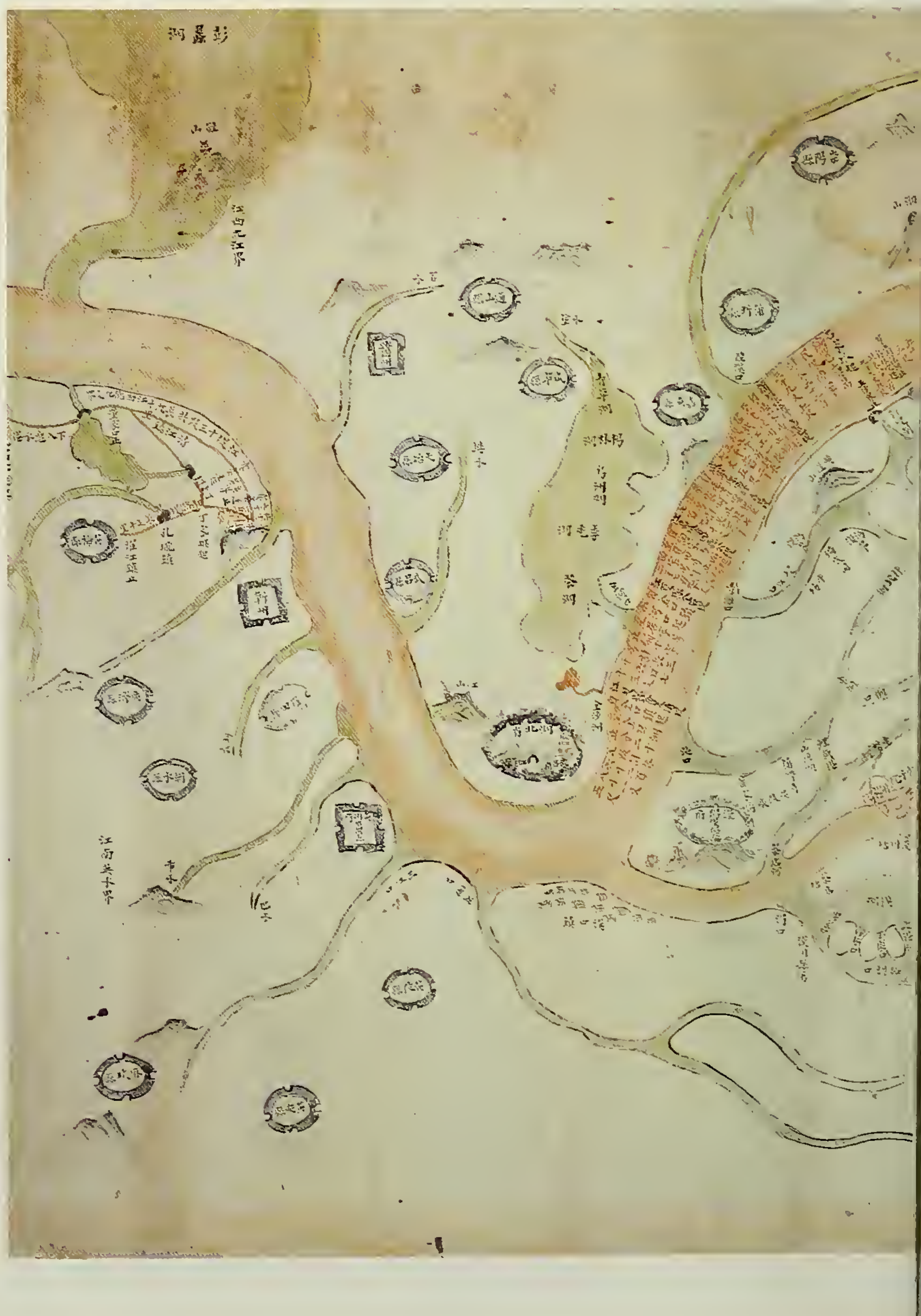
The History of Cartography, edited by J. B. Harley and David Woodward, vol. 2, book 2. *University of Chicago Press, $150; 950 pp.; illus.*

What do all these artifacts have in common? More simply put, what is a map? Historians of cartography have had to choose between a narrow view, in which faithfulness to the earth's surface is of primary importance, and a liberal view, which, in contrast, regards a map as any attempt to picture the spatial qualities of the world, actual or imagined. The narrow view is heavily Western, with an emphasis on progress toward systematic measurement and precision. The liberal view emphasizes the multiplicity of styles, incommensurate as to purpose, hence not to be ranked on a uniform scale of achievement.

Kuwagata Keisai's 1804 woodblock print was the first aerial image of Japan.
Bibliotheek der Rijksuniversiteit, Leiden

Museum für Indische Kunst, Staatliche Museen zu Berlin

A Thai map of Asia, from the Arabian Sea to Korea and Japan, above, is dated 1176 and signed by four artists. India appears near the right border, while China dominates the left half of the map. The islands along the top depict the archipelagoes of Japan and what is now Indonesia. Right: A nineteenth-century Chinese pictorial map of the Yangtze and Han Rivers show flood control works in Hubei Province.



Unlike earlier historians of cartography, Harley and Woodward have wholeheartedly embraced the liberal view.

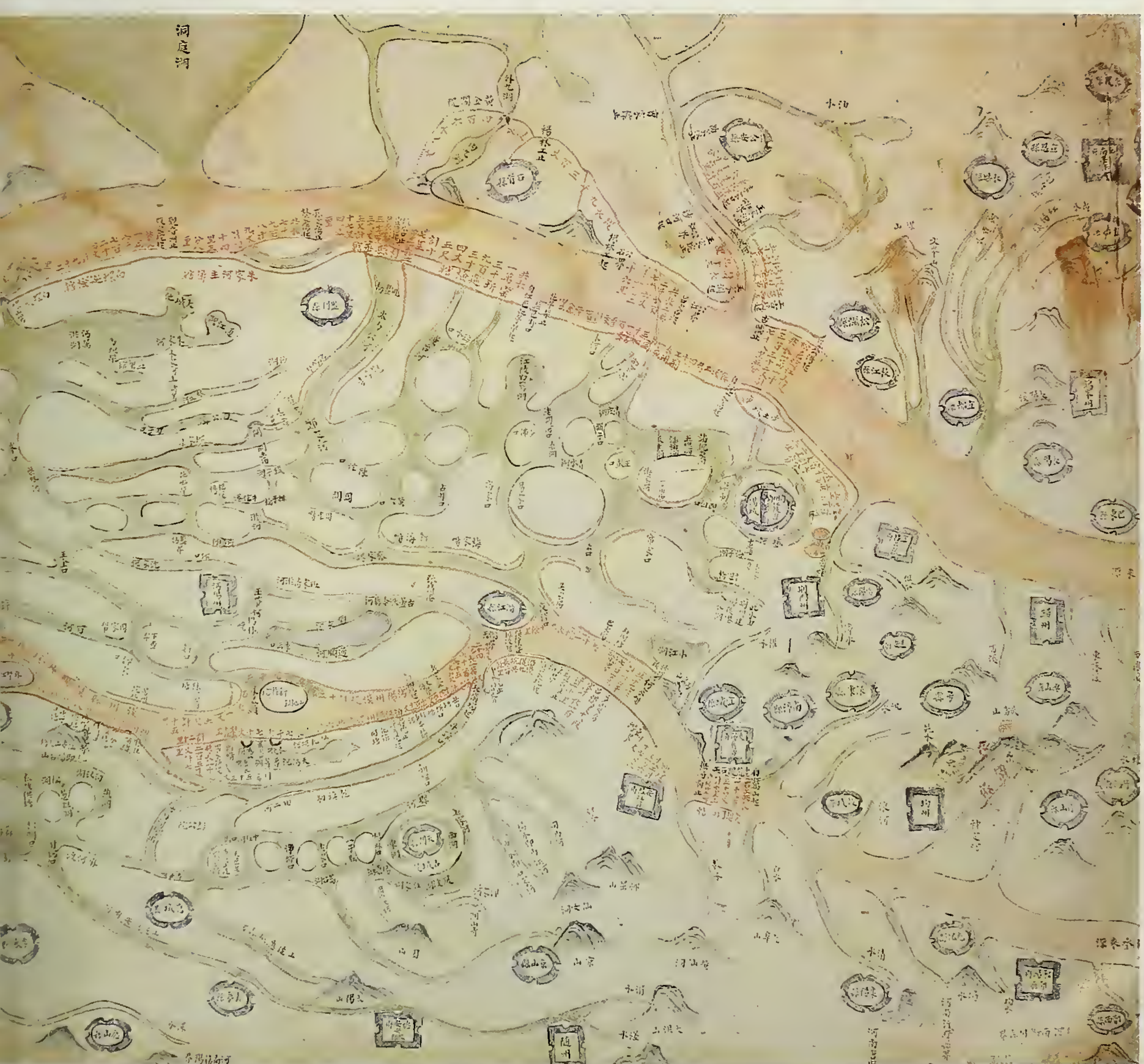
China, Korea, Japan, Tibet, and Southeast Asia are the five areas covered in this volume. Of these, Southeast Asia's cartographic artifacts are the most heterogeneous. The area as a whole can hardly be said to have a cartographic tradition. Maps, for instance, bear little similarity to one another even when they come from the same Malay world. Moreoever, parts of Southeast Asia, including the Philippines, Laos, and Cambodia, have not yielded a single premodern noncosmographic map. Writing a coherent chapter on Southeast Asian cartography is therefore a special challenge, one that its author, Joseph Schwartzberg, gallantly tries to meet.

Tibet presents another kind of challenge. A rich cartographic tradition does indeed exist there, but only if one assumes an exceptionally broad understanding of a map. The innumerable mandalas and the chortens (shrines for the housing of reliquaries) can be included in Tibet's cartographic heritage, for they may all be viewed as attempts to envisage and reproduce the Buddhist cosmos, often in a highly schematic manner. Paintings that illustrate Tibetan works of mythology and hagiography are not maps in any sense, yet they, too, furnish maplike components and scenes if one searches hard enough.

The dominant role of religion in Tibet's cultural heritage, which is a distillation of Hindu and Chinese civilizations in almost equal parts, makes the customs and artifacts of that country, including maps, highly distinctive. Mapmaking in Korea and Japan is more mainstream, being part of a large cartographic realm that has China at its historical core. However, despite strong Chinese influence, Korea and Japan have developed their own mapping traditions.

Korea's form of government became highly centralized, after the Chinese model, during the Koryo dynasty, from A.D. 918 to 1392. Such centralization necessitated detailed knowledge of local units, including the sort of information best displayed on maps. Moreover, this was a time when the Koreans, even more than the Chinese, were enamored of geomancy, or divination by means of the earth's configuration. The geomantic analysis of site and location at different scales required mapping skills. As Gari Ledyard, the author of the chapter on Korea, puts it: "During the ninth and tenth centuries the mountain paths must have been thronged with monks and geomancers searching out the secrets of the nation's arterial system." Measurement became a requirement (although clearly not the only one) as early as the fifteenth century, when a landscape artist, a mathematician-surveyor, a cartographer, and a geomancer might all cooperate to produce a good likeness of Seoul. Korea, moreover, has always been sensitive to threats by external enemies, and one way to cope with such threats, particularly during the seventeenth century, was to produce good maps. Although functional, these nevertheless were drawn to appeal to the eye.

Korea can boast the earliest world map (circa 1402) in East Asia. Its purpose would seem to have been to show the country as large and important, unlike



Geography and Map Division, Library of Congress

Japan, which is pushed to the side. China has produced a number of empire maps that, from its ethnocentric viewpoint, were world maps. Ethnocentric in its own way, Japan was too interested in itself to map the rest of the world. Maps of its own islands were abundantly drawn at different scales as early as the Nara period, from 710 to 784.

Japan, as Kazutaka Unno says in his chapter, is "a pragmatically oriented society." The vast majority of premodern maps catered to practical uses, including administration, the settling of boundary disputes, way-finding for pilgrims and, increasingly, for tourists during the Edo period from 1603 until 1867. Indeed, from 1700 onward, as more and more ordinary people could afford to travel for pleasure, they took to consulting gazetteers and buying printed maps that showed places worthy of a visit. Japanese mapmaking throughout the Edo period, although concerned foremost with use, also aspired to high aesthetic quality. Cartographers were artists, and many maps had only a decorative purpose—for instance, those that appeared on folding screens, hanging scrolls, sword guards, and plates.

I have left China until the last because of the questions raised by Cordell D. K. Yee. What is a map? And what constitutes cartographic excellence? His chapters on China have a narrative flow that the other chapters lack, in part because Yee is more successful in presenting facts within a context of general ideas and arguments. China, in its long imperial history, has produced many cartographic artifacts, including cosmographic schemata, geographical maps at scales that range from empires to local regions covered in gazetteers, and specialized hydrological and property-line surveys. Even under the narrowest definition, the noncosmographic artifacts must be considered maps.

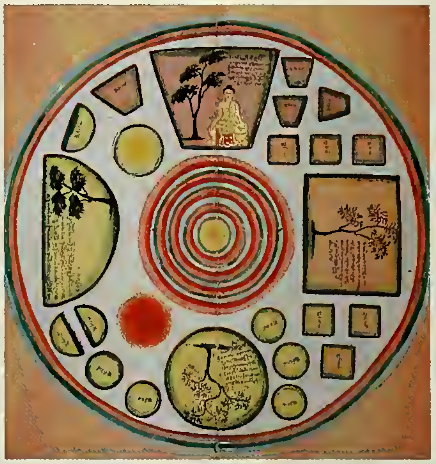
Modern Chinese scholars, swayed by Western cartographic values, have noted how backward even some of their nineteenth-century maps are. Such maps still resort to pictorialism and show no meridians and parallels. On the other hand, the same scholars are surprised and pleased to discover how modern some very old Chinese maps look. Silk maps found in a tomb in Hunan Province, for example, date from about 150 B.C. and show the location of army installations and headquarters; color is used to distinguish different kinds of features and to provide some evidence of scale. Accuracy was at least implicitly a criterion of excellence in ancient China. Indeed, Pei Xiu, who lived in the third century A.D., advocated using measurement and scale for achieving fidelity to geographic actualities.

Given China's remarkable headstart in cartographic science, one can't help but wonder why it didn't blossom there as it did in Europe. Several reasons come to mind. One is that the earliest maps, which were placed in tombs, were icons of quasi-magical potency, not just functional devices. If true, that simply shows what people believed in more than two thousand years ago. A milder version of the same idea is that maps have power—they "command" a territory and can evoke a sense of place. But any informative and attractive map, even a gas station road map, can have this sort of power, which may well be inherent to all maps. Perhaps Chinese cartography was too intimately fused with aesthetics for it to develop separately as a science. In my view, aesthetic considerations have also been a strong historic component of Western mapmaking, yet they did not hinder it from developing into a science.

One significant difference between China and the West is the strong and persistent pictorial element in Chinese cartography. Map and landscape art (which frequently shows maplike scenes from an oblique angle) are more closely integrated in China than they are in Europe. Another difference is the Chinese emphasis on the written text. As Yee has repeatedly noted, Chinese cartographers did not feel the need to indicate accurate scale because they believed that quantitative information could be accommodated more readily in words. This textual emphasis reflects China's traditional allocation of prestige to verbal, as distinct from spatial-technical, skills. And finally, China's attitude to knowledge has always been pragmatic: there was little desire to pursue knowledge systematically for its own sake. Cartography was essentially a tool of government, a skill that all officials should have, along with other technical skills such as engineering, building and dam construction, and military strategy.

The questions I have raised are not (except for Yee's chapters) the ones *The History of Cartography,* as a whole, seeks to address. The *History*'s basic premise is that maps are different, as are cultures. Its purpose is to display the richness of artifacts, and it has done so magnificently and with exemplary thoroughness. What I miss in this authoritative work, however, is a sense of story—of theses and themes. Some chapters have almost the texture of a *catalogue raisonné,* rather than of essays that one would want to read through. Is there now a general agreement among students of cartography that maps, like other artistic creations, have no history of development? Tibetan students may well say yes, and so remove their maps from the onus of comparison. By contrast, East Asian students have accepted the values of Western cartography, even though, in doing so, they risk finding their own heritage deficient. They have embraced modern Western cartography as they have embraced modernization, because they know that only it has the power to make their countries politically and economically strong. Ironically, not Asian but Western scholars now see cartography more as works of art and culture than as works of applied knowledge that can improve over time.

The British Library, London



Painted on heavy mulberry bark paper, a Burmese cosmological map, above, is part of an illustrated, late-nineteenth-century manuscript. Right: A map of the Potala and other holy places of central Tibet, probably painted in the late eighteenth century, represents an area of several thousand square miles. The two elephants in front of the Potala were gifts from the king of Nepal to the Dalai Lama and were said to have died not long after their arrival on the high plateau.

Yi-Fu Tuan is the J. K. Wright and Vilas Professor of Geography at the University of Wisconsin-Madison. His books include: Passing Strange and Wonderful, Topophilia, Landscapes of Fear, *and* Morality and Imagination.

Réunion des Musées Nationaux, Paris

Mussels, periwinkles, barnacles, and rockweed, left, flourish in tidal pools, such as those along the rocky shoreline of Mount Desert Island, Maine, bottom.
Anne Heimann

Give Me Your Shelled, Your Clawed

The community of mollusks and crustaceans along America's North Atlantic shores is a melting pot of natives and immigrants

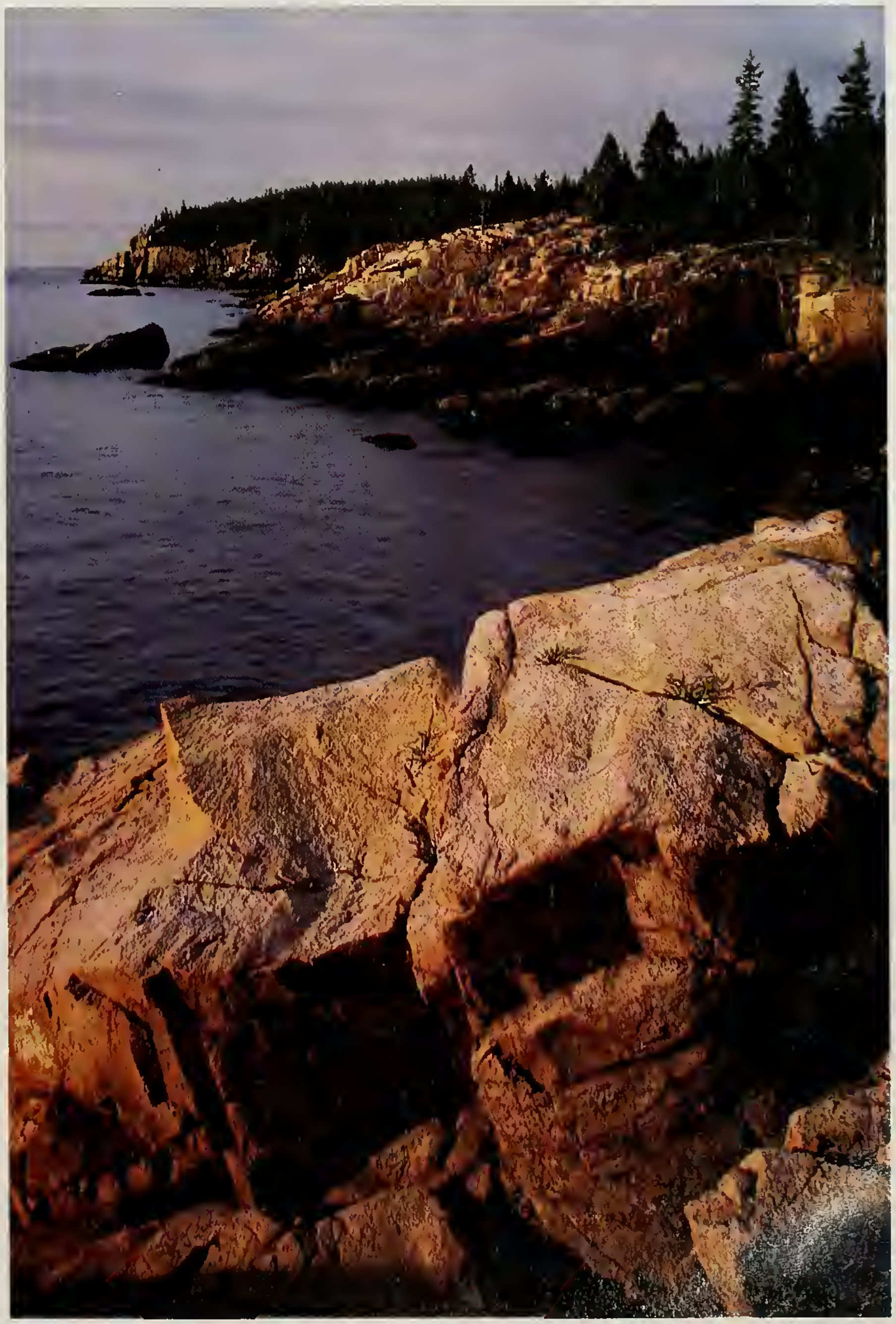
by Geerat J. Vermeij

To the New England naturalist, the tide pools on the rockbound shores of Maine and southeastern Canada present a familiar scene. While mussels and acorn barnacles are busily filtering small food particles out of the water that bathes them, periwinkles are quietly grazing the lush growth of delicate green sea lettuce. Dog whelks crawl slowly about in search of barnacles and mussels. Deeper in the pool, under a canopy of brown kelp, sea urchins scrape away encrusting plants and animals, while crabs and lobsters scuttle to places of shelter.

So familiar and unremarkable is this community that we are apt to think of it as timeless, existing in balance, if not in harmony, for ages. Yet beneath this superficial serenity lurks the ferment of history. The apparently stable community is in reality a melting pot of natives and immigrants, a "crab bag" thrown together by extraordinary events and circumstances dating from four million years ago to the present. The tale is one of invasion and extinction, and of new links being forged between species that evolved in regions as different as coastal Europe, North America, and the North Pacific.

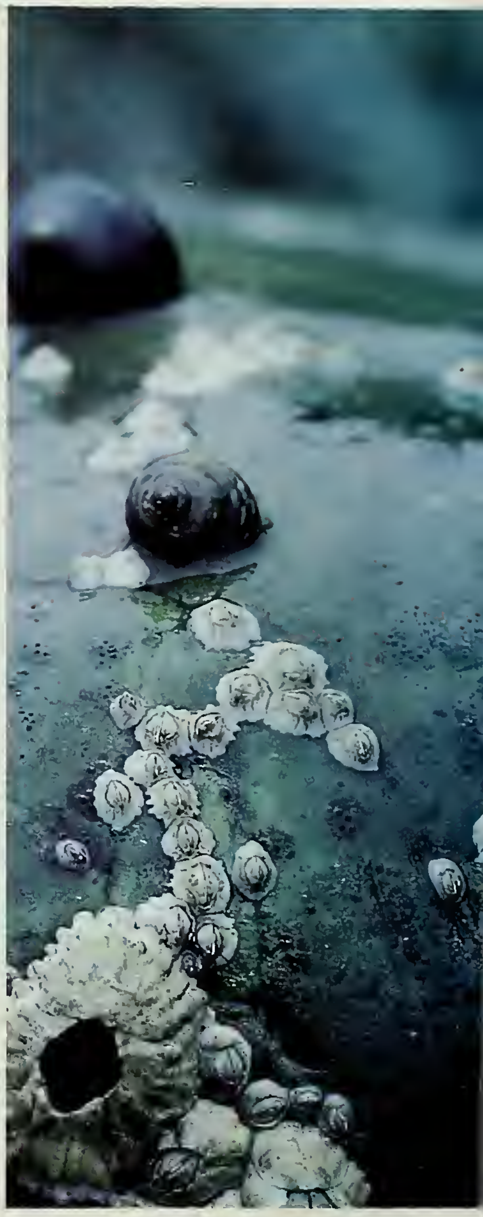
I became interested in this kind of history once I started to compare marine life from biologically distinct, but climatically similar, parts of the world. The shallow-water communities of the cold North Pacific shores, from north of Oregon in the east to Honshu, Japan, in the west, are intriguing because they harbor two to three times as many species as do those of eastern North America north of Cape Cod. Such disparities may reflect subtly different climates, but they also expose the role of history.

Why should we study the history of



Ted Levin

European green crabs, below, mate in the shallow waters of a tidal pool. As commerce between Europe and North America increased in the mid-eighteenth century, the species first appeared south of Cape Cod and eventually spread north to Nova Scotia. The dog whelk, right, migrated from the Pacific to the Atlantic about 2.4 million years ago; when the predatory green crab arrived, the whelk's shell lip thickened.
Herb Segars



communities? The simple answer is that the past is a key to the present and a possible guide to the future. In the human-dominated world of today, invasion and extinction of communities are nearly everyday phenomena that have potentially profound consequences for the humans that depend on them. By reconstructing the comings and goings of species on the geological time scale, we can begin to appreciate the longer-term consequences of changes that are sweeping the biosphere.

The detective work of reconstructing biological history involves fields as diverse as paleontology and molecular biology. Not only must we trace the genealogy of species by inferring the sequence of evolutionary branching events from the ancestral stock to the descendant lineages but we must also assign dates and places to these events. Of course, species did not evolve in a vacuum. We must therefore probe the everyday circumstances of life for species in the past as well as for those in the present.

Consider the dog whelk. This snail, which preys on barnacles and mussels, abounds on rocky shores on both sides of the North Atlantic. It has no close relatives in the Atlantic, but at least seven species of dog whelk, as well as many fossil forms, are found in the North Pacific. In collaboration with Kazutaka Amano and his student Ken Narita, of Joetsu University of Education in Japan, I have shown that the earliest dog whelks lived in the waters off what is now California about twenty million years ago, during the Miocene. By the middle Miocene, several million years later, this ancestral species had spread across the Pacific to the coast of Japan.

The history remained an exclusively Pacific affair for the next twelve million years or so. The first evidence of dog whelks in the Atlantic comes from North Sea fossil deposits of late Pliocene age, about 2.4 million years old. Just when these snails reached North America is unknown, but scientists have found dog whelk fossils in Late Pleistocene deposits in Quebec, Maine, and Nova Scotia, indicating that the species has been in those waters for at least forty thousand years.

The fossil record thus implies that the Atlantic species descended from a North Pacific ancestor. But which of the many North Pacific lineages gave rise to the Atlantic dog whelk? And when and how did it migrate out of the Pacific? Timothy Collins, of the University of Michigan, began working with A. Richard Palmer, of the University of Alberta, and with me on these questions about four years ago. He and his student Ken Frazer extracted genetic material from the tissues of dog whelks that we had collected from various Pacific and Atlantic sites to determine their evolutionary history.

The Atlantic dog whelk, it turns out, is most closely related to a species whose stock can be traced back to middle Miocene time in Japan. A fossil closely resembling the Asian dog whelk is known from a beach deposit of Pliocene age near Nome, Alaska, just north of the Bering Strait. Evidently, it was able to enter the Arctic–Atlantic basin through the Bering Strait at a time when these northern waters were warmer than today. The species then spread to European shores, where the typical Atlantic dog whelk evolved.

The dog whelk is only one of hundreds of Atlantic marine species whose evolutionary origins can be traced to the North Pacific. By my most recent count, at least 274 fossil and living species of shell-bear-

Stephen P. Parker; Photo Researchers, Inc.

ing mollusks of the Arctic and North Atlantic spread from the Pacific through the Bering Strait—or are descended from those that did. Of this number, 108 are found on the American side of the Atlantic and account for about 33 percent of the 335 shell-bearing species living between southern Labrador and Cape Cod, Massachusetts. Most of them, about 80 percent, live in rocky-shore communities. Among the animals and plants of Pacific origin that have been in the North Atlantic for less than three million years are acorn barnacles, mussels, periwinkles, sea urchins, starfishes, eelgrass, and kelps. Even in sandy areas, invaders form a conspicuous part of the community of organisms, familiar examples being the soft-shelled clam and the sand dollar.

The common periwinkle represents another particularly interesting case of invasion. Today, this snail is the most abundant mollusk on rocky shores from Newfoundland to New York. It is the most important consumer of seaweeds, on which it grazes with its tonguelike radula. Like the dog whelk, the periwinkle originated in the North Pacific. After the Bering Strait opened, the Asian periwinkle—or a species very much like it—expanded its range to the Arctic Ocean and thence to Europe. Early forms of the common periwinkle—dating to about 2.4 million years ago—have been found in the North Sea region; the sculptured surface pattern of their shells is remarkably like that of the Asian species and of a closely related fossil species from California. Typical common periwinkles appeared a little later, during the early Pleistocene, about 1.6 million years ago.

Some evidence exists that this periwinkle may have grazed along the Nova Scotia shore during the last interglacial stage of the Pleistocene, about 40,000 years ago, as well as during the time of Viking occupation in Newfoundland after the year A.D. 1000. Before 1840, however, the common periwinkle was unknown to observers in Canada and the United States. After its discovery in Nova Scotia, the common periwinkle began to spread rapidly, reaching Maine by 1869 and Atlantic City, New Jersey, by 1892.

The new periwinkle must have had a drastic effect on the native animals and vegetation of the rocky shore. Before it arrived, the only other grazing snails in the area were two small, native species—both also of Pacific origin—that do not graze as intensively. By monitoring experimental plots with and without the new species, my former student Mark Bertness, now a professor at Brown University, showed that a luxuriant cover of seaweeds develops in its absence.

In historic times, European discovery of the Americas profoundly affected the animal inhabitants of shore communities. The green crab, one of the most common predators of shore snails and mussels in eastern North America, seems to have been introduced to the mid-Atlantic coast by human commerce as early as the eighteenth century; the species belongs to a lineage whose fossils are known exclusively from Europe. But it was not until the early twentieth century that the green crab began to spread north of Cape Cod. By the 1950s, it had reached its present northern and eastern limits in Nova Scotia.

In 1980, I decided to find out whether the addition of this predator to the rocky-shore community was "noticed" by potential prey. Crabs often attack by breaking the outer lip of a prey's shell. If the predator is unsuccessful, the surviving snail can repair the damage. Such repair work is recorded as a jagged scar on the shell's exterior. The northward spread of the green crab into Maine and the Maritime Provinces should, I reasoned, have coincided with a rise in the frequency of scars.

To test this idea, I needed to find collections of periwinkles and dog whelks from before as well as after the green crab's arrival. Fortunately, many museums house beautifully documented collections made from the mid-nineteenth century onward,

which have enabled us to track the responses of species to environmental changes through time. I was thus able to inspect large samples of common species from many dates and places. To my delight, a distinct rise in the frequency of shell repair was detectable in periwinkles, as well as in dog whelks.

The next question was obvious: Did the arrival of the green crab result in evolutionary changes in shell defense that would make the shell a better fortress? Did, for example, snail shells become thicker? or did the shells' openings become relatively smaller so that breaking and entering would become more difficult and time-consuming for the predator? In the case of the common periwinkle, the answer was an unequivocal no. Neither shell shape nor thickness showed any change during the last 150 years.

For the dog whelk, however, the answer was different. Shells collected after the arrival of the green crab had thicker lips than those at the same sites before green crabs appeared there. One is, of course, tempted to interpret this change in evolutionary terms: natural selection, affected by the predators, favored the survival and reproduction of individuals with thick-lipped shells.

This may not be the whole story, however. In clever experiments with the Atlantic dog whelk and with the related North Pacific dog whelk, A. Richard Palmer has shown that in the presence of crabs, individual snails develop a thickened shell lip, perhaps because they spend more time hiding and less time moving, feeding, and growing than do snails not exposed to the presence or even the scent of predatory crabs. In other words, the change in lip thickness over time may reflect individual responses rather than, or perhaps in addition to, natural selection in the dog whelk.

The flat periwinkle has also changed since the green crab came to the western Atlantic's rocky shore. Robin Hadlock's work at Yale University has shown that periwinkle shells have become higher spired and have a smaller opening since the predator's arrival, and that populations living where green crabs are absent have retained their ancestral, thin, high-spired shells. We do not know whether this change is genetic or an individual response.

These case studies make two important points. The first is that invading species can have substantial effects on native species in a recipient community. Although these effects may not always be evolutionary at first, they have the potential for becoming so over time. The second point is that such inferences of change would be impossible without museum collections of common animals. These collections are not only necessary for the proper identification of species but also for tracking recent biological history. The collections are essential as a means of documenting envi-

David Cavagnaro

Dog whelks and small barnacles, predators and prey, cluster on a rocky outcrop on Deer Island, Maine, left. A ten-rayed sea star, below, another immigrant from the Pacific, lies in a bed of mussels waiting for smaller sea stars to prey upon.

Bill Curtsinger

ronmental changes and the responses of species to them.

Some clams and snails may have extended their range from Europe to North America before human commerce brought the common periwinkle and the green crab to the New World. Still others, such as the predatory moon snail, have long histories in eastern North America. The moon snail is the most recent species in an ancient lineage traceable to the early Miocene and beyond in the great fossil deposits of the Chesapeake embayment. The quahog clam, sea scallop, bay scallop, slipper limpet, and oyster drill are other North American species that can be traced to the Miocene or earlier.

Some species belonging to native lineages have forged intimate links with immigrants. The Pacific-derived flat periwinkle, a specialized herbivore, preys on several species of bladderweeds, which likely had an Atlantic origin. None of the living North Pacific relatives of the flat periwinkle have evolved the same dietary specialization.

Why has the east coast of the United States and Canada been so kind to marine immigrants? Only about 12 percent of species in Europe's North Atlantic are of immigrant stock. In the North Pacific, the proportion is 3 percent or less, and in most tropical regions it is lower still. Perhaps currents in the northwestern Atlantic presented opportunities for species from neighboring regions to disperse here. But why—once the Bering Strait opened—did only a trickle of species from the Atlantic move into the Pacific while so many went the other way?

I think the explanation lies in the preinvasion history of the waters off eastern North America. Invading species are most likely to establish viable populations if there are few incumbents. Extinction and overexploitation of native species could therefore have provided unparalleled opportunities for the subsequent success of immigrants.

These waters witnessed an extraordinary biological impoverishment during the Pliocene, before the invasions from the North Pacific began in earnest. Stephen Stanley, of Johns Hopkins University, estimates that more than 75 percent of clam species living along the east coast of the United States during the early Pliocene became extinct before the beginning of the Pleistocene's glacial cycles. Extinction among snails may have been even more severe. Losses in other parts of the world, although still substantial, were much smaller.

Some of the void left by these extinctions was filled by immigrants from Europe and the Pacific. Surprisingly, few if any of the surviving native lineages underwent evolutionary branching to give rise to new daughter species; most simply changed or remained the same without branching. Why these survivors did not diversify is unclear. Another puzzle is why species living in the subtropical waters from the Carolinas southward did not give rise to cold-adapted offshoots along the coast from Virginia northward.

Extinctions have continued to plague species of the northwestern Atlantic even in our own day. During the last 150 years, four have become extinct: the great auk, Labrador duck, sea mink, and eelgrass limpet. Atlantic populations of the gray whale may have been exterminated as early as 1675. All these species played important ecological roles in nearshore communities. The auk appears to have been an important predator of fish, while the Labrador duck and sea mink probably preyed on marine invertebrates, including mollusks. The Pacific-derived eelgrass limpet, a small, cap-shaped snail, evidently lived and fed exclusively on the blades of eelgrass. During the early 1930s, the plant was decimated by a wasting disease that resulted in its extinction. The gray whale, which survives today in the Pacific, intensively churns the sea bottom in search of its invertebrate prey. The loss of these species in the Atlantic had potentially drastic ecological consequences for the marine communities of New England and southeastern Canada.

To make matters worse, several key players in the marine ecosystem have been very heavily exploited during the past few centuries. Visitors and settlers in the colonial period found lobsters and cod so abundant just offshore that gathering them required no special effort. Intensive cod fishing and the invention of lobster canning during the 1840s led to sharp declines in nearshore populations of these predators. Prey species, perhaps including new European immigrants, were thus released from the population control previously exercised by lobsters, cod, and the extinct predatory birds and mammals.

The history of marine life in New England and the Maritime Provinces may be unusual in that the magnitude of extinction and the proportion of immigrants were very high, but the lessons to be drawn from this history must not be ignored. Everywhere in the world, species are being driven to extinction while others continue to be harvested to population levels far below those encountered by our ancestors. More than ever before, species have been handed opportunities to found immigrant populations, with or without help from people. History tells us that extinctions and introductions bring about major changes that affect all members of the community, often in unanticipated ways. Visitors to the tide pools of Maine a century from now may well behold a scene quite different from the one we now take for granted. □

Flat periwinkles of the Atlantic coast graze on native bladderweeds, a dietary specialty their Pacific relatives never evolved.
Heather Angel

Photo/Spike Osler.

A red fox, below, may wander within a few yards of adult brown hares about once every four nights, even when not stalking them. Experienced hares stand up, right, when they spot a fox getting too close for comfort.

Both photographs by Manfred Danegger; NHPA

No Hide, No Seek

All bets are off when the fox is having a bad hare day

by Tony Holley

Half an hour after sunset on a September evening in 1988, a brown hare crouches, grazing short grass some ten yards from the thick hedgerow of a pasture. The field is one of many at Brent Knoll on the Somerset plains, a flat expanse, crisscrossed with drainage channels, that stretches inward from the Bristol Channel coast for about fifteen miles. The failing light is just at that moment when all countryside objects switch from full color to shades of gray, black, and white. Suddenly, the hare rises and stands erect on its long back legs, its raised ears facing to the right. Watching from my attic window, 350 yards away, I swing my 20 × 80 binocular telescope to the right; at the same time I place a bet with myself. About thirty yards away and casually making its way toward the hare is a red fox. I win my bet.

As the fox approaches, the hare continues to stand, facing the danger. As I watch the hare, fanciful ideas cross my mind. Is it challenging the predator to a bout of fisticuffs or perhaps showing respect to the visitor? When the gap between them has narrowed to no more than ten yards, the hare drops and squats on its haunches. The fox stops and adopts the same posture. For nearly two minutes the animals hug the ground while looking at each other. Finally, the fox gets up and wanders past the hare into the hedgerow. The hare remains alert and, when the fox pops its head out of the hedge for another peek, again briefly rises up stiffly on its hind legs.

In the same field at sunset on a June evening in 1990, there are five hares: a doe, which is resting; three bucks, which earlier had been competing for the doe; and a six-week-old youngster, or leveret. The grass is low, having been mowed for silage only three weeks previously. Fifteen minutes after sunset a fox starts to cross the field toward the three bucks. When the fox is about forty yards off, the nearest buck stands up on two legs. The next one stands up when the fox has approached to within twenty-five yards, and the third at twenty yards. The first two hares remain in position, but the last buck moves about thirty yards away. Those farthest from the fox do not stand or show any other reaction to it.

Between 1980 and 1990 I spent more than 5,000 hours observing and recording the behavior of these animals by day, at twilight, and in the night hours. The attic of my house, which is surrounded by seventeen fields, served as a permanent blind, with windows overlooking every part of the area. I used the binocular telescope and, when a closer view was required, a modified eleven-inch astronomical telescope lens. I could determine the sex of many of the hares, and I could also identify individuals by their ears, many of which bore nicks or tears.

I kept records of all the interactions I observed between hares and foxes. If the fox was foraging, it might remain within sight of a hare for twenty minutes or more. (Such prolonged proximity was particularly common when the fox was feeding on earthworms—which in some months can provide over 60 percent of its caloric intake.) Hares generally continued feeding until the fox approached closer than about fifty yards, when the hares stood up on their hind legs, facing the fox. In a few cases, when the fox drew even closer, the hare moved away a short distance, sometimes on two legs but more often on four.

Mark Hamblin; Oxford Scientific Films

Able to attain a maximum speed of about forty-five miles per hour, a hare, below, can easily outrun a fox. Right: Unlike rabbits, brown hares have no burrows to hide in, but depend on their superb senses to warn them of danger.

Manfred Danegger

Hares can form a substantial part of a fox's diet. In one study of Hampshire foxes, hares made up 30 percent of the foxes' fare in summer and about 16 percent in winter. A high proportion of the total catch consisted of leverets. Another study, conducted in Poland, showed that foxes average six adult hares and thirty-five leverets annually. On only two occasions did I observe foxes chasing adult hares. These episodes did not last long, and the foxes were unsuccessful both times. To capture a grown hare, an animal with a maximum speed almost half again as fast as its own, the fox must depend either on stealth or ambush. Why, therefore, should a potential victim draw attention to itself by standing up when it sees a predator, seemingly inviting unnecessary risk?

Standing on the back legs is the standard response of a hare to a fox approaching it in the open, but not to a fox emerging suddenly from cover. Whenever a fox made a sudden appearance from a nearby ditch or hedge, hares either moved away or half-crouched, primed for a quick getaway. In an open field, however, a fox could not get closer than thirty yards without the hares standing up on their back legs.

Hares stood up in all heights of vegetation, from tall, flowering grasses to low-cropped sward; in darkness as well as bright daylight; when solitary as well as in groups. As the fox moved away from them, 70 percent of the hares immediately resumed the crouching posture.

When a fox approached to within thirty yards, some of the hares simply moved a short distance away. None of the hares were chased by foxes, and none left the field. When domestic dogs approached, the hares usually crouched lower and finally took flight. They never stood.

Do the hares stand in order to see the foxes better? I think not. They stand even when a fox is clearly visible from a low angle across a close-cropped pasture, and they do not stand up to observe dogs.

Is the standing hare giving an alarm signal to other hares, as some other animals are known to do? Probably not, since on 42 percent of the occasions that hares stood, they were solitary, with no others in sight. And the signal was clearly directed to the fox and never to domestic dogs.

If the standing hare is indeed signaling to the fox, what is the message? Foxes do not chase down their prey, but are likely to be ambushers and, possibly, stalkers. Dogs, on the other hand, are runners, some breeds relying on speed and others upon

stamina in the hunt. I believe that when a fox sees a hare standing up, the predator understands that it has been spotted and that a sneak attack will not be successful. A signal that the game is already over can benefit both animals, since it saves the exertion of a pointless chase. On the other hand, dogs probably do not understand this signal. A hare that stood before them would be actually inviting a chase.

Signals to predators that they have been observed—zoologists call them pursuit deterrence signals—are known from other species. Klipspringers, a kind of small African antelope, give them to black-backed jackals. Moorhens and purple gallinules similarly signal the marsh harriers that prey on them, and Thomson's gazelles signal to cheetahs (*see* "Why Do Tommies Stott?" *Natural History,* September 1988). Of related species, only the arctic hare is known to stand in the presence of its predators, such as the arctic fox, gyrfalcon, snowy owl, raven, and also, at times, humans. The function of this behavior in the arctic hare has not been investigated; but when brown hares stand up on their back legs, they are giving the fox a clear signal that cannot be mistaken for anything else. □

Its nest a simple cup in the sand, an adult least tern incubates its two eggs on Mississippi's gulf coast.
Dan Guravich

Terns on Tar Beach

As the shore becomes a dangerous place to nest, some least terns have quit the sand for another precarious site

by Jerome A. Jackson

Ooo-eee! Every time I stopped, I stuck for a second and then took a bit of bubbling black tar with me as I moved on. The glare from the noonday sun made me squint. The heat was unbearable—and the cause of the sticky tar and thick tar fumes. A little glimpse of hell? No, it was simply the roof of the Singing River Mall in Gautier (pronounced "Go-shay"), Mississippi, on a July day in 1981. I had stopped at the mall for lunch and noticed least terns flying to and from the roof. Could they be nesting there? The mall manager assured me they were and invited me to take a look, but admonished me not to stay too long or disturb the birds. I knew better than to do that, and I couldn't have withstood the heat if I'd wanted to stay. Yet about 200 pairs of least terns were nesting on the roof, their simple nest scrapes scattered across the veneer of pea-sized gravel atop the hot, viscous tar. Dozens of chicks crowded together in the shade along the walls at the roof's edge. Why were they here? Could they possibly survive?

Least terns, which winter in the West Indies and nest on coastal beaches and river sandbars in North America, have had troubled times since the late 1800s, when they were considered just the right size to adorn ladies' hats. The birds were taken by the thousands, particularly from the Atlantic and Florida coasts. Throughout most of the twentieth century, California and Atlantic coast populations also declined as prime beach property was invaded by growing human populations. In the interior, least terns that nest along major rivers also suffered losses as their sandbar nesting areas were eliminated by channel dredging, damming and flooding, and runoff of pollutants.

On the northern gulf coast, however, the lot of least terns improved when plume hunting ended. Because the mainland coast lacked extensive beaches, these birds nested primarily on barrier islands, which had the advantage of being too far offshore to attract many beachgoers and too vulnerable to tropical storms to allow human settlement.

When mainland colonies of least terns were discovered in coastal Mississippi in 1936, they were invariably in habitats created by humans: bare areas next to bridges and construction sites, dredge spoil dumped in marshes, and man-made beaches. The longest such beach in the world is a twenty-six-mile-long, hundred-yard-wide strip created in 1952 along the Mississippi Sound in Harrison County, Mississippi. The sound's sheltered waters provide good fishing, and busy U. S. 90, which runs along the entire length of the beach, selects heavily against dogs and cats that might otherwise find an easy lunch. This would have been a paradise for nesting terns were it not for the throngs of beachgoers and the regular beach maintenance by tractors that raked the sand at about two-week intervals.

Least terns tried nesting on the new beach anyway. Time after time, eggs would be laid, only to be raked away before they could hatch. The beach had become what is known today as an ecological sink—a place attractive to wildlife, but one in which little, if any, successful reproduction can occur.

In 1974, concerned citizens began marking least tern nests and urging their protection, and their efforts paid off. In 1975, more than 1,000 pairs nested on the

The roof of the Singing River Mall in Gautier, Mississippi, nearly three miles from the coast, was first adopted as a nesting site by least terns in 1981.
Stephen Kirkpatrick

Speckled tern eggs (foreground) are camouflaged against the superficially beachlike surface of a mall roof, below. Shade and water condensation afforded by air-conditioning units substitute for the readily available water and ocean breezes of the birds' natural nest sites.
Dan Guravich

mainland (non-barrier-island) beaches; in 1983, more than 6,000 pairs. Since then, the main nesting colony in Gulfport has annually supported from 2,000 to more than 3,000 pairs, making it the largest least tern colony in the world.

As tern populations have grown, so have the sheer numbers of beachgoers and consequent disturbance of mainland colonies. Despite efforts to protect nesting areas, the Fourth of July has always meant trouble for the terns. Fireworks turn beach colonies into war zones with casualties all too obvious on the morning of the fifth. Notwithstanding the setbacks, however, the terns have adapted and resisted. Terns nesting on the mainland beaches, for instance, are much more aggressive in defending their colonies than are barrier island nesters. A human straying into a mainland colony can expect to be defecated on or even hit by the bill of a diving kamikaze tern. Small groups of least terns have nested with some success on areas of the mainland beach outside of the main protected sites, but numbers of these splinter colonies have steadily declined. Not one was found in 1992, when human use of the beaches seemed at an all-time high. Newly established jet ski rental businesses now attract more people to the beach. Jet skis also create constant ripples and waves on the usually placid waters near the colony that the terns use for feeding. This means that the tiny fishes the terns feed on are harder for them to see, and the birds must go farther to find food for their young.

Least terns are relatively long-lived birds; some survive twenty years or more. After the tern population explosion of the 1970s, the numbers of Gulf Coast terns may have reached a plateau, once again limited by availability of nesting habitat. With their numbers all built up and no place to nest, breeding terns have pioneered some nontraditional nesting sites, including the graveled rooftop of the Singing River Mall.

Rooftop-nesting least terns were first discovered in Mississippi at the Navy

Jerome Jackson

Dan Guravich

Least tern chicks, hatched on a rooftop, huddle in a shaded corner for relief from unrelenting heat, left. Such chicks often suffer burned feet from sticky tar. When gathered in such congregations, they are easy pickings for predatory crows. Young siblings, above, reveal the color variation in the down of tern chicks: one is the color of dry sand; the other, of wet sand.

Seabee base in Gulfport in 1977. They have also nested on rooftops in Florida and other coastal states. Are these terns on the leading edge of adaptation to the modern world? Perhaps. They certainly illustrate an important level of flexibility in their choice of nest sites. Graveled rooftops do have some characteristics in common with the bare beaches the terns have always used: they are large, flat, open areas with no vegetation. Natural colony sites often have bits of shell and other materials that give a varied color and texture to the nesting area, helping the mottled eggs to blend in, and the multicolored pea-sized gravel atop the Singing River Mall might serve a similar function. But a roof is not a beach, the most obvious differences being that roofs are not next to bodies of water, are well above ground level, are devoid of sand, and are often sites of air-conditioning units, vents, and other unnatural structures. Twentieth-century terns have learned to accept the accouterments of the human world as part of their own. The advantages are freedom from human disturbance and protection from dogs and cats. Roofs are unaffected by storm tides and not subject to the natural succession of plant growth that limits the years of usefulness of natural sites. But other problems can be so severe that rooftops may be another example of an ecological sink.

When I first began studying the least terns at the Singing River Mall, I was amazed at the difficulties the birds faced. The pea-sized gravel was so sparse that most pebbles were stuck in the asphalt base, leaving the birds little loose gravel into which they could hollow their cuplike nests. Much more than on a beach, tern eggs were simply laid on the bare surface. One section of the mall roof had a slight slope to it, and terns nesting there lost their eggs if they left them unattended for mere

Jerome Jackson

A discarded paper cup, left, evidence of burgeoning numbers of beachgoers, below, offers a week-old chick temporary protection from the sun and from predators.
Dan Guravich

seconds during high wind or rain—the eggs simply rolled downhill. Another obstacle to success was the distance the terns had to travel for food. Mississippi Sound is nearly three miles to the south and, to the north, the Intra-coastal Waterway is not much closer. Birds went in both directions for food, mostly to and from the south, in a steady flow over mall parking lots, a K-Mart, two highways, a pine forest, and an urban residential area.

Another hazard the terns faced was the fish crows that found eggs and chicks were easy meals. Eggs were conspicuous against the fine gravel, and chicks had no clumps of vegetation in which to hide. Instead, they congregated in the shadow of the three-foot-high wall surrounding the roof's edge. Marauding crows could herd them into corners, where there was no escape. The only defense was the continual mobbing of crows by adult terns, but often while one crow was being mobbed, another would slip through tern defenses to snatch a chick.

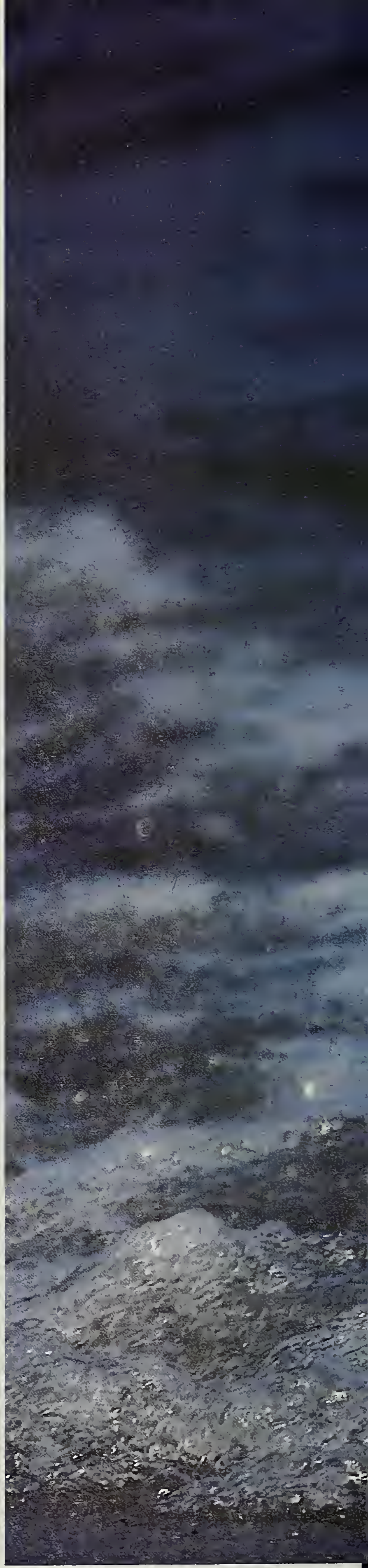
By far the greatest threat to the terns, however, was heat. Black asphalt showing through the veil of pebbles heated quickly, becoming so soft at midday that unattended eggs would sometimes stick to the roof like Br'er Rabbit to the fabled tar baby. My students and I monitor the colony each year, but we work at nests and band chicks only in early morning and late afternoon to minimize stress to the birds. What we found when we started banding chicks was appalling. Nearly every chick had burned and blistered feet. Often the webbing between chick toes was missing or perforated as a result of the sores.

Least terns are birds of the open beach and hot environments, but in a natural setting, sea breezes provide some relief. On the Singing River Mall roof, the three-foot-high parapet may keep the chicks from plunging to the parking lot below, but on most days it also blocks even a whisper of wind from cooling the roof surface, which at times exceeds 114° F.

Each year I have studied them, some chicks have fledged, and the next year the birds have returned to nest. Salvation from the heat came from several quarters. The parapet surrounding the mall roof, though blocking air flow, cast a shadow on one side or another at most times of the day, and chicks followed the shadow as it moved. In good years, a shaded corner might host a crèche of thirty downy chicks. A second fortuitous feature of the rooftop is the set of widely dispersed air-conditioning units. On the hottest days these run constantly, wringing moisture from the mall air and depositing the condensation in shallow puddles adjacent to the units. Both chicks and adults use this water for bathing and drinking.

The third defense against the heat is something that was first described along the Mississippi River in 1896 by one Guideon Mabbett, who noticed that eggs often had tiny, mysterious droplets of water left on them. The purpose of the droplets is now known. In a behavior known today as "belly-soaking," an adult

Dan Guravich



Chicks that stray from patrolled and protected nesting areas often die beneath the wheels of beach maintenance vehicles, below, or the feet of beachgoing humans. To feed itself and its young, an adult least tern, right, must find calm, unrippled waters in which it can spot tiny fish.

Jerome Jackson

bird wets its belly feathers and then drips water from its breast onto eggs or chicks to keep them cool in unusually hot environments. On the Singing River Mall, belly-soaking is often an everyday necessity. By midmorning, the terns no longer need to sit on eggs to keep them at a warm enough temperature for the embryos to develop. Instead, they have to stand over the eggs to shade them. As temperatures continue to rise, each adult dips into nearby water—often the air-conditioning condensate—returns to the nest, and drips water onto the eggs or chicks. A chick may even reach up and swallow droplets, looking like a suckling mammal. As belly feathers dry out, the attendant parent becomes fidgety as it waits for its returning mate and may risk leaving its nest in the open sun for a few seconds to quickly dip in nearby water, for only that can cool its eggs or chicks. On the hottest afternoons, exchanges at the nest become increasingly frequent as adults are stressed by the heat and belly feathers dry out more rapidly.

By the mid-1980s, the Singing River Mall colony was dwindling. Fewer chicks fledged. Fish crows had honed their chick-capture strategies and were eating themselves out of a food supply. The chicks and eggs were too conspicuous against the pea gravel. But then along came Sears.

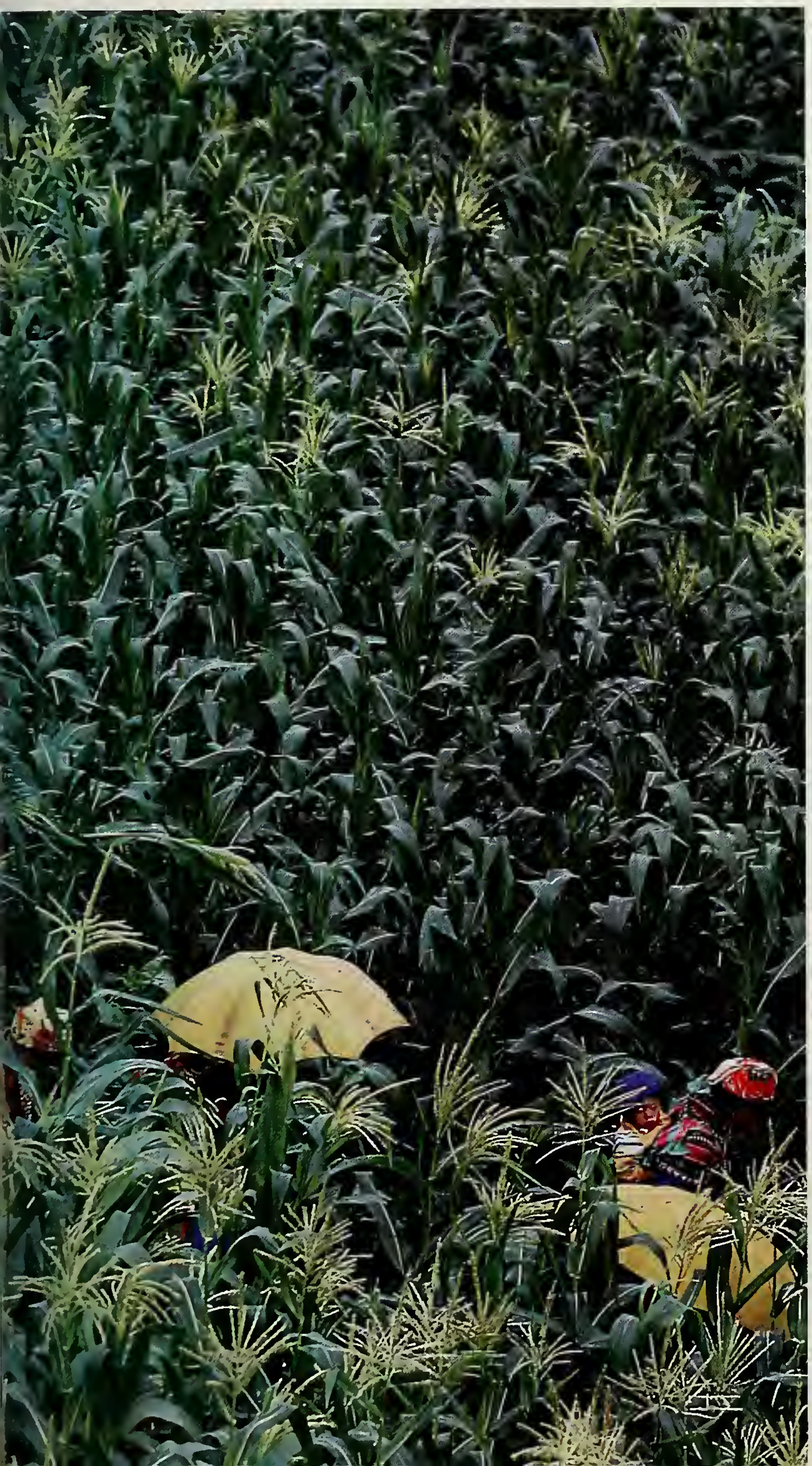
When a Sears Roebuck store was added to the mall, a different type of gravel roof was used. Instead of small pebbles on tar, one- to two-inch white and tan rocks covered a plastic mat. Although the rocks were not embedded in the mat, they were simply too large for the terns to move. Nonetheless, the Sears roof was adopted immediately. The light-colored rocks reflected more of the heat. They were also mottled in much the same manner as eggs and chicks, allowing them to blend in extremely well. In 1992, a few terns attempted to nest on the old roof, but all nests were lost. The main colony was on the Sears roof and, although fish crows still took a toll as chicks congregated in the shade of the parapets, many young fledged. This summer, we plan to scatter small, wooden-slatted teepees about the roof as chick shelters, We hope their design, which provides room for chicks to hide out of reach of crows, will lessen losses to these predators. With their determination and adaptability and a bit of help from us, least terns are hanging on—some say thriving—in this bit of the human world. □

At the end of a summer New Year festival in the Yunnan village of Puge, celebrants troop away from the festival grounds and return to their fields.
Nevada Wier

When the New Year Comes Twice

In southwest China, the Yi people greet the New Year in winter—and again in summer

by Li Weibao



In the provinces of the Chinese southwest—Yunnan, Guizhou, and Sichuan—live some six million Yi people, one of China's fifty-five minority groups. Although the Han people make up the vast bulk (92 percent) of China's population, the Yi have maintained their distinct traditions, language, and culture, mainly because of their relative geographical isolation. One of the most interesting survivals is the Yi custom of two separate New Year celebrations, one in winter and one in summer. These festivals are perhaps the last vestiges of a ten-month calendar that was once widespread in southern China and that had been in operation for several thousand years—possibly longer than any other in world history—and was still used in some remote Yi villages as recently as forty years ago.

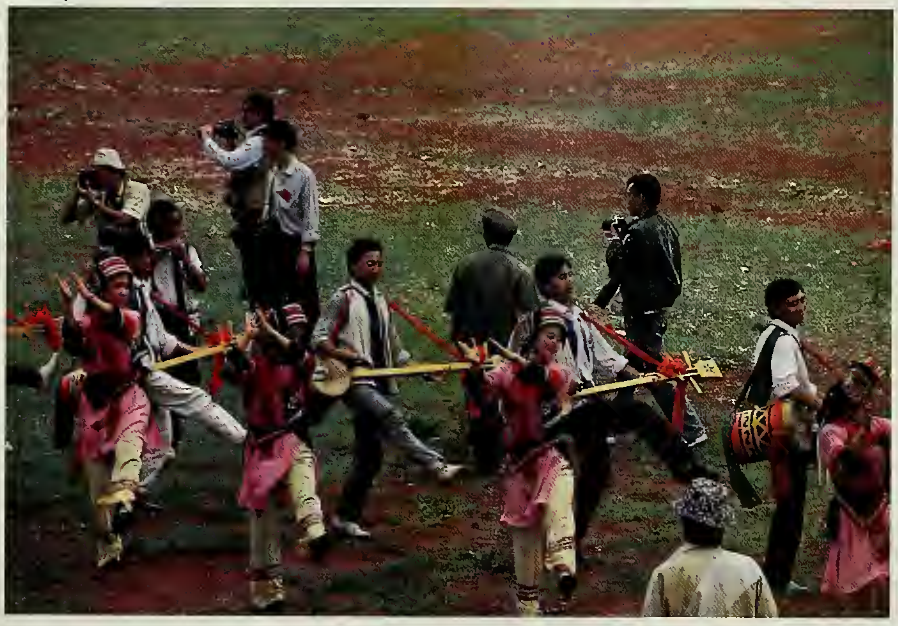
Until early in the present century, the standard Chinese calendar was luni-solar. The year consisted of twelve lunar months of 29 or 30 days (between new moons), making some 354 days in all. To keep the year in step with the solar year (365¼ days) and the seasons, a thirteenth month was inserted every three years or so, according to carefully prescribed rules. Although this calendar was replaced for official purposes by the Gregorian calendar in 1912, it is still used in the countryside, as well as in Hong Kong and Taiwan. Chinese communities throughout the world continue to celebrate the lunar New Year at the second new moon after the beginning of winter, no earlier than January 20 or later than February 20.

The ten-month calendar of the Yi people was devised in ancient times by an astronomer named Shidi Tianzi, whose calculations accorded with solar observations. With the help of four assistants, Shidi used a vertical pole as a gnomon, or sundial, to mark the positions of sunrise and sunset during the year. He also noted the seasonal changes in the length of the noon shadow of the gnomon. After protracted observations, he was able to accurately fix the dates of the winter and summer solstices and to make a precise determination of a year's length.

Lois Riley Wheeler

In some Yi villages, New Year festivals open with a parade of colorful flags, right. Far right: Women perform a circle dance under yellow parasols. Below: Musicians play stringed instruments while dancers keep step with the melody; below right, they promenade onto the ceremonial grounds.

Lois Riley Wheeler



Just when Shidi lived is not known with any certainty; however, legend has it that his descendants are in the 248th generation. Allowing an average of twenty-five years from one generation to the next would mean that the ten-month calendar could have originated as long ago as 4000 B.C. According to astronomical records, however, it probably developed about 1500 B.C. during the Xia dynasty. By the first century A.D., the calendar was used throughout southern China and as far north as the central plains.

Shidi's ten months were simply artificial divisions of the solar year, not unlike the twelve months of the Gregorian calendar worked out in 1582 by Pope Gregory XIII. The year began about the time of the winter solstice, and each of the ten months contained thirty-six days; the remaining

Lois Riley Wheeler

Nevada Wier

five or six days were set aside for festivities. Here we have an interesting parallel with the predominantly solar calendars of ancient Egypt and pre-Columbian America, in which a year consisted of twelve months of thirty days, followed by five or six additional days.

The New Year in the ten-month calendar was called by a variety of names meaning "the days when a new year replaces the old one and sacrifices should be offered to the deities of ancestors." Originally, individual months were named after wild animals: the tiger, otter, crocodile, boa, pangolin (scaly anteater), muntjac (barking deer), blue sheep, ape, leopard, and lizard. Days were also named after these same animals, and during the course of a year, each was used in rotation thirty-six times.

The five or six extra days at the beginning of a year were numbered rather than named, a practice dating from about 1000 B.C. that became so widespread for a time that it left its mark on ancient Chinese folksongs of the *Shijing* (*Book of Songs*). The ten mystical numbers of Heaven found in the Chinese *Book of Changes*—known to us as the *I Ching*—are also thought to be derived from the ten months of the Yi year.

With the Tang dynasty and the influence of Han culture, animal names for the months were replaced by the five elements of Chinese philosophy: *tu* (earth), *jin* (metal), *shui* (water), *mu* (wood), and *huo* (fire). The first five months formed the yang year, and the next five months made up the yin year. Each season consisted of two months (or seventy-two days), containing a yang and a yin month for the same element. These archaic month names still remain fresh in the memory of some elderly Yi people who live in the villages of northwest Yunnan.

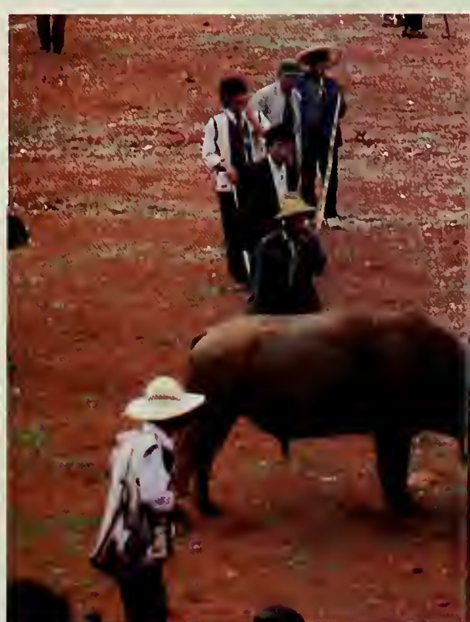
The ten-month year was divided into two halves, each ending at one of the solstices. The yang year was the period of plant growth, while the yin year was the period of plant maturation. Festivities marked the end of each short year. Although the ten-month calendar now belongs to history, these two New Year celebrations are still an important part of Yi life in parts of Yunnan.

Traditionally, the *Kushi* festival was celebrated at the winter solstice and the *Zhai* festival 180 days later at the summer solstice; today, however, there are marked local variations in the dates of these events

because of the development of divergent customs in the various provinces where the Yi live. By 1800 B.C. in certain regions, observations of the Big Dipper determined when the year began. Since the length of a sidereal year is slightly longer than that of a solar year, the people who followed this practice gradually celebrated the two New Year's days later and later in the year. The difference amounted to nearly one and a half days per century. Also, after about A.D.700, the lunar calendar, which had already been adopted throughout much of northern China, became even more widespread. Gradually, the two New Year festivals became linked to the lunar calendar and thus not closely tied to the seasons.

Nowadays, the *Zhai* festival in Yunnan is celebrated on the twenty-fourth day of the sixth lunar month, which usually falls any time from mid-July to late August in the Gregorian calendar. In some villages, the festival lasts for three days and is called the Great New Year. The *Kushi* festival, on the other hand, is celebrated in eastern Yunnan from December 25 to 29 (or 30) and in western Yunnan a month earlier. Certain villages even hold the event for five days in mid-October. In parts of Sichuan Province, the festival has no fixed dates but is held some time in November or December on auspicious dates selected by a shaman.

Regardless of when they fall in the year, the festivals are enthusiastically celebrated by the Yi. Originally the *Zhai* festival was a time when sacrifices were offered to the ancestors. This gradually evolved into a lively ceremony in which prayers, songs, dances, and torch displays

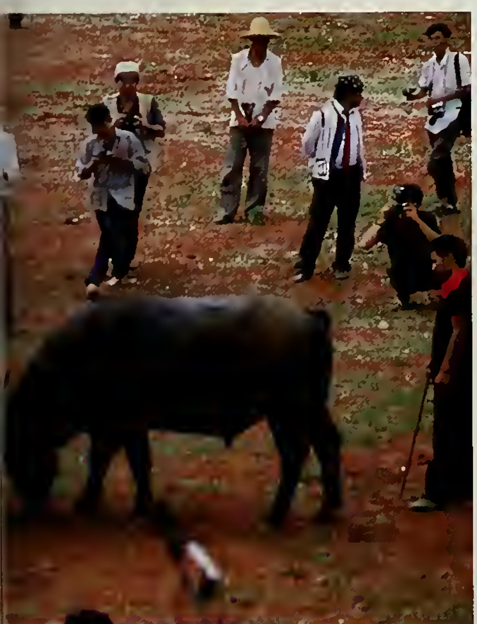


Lois Riley Wheeler

Nevada Wier

Horse racing, left, has become an important event in recent New Year celebrations. Bottom left: In another type of competition, bulls meet head on in the arena as their handlers look on. Below: Long ago, the summer New Year celebration culminated in a parade of men carrying burning tree trunks, but because timber is scarce today, branches and grasses are used for torches.

Nevada Wier



were offered to the deities and ancestors to ask for a bumper harvest of cereal crops.

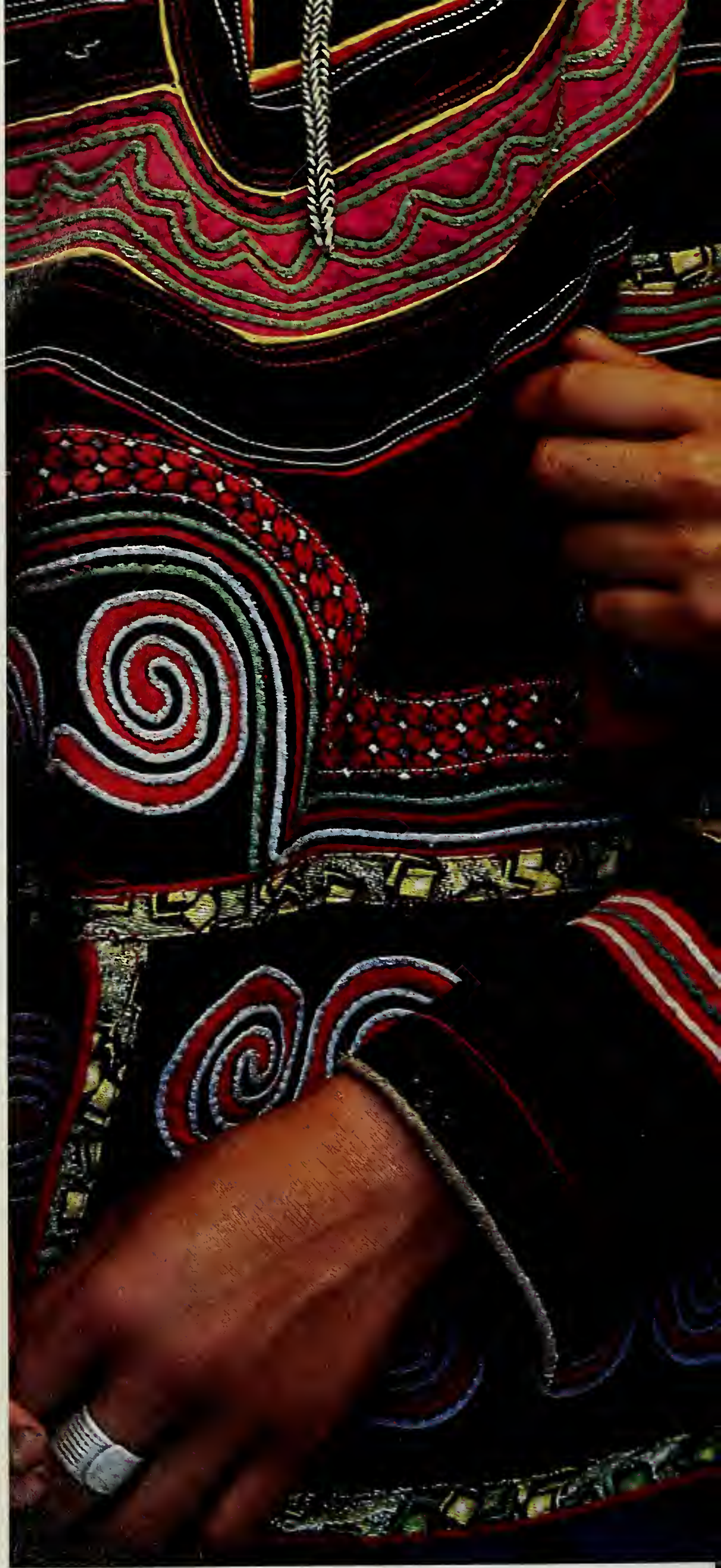
In Mile County, in the central part of Yunnan Province, the summer *Zhai* festival is fairly typical in that on the morning of the first day, the farmers of one or more villages assemble on a fixed open ground (in large villages, a center marker is erected). People who are talented in singing, dancing, and playing of musical instruments take the lead in going to the center ground to perform the traditional rites for a good harvest. As the gaiety increases, the festival loses some of its formality. Spectators often give impromptu performances, and children form their own recreational circle. Festivities do not end until sunset.

On the second day, those elderly people who are held in high esteem take charge of sporting activities. Archery contests have been replaced by wrestling contests, probably because of the limited space of the competition area, which is located inside the village or on open ground nearby. In bygone days, wrestlers could take up a challenge on the spot, but today, rules are more formalized, and competitors are organized into groups and must enter their names in advance. The contest opens with an entrance ceremony, after which the individual bouts commence. Women's wrestling has gained in popularity in recent years, and in some villages ox-fighting is also practiced. Winners of the various events may be given prizes or cash awards; however, this is by no means the rule, as the main purpose of the sports is entertainment.

After dark on the evening of the third day of celebrations, torches are lit. In the past, every family prepared a pine trunk at least six and a half feet in length, which was processed in advance so it would burn more easily. The entire village was involved in making a huge torch and placing it in the village center. With nightfall, the torches were lit simultaneously and carried through the village and out into the fields. The procession of torchbearers resembled a long snake glittering under the night sky and was accompanied by a display of fireworks that, according to the elders, drove away insect pests. Today, owing to the shortage of trees—and the need to conserve those that remain—this magnificent spectacle is seldom witnessed.

The winter's *Kushi* festival is highly colorful because the women make new clothes to be worn for the event, and all the villagers, especially the children, dress up.

All Yi women dress up elaborately for both winter and summer New Year festivals, but these embroidered jackets are traditionally worn by women of a particular group, the Nisu.
Nevada Wier

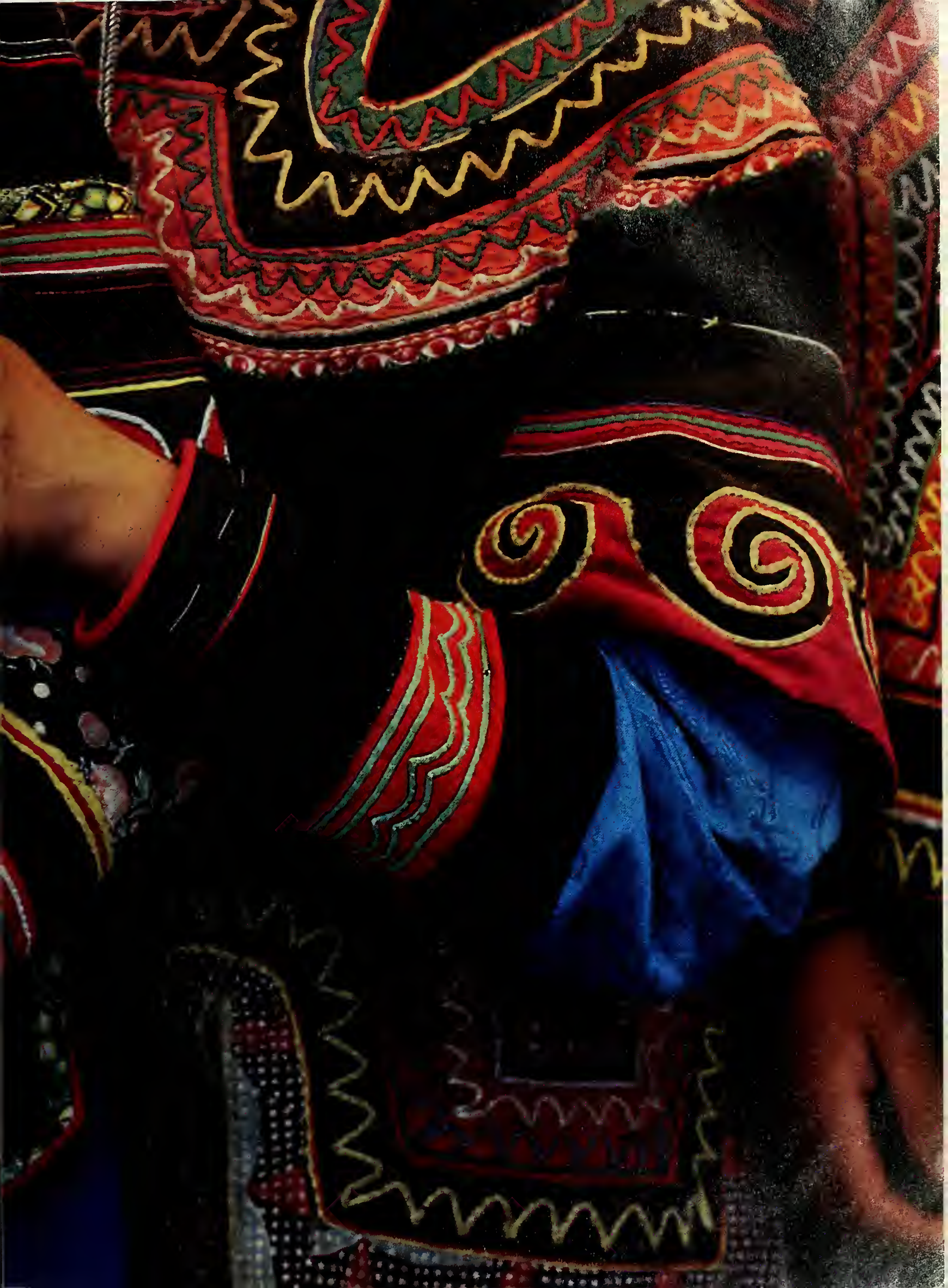


Pork, vegetables, and wine—purchased by the men, often from faraway markets, and prepared by the women—are served. The ceremonies in Honghe and Shiping counties are typical of *Kushi* festivals throughout Yunnan.

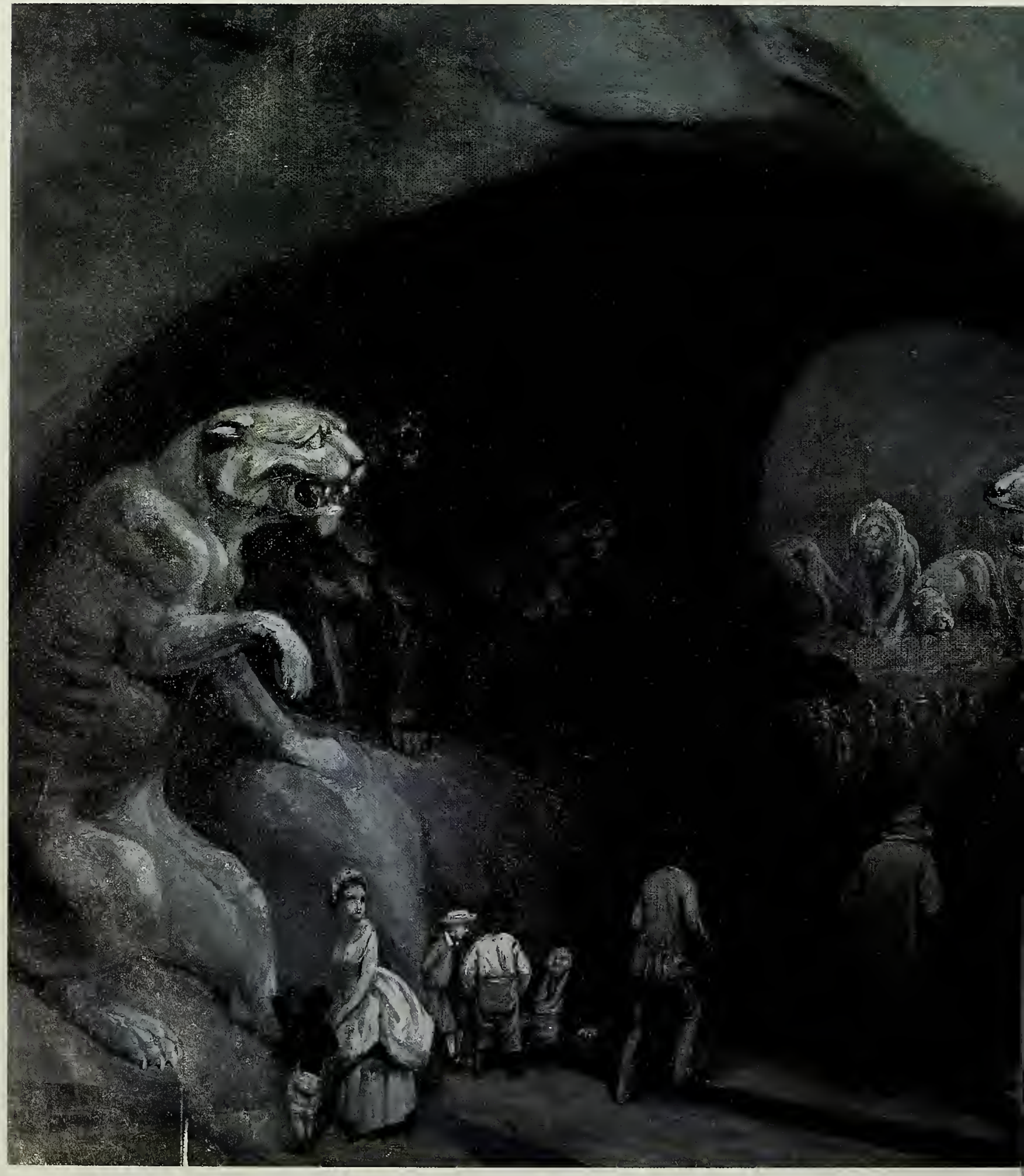
What started as a sacrificial rite has become a great thanksgiving to the deities and ancestors for the crops that have been harvested. Today much of the religious significance of the festival has been lost, although sacrifices are offered twice daily while the event continues. Every day before breakfast and again before supper, an elderly man from each family takes a serving tray bearing four bowls of rice (each containing some pork), four pairs of chopsticks, and four cups of wine to the family altar. Bending down before the altar, he raises the tray above his head for a moment; then piously invites the ancestors and the various deities to enjoy their meal. Before the whole family sits down to enjoy the sumptuous feast, the children also pay homage to the deities and ancestors (although this has become little more than a perfunctory gesture).

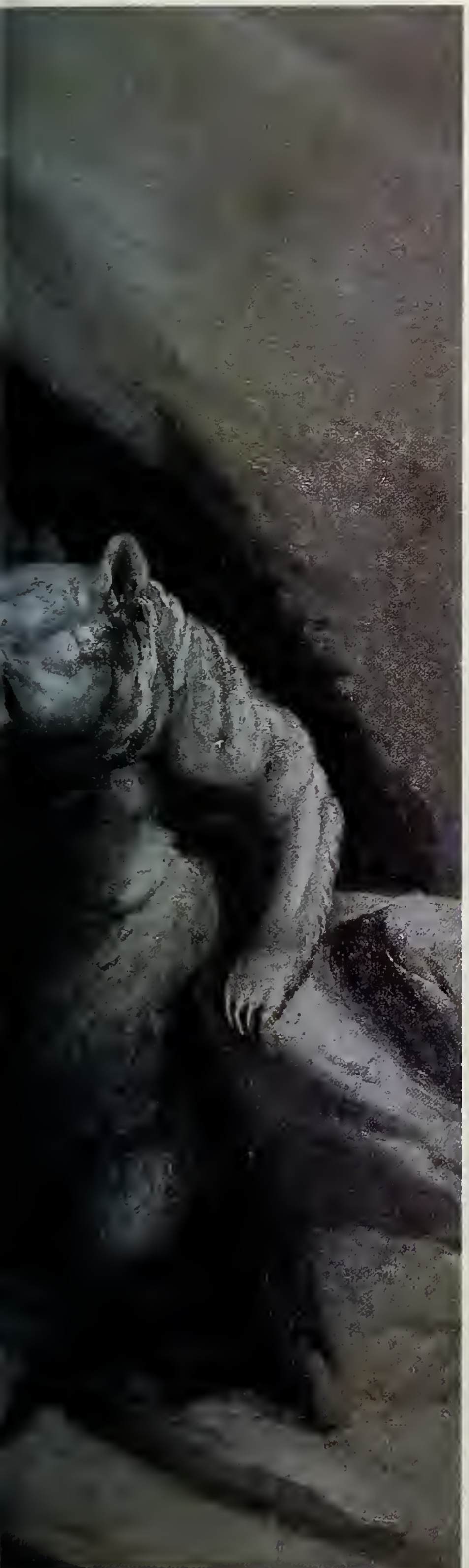
In ancient times, hunting of wild animals was a feature of the first day of the *Kushi* festival, and those who caught ferocious animals were feted as heroes, and the animal skins were used to make clothes for them. In more recent days, however, as wild animals have become more and more scarce, this aspect of the festival has gradually died out.

Before 481 B.C., the *Kushi* festival was a time of great revelry, when people disguised themselves with masks. Today, young men and women still meet and court on the outskirts of the village, where they entertain one another with specially composed songs and dances. Often this occasion is where future marriages are arranged, and the ceremonies take place the following autumn before the next *Kushi* festival. After dark, the young men and women sing and dance both indoors and outdoors to the delight of the elderly onlookers. In Yunnan Province, the boisterous revelry of ancient times persists today in the bold and unrestrained ceremonies of a bygone age. □



The American Museum of Natural History celebrates its 125th anniversary this year. If New York City politics had gone differently in the 1860s, another kind of institution might now be standing on the Museum's present site next to Central Park.





The Museum That Never Was

by Robert McCracken Peck

When President Ulysses S. Grant laid the cornerstone of the American Museum of Natural History on June 2, 1874, he ended the debate about how to utilize a nineteen-acre site administered since 1864 as part of New York's Central Park. This "rugged and unimproved ground," known as Manhattan Square, extended from Eighth Avenue (Central Park West) to Ninth Avenue (Columbus Avenue) and from Eight-first to Seventy-seventh Streets.

After the speechmaking, the Museum's first superintendent, Albert S. Bickmore, placed a collection of souvenirs—a dozen daily newspapers, a dollar bill, some coins, and some official documents—into a small copper box in the cornerstone, and the ceremony drew to a close. For Bickmore, the occasion was a particularly exciting one, for he had been planning a natural history museum for New York City ever since his graduate studies with the Swiss-born naturalist Louis Agassiz, founder of Harvard University's Museum of Comparative Zoology. So intent was he on the idea that before embarking on an overseas research expedition in 1865, he had gone so far as to commission plans for the museum he hoped one day to build.

When Bickmore settled permanently in New York in 1867, the city had a population of almost a million. It surpassed Boston, Philadelphia, and Baltimore in size and wealth, yet could boast no museums of distinction. Among New Yorkers eager to prove themselves cultured citizens, Bickmore found backers for his scheme. He also discovered that his was not the only museum plan afoot. Of the various competing proposals under consideration, two others also focused on Manhattan Square.

The first of these came in 1866 from Frederick Law Olmsted and Calvert Vaux, who had designed New York's 840-acre Central Park less than a decade before. To augment their original scheme for the park, they now suggested creating a zoological garden and natural history museum and placing both in Manhattan Square. The two men wrote a letter to the Central Park commissioners, in which they outlined their ideas.

> It seems eminently proper that the Park should contain within its limits, a collection representative of the animal kingdom so liberally arranged, that it will afford ample gratification and entertainment to the public generally and at the same time be especially valuable, as an adjunct to the Common School System of education.

The designers planned an arched tunnel entrance from the park, entering the square just south of Seventy-ninth Street. The project received enough support to find its way into the commissioner's 1866 annual report and the map that accompanied it.

Not long after Olmsted and Vaux's proposal reached the Central Park commissioners, artist William Holbrook Beard came up with an even more ambitious plan for Manhattan Square: a National Academy for the Advancement of Art. Al-

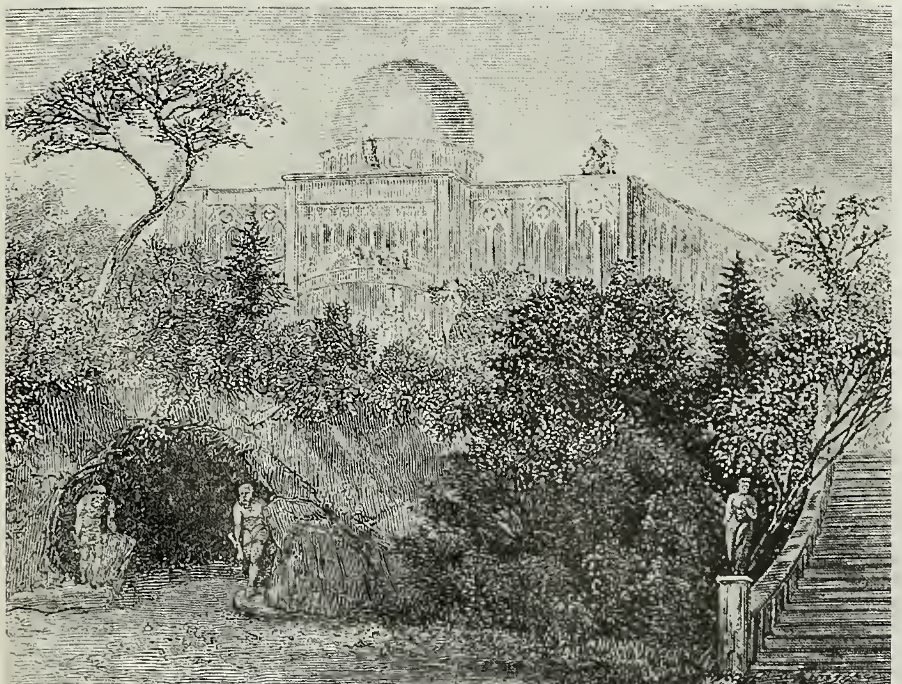
Grotesque figures would have lined William Holbrook Beard's proposed subterranean entrance from Central Park to a museum in Manhattan Square.
Private collection

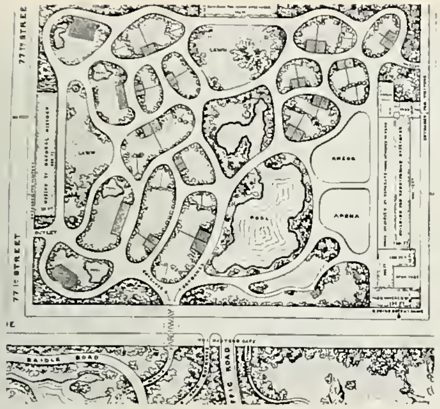
though he had no previous experience as an architect, Beard was well known as an artist. He was especially admired for his ability to paint animals—both as themselves and as caricatures through which he lampooned Victorian society. Beard traveled in influential circles in the art world, sharing studio space in New York with Albert Bierstadt, Frederic Church, John LaFarge, and later, Winslow Homer—artists of immense popularity whose paintings captivated audiences with their strong visions of America. Both Bierstadt and Church contributed to the planning of the Metropolitan Museum of Art in the late 1860s, and Church, in 1872, became a member of the powerful Central Park Commission. Beard's museum design was backed by many of his artist friends and by Henry Keep, a wealthy businessman who was, to use a contemporary phrase, "an architect of his own fortune." While not a member of the highest level of New York society, Keep was eager to join its ranks. With little more than a high-school education, he had worked his way from a poorhouse orphan and teamster on the Erie Canal to a position of great wealth and power. Keep's competitive spirit may have prompted his pledge of \$1.5 million of his own money in support of Beard's museum—an astounding sum for its day.

With Keep's encouragement, Beard began planning his museum sometime in the late 1860s. Although Beard himself never wrote about the project, his ideas were summarized and his designs reproduced in *Scribner's Monthly*, an influential and popular magazine of the period with a national circulation.

According to *Scribner's*, Beard's Manhattan Square museum was to have been housed in an immense, domed building of a hybrid architectural style. His main focus, however, was on the museum's two entrances which, like Olmsted and Vaux's

Beard planned to have stone figures representing Ignorance and Superstition at the main museum entrance, below. In his depiction of the antechamber, right, a colossal, seated figure guarded the museum's portals.
Both photographs by Peter Goldberg



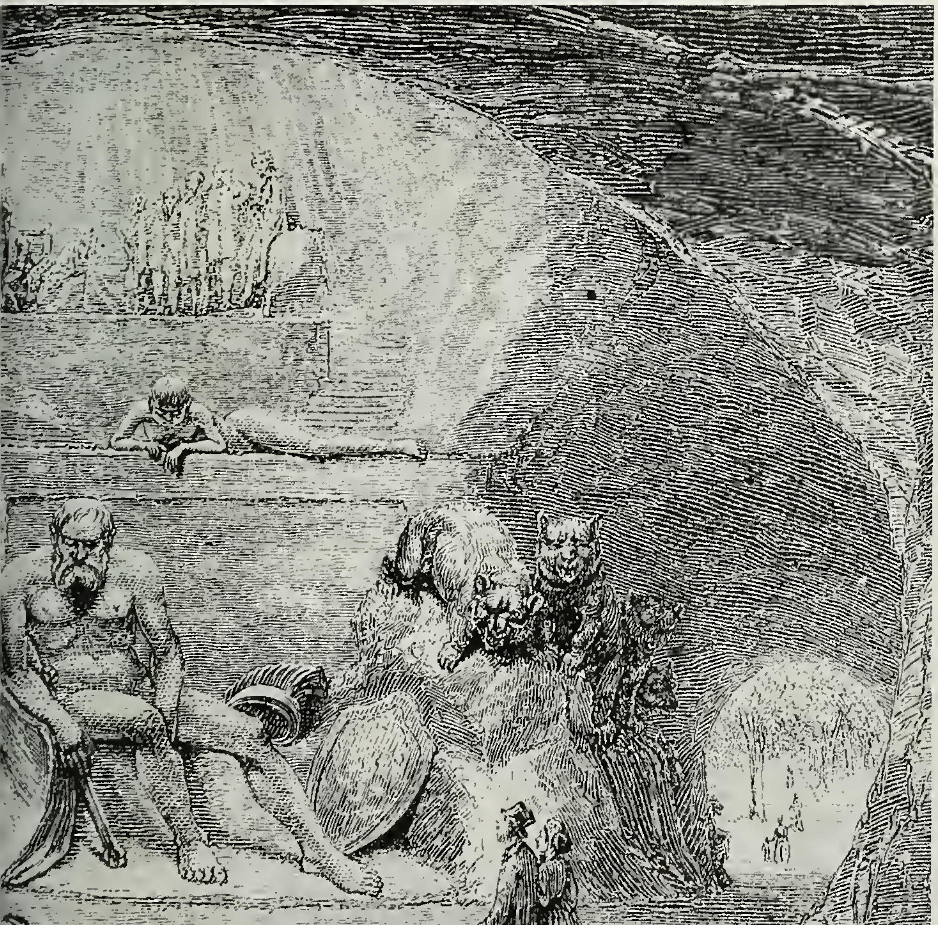


A map of Central Park from the park commissioners' 1868 annual report, far left. Left: Frederick Law Olmsted and Calvert Vaux's 1866 plan for a zoological garden and natural history museum in Manhattan Square, with an underground archway entrance from Central Park.
Both photographs AMNH

proposed archway, were intended to provide the public with an underground passage from Central Park into Manhattan Square.

At the main entrance, visitors would see a pair of "colossal stone figures" representing Ignorance and Superstition. Twenty-foot lions, tigers, and bears—symbolizing "the difficulties to be overcome before the student enters into the real enjoyment and comprehension of the beautiful"—guarded the second entrance. Once past these imposing statues, visitors would move along the subterranean walkway past a menagerie of "grotesque antediluvian animals of immense size" toward a large antechamber dominated by a seated figure, "the guardian genius of the place."

Then they would climb a flight of stone stairs into the museum proper and experience "the gradual progress of the world from barbarism to civilization." The logical culmination of this evolutionary journey was to be a gallery filled with artistic depictions of "the famous characters of recent times...our statesmen, soldiers, orators, and poets, the type of a perfect civilization."



Beard's museum never moved beyond the planning stage because of two major complications: the death at age fifty-one of Keep, the project's chief benefactor, in July 1869, and the rise to power of William Marcy "Boss" Tweed and Tammany Hall, a political emergence that also brought to an end the earlier plans of Olmsted and Vaux. Tweed was a figure of immense power, controlling both the State House and City Hall from his position in the state senate. For a time, the Tweed Ring even took over the administration of Central Park. Olmsted and Vaux were discharged as chief landscape architects, and plans for all building operations in the park, including the zoological gardens and Beard's museum in Manhattan Square, were rescinded, changed, or ignored.

Ironically, Tweed's total control of political power in the state contributed to the eventual success of Bickmore's plan. To purchase European collections of natural history specimens for the institution in 1868 and 1869, Bickmore had enlisted the support of a number of wealthy and influential New Yorkers, including Theodore Roosevelt, Sr., Joseph Choate, Morris K. Jesup, and J. Pierpont Morgan. They petitioned the legislature for a charter incorporating a museum and library of natural history "for the purpose...of encouraging and developing the study of Natural Science [and] of advancing the general knowledge of kindred subjects, and to that end of furnishing popular instruction and recreation."

Through the intervention of Samuel Tilden, later a reform governor of New York but at that time chairman of the Democratic State Committee, Bickmore secured a letter of introduction to Tweed in the state senate. Recognizing the influence of Bickmore's backers and responding favorably to Tilden's support, Tweed swiftly shepherded the proposal through the legislature, obtaining for the American Museum of Natural History an official state charter on April 6, 1869.

Two years later, the legislature approved the joint petition of the American Museum and the Metropolitan Museum of Art (which had obtained its charter in 1870) for permission to build suitable facilities to house their respective collections in Central Park. The commissioners designated Manhattan Square as the site for a structure that would jointly house the two museums and, despite protests from the trustees of both institutions, had the land graded and prepared for construction.

Before construction could begin, however, the Tweed Ring was overthrown. The previous park commissioners were reinstated, and Olmsted and Vaux came back to oversee the further development of the park. With the sympathetic support of the new administration, the Metropolitan Museum of Art negotiated its present site on the east side of Central Park at Eighty-first Street. The American Museum of Natural History chose to remain on the west side in Manhattan Square.

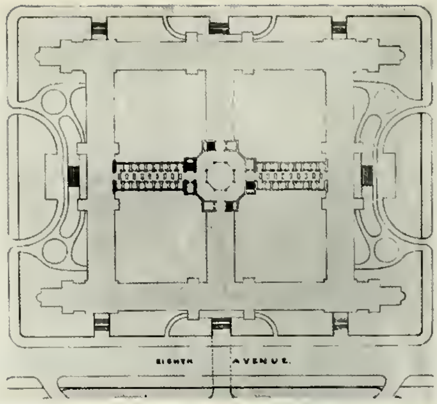
Despite his delight at the city's approval of plans for a museum, Bickmore had misgivings about the site. Writing many years later, he recalled that in 1871,

> within the boundaries of our area the prospect was most desolate and forbidding.... In the southern and central part of the square, just where the first section of our building was to be erected, was a...hill, whose crest rose as high as the ceiling of our present Hall of Birds. As I sat on the top of this rock, the surrounding view was dreary and my only companions were scores of goats.... On the west were only shanties perched on rough rocks, and south of us there was no building near, except the "Dacotah," a fine apartment hotel at the corner of Central Park West and Seventy-second Street.

Bickmore's pessimism was short-lived, however. At the trustees' request, Calvert Vaux and his associate J. Wrey Mould replaced the original plan for a modest, two-story museum building with an ambitious design—740 feet on each side—that encompassed the entire square. A domed tower in the center of four inner courtyards was reminiscent of the one in Bickmore's 1865 design. The buildings, faced with red granite, would have four floors of exhibits and a fifth floor for curators' work space. The section that went up first, beginning late in 1872, was about one-fourteenth of the proposed building. By the time the cornerstone was laid, the foundations and the walls of the first floor had been put in place. As President Grant daubed mortar on the foundation with a silver trowel, Governor John Adams Dix expressed his lofty hopes for the future:

> I know no locality so suitable for this, for such a Museum.... Most of us remember when, but a few years ago, this whole district, which now forms the Central Park, was an unsightly and shapely mass—"*rudis indigestaque moles.*" Now it is the very miracle of rural beauty, where the most unpromising and stubborn natural feature has been made to blend and harmonize with the general aspect of order and grace.

By 1894, when the Museum celebrated the twenty-fifth anniversary of its charter, both Governor Dix's ambitious projections and Albert Bickmore's dreams had been fulfilled. Manhattan Square had been transformed from a rocky, rutted goat pasture into an international center for research and scientific education. □



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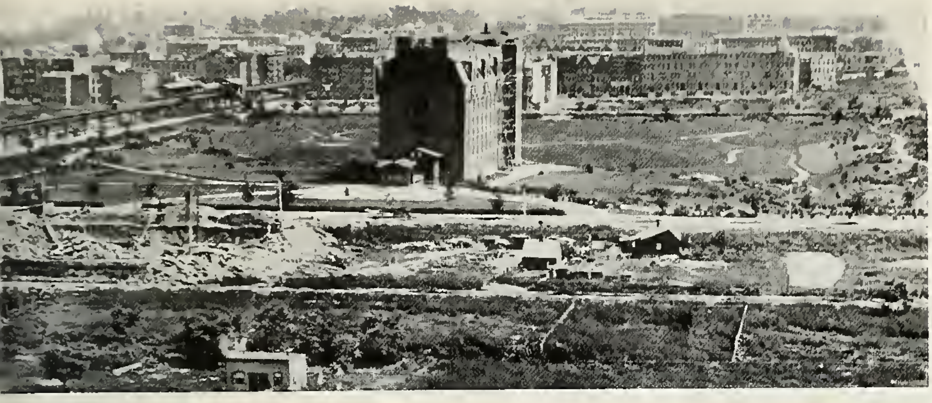

In 1871, Vaux and Mould drafted a master plan for the Museum, far left, but only one of the sections was completed, left. Architects Josiah Cleaveland, Louis DeCoppet Berg, and Milton See submitted a perspective rendering, below, in 1888, incorporating Vaux and Mould's motif of a Greek cross, but only the 77th Street side of their proposed building (foreground) was built.

AMNH

I Have a Dream

Gypsy Witch 1; Freud 0

by Roger L. Welsch

Psychologists say we all dream and that we all dream every night. No doubt they're right, although I rarely recall my dreams—but then, I can hardly manage to recall why Linda sent me to the grocery store only moments after she's sent me. What's curious about the dreams I do remember the next morning is that the inventory is remarkably thin—a total of maybe three. And they are all bad. Just my luck.

Roger Dream Number 1: I open my mail to find that someone has finally discovered that I served only six years and seven months of my seven-year military obligation back in the bad old days. I show up at my base and am standing there in the ranks...but I cannot find my cap. So, there I am, at attention without my cap, knowing that Sergeant Ericson is going to ream me but good, just as he always did. (I often wonder if Sergeant Ericson maybe has the same dream but smiles in his sleep.)

Roger Dream Number 2: I suddenly remember that school is about to start—although in real life I haven't taught in a classroom for more than seven years. Sometimes I am allowed a couple of days before I step into the class, but other times I am in my office and the bell is about to ring. I realize that not only have I not prepared my lesson plans but that I also don't know where I've put my transparencies—a professorial nightmare indeed.

Roger Dream Number 3: I am about to return home from Europe from a field trip for the Smithsonian Institution (I frequently went on these trips twenty years ago). The train is leaving in a matter of minutes for the city where I am to catch my plane, but I have lost my room key and forgotten my room number. I will never get everything thrown together in time. Sometimes I eventually find my key, remember my room number, and make it to the airport all right, but as I stand there watching my luggage go up a carousel ramp, I realize that I have packed my ticket and passport in the luggage, which is about to go onto the plane—and home—without me.

What's uncanny about these dreams is that I am always in the exact same room, hangar, hotel, or airport. I don't know if these places really exist, but I know them like the back of my hand after years of sweating out the complications of my dreams in these settings. My dreams never contain any surprises.

The real mystery to me, however, is the contrast between my dreams and my wife's. I am big, loud, brash, opinionated, independent, and blunt; I dream about losing my cap, hotel key, or passport. Linda is shy, quiet, gentle, uncertain, and subtle; she dreams about distant planets where fire-breathing gorgons with coppery teeth fight wars, tearing great hunks of flesh from their extragalactic enemies and throwing the pieces they do not eat themselves down long Martian cliffs to packs of green, screeching centaurs who pound the still quivering flesh into the pink soil.

When Linda struggles and groans in her sleep and I wake her up, she tells me about horrors that only special-effects experts can dream up. I, noting that such scenes are clearly outside any conceivable realm of possibility, say, "There, there" and go back to sleep.

On the other hand, when I wake up screaming and kicking the finials off the footboard of our bed and explain to Linda that I had this terrible experience of thinking I packed my passport in my suitcase and checked it in prematurely, Linda says, "Poor baby. At least the airport was in this solar system," laughs out loud, and goes back to sleep.

What would Freud have said about my dilemma? "Forbidden desires cloaked in symbolism"? Maybe in Sergeant Ericson's dream, but not in mine (Sarge always seemed to take special delight in calling attention to my shortcomings). "Resolution or relief of fear and anxiety"? When I wake up moaning and yelling because of a dream, our dog Lucky runs out of his sleeping porch, barking at the primal

sounds emanating from the house above, and I spend a good part of the rest of the night calming him down and persuading Linda not to start him up again by laughing too loud. I suspect that even Freud wouldn't find many tantalizing secrets buried in my unconscious. "Herr Velsch," he would say, "my analyziz zuggests, take it a liddle easier on de barbecue zauce next time you pig out on ribs."

One of the first books I remember encountering in my parents' home was *The Gypsy Witch Dream Book: New and Revised, Complete and Up-to-Date,* by the Queen of the Romanies (which beats the living heck out of "Sigmund Freud, M.D."). Whenever I consulted the book fifty years ago to interpret the hidden meanings of my own dreams, I was impressed by how goofy the Gypsy interpretations seemed to be—as I was to learn later, right up there with Freud's. Since I've never thrown the book away (I've never thrown anything away), in desperation I decided to turn to it once again for some idea of what is going on in my tortured nocturnal psyche.

I dug out *The Gypsy Witch Dream Book,* still mysterious in its plain black binding after all these years. It had "reindeer" and "rhinoceros," "stovepipe" and "lemonade," but nothing under "passport," "lesson plans," "airport," or "Sergeant Ericson." But whoops, what was this? "Lose: to dream of losing anything foretells sorrow and remorse." Yep, that was it, all right. When I dream about losing my cap, passport, or lesson plan, everyone from Lucky to Linda is filled with sorrow and remorse.

Eagerly, I read on: "To lose your hat or cap can be an unpleasant experience…but you'll have to admit, it beats fire-breathing gorgons and green, screeching centaurs. And, by the way, next time you dig into the ribs, take it easy on the barbecue sauce."

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

Crash Landing on Jupiter

by Gail S. Cleere

This month, fragments of Comet Shoemaker-Levy 9 will smash into Jupiter's atmosphere at a speed of 133,200 miles per hour. Scientists calculate that some of the resultant explosions will be equivalent to the detonation of 200,000 megatons of TNT—more than the force of all the world's nuclear arsenals. The combined effects of the collision of the twenty-one or more fragments could equal the energy level of the great Yucatan impact on our own planet sixty-five million years ago, a catastrophe that ended the age of the dinosaurs. The action will take place over a seven-day period, from July 16 through July 22.

Originally, the comet may have measured from one to six miles in diameter and the estimates of its largest fragments, which are now stretched out in a procession three million miles long, are equally uncertain. From the earth, the chain appears to be roughly half the size of the moon's angular diameter (twenty arc minutes of the sky).

Since its discovery in March 1993, Comet Shoemaker-Levy 9 has attracted the attention of astronomers around the world. It is one of a handful of comets known to orbit Jupiter, instead of the sun, and it is the only one actually observed in orbit (the paths of others were determined from their motion). Brian Marsden, an astronomer at the Harvard-Smithsonian Astrophysical Observatory, believes the comet was drawn away from a solar orbit in the early 1970s by Jupiter's strong gravitational pull. Given its current orbit, the comet must have made a close approach to the massive planet in July 1992, passing just 13,000 miles above Jupiter's cloudtops. Immense Jovian tidal forces caused the comet to crack, crumble, and fly apart. The pieces then spread out in a line as they continued in their orbit.

Other comets have been observed in the act of breaking apart, but in this case the real excitement comes from the prediction of the comet's imminent demise. Just after the comet's initial discovery, Marsden and Paul Chodas, of NASA's Jet Propulsion Laboratory, calculated its orbit. They found that the comet would crash into Jupiter on its next close approach, in the summer of 1994.

"The planetary science community is very excited about this event," says Hal Weaver, of the Space Telescope Institute in Baltimore. "Luckily it's not happening to us, so the bigger the better." Jupiter will take its hits on its dark, far side, just out of sight of earth-bound observers. Each impact will take place some five to nine degrees behind the planet's eastern edge. Because of Jupiter's rapid rotation, each impact site will become visible from the earth in only twenty to forty minutes after the crash; another seventeen minutes will pass before each site crosses into sunlight.

The *Galileo* spacecraft, due to reach Jupiter in 1995, will have fine views of the impact explosions, but the earth-orbiting Hubble Space Telescope will not be in a position to see the collisions. (It will, however, be able to monitor atmospheric changes on the planet.) The sun-orbiting *Ulysses* spacecraft will have a view of some of the collisions and will be able to monitor the impacts in radio wavelengths. Both *Voyager* spacecraft, now on their way out of the solar system, might have observed the impacts had their cameras not been turned off. There is now too little time for NASA to restore these on-board cameras.

An artist's rendition of the upcoming destruction of Comet Shoemaker-Levy 9. Seen from the perspective of the Galileo *spacecraft, the cometary fragments slam into the dark side of Jupiter.*
D. A. Seal; Jet Propulsion Laboratory

Astronomer Reta Beebe, of New Mexico State University, explains, "All the action will happen about forty to forty-five degrees south latitude," just below Jupiter's Great Red Spot. "This region has no outstanding, long-lived cloud structures like the Great Red Spot, but it is actually quite a turbulent, cyclonic region on the planet, where clouds tend to come apart." After impact, each cometary fragment will blow up not far below Jupiter's cloudtops, and the hot gas that results (54,000° F) will create a huge fireball similar to a nuclear explosion. According to the computer models, the descending fireball will dig itself a chimney and blow itself back out. There is a slim chance that the later impacts will eject material high enough to be visible even to those with backyard telescopes who are familiar with Jupiter's normal appearance.

At the time of this writing, the fiery end of Comet Shoemaker-Levy 9 is expected to begin at approximately 3:30 P.M., EDT, on the 16th. As the sky darkens, look in the southwest for the striking configuration of Jupiter, the waxing gibbous moon below, and Virgo's bright star Spica to the west. As the cometary collision draws near, check local papers or astronomy publications for updates on the timing.

THE PLANETS IN JULY:

Mercury is now moving into the early morning sky and may be seen, although with some difficulty, to the east–northeast in the dawn twilight. On the 7th, the planet is about two moon widths below a slim crescent moon. At the end of the month, Pollux, in Gemini, can be seen twinkling just above Mercury.

Venus moves lower in the southwestern sky, where it is visible just after sundown. What the planet lacks in position, however, will be made up in brilliance as it moves toward its greatest elongation east of the sun. On the 10th, Venus is one degree above the bright star Regulus, in Leo. On the 11th, Venus will be riding high above the thin crescent moon.

Mars has moved into Taurus and can be seen rising about three hours before the sun. On the 5th, Mars will be positioned about five moon widths above and to the right of the crescent moon. By midmonth, the red planet rivals the reddish star Aldebaran, which is just below it.

Jupiter is past the meridian (the arc of sky stretching from due south to due north) as the sun sets. On the 16th, as the planet is hit by the first fragments of Comet Shoemaker-Levy, look for the giant planet about six moon widths above and to the left of the waxing gibbous moon.

Saturn rises before midnight among the faint stars of Aquarius and by dawn is well placed in the southern sky. On the 25th, the ringed planet is seen well below and slightly to the right of the waning gibbous moon.

Uranus and **Neptune** are both at opposition this month (seen opposite the sun in the sky), rising as the sun sets and setting as the sun rises. Using binoculars and a detailed sky chart, you have a chance of spotting these two blue-green worlds just east of the constellation Sagittarius.

Pluto remains in Libra, plodding along at about 7,000 miles per hour not far from the bright stars of Scorpius. When looking in the direction of Pluto, we face the center of our Milky Way galaxy.

The **Moon** is new on the 8th at 5:37 P.M., EDT, and reaches first quarter at 9:12 P.M., EDT, on the 15th. The full moon occurs on the 22d at 4:16 P.M., EDT, and last quarter occurs on the 30th at 8:40 A.M., EDT.

Gail S. Cleere lives in Washington, D.C., and writes on popular astronomy.

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At the American Museum of Natural History

125 Years of Collecting Photographs

Since its founding in 1869, the American Museum of Natural History has not only collected photographs from well-known photographers around the world but has also used the camera as an essential tool in documenting expeditions, cultures, artifacts, fauna, and habitats.

Drawn from the Museum's Library, which houses more than a million images and 3,000 reels of film, the exhibition "The World Explored: 125 Years of Collecting Photographs" will feature lantern slides collected by the Museum's founder, Albert Bickmore; arctic photographs from the 1880s, taken by John Dunmore; and Native American images from the Wanamaker expeditions, taken by Joseph Dixon.

The exhibits will be on display in the Library Gallery through January 1995. The Gallery is located on the fourth floor and is open Monday through Friday, from 10:00 A.M. to 4:30 P.M.

The Apollo Adventure

On Wednesday, July 13, Andrew Chaikin, author of the recently published *A Man on the Moon,* will present "An *Apollo* Retrospective," the scientific findings from the first manned moon landing. On Thursday, July 21, Peter G. Wilhelm, director of the Naval Center for Space Technology, will discuss what has happened since *Apollo* in "Project Clementine: A Return to the Moon." Both lectures, part of the "Frontiers in Astronomy and Astrophysics" series, begin at 7:30 P.M. in the Sky Theater. Tickets are $8 ($6 for members).

"Man on the Moon: The *Apollo* Adventure," the Planetarium's special exhibition marking the twenty-fifth anniversary of the *Apollo 11* moon landing, will run through the end of September. Featured are a model of the original *Apollo 11* lunar module, *Eagle;* a full-size replica of the Lunar Rover; and memorabilia from the *Apollo* flights. The award-winning film *The Eagle Has Landed* will be shown continuously at the exhibition. For information about all Planetarium events, call (212) 769-5900.

These events take place at the American Museum of Natural History, Central Park West at 79th Street in New York City. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

Martin Johnson (center) is one of the many photographers whose work is featured in the Library's exhibition, "The World Explored."
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Raw Bar

In early summer, an Alaskan brown bear attempts to open a razor clam it has excavated from a sandbar on the Katmai coast. Standing on the clam with one foot, the bear delicately pries the halves of the shell apart with its claw to expose the meat (other bears use their teeth to crush clams). After slurping down the contents of the shell, the bear moves on, nose to the ground, looking for more food. The razor clam's half-foot-long neck may just be visible at the surface, but when the bear grabs for it, the clam retreats farther into the sand, making the predator dig for its meal. Only occasionally does the bear snag the prey before it retreats into the muck. Foxes (inset), seagulls, and other animals often follow closely behind clamming bears, picking over the discarded shells for scraps.

For the bears, the clams are more than an occasional treat. During the four hours or so that the tides left this sandbar exposed, this bear left a trail of more than one hundred holes; each had yielded a razor clam. Until the salmon runs begin at the end of the summer, the mollusks provide a welcome source of protein to augment the sedge grass that the bears graze on in the coastal meadows.—*R. A.*

Photographs by Will Troyer

"My unwavering interest in shells began at the age of ten, when my fourth-grade teacher brought Florida shells to us in Dover, New Jersey," says ecologist-geologist **Geerat J. Vermeij** (page 32), who has been blind since the age of three and uses touch in the study of marine life. "These clam and snail shells, many adorned with neatly arranged ribs, knobs, and even spines, were so vastly prettier and more elegant than the chalky (although still nice) shells I had known in the Netherlands that I resolved to collect and study them." In 1968, he graduated from Princeton University, where he majored in biology, and then went on to earn his Ph.D. from Yale University. Now a professor at the University of California at Davis, Vermeij continues to do fieldwork throughout the world, especially in Guam and other parts of the western Pacific. The evolution of labral spines (sharp downward protrusions) in predatory snails is one of his current research interests, as is his formulation of a history of life based on the "market" forces of risk, reward, benefit, cost, supply, and demand. For additional reading, Vermeij recommends *Extinct Birds*, by E. Fuller (London: Viking/Rainbird, 1987) and his own 1991 article "When Biotas Meet: Understanding Biotic Interchange," in *Science*, vol. 253, pp. 1099–1104.

"As an anthropologist," says **Eugenie C. Scott** (page 10), "I have done fieldwork in rural Kentucky, in Belize, and on Florida's Seminole Reservation, but in my present job I work in the fields of television shows, radio talk shows, and teacher conferences." Executive director of the National Center for Science Education, located in Berkeley, California, Scott studies the activities of the religious right and scientific creationists and helps teachers around the nation keep evolution at the core of the science curriculum. She finds her work satisfying but is often dismayed by the extent of scientific illiteracy in America. For additional reading she recommends *Science and Earth History: The Creation-Evolution Controversy*, by Arthur Strahler (Buffalo: Prometheus Books Publishing Co., 1988); *The Creationists*, by Ronald Numbers (New York: Alfred A. Knopf, Inc., 1992); and *The Creationist Movement in Modern America*, by Raymond A. Eve and Francis B. Harrold (Boston: Twayne Publishers, 1990).

By day, **Tony Holley** (page 42) is a partner in a law firm in Somerset, England, but his evenings are reserved for watching foxes stalk hares in the nearby countryside. The foxes, it seems, win less often than most people imagine. Holley qualified as a solicitor in 1954. Almost forty years later, in 1992, at the age of sixty, he completed his doctorate in zoology at Durham University, working first on the gulls of Bridgwater Bay, and later on the behavior of the brown hare. He writes that "hares are particularly obliging subjects for a researcher who is also involved in a full-time nonscientific profession. Virtually the whole time the researcher is sitting at his lawyer's desk during the day, the hares are lying motionless, asleep. They become active just before dusk, when the researcher can watch them comfortably from the attic windows of his country home." For the general natural history and folklore attached to the brown hare, Holley recommends *The Leaping Hare*, by G. E. Evans

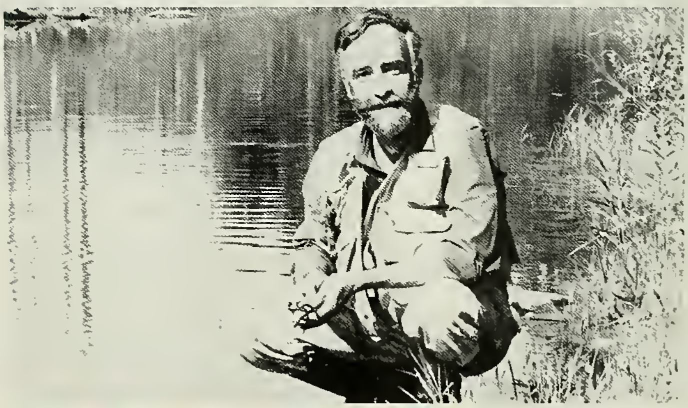
Although he had originally planned to write a dissertation on archeology in Ireland, **Christopher P. Toumey** (page 4) was so disturbed to read about the rise of creation "science" that he decided to do an ethnographic study of the modern creationist movement. A book based on his doctoral research has just been published: *God's Own Scientists: Creationists in a Secular World* (New Brunswick: Rutgers University Press, 1994). Toumey, a visiting lecturer in anthropology at the University of North Carolina, Chapel Hill, also teaches at a maximum security prison in Raleigh, North Carolina. He is currently writing a book on science in American life, including theories of AIDS/HIV infection, the fluoridation controversy, and cold fusion. For additional reading, Toumey recommends *Anti-Evolution*, by Tom McIver (Jefferson: McFarland, 1988), and *The Evolution Controversy in America*, by George E. Webb (Lexington: University of Kentucky Press, 1994).

and D. Thomson (London: Faber, 1972) and "Pursuit-deterrent Signals: Communication between prey and predator," by O. Hasson in *Trends in Ecology and Evolution*, vol. 6, pp. 325–29 (1991).

In 1984, when astronomer **Li Weibao** (page 54) compiled the astronomy annals of Yunnan, he discovered the customs associated with the ancient calendar of the Yi people. "These traditions were on the verge of disappearing," writes Li, "but I felt that it was a national and historical responsibility to preserve them." Born in Yunnan Province, Li earned a physics degree from Beijing University in 1973 and then an advanced degree from the University of Science and Technology in Hefei, Anhui Province. For many years, he has studied sunspots and continues this research at the Yunnan Observatory, along with additional documentation of the history and culture of minority groups. Chinese history and classical poems and songs intrigue Li, as do traditional Chinese paintings and calligraphy. Unfortunately, recommending additional reading about the Yi calendar in English is virtually impossible. For those who can read Chinese, however, Li suggests *A Collection of Ancient Chinese Astronomical Phenomenon Records* (1988), published by Tiansu Science and Technology Publishing House.

On a summer day in 1981, **Jerome A. Jackson** (page 46) stopped for lunch at a local mall and noticed the unusual least tern traffic there. Since then, Jackson, a professor of biological sciences at Mississippi State University, and his students have monitored the terns nesting on the mall rooftops and have also been actively involved in efforts to protect terns nesting on beaches. Jackson served for eight years as the head of the U. S. Fish and Wildlife Endangered Species Recovery Team working to save the red-cockaded woodpecker of southeastern forests. He has searched for evidence of the ivory-billed woodpecker in Cuba (perhaps the only place on earth where the bird still exists) and is now in the field in Indonesia. He has edited various scientific journals, including *The Wilson Bulletin*, and also enjoys bringing science to lay audiences. A frequent contributor to *Birder's World* magazine, for the past five years Jackson has also been co-host of a weekly television nature program, "Mississippi Outdoors." He is the coauthor, with Judith A. Toups, of *Birds and Birding on the Mississippi Coast* (Jackson: Mississippi University Press, 1987). For more information on terns in general, readers can turn to a popular classic, John Hays's *Spirit of Survival: A Natural and Personal History of Terns* (New York: E. P. Dutton and Co., 1974).

"Museums can tell us as much about the people (and societies) who make them as about the subjects they were designed to explain," says **Robert McCracken Peck** (page 62) by way of explaining how he became interested in the American Museum of Natural History. As Fellow of the Academy of Natural Sciences of Philadelphia, Peck has the enviable job of chronicling the collections of the nation's oldest continually operating natural history museum. When not accompanying Academy research expeditions to Asia, Africa, or South America, Peck lectures and writes articles, grant proposals, and books—his subjects have included John James Audubon, Louis Agassiz Fuertes, and William Bartram. Next year he will take a temporary leave of absence from the Academy for a fellowship at Harvard University, where he will study the life and art of Edward Lear (1812–1888). For further reading, Peck recommends: *Dinosaurs in the Attic*, by Douglas J. Preston (New York: St. Martin's Press, 1986), *The City That Never Was*, by Rebecca R. Shanor (New York: Penguin Books, 1991), and *The Park and the People*, by Roy Rosenzweig and Elizabeth Blackmar (Ithaca: Cornell University Press, 1992).



Will Troyer (page 76) poses with his canoe on the Katmai Peninsula, where he photographed the bear digging clams for this month's "Natural Moment." Troyer received his B.S. and M.S. in wildlife management from Oregon State College in Corvallis, and Montana State University in Missoula, respectively. After graduating in 1952, he immediately headed for Alaska, where he has worked as a biologist ever since—including twenty-three years with the U. S. Fish and Wildlife Service and seven with the National Park Service. In his early years, Troyer was one of a few biologists working on a diversity of species in the remote regions of the state. He pioneered techniques for trapping brown bears for scientific study (at first using a bucket of ether over the animal's head). Troyer has also conducted studies of caribou, moose, Dall sheep, bald eagles, and trumpeter swans. After his retirement in 1981, Troyer and his wife, LuRue, spent two and a half years building a log home near the Kanai Mountains, "where," he says, "I can watch Dall sheep and mountain goats from my deck." He keeps busy with photography, birding, fishing, and hunting, but confesses to leaving his beloved Alaska during the short winter days of December and January to photograph wildlife in such warm climes as Africa and Australia. To photograph the bear digging clams, Troyer used a Nikon camera with a 600mm Nikon lens.

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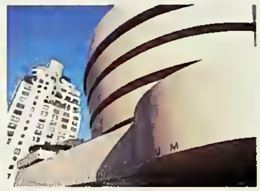

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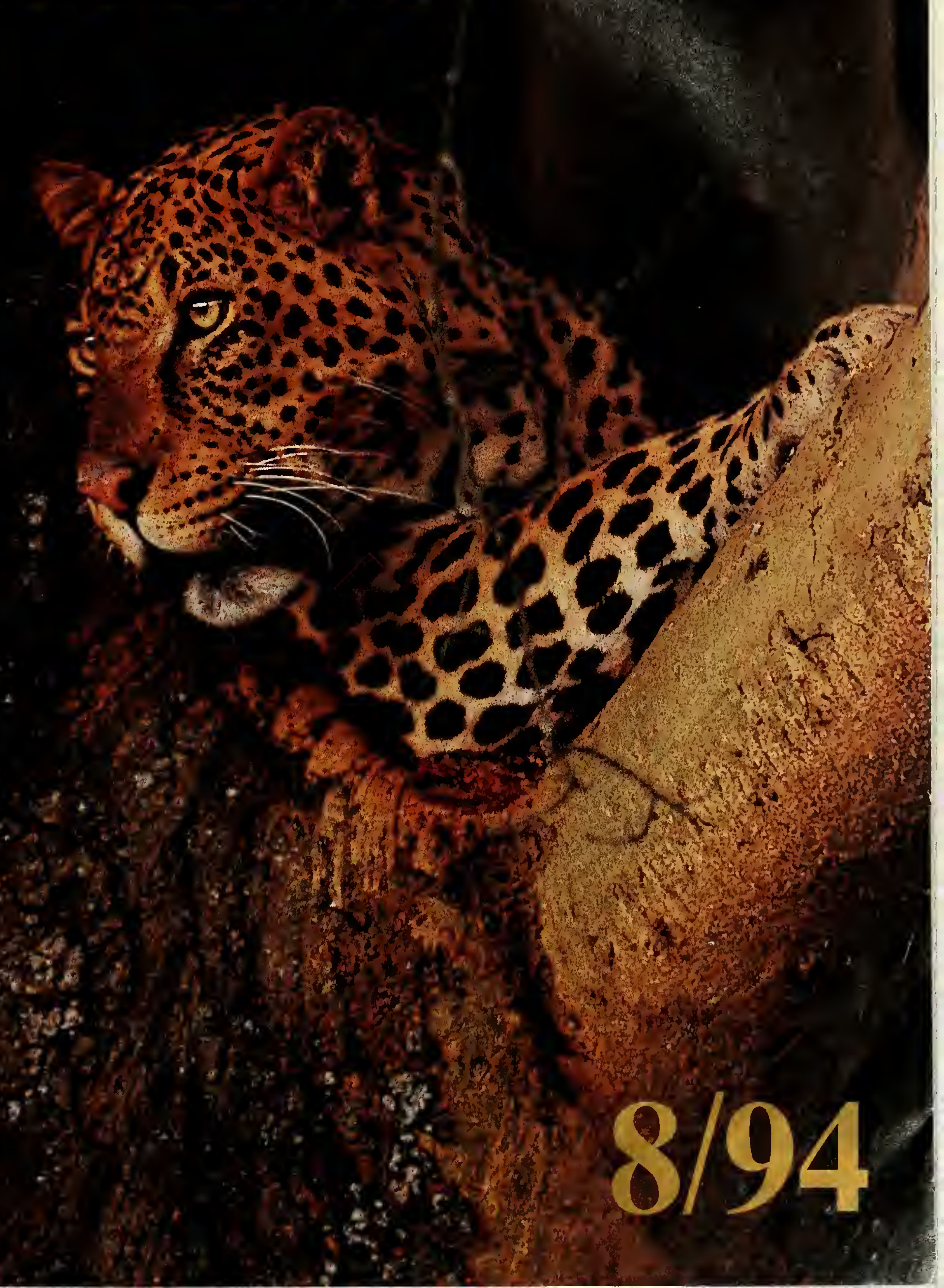

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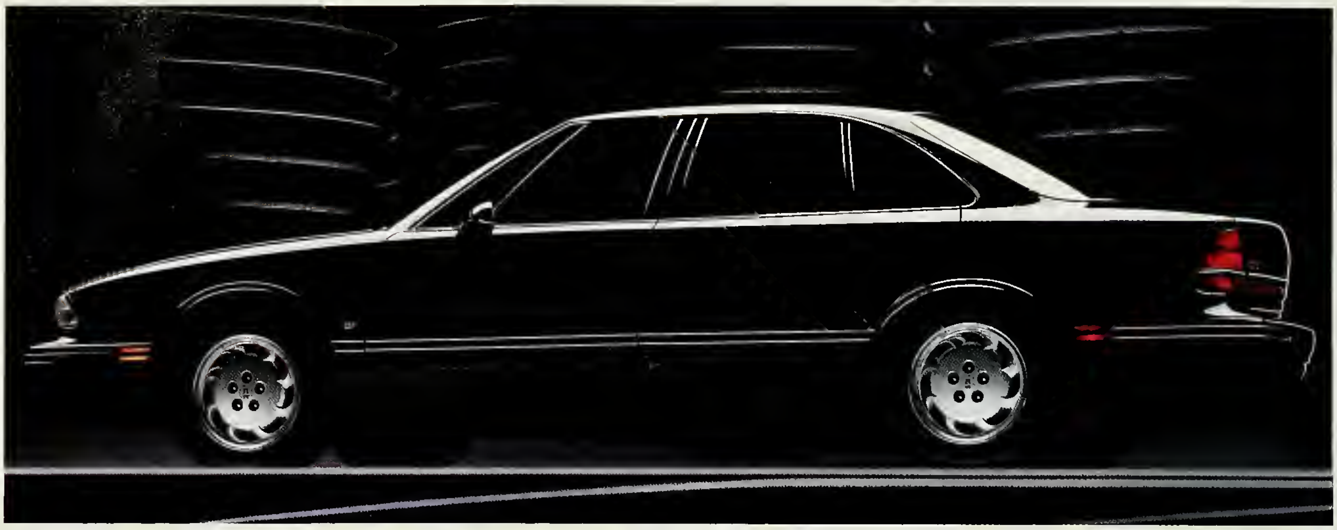

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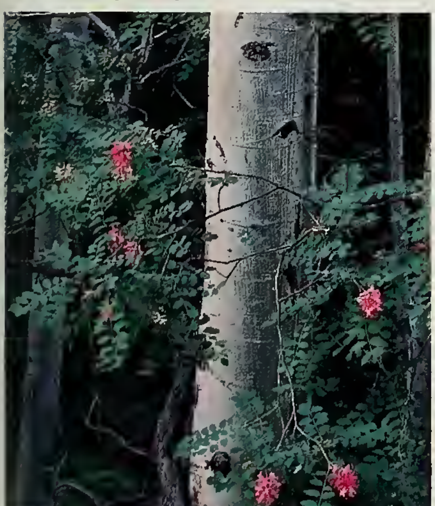
Vol. 103, No. 8, August 1994

COVER: In East Africa, a leopard peers from its arboreal perch, where it often carries the carcasses of monkeys and small gazelles. Story on page 48.
Photograph by Mary Ann McDonald.

A desolate North Atlantic island thirty-five miles off the northeast coast of Newfoundland was once the nesting ground of some 200,000 great auks. The large, flightless seabird became extinct 150 years ago. Its demise is a sad tale of careless human exploitation.



The detritus of a war half a century ago still litters the bottom of the South Pacific. Islanders recycle some materiel

(including explosives) and turn famous battle sites such as Truk Lagoon, where more than thirty Japanese ships were sunk in a few days, into tourist destinations for divers.

The gigantic mola, a relative of the puffer, can weigh as much as 5,000 pounds. The disk-shaped fish lacks a true tail and propels itself with its long dorsal and anal fins. It often rests on its side at the water's surface and basks in the sun.

The mola is impervious to most predators, but killer whales, sea lions, and humans take a toll on the gentle giant.

One species of slave-making ants raids other ant nests, drives off the queen and her workers, and steals and rears the brood. The pupae emerge as slaves, foraging for the colony, removing wastes,

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and excavating new chambers. Another species of slave-making ants depends on the ability of the queen to invade a foreign colony and kill the resident queen. She gets the workers to accept her as their new queen by covering herself with the perfume of the slain queen. Cuckoos, minnows, and many other creatures have evolved successful parasitic strategies, but slave-making ants are the supreme social parasites.

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The Vervets' Year of Doom

Lynne A. Isbell

Scientists became alarmed when their study population of vervets, modest-sized monkeys found in Kenya's Amboseli National Park, fell drastically,

disappearing in growing numbers. In addition, the decline was exaggerated by the "Nairobi effect"—more monkeys disappeared each time the researchers left their camp for a few days to visit Kenya's capital city. As with many natural mysteries, the solution has several interacting elements: the behavior of leopards, the century-long cycle of fever trees, and the dangers for territorial monkeys when they must move to strange turf.

56
Desert Snails' Daily Grind

Clive G. Jones and Moshe Shachak

Photographs by Jeffrey L. Rotman

Most snails thrive in cool, moist climates, so researchers were surprised by the extent of the populations of three different snails in the arid highlands of Israel's Negev Desert. Furthermore, these snails graze heavily on lichens and even

eat bare rock by scraping it into fine particles with their tough, tonguelike radula. During the heat of the day, the snails retreat beneath the rocks, where they defecate nutritious pellets that contribute significantly—about 800 pounds per acre per year—to the region's limited soils.


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LEVIATHAN LOCOMOTION

In "Hooking Leviathan by Its Past" ("This View of Life," May 1994), Stephen Jay Gould appropriately notes that cetacean evolution required only slight modification of terrestrial locomotor movements in the transition to aquatic propulsion. Mechanically, however, the transition required a major change in the manner propulsive force was generated.

Semiaquatic mammals (such as beavers, muskrats, or river otters) swim by paddling, whereas fully aquatic animals (such as dolphins or seals) oscillate their hydrofoil-like flukes or flippers. The latter method is at least twice as efficient as paddling. Ancestral cetaceans changed from paddling to hydrofoil oscillation probably through the use of a modified underwater gallop. Paddling with the feet while flexing and extending the body—otters do this when they are in a hurry—generates propulsive force by both means. A long tail would enhance propulsion and aid in selection for the more efficient mode. The discovery of *Ambulocetus* strongly argues for this scenario.

Why did pinnipeds (seals and sea lions) differ from cetaceans in evolving the use of flippers instead of flukes? The answer may be that their ancestors lacked the elongated tail so wonderfully exploited by cetaceans and sirenians.

FRANK E. FISH
West Chester, Pennsylvania

KUDOS FOR FOSSIL MAMMALS...

I want to compliment you on the special edition on the rise of mammals ("The Marvelous Mammalian Parade," April 1994). Please give us more. Does that issue signal, I hope, the end of dinosaurmania?

FRANCIS A. KORNEGAY, JR.
Silver Spring, Maryland

AND A CORRECTION

As a carpenter, I was intrigued by the caption to the right of the opening illustration of "Successful in Spite of Themselves," (April 1994). It refers to glyptodonts' having 200-pound carapaces sixty feet in diameter. If the glyptodonts in the painting are drawn to scale, they are also thirty-five to forty feet high.

With wood prices going through the roof, the domelike carapaces may well be a boon to the housing industry. Two men could easily carry a "Glyptodome" (I've already registered the trademark) large enough to house several families. I won't be fooled by such sly disclaimers as "We really meant sixty inches or six feet." I'm sure there are enough of these things to make us all a bundle.

PHILIP MCDONALD
Saugerties, New York

THE EDITORS REPLY: As noted in our caption, South American glyptodonts "reached giant proportions," and their carapaces did weigh some 200 pounds. Unfortunately, because of a typographical error, we inflated the diameter of this extinct creature's shell by a factor of ten. So, rather than a disclaimer, we offer an apology to the author, David Webb, and to our readers. While a disappointment to carpenters, the news may be of interest to plumbers. Webb says that "some families in fossil-rich parts of Patagonia have used the shells as bathtubs."

A South American glyptodont fossil on display at the American Museum of Natural History. Carapaces could be as large as six feet in diameter.
J. Beckett and Denis Finnin; AMNH

IS THE RAIN FOREST REALLY A MEDICINE CHEST?

In his review of Mark Plotkin's "Tales of a Shaman's Apprentice" ("Reviews," March 1994), J. Worth Estes downplays Plotkin's (and other ethnobotanists') claims for the pharmacological value of "the nearly infinite variety of plants" to be found in the rain forests. Estes writes, "I have found no convincing evidence that untold numbers of valuable medicines await us in the Amazon basin."

Yet Foster and Duke in *Field Guide to Medicinal Plants* (Houghton Mifflin, 1990) cite numerous native and rain forest plants currently used for medicinal purposes. They note that China and India are both "prime example[s] of 5,000-year-old...medical systems that are constantly vindicated."

Are we to believe the ethnobotanists or the pharmacologist?

JAMES E. WILKINSON
Barre, Vermont

J. WORTH ESTES REPLIES: I have not seen the book Mr. Wilkinson cites, but I have seen many like it, including a number that were originally published in China. Save in the relatively few instances in which plants have yielded valuable drugs (e.g., digitalis, atropine, and penicillin), such books often ascribe medicinal values to plants on the basis of anecdotal data alone. The most common such claims state only that the plant is "used" by a given population to treat some condition. These books do not cite supporting evidence of the kind that pharmacologists and physicians need to have in hand before they can conclude that any drug provides truly effective therapy (however efficacy is assessed) for some specified illness. I did not write that there are *no* drugs waiting for us to find them in the rain forests of the world—indeed, the National Cancer Institute has just launched a massive search for therapeutic natural products. I only argue that we have precious little evidence that they are there.

The Great Auk Cemetery

How a tiny North Atlantic island became the main burial ground for an entire species

by Bill Montevecchi

For decades now, I have returned each summer to the seabird capital of the North Atlantic, a desolate, foul-smelling, surf-pounded mass of granite, known as Funk Island, off Newfoundland's northeast coast. On this "marvelously terrible place," as a local skipper calls it, I have studied the colonies of gannets, murres, and puffins that help me monitor ecological changes in the ocean. But as I study the living birds, I cannot ignore the constant presence of a ghost species: the extinct great auk, once known (inaccurately) as "the penguin of the North Atlantic." Funk Island once contained as many as 200,000 of these magnificent seabirds, and its very soil is made of their decomposed carcasses. This year marks a somber anniversary—it was 150 years ago that humans wiped out the last survivors of this species.

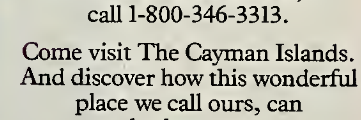
A relative of the razorbills and puffins, and about the size of a small goose, the great auk was black-bodied with a white underbelly, and walked erect, like a penguin. A large, oblong white spot marked the space between its eyes and powerful bill. Although flightless, great auks could "fly" rapidly and gracefully underwater, where they fed on capelin and bottom-dwelling fishes, such as lumpfishes. These auks were also capable of making long sea journeys, and spent much time on the Grand Banks of Newfoundland. Auks were so numerous there that they were depicted in eighteenth-century editions of *The English Pilot*, a guide to North American waters, as indicators to navigators that the Grand Banks were near. At one time the great auk population was so large that most people scoffed at the idea that the birds could ever become extinct.

Auks, however, had the misfortune of being docile and defenseless on land, and much sought after by humans. Millenniums before Europeans came to Newfoundland, Native Americans hunted great auks and collected their eggs, as we know from the quantities of bones and eggshells in paleo-Indian middens. Great auks also held spiritual significance for early aboriginal Americans, and large numbers of auk beaks have been found interred in human graves at the cemetery of Maritime Archaic Peoples at Port aux Choix on Newfoundland's Great Northern Peninsula.

One of the earliest documentations of Funk Island comes from a chart prepared by Pedro Rinel, who was associated with Gaspar Corte-Real's New World exploratory cruise of 1500. Rinel's chart indicates an "Y. dos Aves," or "Island of Birds," near the location of Funk Island. In one of the very first estimates of North American seabird populations, a sixteenth-century observer named Sir Richard Whitbourne thought that the Funk Island auks "multiply infinitely." "God made the innocencie of so poor a creature to become such an admirabel instrument for the sustenation of man," he wrote.

The great auk, or "penguin of the North Atlantic," was hunted to extinction 150 years ago.
From *Extinct Birds*, by Walter Rothschild; AMNH

In 1534, Jacques Cartier was among the first European explorers to land there, and he loaded several barrels of salted great auks aboard his ship before continuing his voyage. The birds proved so delectable that Cartier sailed directly to Funk Island the following year, before making his way to the Gulf of Saint Lawrence. "In less than halfe an hour," he wrote, "we filled two boats full of [auks], as if they have bene stones, so that besides them which we did eat fresh, every ship did powder and salt five or sixe barrels of them." Raids on the island to stock ships' larders continued for more than four hundred years. Fresh food supplies became quickly depleted on long ocean voyages, and by the time vessels crossed the Atlantic their crews and passengers were hungry for fresh protein. Near the journey's end, a quick stop at one of Newfoundland's seabird rookeries, particularly Funk Is-



land, became a necessity. In this respect, Funk Island may be regarded as the New World's first fast-food takeout.

The use of great auks for mariners' fare, however, did not dent the species' prolific population nearly as much as the subsequent mass slaughters to obtain feathers, fat, and oil. During the second half of the eighteenth century, crews lived on Funk Island all summer to gather tons of feathers. "As the birds could not fly," according to one eyewitness report, "the fishermen would surround them in small boats and drive them ashore." There the birds were herded into stone corrals, then thrown live into caldrons of boiling water, plucked, and cast aside. Their feathers became the basis of a mattress and puff pillow industry. Oil was extracted for fueling lamps. As there was no wood on the island, thousands of the auk's fat-laden bodies were used to feed the fires under the great boiling pots. Thousands more were simply thrown into a rocky field, where they eventually composted into the rich soil that supports the island's only grassy area.

Apparently, the auk's lack of flexibility in its breeding habits contributed to its extinction. Great numbers of them were attracted to very few breeding places. Auks built no nests, and usually laid a single egg on bare rock. Maine and Labrador had plenty of suitable breeding grounds, and some ornithologists have speculated that if the bird had bred in small colonies scattered along this wide expanse of territory, instead of in a few island rookeries, it might have survived. On the other hand, there is evidence that they once occupied a much wider range, even including the coasts of Maine and Massachussetts, and were driven to a few remote, rocky islands by relentless overexploitation.

As early as 1785, Capt. George Cartwright sounded an unambiguous warning. "It has been customary of late years," he wrote,

> for several crews of men to live all summer on [Funk] island for the sole purpose of killing birds for the sake of the feathers, the destruction which they have made is incredible. If a stop is not soon put to that practice, the whole breed will be diminished to almost nothing, particularly the penguins [auks]: for this is now the only island they have left to breed upon: all the others lying so near the shores of Newfoundland, they are continually robbed.

By the early nineteenth century, magistates at Saint John's prohibited further taking of auks and eggs, on penalty of public floggings for offenders. Nevertheless, the ban came too late to save the auks, which perhaps had already passed their point of no return.

The last two known great auks were killed on June 3, 1844, on a rocky islet off southwest Iceland. Visitors to Funk Island in the late nineteenth century found huge piles of great auk bones, and small populations of nesting seabirds of other species. About 1860, a vessel removed a load of auk remains to be used as farm fertilizer in the countryside around Boston, Baltimore, and New York.

Huge collections of great auk skeletal fragments have made their way into various museums around the world. Yet some 200-year-old remains of the birds can still be found on Funk Island. Atlantic puffins have burrowed into the peaty soil and established a breeding colony of some 2,000 pairs on the island. Every now and again a great auk bone is kicked outside a burrow entrance by a puffin enlarging a subterranean nest site. About fifteen years ago, I began searching for great auk bones, and soon gathered almost enough to begin constructing a skeleton. Eventually, with the generous help and expertise of several zoologists (and a few key bones from Funk Island that had found their way into the collections of Harvard's Museum of Comparative Zoology), we re-created the first complete skeleton of the great auk in Canada. It is now housed in the Centre for Newfoundland Studies at Memorial University of Newfoundland. While an admittedly futile gesture, it helped me feel that we were trying to make amends for past crimes against the seabirds, and had at least restored one great auk to its home.

From the air, Funk Island's gannet colony appears as a white area, while the green patches are grass growing from the composting remains of thousands of great auk carcasses.
Bill Montevecchi

Each summer, I return to Funk Island, studying living seabirds to assess the health of the world's oceans. As the most visible, most accessible, and widest-ranging biological indicators of the marine environment, they offer much information to a scientist. However, I also feel deeply protective toward these birds of the ocean. I understand their ultimate fragility and how vulnerable they are to human-induced pollution, disturbance, and overfishing. On Funk Island, the lessons and spirits of the great auks are an ever present reminder that I study living birds in the midst of the great "penguin" cemetery of the North Atlantic.

Bill Montevecchi is a professor of biology and psychology at Memorial University of Newfoundland, where he also chairs the biopsychology program. With L. M. Tuck, he co-authored Newfoundland Birds *(Cambridge: Nuttall Press, 1987).*

Happy Thoughts on a Sunny Day in New York City

Scientific curiosity kills the cynic

by Stephen Jay Gould

Galileo described the universe in his most famous line: "This grand book is written in the language of mathematics, and its characters are triangles, circles, and other geometrical figures." Why should the laws of nature be subject to statement in such elegantly basic algebra? Why does gravity work by the principle of inverse squares? Why do simple geometries pervade nature—from the hexagons of the honeycomb to the complex architecture of crystals? D'Arcy Thompson, author of *Growth and Form* and my earliest intellectual hero (along with my father and Charles Darwin), wrote that "the harmony of the world is made manifest in Form and Number, and the heart and soul and all the poetry of Natural Philosophy are embodied in the concept of mathematical beauty." Many scientists, if only to coin a striking metaphor, depict a creating God as a mathematician from the realm of Plato or Pythagoras. The physicist James Jeans wrote: "From the intrinsic evidence of his creation, the Great Architect of the Universe now begins to appear as a pure mathematician."

But much of nature is messy and multifarious, markedly resistant to simple mathematical expression (at least before fractals gave us a way to formulate the complexities of a mountaintop, a coastline, or a leaf). And other scientists have developed equally striking metaphors about a creator who revels in the unquantifiable details—as in J. B. S. Haldane's famous quip (see my column of January 1993) that God must have an inordinate fondness for beetles.

We have, in many respects, been oversold on the mathematical precision of nature. Even the preeminent field for abstract, quantified beauty—a domain whose very name, celestial mechanics, seems to evoke ethereal harmony—includes ever so many awfully messy and downright inconvenient irregularities. Why, for example, couldn't God have arranged some simple and decent proportionality between the earth's axial rotation and solar revolution. Why didn't he give the year a nice even number of days, without elaborate fractions that demand complex seat-of-the-pants corrections in our calendars. Why 365 days and almost (but not quite) an extra quarter?—so that we have to add a leap day every fourth time round, but remove it again every hundred years (because God ordained a little less than an extra quarter after 365), except for every four hundred years when we put it back again. (And thus, if you penetrated that sentence, you will grasp why 2000 will be a leap year, even if, among some purists, it will not make a millennium.)

Nature also mocks our attempt to encase her in a Platonic straitjacket by establishing an almost laughably fortuitous reason for some apparent, highly visible regularities that have played a major role in human history. In my favorite example, much discussed by many commentators, solar and lunar eclipses produce a gorgeously precise and tight fit (as the moon's shadow snugly covers the sun and vice versa). Must not such exactitude be explicitly arranged, or at least arise as a predictable consequence from one of those mathematically elegant laws of nature? But the effect is only a happenstance of history. The sun's diameter is about 400 times larger than the moon's. But the sun is also about 400 times more distant—so their disks appear the same size to an observer on earth. (Now consider how much of human mythology rests upon an image of two guardians, intimately related by their common size: "And God made two great lights: the greater light to rule the day, and the lesser light to rule the night.")

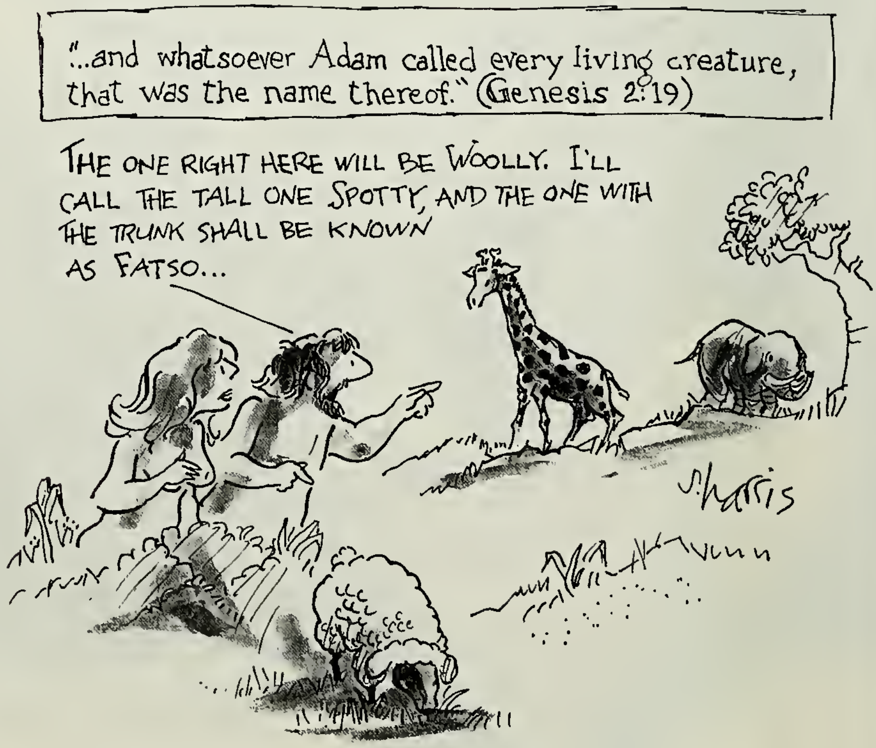
When nature so mocks us, she often comes clean every once in a while, as if to offer confession for such a sublime joke. On May 10, 1994, a rare form of solar eclipse, far less spectacular than the conventional lid of darkness, but immensely fascinating for its own more subtle strangeness, enveloped much of North America. The moon's distance from the earth varies quite a bit during its revolution (planetary orbits are also not so regular as the charts in our high-school textbooks implied). If a solar eclipse occurs when the moon lies at maximal distance from the earth, then the lunar shadow does not fully cover the sun's disk. At totality, therefore, a ring of bright light remains at the sun's periphery. Such eclipses are called annular, from a Latin word for ring. (Annular eclipses are much less spectacular than total eclipses at normal lunar distances, for a ring of bright sunshine still yields substantial light—as much or more than on an ordinary cloudy day—while the sky turns off as if God threw a light switch when the moon's larger disk fully covers the sun.)

I was angry with myself on May 10. The eclipse was 88 percent complete at my Boston home, while totality beckoned only an hour or two north at Concord, New Hampshire, and many other pleasant sites throughout New England. The next annular eclipse in New England will occur July 23, 2093, long past my watch—so it was May 10 or never (at least without substantial travel) for me. I ordered all my students to drive into the region of totality on pain of instant expulsion. (Professors—reveling in these odd moments of surcease from Shaw's observation that those who can, do; while those who can't, teach—really do enjoy such application of limited power. I so ordered, and not a one of them went—to their eternal shame, but otherwise without consequence.) Meanwhile, duty bound to honor a commitment made before I heard about the eclipse, I went south to New York City, toward less solar coverage by an already compromised lunar shadow.

Many things keep us going through this vale of tears—a baby's smile, Bach's B Minor Mass, a decent bagel. Every once in a while, as if to grant us the courage to go on, the powers that be turn one of life's little disasters into a bit of joy or an episode of instruction. The Lord of the (Partial) Ring must have been smiling on me this May 10, for he brought me in a sour mood to my natal city of New York and then rewarded me with a better experience than totality in Concord could ever have provided.

I love pristine nature, but I am a humanist at heart, and I revel more in complex interactions between fellow members of *Homo sapiens* and the great external world. Now think of every stereotype you hold about New Yorkers. (They are untrue, of course, but culturally powerful as a recognized type or icon nonetheless.) New Yorkers are harried, self-centered, cynical, rushed, acquisitive, incurious, uncommunicative, and downright nasty to all humans who cannot be wheedled or manipulated for material gain. Right? Of course, as all Americans know, even those who have never been east of the Mississippi! A solar eclipse must therefore rank as the last thing that could ever intrigue a real New Yorker. I mean, gimme a break, Mister. You want me to stop what I'm doing and look into the sky—at a partial and annular eclipse? Get lost—and screw in your own light bulb.

Yet, as Joshua once stopped the sun over Gibeon, New York City returned the compliment on May 10. In midtown Manhattan, in the middle of a busy working day, New York stopped to watch the sun.



Let me not exaggerate. Many folks just went on about their business, as the human tide of midday swept down Seventh Avenue. But large knots of eclipse watchers also stood their ground on every street. What was it about this less spectacular form of the general phenomenon—partial and annular, rather than total and completely covered—that could have inspired the interest of New Yorkers? Consider two aspects of this remarkable event.

First, in this age of artificially induced, full-body shake-me-ups, from roller coasters to all the electronic powers of film, video games, and amplified sound, we hardly think that anything so subtle, albeit pervasive, as the character of surrounding sunlight could move our passions or even invite our notice (but then the impressionist painters did have some insights about the power of light's quality). It does not get very dark when the sun is occluded by 80 percent on a bright day; an ordinary cloud cover reduces visibility by more than this. Thus, the sky did not darken precipitously over New York on May 10. But we are exquisitely sensitive to the usual character of light, even though we may not explicitly credit our awareness and may not be able even to state what feels so odd.

It did not, I repeat, get very dark over New York, but the cloudless sky implied brightness, and the day turned eerily somber, while sunlight continued to reign—and people noticed, and trembled ever so slightly. "Moses and the children of Israel" sang a song to God to praise the stunning power of altered celestial events: "The people shall hear and be afraid...the dukes of Edom shall be amazed; the mighty men of Moab, trembling shall take hold upon them...they shall be as still as a stone" (Exodus, chapter 15). And so New York, mightier by far and incomparably more sophisticated than these old kingdoms of the Middle East, noticed and stood still as a sky full of daylight darkened to the level of a clearly nonexistent thunderstorm. A woman said to her friend: "Holy shit, either the world is about to end, or it's going to rain—and it sure as hell ain't gonna rain."

Second, the sight of a crescent sun is so unusual, so outside our daily experience, that people do pause to notice, and wonder. If the first phenomenon, eerie (if slight) darkness, impelled a kind of visceral attention, the crescent sun, by contrast, provoked a more intellectual response.

At every eclipse, official purveyors of the news deluge us with warnings about

grave dangers to our sight should we stare at the eclipsing sun. Don't look up, even for a moment. The sun will burn a painless hole in your retina faster than masturbating boys went blind in the bad old days of dire warnings. I do understand why such exaggerations must be presented. Staring at the sun for minutes on end is a very bad idea and can have all the consequences stated in eclipse warnings—so news sources must say "don't look at all" in order to impart sufficient fear for preventing these longer starings. So strident are these warnings that many people actually come to believe in a special power of eclipse light to do such harm. But one can, of course, look directly at the sun for a moment without danger on all days, both regular and eclipsed. After all, we do glance inadvertently into the sun's disk every once in a while, and we do not go blind.

I was standing on the corner of Seventh Avenue and Fifty-third Street looking up at the sun and an older woman pointedly stated as she passed by: "Don't look at it; you'll go blind." I was about to give her a minilecture on understandable journalistic exaggeration, but I desisted and took pleasure instead. Go back to all those stereotypes about New Yorkers. Legend holds that we never talk to strangers, but she had reached out to me. The crescent of the sun beamed upon this domain of anomie and made us a momentary community.

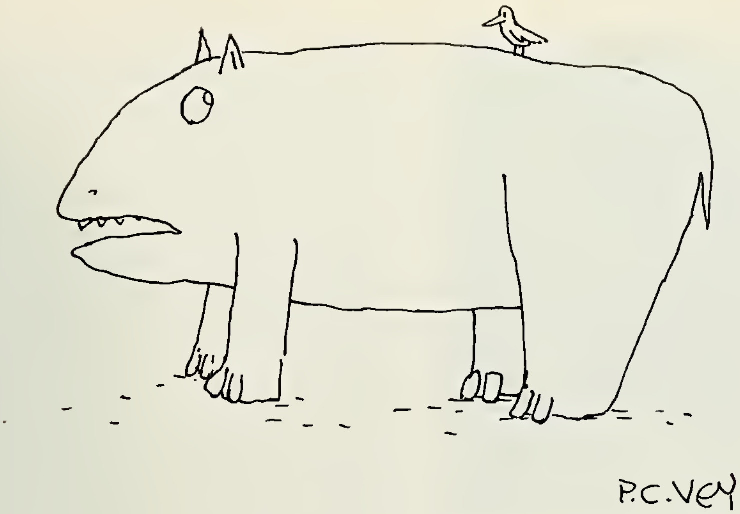
But most people, and quite rightly, did not look directly at the sun, and took official advice for observation by a clever set of devices for filtering or projecting images. And I became grateful for this panoply of strategies during my humanistic "field trip" for science through the streets of New York, for the viewing devices provoked discussion and encouraged sharing, and thus helped to forge the eclipse community.

Some people looked up through filters. A young man had prepared several strips of overdeveloped film, and he passed them around, a double layer for each observer (as the newspapers had advised), to all interested parties. A welder on Fifty-third Street spent his work break sharing his goggles with the gathering crowd.

Others took advantage of a wonderful phenomenon in optics, using the principle that almost any small hole or space will act as a pinhole camera to project the image of the crescent sun. Here New York City even holds an advantage over the country—for an image projects badly upon rumpled ground, but ever so well against a smooth white sidewalk. New York is such a wondrous mixture of colors, classes, dress, and activity (I have seen many cities more beautiful and exotic, but none more diverse). But we so rarely come together, for what can transcend our differences and forge common concern? And what answer to this query could be more elegant or literal than the pervasive sun itself?

On Fifty-eighth Street, a West Indian janitor in his work clothes stood in front of an apartment building, where a ripped awning contained several small holes, each of which projected a beautiful image of the crescent sun upon the sidewalk. The janitor, acting the part of a carnival barker, gathered the passersby under his awning to see the grand sight, gratis of course. At the next building, like the proprietor of the adjacent stall at the same carnival, an Asian man pierced holes in envelopes, sheets of paper, and manila folders, showing people how to project the sun's image upon the ground—again for free and for the sheer pleasure of sharing.

People gathered on every street to show off their newly discovered devices for projecting images. Trees attracted the greatest crowds, for the spaces between leaves act as little cameras, and hundreds of dancing crescent suns appeared on the sidewalk amid the shadows of branches and leaves.



"I think you're becoming too dependent on me."

One woman, elegantly dressed and dangling a cigarette from her lips, held up her hand into the path of sunlight at the eclipse's acme, and a crescent image appeared at the bottom of the space between each pair of adjacent fingers. She squealed with delight and the people around her cheered. A boy then took off his adjustable baseball cap, unsnapped the connecting band, and projected a sun through each tiny hole of the band. And again, people cheered.

I have watched eclipses with relish for all my conscious life. Like all devotees, I have my favorite stories and main events. I remember my best lunar eclipse, seen when I was a teen-ager from the twenty-fifth floor of a friend's apartment, high over Manhattan. The fully covered moon often turns dark, but may also glow with a variety of colors. On this night, the entire disk of the eclipsed moon turned red, a deep dark red that I had never seen in the heavens, or perhaps even on earth. And I understood that two verses from "The Saints" are descriptions of solar and lunar eclipses, not abstract scare stories of eschatology (I played washtub bass in a folk group at the time, and we often performed this song): "When the sun refuse to shine…when the moon turns red with blood; oh Lord, I want to be in that number, when the saints go marching in"—a description, after all, of the Last Judgment, when eclipses will accompany the panoply of awful events. Did not the prophet Joel also speak as an astronomer in citing the same image for the same purpose: "The sun shall be turned into darkness, and the moon into blood, before the great and the terrible day of the Lord come" (Joel 2:31).

And I remember, for how can one blessed with an opportunity to witness this most spectacular of all celestial events ever forget, the total solar eclipse of early 1970. Our department rented a fishing boat to sail off Nantucket, the only bit of New England real estate privileged with a view of totality. I longed to see the moon's shadow fully cover the sun; I thrilled at a chance to observe the sun's corona. But I had not understood the most awesome phenomenon of all. We live in a natural world of shadings. Even catastrophes have foreshadowings: clouds precede thunderstorms, and tornadoes can be seen in the distance. But when the sun enters total eclipse, the sky turns off as if a celestial janitor threw a switch. For the sun is powerful, and a fraction of one percent of sunlight is daytime, while totality is nighttime—and the transition is a moment, a twinkling of an eye. The sky turned off, and my infant son cried in my arms.

We hear so many dire warnings about the poor quality of science teaching in our schools, so many lamentations over the profound ignorance of most Americans about nearly any phenomenon of the natural world. Perhaps these jeremiads have validity; half of my own students could not explain to me why our planet has seasons. Surely we should be struggling to increase literacy in science, for no issue of education could be more important.

Toot Owl
Derek Pell

But I am convinced that the problem does not arise from lack of interest. Such a false charge is often made amid the litany of correct accusations mentioned in the last paragraph. Interest is immense, but not always expressed as activity traditionally called science or ranked among its pursuits (and our misattribution therefore arises from our inadequate taxonomies of intellectual enterprise). My colleague Phil Morrison is fond of cataloging the large number of common activities requiring a good deal of scientific understanding, but not usually so classified: the astronomical knowledge of people who build and maintain telescopes; the deep botanical experience of members in gardening clubs (a fine example of power concentrated in older women); or even the people who frequent race tracks and bet intelligently on horses (some really do!), for misunderstanding of probability may be the greatest of all general impediments to scientific literacy.

May I now add to this list the aggregate intellectual power (how I wish we could quantify it) of all the dinosaur names accurately memorized (and spelled) by millions of five-year-old kids in America today. And also the accumulated joy and pleasure of millions upon millions of Americans who paused to watch the sun and to wonder on May 10, 1994. New York City was the best place to be on that date; my faith in raw interest is fully affirmed—and raw interest is the substrate and sine qua non of any real reform in education and larger understanding.

We often argue that only misfortune can bring us together. We do help one another during snowstorms; we do open our hearts and our houses to victims of an immediate disaster in our vicinity; we will search all night in the woods for a lost child we do not know. All these observations properly give us hope about common humanity in a world more often characterized by thoughtlessness, self-serving action, and even downright cruelty. But we also suppose that only disaster can provoke this effect, never pleasure, and certainly not intellectual as opposed to purely visceral delight. But interest and curiosity can also bring us together—and my observations of New Yorkers delighting in nature and spontaneously talking about the sun somehow give me more hope than our joint courage in times of crisis, even though unity in disaster may make me cry in sublime appreciation, while the bonding of eclipses only makes me smile.

And so I end this essay by quoting the greatest of all tributes to the sun. I have often stated my personal theory about popular writing in science. I divide this genre into two modes, which I call Galilean, for intellectual essays about nature's puzzles, and Franciscan, for lyrical pieces about nature's beauty. I honor Galileo for writing his two major works as dialogues (actually trialogues) in Italian, and therefore addressed to all thinking people in his orbit, and not in the formal Latin of churches and universities. And I honor Saint Francis of Assisi for his tributes to nature's loveliness.

I am an unrepentant Galilean. I work in a tradition extending from the master himself to Thomas Henry Huxley in the last century to J. B. S. Haldane and Peter Medawar in our own. I greatly admire Franciscan lyricism, but I don't know how to write in this mode. I began this essay with a quotation from the eponymous hero of my literary bloodline, Galileo himself. But my essay talks about the power of the sun to unify our diverse cultures and concerns, so I must end with a man I have never quoted before in these columns, the eponym of the other style—Saint Francis of Assisi. Saint Francis composed his beautiful *Canticle of Brother Sun* in 1225. He wrote in the Umbrian dialect of his local people, and his poem is often regarded as the first preserved in any modern language:

Brother Sun, who brings the day...
How beautiful he is, how radiant in all his
 splendor!

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

Chitty Canyon, Arizona

by Robert H. Mohlenbrock

Roughly tracing the route traversed 450 years ago by Francisco Coronado in his search for the fabled Seven Cities of Gold, my student Rod Doolen and I drove south along U. S. Highway 666, a few miles west of the Arizona–New Mexico boundary. We soon came to the brink of the Mogollon Rim (pronounced muggy-OWN), which separates the cool, pine-clad Colorado Plateau to the north from the hot, dry lowlands—and desert—to the south. More than 200 miles long, the Mogollon Rim is the highly irregular edge of the plateau, running from northwestern Arizona southeastward to the vicinity of Strawberry and then more or less eastward across eastern Arizona and western New Mexico, eventually connecting with the Mogollon Mountains. We paused at an observation point where the terrain dropped abruptly nearly 3,000 feet to the valley below. After enjoying the view, we headed to nearby Chitty Canyon, managed by the Apache–Sitgreaves National Forest, to explore the vegetation below the edge of the plateau.

Pipsissewa, a relative of wintergreen, blooms in late summer.
Bob and Clara Calhoun; Bruce Coleman, Inc.

Taking a Forest Service road west from the highway, we arrived close enough to the upper end of Chitty Canyon to park our car and hike in. While a forest dominated by ponderosa pines covers the slightly lower plateau north of the Rim, here we stepped out into a fir-aspen zone, about 9,500 feet above sea level. Closely crowded Douglas firs, white firs, Engelmann spruces, and quaking aspens were enshrouded by low-hanging clouds. The heavy shade of the trees inhibited the growth of understory vegetation, but a number of attractive wildflowers thrived in the moist soil. They included the delicate calypso orchid, the mottle-leaved rattlesnake plantain orchid, wintergreen, pipsissewa (a relative of wintergreen), and spring-flowering coralroot. The last is an orchid that lacks chlorophyll and must obtain its nutrients from the organic matter in the soil.

The dense forest of the fir-aspen zone extended down to about 8,000 feet, continuous except for small openings where the soil was too thin for trees to grow. These openings, all less than five acres in size, were high meadows where, because of overgrazing by domestic livestock, the native vegetation had been replaced by weedy species such as bracken fern and western sneezeweed. (A few miles to the north, pristine Hannagan Meadow presents a high mountain meadow of native grasses and wildflowers.)

As we descended by trail to about 8,000 feet, the forest began to open up, and the Douglas firs, white firs, and Engelmann spruces were replaced by ponderosa pines and smaller trees such as Gambel's oak, gray oak, Rocky Mountain maple, and alligator juniper. The trees were more widely spaced, allowing sunlight to filter through to the forest floor, where the soil was hotter and drier than in the fir-aspen zone. Still, some Douglas firs and quaking aspens were doing well in rocky crevices and other protected areas, even below 8,000 feet.

Conditions were drier still on the steepest south- and west-facing slopes and on the ridgetops, at elevations between 7,000 and 8,000 feet. Gambel's oak and alligator juniper were smaller and more gnarled, and the shrubby, white-fruited snowberry was plentiful. Scattered wildflowers included beargrass, banana yucca, mescal, prickly pear cactus, and wild lotus.

Below 7,000 feet, down to the bottom of Chitty Canyon at 4,500 feet, the vegetation consisted of scattered, round-topped, piñon pines and alligator junipers. Grasses filled in the understory, along with Indian paintbrushes and beardtongues.

Chitty Creek, which long ago carved the canyon, is fed by rainfall, snow melt, and groundwater from several springs. Lining the creek and its tributaries were box elder, Arizona walnut, lance-leaved cottonwood, and thick-leaved alder. Red-osier dogwoods formed occasional thickets, all the more conspicuous because of their scarlet twigs. Wildflowers abounded, including a gorgeous yellow columbine, a tall blue larkspur, bright yellow buttercups, white-flowering violets, and two kinds of false Solomon's seals.

Here and there between 8,000 and 8,200 feet were seeps, places where groundwater oozed to the surface from

A decaying ponderosa pine overlooks the slopes of Chitty Canyon.
Randy A. Prentice

On the plateau near the Mogollon Rim, a New Mexican locust tree grows beneath quaking aspens.
Jack W. Dykinga

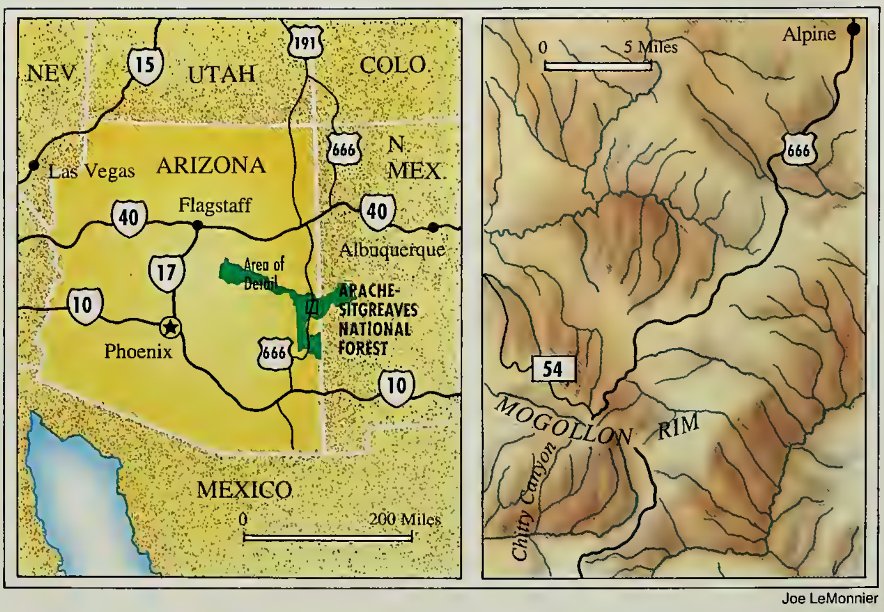
springs. These soggy openings, free from woody plants except for an occasional Bebb's willow, were filled with fall panic grass, bog orchid, yellow-eyed grass (a member of the iris family), golden-glow (a black-eyed Susan with a yellow center rather than a black one), and Macoun's buttercup.

Chitty Canyon is only one of hundreds of inviting areas along the Mogollon Rim, which extends into several national forests. (Because the region includes private holdings as well as part of the Apache Indian Reservation, a Forest Service map is essential for guidance.) There are many places to camp, both on top of the Rim and in the lands below. Few roads link the two areas, however. Where we stopped along the highway was one of only six places in more than 200 miles where a paved road goes from the high country to the low. In fact, only a limited number of hiking trails go up and down the face of the Rim; each is difficult, often strewn with loose, crumbly rocks, and treacherously muddy following a thunderstorm.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U.S. national forests.

Chitty Canyon

For visitor information write:
Forest Supervisor
Apache-Sitgreaves National Forest
Federal Building, Box 640
Springerville, Arizona 85938
(602) 333-4301



Joe LeMonnier

Fiona McDougall, NYT

Terminal Man

It's been real

by Roger L. Welsch

As if one reality weren't more than enough for most of us, computer cybersillies are offering so many alternative realities that there are catalogs for the casual reality browser. A major national magazine recently asked me to review a set of virtual reality computer programs that would have allowed me to wander aimlessly (on my computer screen) around Yellowstone Park, Death Valley, the rilles of the moon, or the plains of Mars. These were not phony ideas of what Yellowstone and Mars might be like; these were the actual landscapes you would find if you ever went to the trouble of going there. For the moon and Mars, as I understand it, the data collected by earth satellites and space robots have been translated into these programs, and rapid reading and display on the part of powerful home computers and compact-information packages allow you the feeling of moving freely even on landscapes no one has ever walked.

So why didn't I do the review? Because I couldn't understand the first paragraph of the instruction book telling me how to install the blasted program into my computer, that's why. But my ignorance is certainly no reason for me not to have opinions about reality, right? I've been exposed to other alternative reality computer programs. Even to alternative realities.

One of my areas of academic interest is "living history" museums. I was, for example, a consultant at the Plimoth Plantation Museum in Plymouth, Massachusetts, where a talented and dedicated team of researchers, artisans, and actors do their best to give visitors the impression they have gone back 370 years in time and are actually within the Pilgrim village of Priscilla Mullens and John Alden.

And how about CityWalk, a Los Angeles alternative reality that opened a little over a year ago? CityWalk is a replica of a street in Los Angeles for people who are in Los Angeles and want the feeling of being *in* Los Angeles without *being* in Los Angeles. For $100 million MCA built a block of Los Angeles without the unpleasant stuff, which is to say, Angelenos. (Don't write me nasty letters; I'm only telling you what they did!) Real earthquakes may occur in CityWalk—I don't know—but I'm betting they simulate earthquakes every day, a little after lunch. The intent of places like Plimoth and CityWalk, whatever their differences, is the same: to distort your sense of reality by giving you an alternative to the reality you already have right in front of you most of the time. When you think about it, that's what writers do, and playwrights, actors, producers, and artists of every other variety.

And it's not as if there is one "real" reality. In fact, there is at least one reality for each human being on earth, maybe more. The world as seen by a traditional Omaha from the tribal reservation in eastern Nebraska is distinctly different from the reality of an academic at the University of Nebraska or a farmer on the central Plains or a corporate executive in New York, in ascending degrees of separation. What each sees as he or she looks out the window in the morning is not what the others see. It is no less valid, no less real, no less important, but it is not the same.

I was once visiting my mother and father's home with my son, Chris, when he was just a tyke, maybe a year old. He had been there many times before. In those days we lived in a woodsy area, and our neighbors on two sides were horses. As a result, Chris's world revolved around his parents (BOR-ing!) and horses (FAScinating!). On this occasion I carried Chris into my parents' home and he immediately began a pounding repetition of one of the few words he knew, "Horsie, horsie, horsie, HORSIE, HORSIE, HORSIE!"

But there were no horsies. My folks live in a thoroughly residential area where there is no livestock. None. No horsies.

We tried to tell Chris that. But he was firm. He screamed, he yelled, he insisted.

Finally, in desperation, I picked him up and held him out in front of me, like a small, human Geiger counter. As he pointed and beeped "Horsie, horsie, horsie," I responded to his pointed finger and the volume and frequency of his beeping to find out what was arousing his excitement. I followed his finger out of the living room, through the dining room, and into the kitchen. I wound up with Chris a little above waist level, pointing intently into a corner of Mom's cupboard at a toaster.

"No horsie, Chris," I tried. He insisted. He insisted so intently, in fact, that I finally put him on the floor, still screaming "Horsie," and leaned forward into the dark corner where he pointed. I pulled out the toaster. Chris went berserk: "Horsiehorsiehorsiehorsiehorsiehorsiehorsie." I looked at the toaster. I took off the plastic cover. Chris pointed at the cover.

I found that if I looked at the cover closely, if I squinted and held it just right in the light from the window, I could see that the pattern on the toaster cover was actually an interlocking set of stylized, geometric horses. "My God, the kid is a genius," Mom sobbed.

Well, yes, in keeping with family tradition, he is a genius, but the thing is, at that point his life was horsies. He didn't give diddly about hundred-dollar bills falling from the sky or Madonna at our door asking for help with the flat tires on her limo or Mick Jagger asking his dad to play bass for just a couple of gigs along the West Coast. What Chris cared about, what his reality consisted of, was horsies. And that's what he saw.

Chris had no choice. Most of us don't. We have whatever reality was issued us or whatever reality we have stumbled into, but we don't get to pick and choose.

Well, brace yourself: Computer jigglers are giving us the chance to go somewhere without going anywhere. Bill Orr, erstwhile First Gentleman of Nebraska, once told me that he liked to think of *National Geographic* and *Playboy* magazines as being pretty much akin, each showing us exotic and romantic places we were almost certain never to visit. Well, Bill, that day is over. Now you can visit such places at will: You can climb the sheer face of El Capitan while seated at your own computer or (if you're not in shape) use the *Penthouse* interactive CD-ROM to freeze-frame *Photograph* "while three *Penthouse* Pets cavort."

Zygon's SuperMind *Virtual Sex* experiment may be beyond virtual reality, since it provides no images, just a set of "erotic" brain wave impressions. Zygon promises to "implant erotic 'virtual sex' fantasies onto your brain cells." I found myself confronted with my own experiential limitations, however, when I tried to imagine how the "sounds of crickets," one of the effects promised by Zygon, fit into romance. Every woman I've ever had anything to do with finds crickets and sex mutually exclusive.

After surveying the literature, I was so confused, I felt I needed to talk with a philosopher. So I sat down with Lovely Linda and told her what is going on out there in front of computer terminals. "I can't figure out," I said, "whether people who want to stroll on Mars and play footsie with Doxie Lustina are overwhelmed by the kind of reality I find charming or are so bored by it they need more."

Linda started thumbing through the brochures I had put on the table.

"What are you looking for?" I asked.

"I'm not interested in hiking on Venus or cavorting with Fabio," she said, still looking through my file. "I want to see if they have a program that will give me the feeling of what it's like to walk through a clean house."

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

Sirius Matters

by Gail S. Cleere

On or about August 10, shortly before dawn, the snout of the constellation Canis Major (the Great Dog) will poke its way up over our eastern horizon, carrying with it the jewellike star called by the Greeks "the sparkling one." This is Sirius (the Dog Star) making its annual appearance in our summertime sky. Astronomers call the event "the heliacal rising of Sirius." To the ancient Egyptians, Greeks, and Romans, the appearance of Sirius in the morning sky heralded the hot days of summer—the dog days.

The ancient Egyptians looked forward to the summertime appearance of the Dog Star because its arrival preceded the annual flooding of the Nile, upon which Egyptian agriculture depended. About 3000 B.C., the rising of Sirius occurred earlier in the year, near the time of the summer solstice. A few thousand years later, however, Sirius acquired the bad reputation of bringing on "fever in men" and "madness in dogs." Homer described it in the *Iliad,* when from the walls of Troy, King Priam watched Achilles advance:

> Blazing as the star that cometh forth at Harvest-time, shining forth amid the host of stars in the darkness of the night, the star whose name men call Orion's Dog. Brightest of all is he, yet for an evil sign is he set, and bringeth much fever upon hapless men.

The Romans sacrificed young dogs at Sirius's appearance, and Dante spoke of the "scourge of days canicular." Even in our own times, researchers at the National Institute of Mental Health (NIMH) study the links between the hot days of summer and the manic behavior of those suffering from manic-depressive illness. In his book on seasonal affective disorders, *Winter Blues,* NIMH psychiatrist Norman Rosenthal details the history of Anne Grenville in the late 1600s, whose seasonal mania became so troublesome in the summer that one of her physicians suggested special treatments "at the approach of the dog days." I wonder what they were.

Today we recognize Sirius, at −1.46 magnitude, as the brightest of the fixed stars visible to the naked eye, and at 8½ light-years distance, it is the third closest "naked-eye" star to us. We moderns may no longer be aware of Sirius's ancient relationship with summertime heat, but we do recognize it as that brilliant wintertime object just below the right foot of the great constellation Orion the Hunter. (Sirius is ten times brighter than any of the neighboring stars in that constellation.) At the Christmas season, Sirius rises over the horizon at about 7:00 P.M.

But the brilliant light of Sirius is not from Sirius alone. In 1862 a mild-mannered telescope maker in Massachusetts looked through the new 18½-inch lens he had just made and discovered that Sirius was actually two stars—a discovery that, like so many in astronomy, had actually been predicted. What Alvan Clark had found was Sirius's white dwarf star companion, now called Sirius B, or the Pup. Clark had been fantastically lucky. The atmospheric "seeing" conditions had to have been superb, for many others had searched for this suspected companion and had not found it. Today it can be seen with much smaller telescopes, but only if conditions are right and if one knows exactly where to look.

We now know that Sirius B represents what will happen to more than 95 percent of all stars, including our own sun; after it burns all its available fuel, it will swell to a red giant and then collapse in on itself into a superdense, superheated ball. Shining at 8.65 magnitude, Sirius B is about the size of the earth. A cubic inch of Sirius B weighs as much as a dump truck. This washed-up star's crushing gravity is awesome, and its stupendous temperatures are thousands of degrees Kelvin hotter than the sun. The Pup is ending its days as our own star will—but in the sun's case there will be a sad collection of airless worlds all around it, and in at least one case, a world whose oceans have boiled away.

Nonetheless, it is the main star of this duo, Sirius A, that provides us with the brilliance we appreciate. When seen through the thick layer of atmosphere along the horizon, Sirius's blue-white fire can appear to flicker with the colors of the rainbow and may explain the ancient descriptions of the star by Aratus, Cicero, Horace, Seneca, and Ptolemy as "yellow," "ruddy," "reddish," "blazing as fire," and "shining like copper."

As the days go by, try to find Sirius in the hours before dawn, rising just south of due east along the compass. As the year progresses, Sirius rises earlier by four minutes each day, becoming easier and easier to find in the night sky.

THE PLANETS IN AUGUST

Mercury will likely become lost in solar glare after August 2.

Venus remains in the southwestern sky this month, but proceeds to get lower in altitude because the angle of the planet's path across the sky is quite low relative to our horizon. Look for bright Venus about fifteen degrees above the west–southwest horizon at sundown. On the evening of the 10th, the waxing crescent moon sails three degrees below Venus. On the 31st, look for the star Spica just above and to the left of the planet. The *Magellan* spacecraft—currently in orbit around Venus and scheduled to have been turned off by NASA in April—has received additional funding to keep it up and running. It will continue its gravity-mapping mission through the end of this fiscal year.

Mars rises well after midnight in August, moving from Taurus into Gemini. On the morning of August 3, look for Mars shining like a yellowish orange star roughly six moon widths above and slightly to the left of Orion.

The 1996 Russian mission to put rovers and balloons on Mars has been pushed back to 1998. This is because the monies for the project have been diverted to the Mars '94 mission, now rescheduled for 1996. NASA has also proposed an exploration program for Mars, called the Mars Surveyor, to begin in 1996. At that time, the space agency proposes to begin launching both orbiters and landers every two years to the planet.

Jupiter is a wonderful summertime planet this year and in August moves eastward into Libra, heading toward the "claw" stars of the Scorpion. (The giant gas planet's collision with Comet Shoemaker-Levy 9 in July is not expected to have any lasting effects.) It can be seen well up in the southwest at sundown. On the 15th, look for Venus, Spica, Jupiter, Antares, and the first-quarter moon spread like jewels along the southwestern sky.

Saturn rises shortly after sunset and is visible throughout the night in Aquarius—a rather dim constellation well east of the bright stars of Scorpius and Sagittarius—and Saturn is by far the brightest "star" in the area. On the evening of August 21, you'll find Saturn shining roughly eleven moon widths below and to the right of the nearly full moon. Look for the ringed planet below the full moon on the 22d.

Uranus and **Neptune** steadfastly cling to the eastern region of the constellation Sagittarius, edging ever so slowly toward the constellation Capricornus. Look with binoculars for two bluish green disks well up in the southeast at sundown.

Pluto is the wallflower of the solar system, difficult to spot, elusive, and all but lost among even the faintest stars in our August night sky. He watches the goings-on of Jupiter, Saturn, Uranus, and Neptune, from his perch in the sky above the stars of Scorpius and Libra.

The **Moon** is new at 4:45 A.M., EDT, on August 7; reaches first quarter at 1:57 A.M., EDT, on August 14; is full on the 21st at 2:47 A.M., EDT; and reaches last quarter on the 29th at 2:41 A.M., EDT. The full moon of August is traditionally called the grain moon, the woodcutter's moon, or the dog day's moon. The Algonquin Indians called it the sturgeon moon. The Sioux called it "the moon when the cherries turn black."

The Perseid meteor shower, one of the best known of the annually occurring meteor showers, reaches its peak on the night of August 12–13. In dark skies, some fifty to sixty meteors an hour can generally be seen at the Perseid shower's peak, and these are typically yellow and white, with some that can be very bright green, orange, and red, leaving spectacular trails up to two degrees wide. The Perseids are remnants of Comet Swift-Tuttle, first seen in 1862 by astronomers Lewis Swift and Horace Tuttle, and rediscovered in September 1992 by Japanese amateur Tsuruhiko Kiuchi. Last year's predicted spectacular display of the Perseids never materialized, and some astronomers believe 1994 might be the year the earth passes through the particularly dense knot of cometary matter that is theorized to follow the comet itself. With the moon setting shortly after 11:00 P.M., EDT, the dark hours following moonset are the time to watch for these meteors.

Gail S. Cleere lives in Washington, D.C., and writes on popular astronomy.

Pacific Requiem

A half century after the defeat of the Japanese at Guam, Micronesia still bears the scars of war

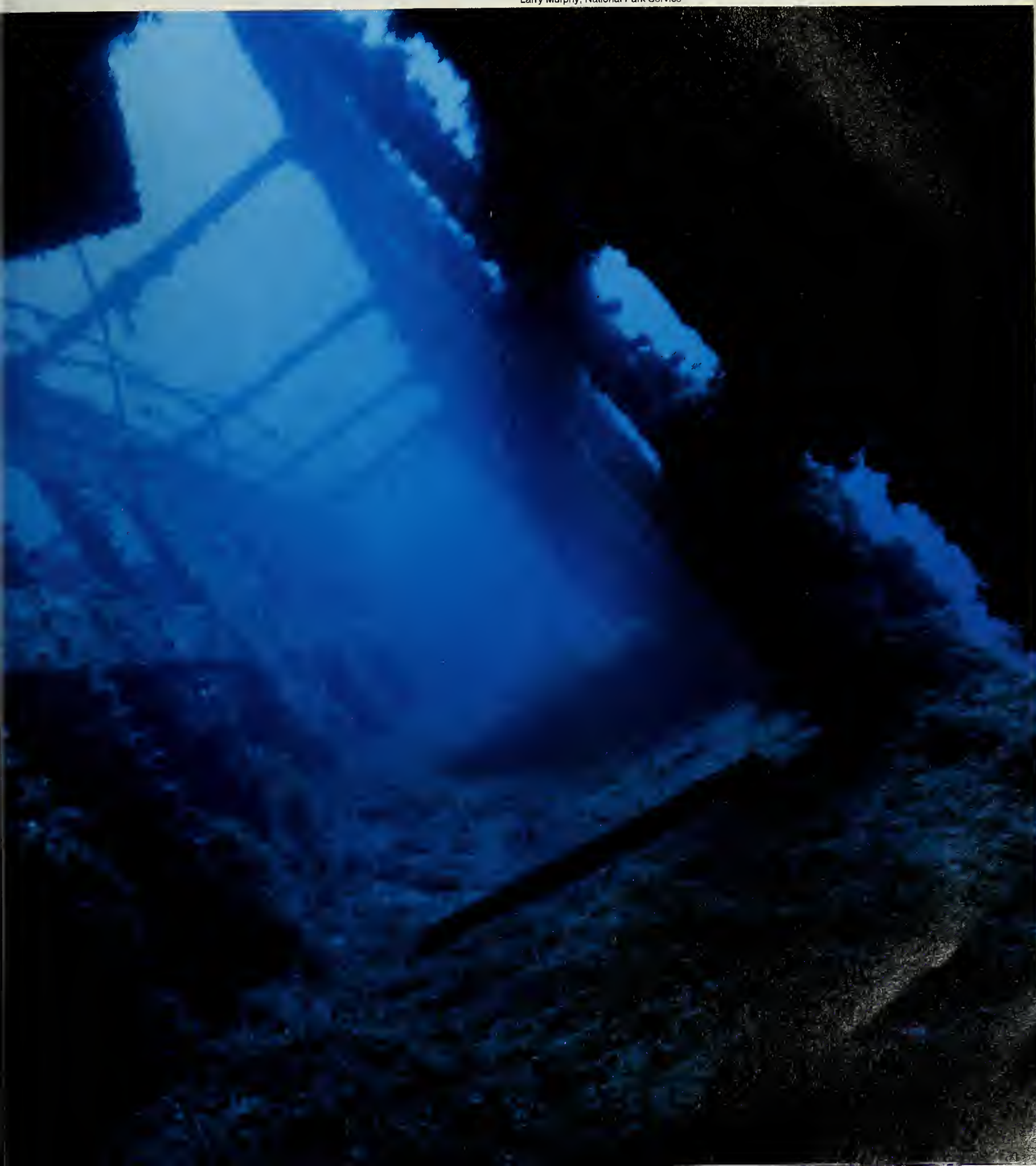
by Daniel J. Lenihan

The *Cormoran* lies in its grave, steel coming to terms with seawater. The ocean always prevails in these cases, but the process is long and intriguing. Swimming slowly aft along the port side of the ship, which rests on its starboard side, my companions and I leave an ever widening trail of bubbles from our regulator mouthpieces. I lead a team of National Park Service underwater archeologists that first came to this site off the Pacific island of Guam several years ago. We are curious to see how time and increased sport diving have affected the site.

A commerce raider—a warship designed to prey on enemy merchant shipping—the SMS *Cormoran* was built in Russia but flew a German flag. It was scuttled in Apra Harbor under orders from its captain on April 6, 1917, the day the United States entered the Great War. Through this act of defiance, the interned vessel was kept from falling into enemy hands and its crew became some of America's first prisoners of war.

Guam has an active community of sport divers, augmented by American military personnel and tourists. Barely visible above us, the bobbing forms of a large group of Japanese divers begin their descent from a tour boat. With pristine reefs to dive on nearby, one might wonder what attracts so many Japanese sport divers to a World War I relic during their weekend getaway from Tokyo. Most likely their attention is focused on the object that is casting a shadow over the *Cormoran*'s stern—the looming hulk of a World War II Japanese transport. Lying keel to keel with the scuttled German ship is the *Tokai Maru*, a World War II casualty of American torpedoes.

One of America's most far-removed possessions, Guam lay deep within the zone that the architects of imperial Japan termed the Greater East Asia Co-Prosperity Sphere—a huge, vaguely defined region that would achieve economic independence from the West through Japan's military protection and administrative leadership. The Co-Prosperity Sphere included most of East and Southeast Asia,



Light filters through the starboard railing of an upper deck of the Tokai Maru, *a Japanese transport. Sunk by American torpedoes during World War II, the ship lies on its port side at the bottom of Guam's Apra Harbor.*

Larry Murphy; National Park Service

encompassing territories the Japanese already controlled and others they wanted to control. Among the key components were Korea, a reconstituted China, the Philippines, and Japan's "Micronesian mandate"—areas that Japan had seized from Germany during World War I. For a brief period from 1940 to 1942, Japan's sights were also set on the Hawaiian Islands.

Guam, west of the International Date Line, was plunged into World War II on December 8, 1941. Within hours of the attack on Pearl Harbor, American forces on Guam withstood a Japanese air raid; two days later they surrendered the island to invading ground troops. In July and August of 1944, the reinvasion of Guam by U. S. troops, following on the heels of the fall of Saipan, made it clear the sun would soon set on the Japanese empire and any vision of a Japan-controlled Pacific.

Over the course of a half-dozen field trips to Micronesia during the past fourteen years, I have been impressed with the detritus of war. Nowhere is it more evident than in these islands, especially underwater. Given that a rage to reorder and rebuild typically follows periods of human conflict, the past is less likely to be trampled if it is beneath the sea.

As we glide effortlessly between the *Cormoran* and the *Tokai Maru* on the bottom of Apra Harbor, images of two wars slip by in metallic shades of blue. The color blue is the only concession allowed the sun one hundred feet below the water's surface, as the ocean asserts its dominance over the warmer colors of the spectrum. Not far from here is the darkest blue of all—the Mariana Trench.

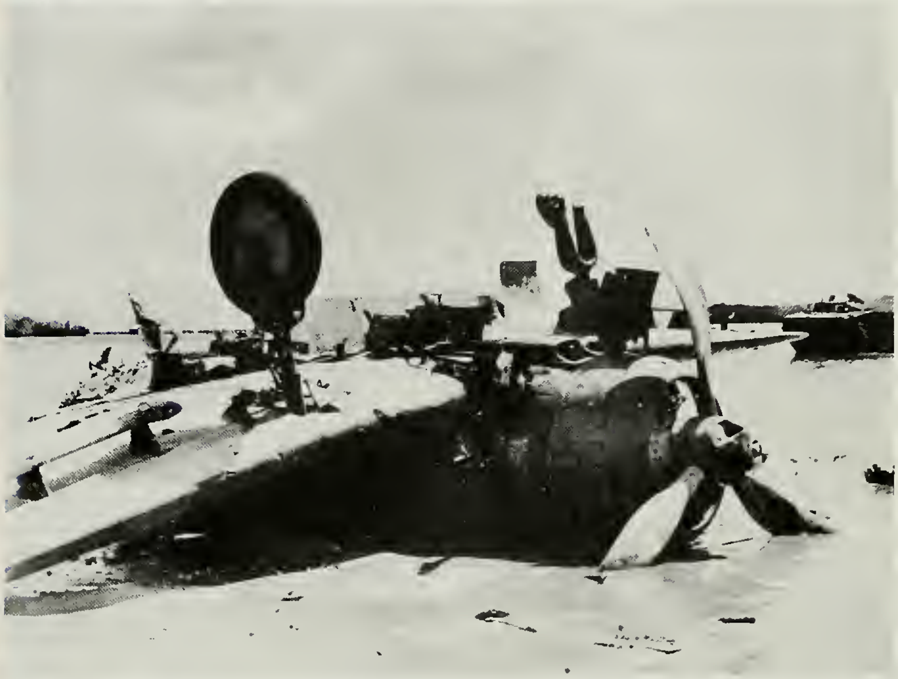
The most dramatic change we note during our swim is that the stacks of the German raider have fallen into the mud. The Japanese divers, using the bicycling motion typical of inexperienced scuba enthusiasts, stir clouds of silt as they pedal to a perch on the deck of the *Tokai*. They glance down curiously at us as we make our way to the point where the *Cormoran*'s propeller (now removed) punched a hole in the side of the Japanese vessel when the latter settled on the harbor bottom.

We surface from our examination of the two ships and watch the diving "head boat" gather up its covey of flipper-clad tourists. An easy few hours by airplane

John Brooks; National Park Service

One of the engines of a B-24 "liberator" bomber, left, lies off Majuro, an atoll, in the Marshall Islands. Surviving crew members were reportedly captured and executed by the Japanese. Below: A Japanese plane downed by U. S. Navy gunfire greeted Marines streaming ashore at Agat, on Guam, on July 28, 1944.

National Archive; Courtesy of the War in the Pacific National Historic Park, Guam



from Tokyo, Micronesia is to the Japanese what the Caribbean is to many Americans, the difference being that those who are vacationing in the Pacific islands are also gathering on the battlefields of their fathers. Kwajalein, Truk, Palau, Saipan, Guam, Tinian, the Philippines—in 1944 all were part of the string of costly victories for America, and a distant wake-up call for Japan.

The disaster at Pearl Harbor, followed by six months of additional American defeats and setbacks, was dramatically reversed at the battle of Midway and the Aleutians in June of 1942 (*see* "The *Arizona* Revisited," *Natural History,* November 1991, and "Aleutian Affair," *Natural History,* June 1992). The Allied offensive steadily picked up steam through 1943, and the Japanese found themselves fighting desperately to retain control of key Pacific islands and forestall the impending invasion of Japan. By 1944 the war-energized industrial capabilities of the United States had generated an awesome array of high-speed aircraft carriers to carry fierce aerial attacks to Japan's doorstep. Attacks on Truk and Palau (present-day Chuuk and Belau) and the invasion of Guam were setting the stage for anticipated incursions into Japan in 1945.

While thousands of American veterans of the fighting in Europe make their pilgrimage this year to France, especially the beaches of Normandy, their countrymen who fought in the Pacific will reconnect with memories of 1944 in a very different part of the globe. Today, the tropical foliage of these Western Pacific islands, with its peaceful chirping of birds and scurrying of lizards, belies the carnage and horror of the scenes that played themselves out here fifty years ago. For visitors of my baby-boom generation, the awareness that the war was fought in color and not Movietone News black-and-white is often the first revelation.

On Peleliu, an island in the Belauan (Palauan) archipelago, we interspersed our marine surveys with walks through the jungle. Our native colleagues guided us around abandoned tanks, gun emplacements overgrown with hardy tropical vegetation, and caves that had been sealed by the advancing Allies. The complex caves and bunkers built into the hillsides by the Japanese could withstand heavy artillery barrages but became self-made tombs once the enemy had landed and could bring heavy earthmoving equipment to bear. Many caves were simply sealed, their defenders left to suffocate; in other cases flame throwers effectively used up the available oxygen, or fifty-five-gallon drums of gasoline were emptied into the caves followed by a lighted match.

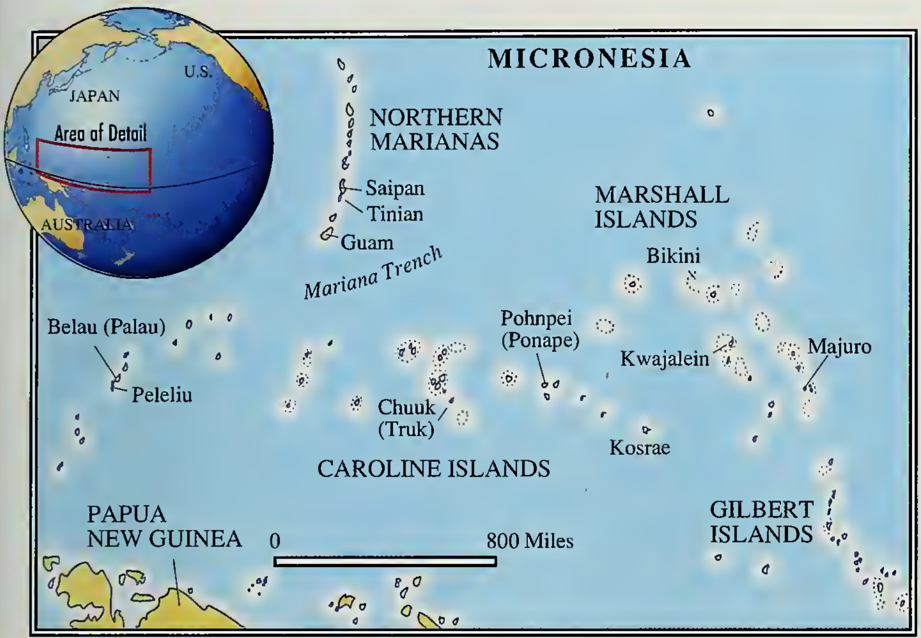
Islands not critical to the Allies' sweep through the Pacific were simply bypassed. Their contingent of imperial soldiers became increasingly isolated as supply lines dwindled, and they prepared for invasions that never came. Pohnpei (Ponape) and Kosrae, in the Caroline Islands, received the attention of the Allies in the form of air raids and naval bombardments, but were not occupied until the end of the war.

Most of the Northern Marianas and the

Larry Murphy; National Park Service

Assisting surveyors from the National Park Service, three Bikinian divers map the deck of the aircraft carrier Saratoga, *left. The ship had survived World War II but was sunk at Bikini during Operation Crossroads, a postwar experiment designed to test the effects of nuclear weapons on naval forces. The small tower erected on the deck held instruments to measure the pressure waves from the blasts.*

Joe LeMonnier



Caroline Islands, which had passed through the administrative hands of Spain and Germany, were taken over by Japan at the outset of World War I. With the buildup for, and commencement of, World War II, the comparatively benign civilian Japanese government was replaced by a military administration that summarily evicted inhabitants of entire villages.

Two years ago my family and I were witnesses to a Kosraean feast day that commemorated the fiftieth anniversary of the June 6, 1942, displacement of the residents of Malem, a village on the southern coast. In typical Micronesian fashion, the feast day "celebrating" this traumatic event was a joyous occasion of reenactments, parades, floats, and games. My own children were caught up in a sea of brightly dressed adult revelers, who were running races around a schoolyard, throwing candy and money to youngsters, and generally having a marvelous time. I would hate to miss the party the Kosraeans will throw on September 8, 1995, to commemorate the official liberation of the island from the Japanese.

In the tiny harbor of Leluh, on Kosrae, my team worked with a contingent of Micronesian divers to document warships and planes spread beneath the surface. We soon had a string latticework "road map" to follow in the murky water between the World War II relics. Reminding us of the depth of history that can be preserved on harbor bottoms were the nearby remains of a mid-nineteenth-century wooden whaling vessel, its try-pots for blubber still in place. Large lionfish patrolled the debris, their poisonous spines capable of delivering a serious wound to any diver that brushed against them.

The native islanders carry on with remarkable resilience considering the amount of firepower the industrialized world concentrated on their islands and atolls. In many cases, they have recycled the residues of warfare into their livelihoods. In Truk, a fleet of Japanese transport ships took the brunt of Operation Hailstone at a place that is popularly known as Truk Lagoon. During several days of intense bombing raids in February 1944, carrier-based American bombers and fighters sank more than thirty Japanese vessels. Truk Lagoon has since become a world-renowned destination for diving enthusiasts.

Besides recycling ships into tourist attractions, some Chuukese have been recycling the ordnance on the ships into fishing aids. Members of my dive team recently documented the extent of damage to the ships, corals, and fish that results from the practice of "dynamite" fishing in the lagoon. In the hold of one ship, we found antitank mines, with lifting bags in place, abandoned by salvagers. The fabric of history will fare no better than the fragile marine life if these activities continue in the lagoon. Pilfering divers and anchors dragging from dive boats have added to the destruction, but the ships are still marvelous places to visit.

Throughout Micronesia there are also purposeful deposits of World War II remains, places where thousands of war machines were cast to the waves rather than brought back to flood a peacetime economy. Refuse heaps are always grist for the archeological mill; in land-poor Micronesia, some of the most instructive lie underwater. I followed a trail of war materiel two hundred feet down an underwater ravine in Guam. Trucks, tracked vehicles, guns, ordnance, twisted metal—the items became less distinguishable as the pressure of additional fathoms of water increasingly clouded my brain with nitrogen narcosis. The debris fanned out into the depths, with no end in sight. I had a similar experience in Majuro, in the Marshall Islands, where seemingly sound vehicles were arrayed across the lagoon bottom like Matchbox toys in a bathtub. Ambulances, tow trucks, tankers—a regular bonanza of vintage vehicles going through various stages of a sea change.

The sheer magnitude of goods that industrialized nations could produce to wage war must have left a profound impression on the native islanders of Micronesia. Their neighbors to the south, the Melanesians, have earned a place in anthropology textbooks for their "cargo cults," which arose even before World War I as a response to colonial rule. The subjugated indigenous peoples saw a connection between the power and wealth of the dominant cultures. Messianic leaders heralded the "cargo" ship that would come some day, bearing the riches that would enable the islanders to throw off the yoke of foreign rule.

John Brooks; National Park Service

On July 23, 1944, troops of the 77th Division of the U. S. Army moved inland from Agat, on Guam, below. Discarded after the end of hostilities, one of dozens of war vehicles, right, lies in an underwater grave near Majuro.

Signal Corps; Courtesy of the War in the Pacific National Historic Park, Guam

Ever since the sixteenth century, when Manila galleons carried goods from East Asia to Acapulco, there have been foreign ships in Micronesian waters. The great powers of Europe and Asia have been attracted to the region not only by its strategic location but also by its serenity and remoteness. To American veterans returning to Micronesia, the islands represent a pivotal event of their lives, participation in World War II. They remember fallen comrades, youthful aspirations, a time when they were seemingly immortal and the world was a simpler place. Ironically, many of the hotels where American veterans will be staying during their commemorative visit will belong to Japanese chains. Of late, the Japanese have returned to Micronesia pursuing a commercial, more peaceful vision of a Co-Prosperity Sphere. Developers, hoteliers, and dive guides are succeeding economically where their forebears failed militarily.

For the most part, the Micronesian people welcome the returning veterans from both sides. They also embrace their own past, which includes a war that totally absorbed the lives of their entire families, not just their fighting men. And the smoke had hardly cleared before Micronesia was turned into a testing ground: mushroom clouds became a regular feature on the horizon in the Marshall Islands for a dozen years.

At Bikini, major warships from World War II, including the aircraft carrier *Saratoga* and the Japanese battleship *Nagato,* lie amid cruisers, destroyers, and auxiliaries in the most unusual of the Pacific underwater museums. These ships survived 1944 and 1945; their exploits were breathlessly followed on their home fronts through victory and defeat, and their names were household words. Yet they were considered excess property in 1946 and were offered up in a grand nuclear sacrifice, known by the code name Operation Crossroads.

The stated purpose of Operation Crossroads was to determine how naval forces would fare in a nuclear attack. Some 42,000 men (and 36 women) prepared the test fleet, conducted two blasts (code named Able and Baker), and documented the results in 1.5 million feet of movie film, 50,000 stills, and various measure-

Empty shells lie on the breech of a deck gun of the Fujikawa Maru, *a Japanese transport that was sunk in Truk Lagoon, in the island now known as Chuuk. The shells were probably left there by salvagers who extracted the explosives for use in fishing.*
Larry Murphy; National Park Service

ments. Rivalries between different branches of the armed forces—each competing for prominence in the nuclear age—and a desire to impress the Soviet Union were also factors in the operation.

The most surprising result of the tests was not that some ships sank and some didn't but that radioactive contamination was a much more complex and insidious problem than had been anticipated. Many ships only moderately damaged from the blasts at Bikini had to be sunk elsewhere because attempts to decontaminate them failed. As part of plans to resettle Bikini, I have recommended that the sunken ships there be made into a marine park, a place to dive into history and experience the remains of global conflict, of wars hot and cold (the ships have now "cooled" to safe levels).

From my home in Santa Fe, New Mexico, I can see the lights of White Rock, a bedroom community for Los Alamos. This is where the bombs destined for Bikini were born. A coffee cup that sits on my desk is decorated with the stars and stripes of the Bikinian flag. Inspired by the American flag, it has a few noteworthy differences. The three stars on the right symbolize the islets vaporized in 1954 by a thermonuclear blast (code named Bravo), and across the bottom is written: *Men otemjej rejilo bein anij* (Everything is in God's hands). These were the words spoken by "King" Juda, leader of the Bikinian people, when an American naval officer explained that the islanders had to be moved from their home to a different island so the United States could conduct tests to learn how to use nuclear power "for the good of mankind and to end all world wars."

Will that hope be realized? When the veterans have returned from their commemorative visits to Micronesia, when today has become history and a new team of young archeologists visits the site of the *Cormoran* and *Tokai* in Guam's Apra Harbor, what will they find? Will there be a third ship? As they say in the Marshalls, *Men otemjej rejilo bein anij.* □

Swimming Heads

An underwater encounter with the giant ocean sunfish

by Tierney Thys • Photographs by Mike Johnson

Twenty miles off the southern California coast, our research vessel was approaching a drifting kelp mat when a giant ocean sunfish, or mola, breached beside our boat and quickly submerged again. Within a few minutes, two others rose and floated on their sides. We sidled our boat nearer to the kelp, put on our scuba gear, and slipped into the water for a closer look. About ten feet underwater we saw an overwhelming assemblage of huge molas lined up before us, as if awaiting inspection. As we swam closer, we counted sixteen, varying in color and pattern from evenly dark gray or tan to blotchy and mottled, all with white bellies. They seemed unconcerned as we swam freely among them. Juvenile half-moon fish flitted about the molas, picking parasites from their bodies.

Lacking a true tail, the mola appears to be all head, earning it the German sobriquet of *Schwimmenderkopf,* or "swimming head." Its Latin name, *Mola,* coined by the great Swedish naturalist Linnaeus, means millstone. The creature's common English name of sunfish refers to its habit of resting on its side at the surface. Some biologists believe that such basking—a trait shared with swordfish and leatherback sea turtles—may be a method of warming the body to speed up digestive ability. Small fishes and seabirds feed on the copepod parasites clinging to the bodies of basking sunfish.

Found in all tropical and temperate zones, molas eat small fishes, squid, crustaceans, jellyfish, gelatinous plankton, and algae, but their favorite food is the moon jelly. Ocean sunfish can pursue prey in deep waters. In 1987 one was filmed from a submersible in the Bahamas at a depth of 1,800 feet.

A dozen juvenile half-moon fish, above, feast on a mola's body parasites. The mola's fibrous skin is tough, light, and several inches thick. Facing page: Attracted by a floating kelp mat, with its resident population of small invertebrates, a mola swims just below the surface of the Pacific Ocean near San Diego.

Fused teeth give the sunfish a beaklike mouth, part of a specialized anatomy that sets it apart from most bony fish.

Molas, huge relatives of puffers, are the heaviest of all bony fishes and may weigh as much as 5,000 pounds. E. W. Gudger, an American Museum of Natural History ichthyologist who studied them in the 1930s, proclaimed giant sunfish the "growth champion among animals." Beginning as larvae one-tenth of an inch long, they grow to an adult size of more than ten feet—and increase their original weight sixty million times. Gudger calculated that "the larval sunfish is to its mother as a 150-pound rowboat is to sixty *Queen Marys* (the *Queen Mary* weighed 80,773 tons).

Despite their size and shape, molas swim gracefully through the water by synchronously flapping their long dorsal and anal fins on one side and then the other. The rear end, or clavus, is hardly a tail and is nearly useless in propelling the fish, but works as a serviceable rudder.

Molas have an extraordinarily tough skin made of densely packed collagen fibers up to six inches thick. In the last century, fishermen's children would bind chunks of sunfish skin with twine to form bouncy balls. The sunfish's skin supports thousands of parasites belonging to forty different species. Even some of its parasites have parasites.

Humans, killer whales, and sea lions also prey upon these gentle, vulnerable giants. In late summer, when large numbers of young, three-foot-long molas follow warm, food-laden currents into Monterey Bay, California sea lions often attack them. The sea lions tear off a mola's dorsal and anal fins and slam the helpless fish against the water's surface. If they fail to rip through its tough skin, the sea lions may toss the crippled mola about like a giant frisbee and finally abandon it to voracious seagulls. □

Although the mola may weigh as much as two and a half tons, it is gentle and approachable. While most female fish carry between twenty and fifty million eggs, a four-foot female mola was found to contain about 300 million—a possible world's record.

To found a new colony, a queen ant of the slave-making genus Polyergus *(right) must enter a* Formica *nest and launch a fatal attack upon the* Formica *queen (left). After repeated biting and licking, the victor acquires the victim's pheromones and, with them, the services of the dead queen's workers.*
Raymond A. Mendez

The Ant Who Would Be Queen

To enslave a foreign colony, a parasitic queen must first murder her royal counterpart

by Howard Topoff

Recently, I found my daughter Andréa studying for an ecology test—in the fourth grade. Surprised, I took the opportunity to ask her if she could name a parasite. "A tapeworm," she said. "You know, that thing that lives in your stomach. Yuck!" Her reaction was familiar; to most people the mere thought of a parasite is unsettling. But people are usually considering only the familiar parasites of humans: various worms, lice, ticks, and other creatures that attach themselves to the skin or internal organs and feed on blood or other body fluids, sapping their host of energy. A more remarkable type of parasitic relationship exists, however. Known as social parasitism, it involves one species relying on another to raise its young. Among vertebrates, the best-known social parasites are such birds as cuckoos and cowbirds; the female lays an egg in a nest belonging to another species and leaves it for the host to rear.

The dulotic, or slave-making, species of ants, however, are the supreme social parasites. Consider, for example, the unusual behavior of ants belonging to the genus *Polyergus,* which I have been studying for many years in the Chiricahua Mountains of southeastern Arizona (*see* "Invasion of the Booty Snatchers," *Natural History,* October 1984). All species of this ant have lost the ability to care for themselves. The workers do not forage for food, feed their brood or queen, or even clean their own nest. To compensate for these deficits, *Polyergus* has become specialized at obtaining workers from the related genus *Formica* to do these chores.

In a slave raid, several thousand *Polyergus* workers will travel up to 500 feet in search of a *Formica* nest, penetrate it, drive off the queen and her workers, capture the pupal brood, and transport it back to their nest. The captured brood is then reared by the resident *Formica* workers until the developing pupae emerge to add to the slave population, which maintains the mixed-species nest. The *Formica* workers forage for nectar and dead arthropods, and regurgitate food to colony members of both species. They also remove wastes and excavate new chambers as the population increases.

The true extent of the *Polyergus* ants' dependence on their slaves becomes apparent when the worker population grows too large for the existing nest. Scouts of *Formica* locate a new nesting site, return to the mixed-species colony, and recruit additional *Formica* nest mates. During a period that may last seven days, the *Formica* slaves carry to the new nest all the *Polyergus* eggs, larvae, and pupae, every *Polyergus* adult, and even the *Polyergus* queen.

Of the approximately 8,000 species of ants in the world, all 5 species of *Polyergus* and some 200 species in other genera have evolved some degree of parasitic relationship with other ants. At one end of the behavioral continuum are temporary parasites, species capable of caring for themselves, but relying on a host species during the early stages of colony founding. The newly mated queen of the species *Lasius umbratus*, for example, enters a nest of its host, *L. niger,* kills the resident queen, and deposits her own eggs in the invaded nest. The host workers rear her offspring, which as adults scavenge for their own food. Because the host queen is no longer present, the worker force of *L. niger* gradually diminishes through attrition, and the colony becomes a single-species society of *L. umbratus*.

At the other end of the spectrum, the inquiline ants spend their entire life cycle in the nest of the host. In *Teleutomyrmex schneideri,* for example, the entire worker caste has been eliminated and so have the slave raids. The queen of *Teleutomyrmex* is about one-third the size of her host queen, *Tetramorium caespitum,* and capitalizes on her own diminutive size by riding on the host's back. The males and new queens produced by the parasitic female copulate inside the host nest. The newly mated queens then locate other colonies of *Tetramorium* to parasitize, and the cycle of parasitism is repeated. *Teleutomyrmex schneideri* has achieved the highest possible degree of social parasitism, and in so doing it has become utterly dependent on its host. *Polyergus* represents an intermediate stage of parasitic evolution, because it too depends on its host for food and nest maintenance. Unlike *Teleutomyrmex*, however, it still retains a large worker population that must conduct frequent slave raids on other ant species.

But how do such parasitic relationships originate? A cardinal rule in evolutionary biology is that parasitic organisms, be they bacteria, tapeworms, fleas, or slave-making ants, must have evolved from free-living ancestors. For dulotic ants such as *Polyergus,* at least two behavioral adaptations were also essential for social parasitism to evolve. The first is a proficiency for capturing another species' brood in a group raid. This behavior undoubtedly predates parasitism, because many free-living ants conduct predatory raids on other species, as well as territorial raids on neighboring colonies of the same species.

The second adaptation is the ability of queens to found new colonies. In free-living species, winged males and queens fly from their natal nests in search of mates. After this mating flight, a fertile female pulls off her wings, excavates a chamber, lays a few eggs, and later nourishes her larvae with stored nutrients. When the first brood matures into adult workers, they feed the queen and the larvae of her subsequent broods. But this sequence simply will not work for a parasitic ant such as *Polyergus* because the queen can't rear her own larvae. Her only recourse is a seemingly impossible task: to invade a *Formica* colony, kill the host queen, appropriate the brood, and somehow get the workers to accept her as their queen. If she is successful,

During a Polyergus *raid on a* Formica *nest, left, two workers (center, beneath log) carry off a white* Formica *pupa. Below: A* Formica *queen is approached by a worker (right) of her own species after they have been routed from their nest in a slave raid.*
Both photographs by Howard Topoff

resident *Formica* workers will feed her, and within a few days she will start laying eggs. After the eggs hatch, the host workers will rear her brood until her own worker population is large enough to supplement the slave force by staging raids on other *Formica* colonies.

My recent studies of *Polyergus* have focused on the mechanisms by which newly mated queens are able to kill queens of *Formica* and become accepted by the foreign workers. Together with Ellen Zimmerli, one of my graduate students, I returned to the American Museum's Southwestern Research Station, in the Chiricahua Mountains of southeastern Arizona, where I had conducted my original studies. At an elevation of 5,400 feet, the ants inhabit a woodland dominated by Arizona oak, alligator juniper, and Chiricahua pine trees. Here, *Polyergus breviceps* is the only slave-making ant, and *Formica gnava* is its only host.

Like most ants, both species nest underground, so that the interactions between host and parasite queens cannot be observed in the field. Fortunately, colonies of *Formica* are easy to collect, and they thrive in the laboratory, where they can be observed under a low-power microscope. A day prior to each test, we put fifteen *Formica* workers, fifteen pupae, and one queen in a plastic petri dish "nest," which was placed in a larger tray to prevent ants from escaping. At the beginning of each test, these workers stood motionless, surrounding the pupal brood.

When we introduced a newly mated *Polyergus* queen into the tray that surrounded the nest, she would scramble around randomly until she located the small nest entrance. Once inside, however, her actions became deliberate. She bolted straight for the *Formica* queen. Armed with powerful mandibles, she delivered lethal bites to several *Formica* workers who attempted to attack her and repelled the rest with a pheromone secreted from the Dufour's gland in her abdomen. With the worker opposition liquidated or dispersed, she grabbed the *Formica* queen and, for twenty-five minutes, bit her repeatedly in the head, thorax, and abdomen. The *Polyergus* queen's assault is so rapid and formidable that the *Formica* queen can only muster a feeble and futile counterattack. Through the microscope, I could clearly see that between bouts of biting, the attacking queen opened her mandibles wide and, extending her hypopharynx (tongue), continually licked the dead queen's wounds.

Within minutes after the death of the *Formica* queen, the small nest underwent a remarkable transformation. The remaining *Formica* workers behaved as if they were sedated. They calmly approached the *Polyergus* queen and began grooming her as she assembled the scattered *Formica* pupae into a neat pile, and triumphantly stood on top of it. At this point, the colony takeover was complete.

But how did the *Polyergus* queen bring about this dramatic shift in the behavior of the *Formica* workers? Social insects use chemicals, called pheromones, to communicate with one another. Pheromones are similar to hormones, in that both are secreted by glands. But whereas hormones are secreted into the circulatory system within an organism, pheromones are excreted to the outside and affect the behav-

ior of other organisms. One possibility was that naturally occurring pheromones of the *Polyergus* queen were similar to those of the *Formica* queen. If so, she would have been using what ecologists call chemical mimicry to accomplish her takeover. But because the invader was accepted only after she killed the host, I was drawn to an alternative hypothesis, one that I call the "chemical heist." In this view, the *Polyergus* queen acquires chemicals from the *Formica* queen during the very act of killing and licking her.

We repeated the original experiment, introducing a *Polyergus* queen to a *Formica* nest with workers, pupae, and queen, but with a twist: we had already killed the *Formica* queen by rapidly freezing and defrosting her. The chemical heist hypothesis predicted that the *Polyergus* queen would still have to attack the dead host queen, pierce her exoskeleton, and ingest her body fluids. The results were exactly as we had predicted. Upon entering the nest, the *Polyergus* queen ran past the attacking workers, pounced on the motionless *Formica* queen, and proceeded to bite and lick her just as if she were alive. After about twenty minutes of working over the *Formica* queen, the *Polyergus* queen was groomed by the *Formica* workers and accepted by them as their new queen. Apparently the pheromones of the dead queen, and not her murder, triggered the remarkable transition.

To determine whether the chemicals acquired from the dead *Formica* queens are long-lasting, we repeated the experiment, but removed the *Polyergus* queen as soon as she had finished killing and licking her victim. We then placed the queen in a vial for seven days before reintroducing her into a nest of *Formica* workers and pupae. Despite her lengthy absence, she was immediately accepted by the *Formica* workers, who approached her slowly, waved their antennae over her and commenced grooming. We saw no signs of aggression.

One question remained: How does a *Polyergus* queen know which species of ant to parasitize? Many ant species inhabit southeastern Arizona, and a newly mated *Polyergus* queen might easily encounter the nests of more than two dozen species in a single afternoon. But only one will do. Choosing the proper host is crucial because worker ants do not alter their behavior as a result of being parasitized.

Inside a *Polyergus* nest, *Formica* workers forage for the same food (nectar and dead arthropods), construct the same galleries, and defend their colony against the same predators that they do in their own

A Polyergus *worker, left, carries the pupa of a* Formica *ant. Upon emergence from the pupa, the young adult will join the workforce in the new, mixed-species nest. Below: Young* Formica *ants emerge from their cocoons. Within a few days, they will acquire adult pigmentation.*
Both photographs by Howard Topoff

nests. Even if a *Polyergus* queen were somehow able to become adopted by a small colony of harvester ants, it's a good bet that the workers would continue to bring their choice food, seeds, back to the nest. Since neither the *Polyergus* queen nor her larvae could survive on this high fiber diet, such a mixed-species nest would quickly perish. Successful parasitism thus dictates that parasite and host species share an extraordinarily similar ecology, which probably explains why socially parasitic ants and their hosts are often closely related taxonomically.

I tackled this question in the pine barrens of Long Island, New York, where *Polyergus lucidus* (the eastern species of this genus) uses at least three species of *Formica* as slaves. Each *P. lucidus* colony, however, enslaves only one of these three types of *Formica* ants. Linda Goodloe, one of my graduate students, surveyed *P. lucidus* colonies in late summer, when mating flights occur. For several days prior to flying, winged queens emerge from the nest in late afternoon and join several hundred workers milling around the nest entrance. We captured queens from *Polyergus* colonies containing *F. schaufussi* or *F. nitidiventris* slaves, cooled them to immobilize them long enough to dab a streak of enamel paint on their abdomens, and then immediately returned them to their home nests.

For the next few weeks, we watched the ground near the colonies for the presence of marked queens that had recently mated (indicated by the absence of wings). We recaptured thirteen painted *Polyergus* queens from colonies with *F. schaufussi* slaves and brought them to the laboratory, where we presented them with a choice of two host *Formica* species: *F. schaufussi* (the species from their home nest) and *F. nitidiventris* (with which they had no previous experience). All thirteen queens selected colonies of *F. schaufussi* to invade.

We were only able to recapture one painted *Polyergus* queen from a *F. nitidiventris* colony, but given a choice of nests to invade, it chose a colony of *F. nitidiventris*. *Polyergus* queens use a very simple rule: invade any colony containing the same species of host ant that was in the nest in which you were raised. Such specialization probably increases the chances that *Polyergus* queens will be able to find compatible hosts.

But for such parasitism to have evolved, an occasional *Polyergus* queen must have invaded the nest of an unfamiliar species. Imagine a lone, newly mated *Polyergus* queen, scurrying around the field, sticking her nose (actually her antennae) into crevices and under rocks, looking for the nest of a foreign ant species to assault. Sound dangerous? In addition to sheltering a wolf spider, sun scorpion, or centipede, any nook or hole might harbor a colony of carpenter ants whose powerful jaws could instantly decapitate an intruder. Undoubtedly, *Polyergus* queens often ended up as tasty morsels for other arthropods, but a few must have been successfully adopted by a new host species.

To see how *Polyergus* queens might react if given the opportunity to acquire the odor of an unfamiliar *Formica* queen, we returned to Arizona. At an elevation of 8,200 feet, in a forest of ponderosa pine and Douglas fir, *Polyergus* ants raid nests of *Formica occulta* for slaves; at lower elevations, they parasitize *F. gnava*. We collected seven colonies of *F. occulta,* and set them up in laboratory nests. Into each *F. occulta* nest, we introduced a newly mated *Polyergus* queen from a colony found at the lower elevation and that therefore contained *F. gnava* slaves.

The results of the seven trials were mixed. Five of the *Polyergus* queens showed no interest in attacking the *F. occulta* queens; they encountered the foreign queens, brushed them with their antennae briefly, and then ignored them. Attacking *Formica* workers killed three of these passive *Polyergus* queens. The other two queens escaped harm by quickly leaving the nest. Remarkably, two of the seven *Polyergus* queens did seize and kill the foreign *Formica* queen. And when they finished licking their victims, both were promptly adopted by the foreign *Formica* workers.

While this success rate might seem poor, the payoff for *Polyergus* is large. Indeed, social parasitism is such a successful adaptation that it has arisen independently in many unrelated animals, including fishes, birds, and insects. Among fishes, only the most rudimentary form of brood parasitism exists, in which the parasitic female's role ends after egg laying. Females

Raymond A. Mendez

A Polyergus *queen, right and below, usually mates during the a slave raid. Having emitted pheromones to attract the darker, smaller males (below left), the queen mates with one, and after removing her wings, continues with the raid.*

Howard Topoff

of the Asian freshwater minnow *Pungtungia herzi*, for example, deposit their eggs on the same aquatic reed as their host, the perch *Siniperca kawamebari*. Because male *Siniperca* don't discriminate between the two types of eggs, they end up guarding the parasite's eggs along with their own. When the minnow eggs hatch, the parasitic fish assemble with others of their own species and have no further contact with their hosts.

Cuckoos, by contrast, carry brood parasitism several steps further. After depositing an egg in the host's nest, a female cuckoo removes one of the resident eggs. Egg mimicry is also common, so that a cuckoo specializing in meadow pipits lays brown, spotted eggs; while a cuckoo specializing in reed warblers lays greenish eggs. The cuckoo chick enhances the parasitic relationship by hatching first and systematically ejecting the eggs and newly hatched chicks of the host. The host parents clearly do not recognize the deception, and they feed the parasitic chick until it is ready to leave the nest. Like the minnows, however, fledged cuckoos promptly rejoin members of their own species, and have no further interactions with the host species until they are reproductively mature and ready to parasitize another nest.

How does the female cuckoo choose an appropriate host to parasitize? Apparently, she uses the same rule as a *Polyergus* queen. The cuckoo lays her egg in a nest containing the same host species with which she was raised immediately after hatching.

My daughter's fourth-grade science book does a pretty good job illustrating the major principles of ecology. On evolutionary diversity, however, it falls short. Like most biology textbooks, it echoes the fantasy that vertebrates are higher on the evolutionary tree than invertebrates, and are therefore more complex in both structure and function.

Yet the behavior of *Polyergus* queens during colony founding offers perhaps the best illustration that the evolutionary process yields a mosaic of species—often with unique and extremely sophisticated social adaptations—and is not an escalator leading methodically and inexorably to ever greater complexity. Ant societies, with their behaviorally specialized castes, elaborate systems of chemical communication, and huge potential for adjusting to ever changing environments, have evolved levels of social organization that far exceed even those of most vertebrate species. □

S. R. Maglione; Photo Researchers, Inc.

The Vervets' Year of Doom

Can Amboseli's monkeys survive the predation of leopards and the loss of their favorite trees?

by Lynne A. Isbell

The sky is clear in Amboseli National Park, Kenya, and Mount Kilimanjaro rises to meet it. On the plain, Newton, Charing Cross, Gorbachev, and the rest of the group of vervet monkeys stir from the sleeping tree to begin another day of eating, arguing, and grooming one another. Newton, an adult female with a distinctive white moustache, directs her attention to a large *Azima* bush sixty feet away that is thick with ripe berries. Approaching the bush could be risky, as the dense foliage might harbor a leopard or python. She scrutinizes the greenery for a long time, then climbs down the sleeping tree and passes by several smaller bushes, turning over elephant dung along the way to look for juicy insects. Suddenly, a blur of colors darts out from behind one of the bushes. Within seconds, a leopard grabs Newton by her neck, breaking it instantly. Charing Cross, witnessing the kill, emits a rapid series of sharp barks. To the vervets, its meaning is clear: "LEOPARD! LEOPARD!" The call is quickly taken up by the rest of the group as other individuals on the ground race up the nearest fever trees for a safe view. The cat carries Newton's body to a shady spot beneath the dense branches, where it consumes the meat. Charing Cross, Gorbachev, and the others will never see Newton again.

Anyone who visits the numerous national parks in East Africa quickly learns that dangers abound there. Parched bones liberally litter the ground. Many belong to gazelles, wildebeests, and other ungulates taken by lions, hyenas, cheetahs, and leopards. Some smaller animals, however, leave very few bones behind to remind us that they were once dynamic individuals that maneuvered their way around friends and enemies in an attempt to survive and reproduce. Vervet monkeys are the size of

An infant vervet clings to its mother, opposite page, in Kenya's Amboseli National Park. Vervets prefer to sleep in fever trees, above, whose many vertical branches may deter leopards from climbing them.
Mary Ann McDonald

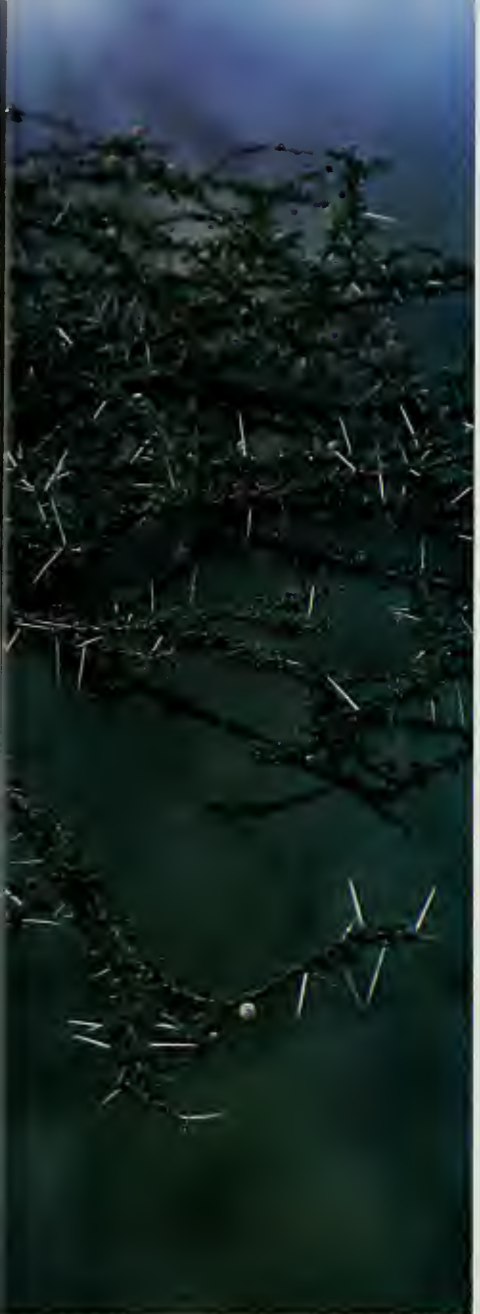
domestic cats; when they are eaten by carnivores, particularly leopards, virtually nothing remains.

Although vervets are found throughout sub-Saharan Africa, they are restricted to savanna–woodlands habitat along rivers, lakes, and swamps. They live in cohesive groups, ranging in size from two to about twenty adult males and females, with accompanying juveniles. Following the typical pattern for Old World monkeys, female vervets usually live and die in their mother's group, while males leave to join other groups when they reach sexual maturity at five or six years of age. Females form the core of a stable but competitive social environment, and their relationships are strictly hierarchical. Whenever a conflict arises over food, grooming partners, or even seating locations on a branch, the highest-ranking female and her daughters can push everyone around, while the lowest-ranking female and her daughters must give way to everyone. Because males are more transient than females, their place in the hierarchy is less fixed and less dependent on kinship.

Researchers have studied Amboseli vervets for three decades, during which they have learned about the kinds of foods vervets prefer during good times and bad, the role of kinship in gaining access to those foods, and how the animals steer clear of danger. Zoologist Tom Struhsaker first recognized that vervets in Amboseli give different alarm calls to different predators, documenting a vocabulary of sorts. Later, Robert Seyfarth and Dorothy Cheney systematically studied the vervets' responses to these alarm calls (*see* "In the Minds of Monkeys," *Natural History,* September 1990). After recording alarm calls, Seyfarth and Cheney played them back to the vervets when predators were absent. When vervets on the ground heard the "snake" alarm, they stood on their hind legs and scanned the ground. When they heard "eagle" alarm calls, they dashed into bushes for cover. And, as on the day that Newton died, when vervets heard "leopard" alarm calls, they retreated quickly to the upper branches of trees.

Predation is a fact of life for vervets. They are vulnerable to pythons, eagles, leopards, and even baboons. Still, when I first went to Amboseli in 1986 to study the vervet's social system, I did not expect to witness the near annihilation of the entire study population. When I arrived, the vervet population consisted of seventy-six

Renee Lynn; Photo Researchers, Inc.



At Lake Nakuru National Park in Kenya, a young vervet maneuvers through an acacia's thorny branches, left, to reach the small, edible white flowers. At the approach of a large python in Amboseli, below, vervets stand on their hind legs while excitedly repeating their "snake" alarm calls.

Richard Wrangham; Anthro Photo

individuals living in six groups that were well habituated to human observers. Indeed, these vervets usually treated us as if we were just another species of gazelle—a neutral species, neither beneficial nor harmful. By the time my study ended more than two years later, the original population had been reduced by two-thirds, to twenty-five individuals in three groups. When I returned in 1992, only two small groups, totaling nine individuals, still remained. What happened to the luckless Amboseli vervets, and can their devastated population survive?

Struhsaker, who in the 1960s was the first scientist to study the Amboseli vervets, found upon returning there in the 1970s that the population had declined. He noticed, too, that there had been a decline of the fever trees, *Acacia xanthophloea*, on whose sap and seeds the vervets feed. The monkeys also use the trees as nightly roosts, descending each morning to forage for berries, insects, and other delicacies. (Fever trees grow quickly but live perhaps only 100 years. And as ecologists Truman Young and Keith Lindsay have pointed out, stands of fever trees usually contain individuals of similar age. Since the trees are aging simultaneously, they die within a few years of one another.) As their food supplies gradually dwindled, so did the monkeys. By the time of my study, however, the last of the fever trees had begun to die, dramatically affecting the lives of the remaining vervets.

As their responses to alarm calls attest, vervets also use fever trees for shelter, primarily when fleeing leopards. About six months into my study, I began to suspect that something unusual was happening after Newton and five juveniles from her group disappeared on the same day. The vervets seemed to be disappearing at a faster rate than in past years. Often, they simply vanished overnight, despite my extensive searches for signs of them. When I did find evidence, it was largely circumstantial. Animal tracks are easily seen in Amboseli's dust, and I sometimes found clues that told of vervets darting out of their sleeping tree in the middle of the night and of a leopard among them. I could easily imagine the terror of the monkeys when they were startled awake by the big cat. Once I found something more substantial: the lower jaw and a clump of hair belonging to Tycho, a low-ranking female who was ten years old at the time of her death. Near her fragmentary remains were leopard tracks and the only pile of leopard dung I ever found in Amboseli.

At about the same time that the vervet population was rapidly shrinking, I began to see leopards more often than observers had in the past. In 1987, I saw leopards nineteen times, sometimes even without the help of the vervets' alarm calls. During the entire previous year, vervet researchers had observed a leopard only once. One of my sightings was an adult female with two cubs. Judging from the tracks I saw under the vervets' sleeping tree the morning Almond Joy and her four-year-old son, Hoola Hoop, disappeared, the female leopard had been hunting that night with at least one of her cubs. Twice I saw an adult female and an adult male leopard together, although most often I saw a lone adult male. Leopards live solitarily when they are adults, and because adult males do not share home ranges, I believe that my sight-

Carol Hughes; Bruce Coleman, Inc.

Vervets eat a wide variety of seeds, fruits, flowers, sap, and insects. An adult in South Africa feeds on flame creeper blossoms, left. Below: An infant that has wandered a few feet away from its mother peers through the foliage in Nairobi Park, Kenya.

Erwin and Peggy Bauer

ings were all of the same individual. Sometimes the vervets' alarm calls and the directions in which they gazed led directly to my leopard sightings. Even so, I was not always able to see the predator that stirred the monkeys. While vervets are undoubtedly better at detecting leopards than I am, at times they also missed seeing the predator—with unfortunate results. Even though the number of observed alarm calls had risen sharply over previous years, the disappearance rate for vervets shot up to 65 percent in 1987. That was the year of vervet doom. During the ten previous years since Seyfarth and Cheney began the long-term project, the yearly average of "disappearing" individuals had been only 22 percent of the population. The increase in my sightings of leopards, the greater frequency of the monkeys' alarm calls, and the increase in such alarms during months when most vervets disappeared all pointed to sharply increased predation by leopards.

My frustration at not actually observing the cause of the vervets' disappearance was exacerbated by what Seyfarth and Cheney have informally labeled "the Nairobi effect," referring to what seemed to be an increased tendency of vervets to disappear while observers went on short trips to the Kenyan capital for supplies. (Fewer monkeys, it seemed, disappeared during the many weeks that fieldworkers remained in Amboseli.) But the Nairobi effect had been difficult to document over the years, partly because predation, although high relative to other primate populations, was still rather uncommon. Also, the behavior of other predators, such as pythons and martial eagles, was unaffected by the presence or absence of humans. With the dramatic increase in leopard predation during my study, however, ecologist Truman Young and I were able to show that the Nairobi effect was real.

At the beginning of my study, I saw leopards only rarely. When I returned from trips to Nairobi, however, vervets were nearly four times more likely to have disappeared than while I was present. Whenever I came back from the city, the leopards apparently took a couple of days to recognize that I was back to stay for a while because I saw them more often in the first two days after returning than at any other time. A ranger station on the edge of the study area had a similar effect in inhibiting the leopards; the closer the vervet groups lived to the ranger station, the fewer losses they suffered.

Then something changed. Eight months into the study, my presence apparently no longer handicapped the leopards. Both leopard sightings and vervet disappearances increased dramatically, and vervets were no more likely to disappear during my trips to Nairobi than during my field days. My guess is that the male leopard was seeing me so often that he was becoming progressively less wary. In the early days, he ran away the instant we saw each other. In later months, he simply walked away whenever I arrived. Finally, on my last day in the field, I felt as though he had granted me a supreme honor when I watched him for over an hour before he casually yawned, stretched, and then ambled down from a tree in which, on many other nights, vervets slept.

Why had leopard predation become more intense during my study than during any of the previous years of continuous research on Amboseli vervets? One explanation is that the increase in predation was a rare event, directly related to the loss of the fever trees, which had provided much of the vervets' food and shelter. Another possibility was that the short-terrm increase in predation was just another in a series of blips that have occurred repeatedly throughout the thousands of generations in which vervets and leopards have coexisted. Both explanations are likely to be partly correct.

This sudden rise in predation was probably an important event in the lifetimes of individual vervets—or researchers—but a common event in the evolutionary history of vervets as a species. In this case, we don't know whether the local leopard population had grown, whether a few were spending more time in the area, or whether a new individual with a decided taste for vervets had moved into the neighborhood. What we do know is that leopards caught more vervets and that at least part of the reason was the loss of the monkeys' favored fever trees.

As the groves of fever trees died, the vervet groups that had lived in the same small home ranges for generations began moving into new and unfamiliar areas. Between 1986 and 1988—with the year of

Stan Osolinski; Oxford Scientific Films

Bearing her youngster on her back, a female vervet, below, feeds on ground plants in Amboseli. Opposite page: In Kenya's Samburu National Park, a leopard carries a vervet it has killed. Leopards usually seek a secluded spot or sturdy branch where they can feed undisturbed.

Erwin and Peggy Bauer

vervet doom in the middle—we observed groups shifting their home ranges away from the dying fever trees and into the drier but healthier woodlands of *Acacia tortilis,* the umbrella tree. Vervet groups are aggressively territorial in Amboseli and do not share their home ranges with other groups. As the largest group moved into the umbrella tree woodlands, it drove out two smaller, neighboring groups that had been established there. These smaller groups were driven farther into umbrella tree woodlands where no other vervets lived.

The largest group gained access to three times as many trees as it had previously occupied; whereas smaller troops were forced to subsist on more limited resources. Regardless of the number of trees that any group acquired or lost, vervets were more likely to disappear when they moved into new and unfamiliar areas.

Many zoologists believe that animals benefit in some way from living in a familiar place. Most animals do not simply wander around randomly over the earth but instead use a much more limited area, their home range. Among mammals, vervets included, females tend to remain in the area where they were born, while males tend to disperse into new areas before settling down. On familiar ground, animals may benefit by knowing where to find food and shelter and by becoming adept at anticipating the behavior of familiar predators and conspecific competitors.

The cost of living in unfamiliar habitats showed itself in another way. Three of the six original vervet groups became so small as a result of predation and decreased reproduction that the straggling survivors abandoned their home ranges and joined neighboring groups. During the first six months of joining new groups, newcomers were more likely to disappear than the long-time residents who were familiar with the same habitat. Apparently, each newcomer has to learn about the new environment through direct experience; little, if any, of the residents' knowledge seems to be communicated. With time, however, any difference in mortality between newcomers and old hands declines steadily, as familiarity with an area appears to reduce an individual's vulnerability to predation.

The value of living in familiar surroundings has always made good intuitive sense. Our study, however, has documented its value in minimizing the risk of predation. Danger from such predators as leopards, however, must be viewed against the larger background of ecology and cycles of vegetation.

If the fever trees had not died, Tycho, Almond Joy, Hoola Hoop, Newton, and more than thirty others might be alive today. Unlike umbrella trees, which grow slowly but live several hundred years, fever trees don't live very long. Long-term research in Amboseli suggests that vervets are intimately tied to the fever tree population's cycle of growth and death. When the trees are middle-aged and healthy, they provide vervets with abundant food. Vervets take advantage of this, reproducing every year. As a result, their groups may become large during the boom years. When the fever trees begin to die, however, females do not have enough food to sustain their high reproductive rates. Over time, vervet groups become smaller as older individuals are not replaced by younger ones. The final stage of decline may occur when the last of the fever trees die and vervets are forced to move into unfamiliar habitats. Vervets become even more vulnerable to predation than before, and if leopards are around to take advantage of the situation, vervet mortality increases until the monkeys become familiar with their new locations.

Newton didn't survive the change, but she left relatives to carry on. Her daughter, Nut Case, and a few individuals are managing to live and reproduce in the umbrella tree woodlands. As a species, vervets may be very good at surviving as long as there are alternative trees available for food and shelter. If the Amboseli ecosystem is not disturbed and fever trees eventually regenerate, Newton's descendants may one day venture into new fever tree woodlands and experience a new population boom. This dynamic cycle involving fever trees, vervets, and leopards may have been played out over and over throughout their coexistence in East Africa. Newton's ancestors probably faced the challenges she failed to meet, and her descendants may be faced with similar challenges one hundred years from now when a new crop of fever trees becomes old and dies in Amboseli. □

In the hot, dry Negev Desert highlands, snails venture out mostly at night, when the air is cool and the rocks they feed on are covered with dew.

Desert Snails' Daily Grind

In scraping out a living on the rocks, small mollusks make a big difference to the Negev

by Clive G. Jones and Moshe Shachak

Photographs by Jeffrey L. Rotman

Apart from a sprinkling of shrubs, the steep, treeless slopes of Israel's Negev Desert highlands seem devoid of life. But just beneath the surfaces of the limestone outcrops, rocks, and small stones that cover much of these hillsides, there is abundant life. Countless communities of lichens—symbiotic associations of algae and fungi—thrive in the spaces between the rock particles. Here they are protected from extremes of temperature and humidity and yet are close enough to the surface to get enough sunlight for photosynthesis.

Among the most striking features of the rocks in the Negev highlands are the white lines—actually gouges about one-half to two millimeters deep—that meander between and around the lichen colonies. These lines—sometimes so numerous that they form a lacy, filigree pattern—were long thought to be the work of the various species of lichens as they competed for living space or extracted nutrients from the

rocks. Recent research, however, has turned up a very different sort of explanation and revealed an unappreciated major player in the Negev ecosystem.

In 1986, while investigating the lichen communities, we became intrigued by the gouges and began to suspect that they had been cut by an animal. Particularly tantalizing were the many slime trails—the characteristic sign left by snails on the move—that we saw on the rocks. We turned our attention to the three closely related species of small snails, *Euchondrus albulus, E. desertorum,* and *E. ramonensis,* that we found living under the rocks in the Negev.

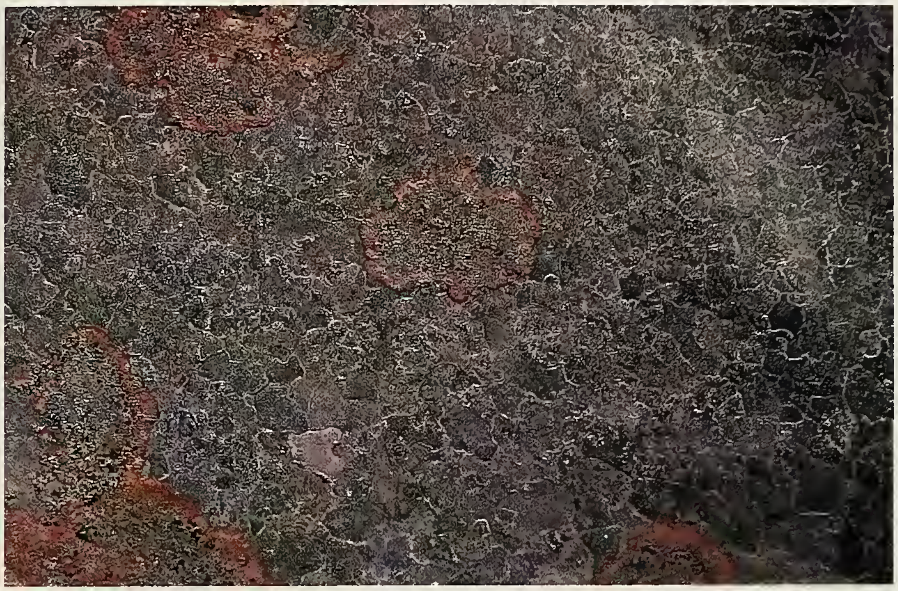
To observe the little snails (no more than one centimeter long), we set some up in our laboratory with rocks and appropriate water, light, and temperature regimens. We soon noticed that when the snails traveled across the rock surface, they stopped every so often, shifted to a more upright position, and began to sway back and forth. After twenty minutes or so, they moved on, leaving behind a new white scar in the rock about ten millimeters long, one millimeter wide, and one-half millimeter deep. A closer look revealed that the snails had gouged the rock, apparently to get at the layers of green algae and fungi, and in the process had left behind a white scar the color of exposed limestone. We later found that the snails were actually consuming the rock—as well as the lichens within—but were digesting only 5 percent of what they had eaten. Most was excreted in small coils of powdered rock and undigested lichens.

Like many other snails, the Negev's *Euchondrus* snails can handle a tough diet because they are equipped with a toothed, tonguelike organ, the radula, that can be scraped back and forth like a file. The snails break a lot of teeth on the rocks, but the radula grows continuously from the back of the mouth, replacing the worn-out and broken teeth at the front. (Somewhat surprisingly, these snails do not have special orthodontic adaptations. Unlike predatory marine mollusks that drill through the hard shells of other mollusks, the teeth of *Euchondrus* snails are not especially thick, nor do they appear to contain iron or other hard metals.)

The rock-eating habits of these snails went undiscovered for so long primarily because the snails hide, immobile, under the rocks during the heat of the daytime and only come out to forage at night and early morning, when the rocks are covered with dew (and when biologists are usually absent). During the cooler seasons, the daytime temperature ranges from 40° to 60° F, while at night it gets as cold as 22° F. So from September to April, on an average of 210 nights a year, dew forms on the rocks as they cool down at the end of the day and keeps them wet until the sun evaporates the moisture the next day. Equivalent to thirty millimeters of rain annually—in a desert that only receives an average of a hundred millimeters of rain each year—the dew is critical to the survival of both lichens and snails. Dew provides the water used in lichen photosynthesis, cools and lubricates the rock surface, and replaces the water lost by the snails in the slime trails they leave behind as they forage over the rocks.

About sunset, the snails start to move out from under the rocks. But before climbing up for a night of foraging, they defecate the indigestible remains of the previous night's meal. It takes them just a few minutes to climb up the rocks, and once they are out in the open, the snails feed until the rising sun heats the air and the dew begins to evaporate. Then they disappear under the rocks again to digest their food. At summer's height, from May to August, it gets as hot as 95° F during the day and 60° to 70° F at night. Dew cannot form, so the snails aestivate under the rocks, sealing themselves in their shells by forming a special, hard operculum, or

Beyond this rocky slope, left, lies a dry river bed, with more of the Negev Desert highlands visible in the distance. Countless lichens live just beneath the surface of the many rocks that litter the ground. Below: A rock is covered by subsurface lichen colonies, as well as a few blotchy patches of brownish surface lichens. Feeding snails have cut so many white grooves into the rock that it resembles a jigsaw puzzle.



plug, over the shell opening. They do not feed at all.

Much of the time, the snails are homebodies, seldom straying from their rock. But from November through April, whenever rain makes the soil wet enough for travel, the snails become more adventurous. After a rain, the patches of soil between the rocks are filled with dozens of snails moving to-and-fro, changing rocks, mating, and laying their eggs in the moist earth.

The more we poked around after the snails, the more we realized how many there were. They were most conspicuous during their rainy day journeys of a few centimeters to a few meters from rock to rock, but even when they weren't out and about, a minimum of effort on our part revealed impressive numbers. Almost every overturned rock exposed one or two snails—about twenty per square meter. That so many snails were able to make a living eating rocks in the desert is somewhat surprising, since snails are usually found in moister, cooler climates eating leaves or detritus. The snails, we were to learn, have an ecological significance in the workings of the Negev Desert that goes well beyond their unexpected abundance and unusual eating and toilet habits.

Of major importance is their effect on the lichens living within the rocks. Windblown lichen spores land on new rocks, germinate, and grow to form colonies that eventually fill up all the space between the rock particles just under the surface. Any further lichen growth depends on the snails. By removing the top layers of rock, the snails expose fresh rock—and also minerals that the lichens need. The grooves made by the feeding snails collect dew and nitrogen-containing dust, both critical resources for lichen growth. However, in the long term, the myriad white trails on the rock surface may increase the albedo, or reflectance properties, of the rock, slowing the rate at which the rock heats up and cools down, and perhaps reducing the amount of dew that forms.

Snails usually feed at the periphery of lichen colonies, which range in size from about one-half to three centimeters in diameter and where most of the nitrogen-rich new growth is to be found. As the snails cut new trails in the centers of colonies, they stimulate regrowth. They thus determine the size, shape, and number of lichen colonies. They probably also affect the species composition of the lichen community by selectively feeding on some colonies, encouraging regrowth of those best able to tolerate continual grazing. Snails may even help lichens that live within the rock outcompete surface-growing forms. The surface species, common on rocks ungrazed by snails, but far less abundant on grazed rocks, block sunlight, ultimately killing any lichens living within. Perhaps the disturbance of the rock surface by snails and the vigorous regrowth of internal lichens following grazing help prevent the surface lichens from establishing a foothold.

Like cows in a field, however, snails can overgraze. If there are too many snails on a rock and no rainfall to allow them to disperse, the snails will cut more and more new trails and graze less and less in old trails. Eventually the food runs out, and the snails must go quiescent (sometimes for as long as a few weeks) or die. While not common, overgrazed rocks covered with hundreds of white lines can be seen throughout the Negev, particularly in the areas with the least rainfall.

To gouge out the rock, facing page, and get at the lichens within, a snail extrudes its head and scrapes at the rock with its powerful, toothed, tonguelike radula. Below: After a night of feeding, a snail retreats under rock, where it excretes little coils of undigested rock and lichens (right and left).

The impact of the snails, however, goes well beyond the Lilliputian world of the lichens. These tiny mollusks are responsible for most of the new soil—in the form of their little fecal coils of powdered rock—that forms in the Negev each year. Annually, the snails graze from 4 to 7 percent of the total rock surface area to a depth of one millimeter or so, turning about 800 pounds of rock into soil per acre of desert. The Negev also receives soil blown in from the Arabian and Sinai Peninsulas, and until the discovery of the snails' activities, such aeolian deposition was considered to be the major source of new soil in the desert. But wind brings in only between 220 and 420 pounds of soil per acre each year, considerably less than the snails' contribution.

The snails do not just create soil; they also fertilize it. Desert environments are generally low in nitrogen, the element that is considered to be the second most important factor (after water) affecting the growth and productivity of higher plants. Foraging snails seek out lichens with the highest nitrogen content, but do not use all the nitrogen they consume. About 5 percent of the dry weight of snail feces deposited under the rocks is nitrogen. These tiny contributions add up: Our calculations indicate that snails transfer about three pounds of nitrogen to each acre of desert soil every year. The most common snail in the area, *E. albulus,* is responsible for 11 percent of all the nitrogen that enters the soil annually, an impressive amount for a single species.

Rain, dust, and the nitrogen-fixing activities of blue-green algal crusts on the soil surface also contribute nitrogen to the desert soil, but much of it is lost when wind erodes the topsoil and rain washes it down from the rocky slopes to the wadis, or temporary rivers, in the valleys below. Snail-produced nitrogen, deposited under the rocks, has more staying power because it is protected from runoff and wind erosion by the rocks and by small dams of soil that form at the base of the upslope side of the rocks. Patches of earth between the rocks support a rich variety of annual plants and woody shrubs. There, the plant roots have access to both the pellets of snail fertilizer and to water that has deeply infiltrated the soil. The growth of plants appears to benefit from the snail fertilizer.

The snails of the Negev Desert are not unique. In the 1920s, similar snails were discovered in the Dolomite Alps of southern Germany, where they also feed on subsurface lichens. Their rock-eating habits, however, were not recognized until our discovery in the Negev. Local alpine geologists can now explain the strange, grooved patterns on the rocks, for which they had previously invoked geomorphological explanations.

Interestingly, both the alpine and Negev species are distributed along the ancient limestone deposits that predate the formation of the Mediterranean Sea. These deposits run south from the Alps in southern Germany, through Italy, and down into the Mediterranean regions of the Middle East. Rock-eating snails may thus have evolved a long time ago and have been eroding and fertilizing both the deserts and mountains for millenniums, even though a sea now separates the regions.

Deserts are harsh environments, where animals as small as snails might be assumed to live at the whim of the elements and to play a limited role in the workings of the ecosystem — perhaps eating a few plants and animals and, via their own death and decay, making a minor contribution to the cycling of nutrients. The rock-eating snails of the Negev, however, have shown this is not a sound assumption. By controlling the growth, productivity, and composition of endolithic lichens, by turning rock into soil, and by then fertilizing that soil, they join the ranks of the desert's other natural engineers.

Porcupines in the Negev dig up and eat the bulbs of some desert plants and, in doing so, make pits in the soil that trap water runoff and seeds, creating ideal habitats for diverse annual plants. Desert isopods, or pill bugs, dig burrows seventy centimeters deep to get down to water, bringing infertile, salty soil to the surface, where it erodes and washes away. Altogether, these creatures have a major effect on their desert environment, albeit less dramatic than the large-scale consequences of the dam building of beavers and less familiar than the improvements to soil fertility and aeration provided by earthworm digging (to which Charles Darwin devoted an entire book). Without the activities of the snails and other ecosystem engineers, the earth would be a much less diverse, fertile, productive, and interesting place. □

Beastly Thinking

by Richard W. Byrne

We are currently seeing a spate of books on animal minds. Even to utter the words "animal mind" used to be considered a near-mortal sin for anyone in the behavioral sciences. Nowadays, however, people even title books with the words. What has been happening?

Twenty years ago, scientists could be neatly divided into two types by their response to the question, "What do you imagine happens inside the minds of animals?" Comparative psychologists, behaviorists, and (to a large extent) ethologists would enthusiastically describe rigid, inflexible, mechanistic goings-on—like the machines that controlled those early sci-fi automatons of 1950s movies. Other scientists—and really everybody else, scientist or not—would reply: "Simple thoughts, I suppose, but I don't see how we'll ever know."

How were the professionals who worked on animal behavior so sure of their answers? They weren't, of course, but they were carefully following the rule that science is supposed to abide by: accepting the simplest hypothesis until there is strong evidence of something more complex. Since evidence was minimal, the automaton theory won out. The various professionals agreed on this but differed about what to do with human minds. Behaviorists denied we had them, or if we did, denied that they had any consequences ("epiphenomenon" is a useful word for something that exists but might as well not, for all the effect it has). Other psychologists generally believed that language had somehow given us minds, on top of animallike reflexes. Ethologists don't study humans, do they? So they kept quiet.

Only cognitive psychologists (a new breed in those days) took the maverick line that minds must be a product of brain processes that are mechanistic and yet not in any way simple, thus managing to offend everybody. (Readers who seek to know a reviewer's bias should know that I was a cognitive psychologist in those days.) Cognitive psychology originally grew from the realization by some people of the implications of computers and artificial intelligence for psychology (a late 1950s conference on "the mechanization of thought processes" had a big impact).

Cognitive psychologists gaily assumed that all human intellect was reducible to machine states and set out to describe complex behavior as the results of software and hardware—of the brain. They did not, however, think 1950s sci-fi efforts or the behaviorists' theories had much to recommend them. In hindsight, the cognitive approach could have made a bridge between psychologists, impressed with human minds, and evolutionists, who expected continuity between humans and animals. Unfortunately, cognitive psychologists ignored animals.

The Animal Mind, by James L. Gould and Carol Grant Gould. *Scientific American Library, $32.95; 236 pp., illus.*

Donald Griffin set the ball rolling, leading to today's interest in animal minds. Griffin was in an unusual position. He had already made a major scientific discovery, bat echolocation, which somewhat "fireproofed" him from ridicule. Also, he remembered being taught as a student that bats couldn't get around well in darkness. He was not about to accept anyone again telling him that animals couldn't do things.

In 1976 he wrote a book cataloging animal behaviors that are not rigid and inflexible, actions that look suspiciously like our own. He also pointed out that an evolving mind in animals would pay reproductive dividends, challenging readers to consider the possibility that not all animal behavior is mindless. In this and in subsequent, similar volumes, he inspired a whole generation of researchers, James and Carol Gould among them, to look again at what too many had considered well-worked ground.

The Animal Mind is an attractive volume, taking us on a tour of some of the discoveries these researchers have made. The Goulds' choices hint at some of the attributes that they assume we all agree are "mindlike"—flexible not fixed actions, learned not innate behavior, conscious decisions not unconscious impulses. But do we all agree? Few doubt flexible animal learning, so I was left wondering if they really meant "consciousness" to define mind but hesitated to say so.

The Goulds' own specialty is the honeybee, and many chapters are illuminated by some of the wonders of bee life. Bee behavior is used to convey the message that we must be careful not to attribute our own experiences to animals that may live in a very different world: Seeing ultraviolet and polarization and feeling the earth's magnetism make a bee's world very different from our own. Other species see infrared (pit vipers), hear ultrasonics (bats), or smell so acutely (bloodhounds) that even a footprint translates into a whole creature; we would be rash to assume that their thoughts (if any) are much like ours.

Another important preliminary to serious consideration of animal minds is accepting that flexibility can result from a rigid, innate program of behavior—again well illustrated by bees. Confronted by alfalfa, a plant whose spring-loaded anthers flick pollen onto the underside of big bumblebees, a small honeybee gets a hefty blow. Some learn to avoid untripped flowers or even cheat by forcing their tongues in from the side. Have they understood the mechanism? Not necessarily. Bees will chew through the side of any flower whose nectar is too deep to reach. In dealing with alfalfa, bees have shown they can learn, but they have only adapted their innate behaviors to a small extent.

Blue tits that broke into milk bottles on British doorsteps to steal the cream provide another example. They learned to tear strips off card tops and, subsequently, to peck through foil caps. But the actions they used are part of a blue tit's normal, innate repertoire; what was learned was simply that doorsteps are a good place to forage. The Goulds spend chapters explaining the widespread innate behaviors of animals and their learning abilities (including innate channeling that makes certain things easier to learn than others), so that readers don't jump to the conclusion that every complex-looking action must imply that the doer has a mind.

The book then goes on to tour the animal kingdom, showing cases that look as if they would be hard for an automaton to cope with—animals acting in ways that look conscious. Perhaps something of a catalog is inevitable in a book obviously intended for a very wide audience, but I found this aspect disappointing; oddly the organization—from insects up to humans—suggests an evolutionary story, but no such case is made. Instead, we are repeatedly shown an action that looks smart, reminded that this "seems to imply" some aspect of mind, and invited to be broad-minded enough to allow that it might.

My favorite is the description of the remarkable flexibility of usage in the famous bee dance, after which the authors are able to say:

> When a human decides whether to recommend a restaurant, taking into account its menu, the tastes of the friends being advised, the cost of the food, the distance to the establishment, the ambience of the dining room, the ease of parking, and all the other factors that enter into such a decision,

The dog in the silent movie The Callahans and the Murphys *was conditioned to cover its ears when music started.*

Courtesy of Culver Pictures, Inc., from *The Animal Mind* we have little hesitation in attributing conscious, decision-making powers to the calculation. When a small, frenetic creature enclosed in an exoskeleton and sporting supernumerary legs performs an analogous integration of factors, however....

Fair point. The feats of some noninsects sometimes get a less gentle ride.

Chimpanzee termite fishing is "readily accounted for by conventional conditioning," and "all the elements of this tool-use seem prewired," which would surprise the researchers who have, from site to site, studied variations in termite fishing that resemble culture. The spread of "food-washing" in one group of Japanese monkeys is called "unsurprising, given the proclivity of primates to imitate: 'monkey see, monkey do' is as true as it is trite." In fact, the debate rages on as to whether any monkey has the cognitive capacity to imitate at all, and if they could, this would help the case that monkeys have minds, not refute it. But these are small quibbles. Most of the book is accurate and well explained, a pleasure to read.

So is the case made? Animals have minds, it's official. Not quite. Drawing attention to ever-more-convincing similarities of behavioral ingenuity between animals and humans cannot compensate for our lack of understanding of what a "mind" is. The Goulds rightly point out, in a last chapter devoted to humans, that many of our actions are innately guided and a good deal less conscious than we often care to think. But some are conscious, and we have no idea why this is beneficial. We do sometimes think things out but don't know how to detect this ability in other humans, let alone other species. Recently, major strides have been made in clarifying issues, as in Marian Dawkins's *Through Our Eyes Only?* Hers is an outstanding analysis of the possibility of animal consciousness.

But I was left just a little pessimistic after reading the Goulds' excellent book. Is the best we can hope for, as a model of animal minds, perhaps a better class of automaton (with reasonably complex software and powerful hardware)? If so, cognitive psychology of animals will be a growing subject.

Richard W. Byrne is a psychologist with the Scottish Primate Research Group of the University of Saint Andrews in Scotland. His latest book, The Thinking Ape: The Evolutionary Origins of Intelligence, *will be published this fall by Oxford University Press.*

A Lizard Found

by Charles J. Cole

Science often progresses in strange ways, but how often do biologists predict the existence of a species and describe it in some detail prior to its discovery? Not often. Darwin did it. When he saw Christmas Star orchids from Madagascar—white flowers that contained nectar at the bottom of a foot-long shaft—he wondered, "What can be the use of a nectary of such disproportionate length?" Convinced that flowers and their pollinators evolved in tandem, he concluded that "in Madagascar there must be moths with proboscides capable of extension to a length of between ten and eleven inches! This belief of mine has been ridiculed by some entomologists." Forty years later, a yellowish moth with a twelve-inch coiled tongue was discovered on the island and named *Xanthopan morgani praedicta*.

In May 1989, I coauthored an article ("A Lizard Foretold") for *Natural History* that predicted a new species of lizard—one that had never been reported in the scientific literature and, as far as I knew, never collected. Without having ever seen a specimen of the lizard, my colleagues and I deduced the number and appearance of its chromosomes and the nature of thirty-three of its proteins, each encoded by individual genes on the chromosomes. We also made certain predictions about the lizard's outward appearance, its general behavior, and its distribution.

The predictions were based on genetic studies of two closely related species of tiny, brown, snakelike lizards in the genus *Gymnophthalmus* found in northern South America. One, *G. underwoodi*, had originally attracted our interest because only female specimens had been found. We suspected they were reproducing without males, as do the unisexual whiptail lizards of the American Southwest, species we have been studying for more than twenty years. In the late 1980s, with funding from the National Geographic Society and the National Science Foundation, we proved that *G. underwoodi* does reproduce by parthenogenesis: the females lay eggs that develop without fertilization into another all-female generation.

While studying *G. underwoodi*, my colleagues and I discovered that its body cells did not contain the typical, matching pairs of chromosomes, but instead had two different-looking sets. We also found that many genes coding for specific proteins were present in two slightly different variants. These traits were a sign that the unisexual lizard had a hybrid origin—that is, it was the outcome of a mating between two different, but closely related, species. And like the whiptail lizards we had worked with before, this species was also an all-female clone. (For reasons still unknown, on rare occasions the mixing of genes from two separate species can eliminate the need for male fertilization, resulting in an all-female lineage.)

We quickly realized that each cell in each *G. underwoodi* lizard held all the evidence needed to identify both parent species. Because their sexless system of reproduction produces clones, each individual *G. underwoodi* carries the original combination of chromosomes received from both. We started by comparing chromosomes in a number of closely related lizards. One species, *G. speciosus*, a lizard that also inhabited northern South America, clearly had contributed half of its chromosomes to *G. underwoodi*. The next step was to subtract the known parent's chromosomes from those of the hybrid. This left us with the chromosomes contributed by the other parent, whose identity and outward appearance remained unknown. Similar reasoning allowed us to predict the nature of thirty-three of the missing parent's proteins, even though we had never seen the lizard.

Hoping to find some living representative of the missing parent species, I looked forward to my upcoming field trips to South America. Working in Venezuela, Carol R. Townsend, an associate in the Department of Herpetology at the American Museum, and I collected a variety of lizards for genetic studies in collaboration

A blue-tailed lizard, Gymnophthalmus cryptus, *rests on a leaf in a Venezuelan rain forest.*
Marinus S. Hoogmoed

with Herbert C. Dessauer of the Louisiana State University Medical Center, New Orleans. We needed fresh specimens because preservation in Formalin destroys much of the genetic information in animal tissues, rendering most old museum specimens useless for this kind of research. And because the outward differences among the various species of *Gymnophthalmus* are often slight, we knew that ultimately we would be able to confirm the identity of the other parent of *G. underwoodi* only by examining its genetic makeup. Unfortunately, none of the lizards we collected turned out to be the predicted species.

Although old museum specimens were unsuitable for our genetic studies, I thought they might hold clues to where the missing lizard could be found. I searched the collections of major natural history museums in North America, South America, and Europe for specimens of *Gymnophthalmus* from the Guiana region to borrow and examine. Several specimens turned out to be particularly interesting; they had been collected relatively recently by Marinus S. Hoogmoed, of the National Museum of Natural History, Leiden, and Jose Ayarzaguena, of the Fundación La Salle, Caracas, working independently in the upper drainage of the Orinoco River in southern Venezuela. The collectors noted the overall similarity of these specimens to *G. speciosus* and *G. underwoodi,* as well as one significant difference—a blue tail. The color was no longer visible on the specimens, however; like chromosomes and proteins, colors are often destroyed in preservatives.

After comparing all the available specimens, Hoogmoed, Ayarzaguena, and I decided that these lizards represented an unnamed species, based primarily on the blue tail, the existence of both sexes, and a slight difference in the number of scales around the middle of the body. Because the lizard was so similar to the other two species, especially in preservative, we decided to name it *G. cryptus*. Only future genetic studies on fresh specimens would reveal whether it was the missing lizard, the unknown parent of *G. underwoodi*.

One September, after returning from fieldwork in Arizona, I received a letter from Allan Markezich, an associate professor of biology at Black Hawk College in Illinois (*see* box) who had read our article about the missing lizard. He described a blue-tailed *Gymnophthalmus* he had just collected in southern Venezuela, not far from where the museum specimens of *G. cryptus* had been found. He had live lizards and offered to send me several if I was interested in examining them. Was it possible that the lizards I had hoped to find in a remote area of South America were actually living in Illinois?

In all, four live blue-tailed lizards arrived by mail in New York. In outward appearance, they matched *G. cryptus* in every respect. Townsend and I isolated and photographed the chromosomes of two of them and found that their twenty-two pairs of chromosomes were identical to those predicted for the missing ancestor. So far, so good, but unfortunately, this did not guarantee that they were the same species; in many lizards the appearance of the chromosomes is not distinctive. A comparison of the specific proteins, coded for by individual genes on the chromosomes, would provide better evidence that these lizards were the predicted species.

For this final test, I flew to New Orleans with frozen tissue samples from each lizard. There, Dessauer and I could analyze the proteins. During transport, the tissue samples needed to be kept at temperatures well below freezing. This basically stops physiological activity, including de-

Gymnophthalmus cryptus, I Presume

by Allan L. Markezich

In the spring of 1991, shortly before embarking on a research expedition to investigate the diversity of reptiles and killifish in a remote, rain-forested area of southern Venezuela, I read an article in *Natural History* that described a particularly interesting situation. Charles J. Cole and his colleagues were predicting the existence of a new species of lizard on the basis of the chromosomes and proteins of two other species. I was intrigued because the expedition I was about to embark on was bound for the upper drainage of the Orinoco River, which was within the predicted range of the new lizard.

In early August, Jim Thomerson, an ichthyologist at Southern Illinois University at Edwardsville, and I arrived in the southern state of Amazonas. Moving through the rain forest, Thomerson looked for killifish in flooded inlets adjacent to the bordering savannas, while I scoured the banks for reptiles. Initially our quarries proved scarce. The third day of the expedition was dark and rainy, and our Piaroa Indian guide, Hector Pérez, suggested we journey to a remote area southeast of San Juan de Manapiare, where he thought we would have better luck. Traveling by dugout canoe, we paddled across a broad stretch of flooded savanna until we came to the edge of a dense, virgin rain forest. As we approached, a troop of howler monkeys, apparently disturbed by our arrival, began bellowing, and a two-hour break in the rain ended as we hit the shore.

We entered the forest, its closed canopy sheltering us—and the mosquitoes—from the rain. Moving along the edge, we skirted a forested inlet. While I searched the ground for reptiles, the others waded into the shallow water with fishing nets. Almost simultaneously, Thomerson yelled "fish!" (signaling that he had a killifish in his net) and I heard a faint rustling in the leaf litter at my feet. I quickly brushed aside the leaves, but all I uncovered were more leaves and dirt. Contrary to popular notions about the abundance of reptiles in the rain forests, they usually are scarce; missing one often means missing the only reptile one might encounter for hours. So, even though the disturbance could have been caused by insects, frogs, rodents, or any number of other creatures, I decided to crouch down and wait silently. The strategy worked; near a decaying log two feet away, I heard the rustling again, and a small, snakelike, bronze-colored lizard cautiously appeared from under a clump of brown leaves. With a lunge and a quick grasp, I had the lizard in hand.

The lizard's smooth, glistening skin, its clear, immovable eyelids permanently covering the eyes, and its four toes on each leg were all characteristic of *Gymnophthalmus*. I was particularly intrigued by the blue color on its tail, as no other species with this characteristic had been previously described.

I collected two more specimens that day, and then Pérez guided us to an abandoned adobe hut in a rain forest clearing that had another population of these little lizards. The tiny animals were more difficult to catch here, as they darted into crevices and holes at the base of the hut when we approached.

By the time the expedition was over, we had captured only six of these little lizards, despite having seen dozens in each of the two populations. I wondered if this small sample would be sufficient to answer all the questions we had about the animals, including whether it was the species predicted in the *Natural History* article.

The only way to answer these questions was to get the live specimens back to a laboratory where their chromosomes and proteins could be analyzed. Because *Gymnophthalmus* are very fragile and especially sensitive to dehydration, I decided to transport them in small cotton bags with rain forest leaf litter to provide moisture, shelter, and small invertebrates for food. By putting them in plastic boxes, sheltering them from the sun, and moistening the bags occasionally during the trip, the lizards did quite well; all but one arrived safely in Illinois. I then made two shipments to Cole in New York.

In October 1991, I received from Cole the results of the lizards' protein analysis and a photomicrograph of its chromosomes on which he had scribbled "It is!" I was elated by the discovery and realized that the rain forest, the global cradle of biodiversity, had told us another interesting story. And I wondered, in view of the high extinction rate in these tropical forests, what other such stories may never be told.

Allan L. Markezich is an associate professor in the Department of Natural Sciences and Engineering at Black Hawk College, Moline, Illinois, and a research associate at the Universidad Nacional Experimental de los Llanos Occidentales Ezequiel Zamora in Venezuela.

composition, and holds the enzymes and other proteins in a state of suspended animation. Upon thawing, physiological activity resumes for a while before decomposition begins. If the samples thawed in the transfer, the fragile molecules needed for the study would be lost.

After two weeks in Dessauer's laboratory, we had analyzed proteins representing thirty-two genes, each procedure being an independent test of whether *G. cryptus* was the predicted lizard. We compared each of these proteins with those from *G. underwoodi*, the parthenogenetic hybrid, and *G. speciosus*, its one known ancestor. Of the thirty-two proteins from *G. cryptus*, thirty-one matched the proteins we had predicted for the missing lizard. Because a certain amount of genetic variation is normal in most populations, a single mismatched protein posed no problem. *G. cryptus* is indeed the lizard foretold.

At some time in the past, somewhere in the upper drainage system of the Orinoco River in southern Venezuela, *G. cryptus* mated with *G. speciosus*, a species that ranges from northern South America to southern Mexico. On one or more occasions, the union produced a successful hybrid, *G. underwoodi*, that could reproduce by parthenogenesis. The clone then dispersed along the Orinoco and its tributaries, spread throughout much of the Guiana region, and finally reached some of the southern West Indies.

The case of these diminutive lizards illustrates the power of genetics to unravel complex relationships between species in ways that were impossible about a decade ago. Without detailed genetic studies, distinguishing one species from another and determining the history of their relationships can be difficult or impossible. Does an unusual animal represent a new species or merely a variant of a known one? We also are wondering how many other cryptic species inhabit Amazonia. Few have produced parthenogenetic hybrids to draw our attention to them, as *G. cryptus* did. We may be underestimating the earth's biodiversity. The identification of species is critical because it is the starting point for understanding an organism's role in the ecosystem. Without such knowledge, we cannot begin to know which species are critically important, which are endangered, or which geographic areas are of special importance for conservation.

Charles J. Cole is a curator in the Department of Herpetology and Ichthyology at the American Museum of Natural History.

At the American Museum of Natural History

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This year, the American Museum of Natural History marks its 125th anniversary. Two-hour walking tours of the Museum's halls will take place on Friday, August 12, at 6:00 P.M., and on Saturday, August 13, at 4:00 P.M. The tours will highlight many of the stories behind the Museum's natural history collection, the largest in the world. Free with admission, tours begin in the second-floor Rotunda near the information desk. Call (212) 769-5562.

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A special exhibition in the Planetarium, "Man on the Moon: The Apollo Adventure," marks the twenty-fifth anniversary of the *Apollo 11* moon landing. The award-winning film, *Eagle Has Landed*, will be shown continuously at the exhibition. Call (212) 769-5900 for information about all Planetarium events.

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Each year, millions of wildebeests, gazelles, and zebras migrate across seven hundred miles of the Serengeti, the vast savanna ecosystem that straddles two East African countries. A new IMAX film, *Africa: The Serengeti*, will feature the wildlife that inhabit these rich plains, including crocodiles, giraffes, lions, leopards, and elephants. Showtimes are 10:30 and 11:30 A.M. and 1:30 and 3:30 P.M. daily. *Search for the Great Sharks* will continue to be shown at 12:30, 2:30, and 4:30 P.M. daily. For information, call (212) 769-5200.

Baby Belugas

The first surviving beluga whales born in captivity are at New York's Aquarium for Wildlife Conservation. The baby whales, two males and one female, are now three years old and will be the subject of a talk by Louis Garibaldi, the Aquarium's director, on Thursday, August 25, at 7:00 P.M. in the Kaufmann Theater. He will also discuss the approximately 65,000 belugas that roam the arctic waters off Canada, Greenland, and Alaska and will examine some of the tremendous threats to these animals from toxic pollution and subsistence hunting. For ticket availability and information, call (212) 769-5606.

These events take place in the American Museum of Natural History, Central Park West at 79th Street in New York City. The Kaufmann Theater is located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

Roy Chapman Andrews, leader of the Museum's Third Asiatic Expedition to Inner Mongolia, July 1926, collects a young kite.
AMNH

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A Bee in Every Blossom

What's wrong with this picture? The honeybees visiting the blooms of this orchid are dead. In its drive for nectar, each bee has become stuck in a blossom, its thorax tightly wedged into the narrow entrance. The orchid, however, is not carnivorous; the dead bees demonstrate what can go wrong when humans introduce a species into a new part of the world. The orchid *Dendrobium stratiotes* is native to the Moluccas and western New Guinea, where smaller, indigenous bees can easily reach the pool

of nectar within and can back out again to visit other flowers. But once transplanted to Hawaii, where this photograph was taken, the orchid becomes a death trap for the common honeybee, *Apis mellifera,* which is itself foreign to the islands.

Such fatal mismatches between bees and flowers are rare, but not surprising. Flowers and their pollinators have evolved into finely tuned systems in which pollinators are rewarded. Orchids, in particular, have evolved features that attract specific pollinators. This exclusivity may confer a reproductive advantage on plants that are widely scattered throughout a rain forest. Common honeybees, however, will visit almost any flower to steal their reward, and in this case they got caught.—*R. A.*

Photograph by Kjell B. Sandved

Authors

The first underwater wreck that **Daniel J. Lenihan** (page 26) examined in Micronesia was the *Leonora,* the ship of the notorious outlaw Bully Hayes, sunk in 1874 off Kosrae. Side trips to Guam and Truk Lagoon soon had him hooked on the region's World War II remains. Chief of the Submerged Cultural Resources Unit of the National Park Service, Lenihan is based in Santa Fe. He is currently working on projects to identify and preserve American historical sites in foreign waters, as well as on a major survey of shipwrecks in Florida's national parks. For additional reading he recommends *The Liberation of Guam,* by Harry Gailey (Novato: Presidio Press, 1988); *Kosrae: The Sleeping Lady Awakens,* by Harvey Gordon Segal (Federated States of Micronesia: Kosrae Tourist Division, 1989); and *Operation Crossroads: The Atomic Tests at Bikini Atoll,* by Jonathan M. Weisgall (Annapolis: Naval Institute Press, 1994).

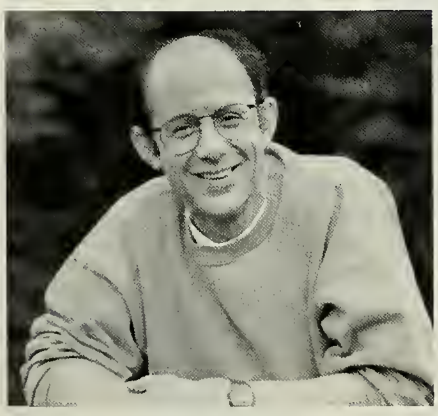
In 1962, while an undergraduate at the City College of New York, **Howard Topoff** (page 40) accepted a part-time research position at the American Museum of Natural History. He never left. His undergraduate project, sponsored by the National Science Foundation, was a behavioral and ecological study of army ants. By the time he entered graduate school, his doctoral thesis was half completed. For the next fifteen years, he continued field studies on the social behavior of army ants, first in Panama and then at the Museum's Southwestern Research Station in the Chiricahua Mountains of Arizona. Then an occupational hazard got in the way. "Army ant colonies have tens of thousand of workers," say Topoff, "and it's virtually impossible to study them without receiving multiple stings. Eventually, I developed a sensitivity to their venom, and my reaction to it became progressively worse each year. During my studies of army ants in Arizona, I frequently encountered raids of slave-making ants, and I gradually became fascinated with the questions of how social parasitism evolved. When I learned that slave-making ants in the genus *Polyergus* don't have stingers, I knew it was a done deal." Topoff is currently a professor of psychology at Hunter College of the City University of New York, where he teaches courses in animal behavior. At the American Museum, he is a research associate in the Department of Entomology. For information on the biology and behavior of ants in general, he recommends *The Ants,* by Bert Hölldobler and Edward O. Wilson (Cambridge: Belknap Press, 1990). For a more detailed account of colony takeover by queens of slave-making ants, see Topoff's article in the journal *Animal Behavior,* vol. 46 (1993).

Marine biologist **Tierney Thys** (page 36) is working toward her Ph.D. in the Department of Zoology at Duke University in North Carolina. A native Californian and avid scuba diver since the age of fifteen, she first became interested in molas while diving in Monterey Bay several years ago. "Monterey Bay has a truly exotic assortment of fishes," she says, "not only molas, but opahs and mako sharks appear from the open ocean, while gulper eels, hatchetfish, and dragonfish emerge from the 7,000-foot-deep Monterey Canyon. Add to that gray whales, orcas, sea otters, seals, and sea lions, and you have a marine biologists' heaven." When she's not doing fieldwork during the summers, Thys teaches comparative vertebrate anatomy at Duke and pines for the Pacific. Her photographic collaborator on the mola article, **Mike Johnson,** has spent four years taking pictures of the marine life associated with drift kelp off the coast of southern California. Johnson holds a bachelor's degree in geography from San Diego State University and is working on his master's degree in educational technology.

"I've always loved watching animals, being out of doors, and learning about peoples of other cultures," **Lynne A. Isbell** (page 48) recalls. "But I didn't realize that you could make a career out of that combination of interests until I read Jane Goodall's books about chimpanzees. Then it all came together for me." A native of southern California, Isbell completed her doctorate in animal behavior at the University of California at Davis in 1990. As a student, she was offered the chance to study Amboseli vervets as part of a long-term research project run by husband-and-wife team Dorothy Cheney and Robert Seyfarth at the University of

Pennsylvania. Now an assistant professor in the Department of Anthropology at Rutgers University, Isbell is researching the comparative behavioral ecology of patas and vervet monkeys. She has observed red colobus monkeys at Kibale Forest in Uganda, vervets in Kenya's Amboseli National Park, and patas and vervets in Laikipia, Kenya. When she is not working, Isbell enjoys playing volleyball, soccer, and slow-pitch softball. She also likes training dogs "and generally, just being around them." Three years ago, she married plant ecologist Truman Young. They have a two-month-old son named Peter.

Clive G. Jones (page 56) is a scientist at the Institute of Ecosystem Studies (IES) in Millbrook, New York. There he studies how animals, from little Negev snails to beavers and humans, affect the functioning of their ecosystems, and how environmental stress, in turn, affects them. Another part of his research focuses on the effects of ozone and other forms of air pollution on cottonwood



trees, on the chewing and sucking insects that feed on them, and on leaf pathogens. Coauthor **Moshe Shachak**, right, has been studying desert isopods, as well as snails, for nearly twenty-five years. The little, monogamous isopods are so abundant that they account for more biomass than any other animal in the deserts of North Africa. As they turn over and aerate the soil, they fill much the same role that earthworms do in moister climates. Shachak is an associate professor at Ben Gurion University, the Blaustein Institute for Desert Research, in Sede Boqer, Israel, and an adjunct associate scientist at IES. He is also interested in the ecology of desertification. Normally an underwater photographer, **Jeffrey L. Rotman**, says the snail assignment was "a breath of fresh air," although it meant getting going very early in the morning, while the desert rocks were still covered with dew. Originally from Boston, Rotman has lived in Israel for fifteen years, but he

travels all over the world on his mostly watery assignments. For more on these subjects, readers might turn to *Linking Species and Ecosystems*, edited by Jones and John Lawton (New York: Chapman and Hall), which is due out this month. A general treatment of how species affect ecosystems can be found in "Organisms as Ecosystem Engineers," by Jones, Lawton, and Shachak, published this year in the journal *Oikos* (69:373–86).

The photographer of this month's "Natural Moment" is **Kjell B. Sandved** (page 74). A native of Norway, he started as a publisher, producing encyclopedias of art and music. In 1960, Sandved arrived at the Smithsonian Institution's Museum of Natural History, intending to spend six months researching and collecting photographs for his next work, an encyclopedia of animals. He was so captivated by the museum's vast collections and exhibits that he became a volunteer there and hasn't left yet. Never having taken a photograph before starting at the museum, he began teaching himself nature microphotography by trial and error. After two years he joined the museum's staff as a "scientist aide photographer" and became the institution's only nature photographer and filmmaker. Working on his own book projects, Sandved has traveled around the world. One of his most popular creations was his "butterfly alphabet," a poster with each letter and Arabic numerals 0 through 9 formed by the naturally occurring patterns of the scales on butterfly wings. After twenty years spent examining the wings of uncounted numbers of butterflies and moths around the world, Sandved finally found all the letters he needed. To photograph the orchid and bees in this issue, Sandved used a Nikon camera with bellows and Zeiss Luminar lenses.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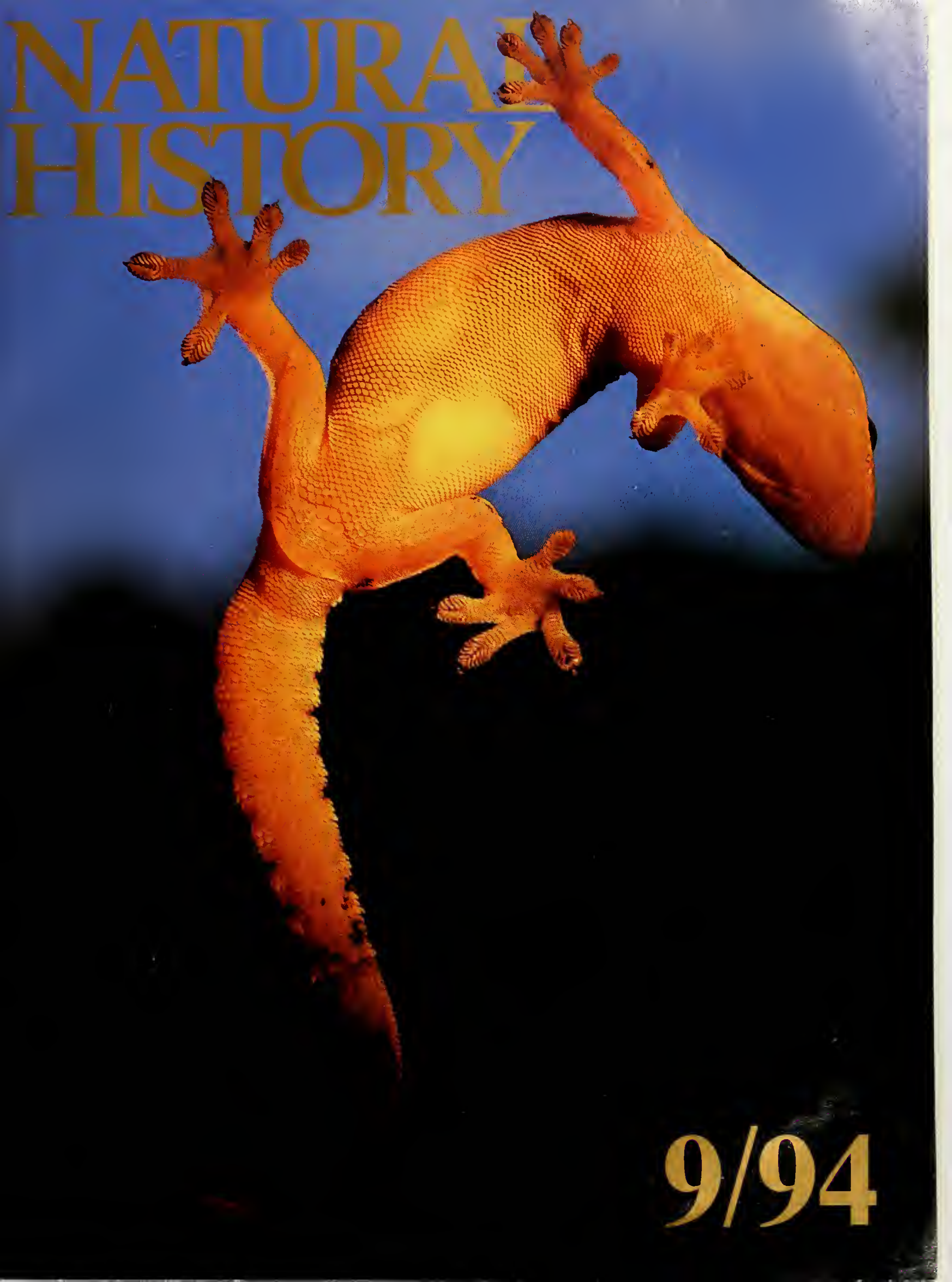
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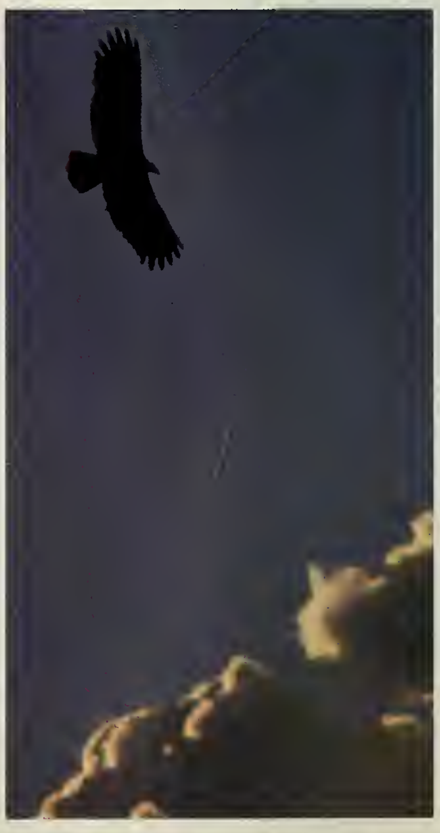
COVER: A mourning gecko, gravid with two eggs, climbs a glass pane. The lizard, once common in urban environments of Hawaii, is being driven out by a new arrival. Story on page 52. *Photograph by Mike Severns.*



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Vol. 103, No. 9, September 1994

venture, and prowess can be enhanced by rituals and magical substances. An indispensable ingredient is a large, green tree frog.

Zebras and the Anna Karenina Principle

What can Tolstoy teach us about our failure to domesticate certain animals?

by Jared Diamond

"Happy families are all alike; every unhappy family is unhappy in its own way." What did Tolstoy mean by that arresting first sentence of his great novel *Anna Karenina*?

I suppose he meant that to be happy a marriage must succeed in many different respects, and that failure in any one of those essential elements can spoil marital happiness. Sexual attraction does not assure agreement about money, while neither sexual attraction nor agreement about money assures likemindedness about child discipline, in-laws, religion, and other touchy issues. Happy marriages are all alike because the couples have achieved a good match in those and other respects. Unhappy marriages are different from one another because there are many possible causes of marital failure.

This Anna Karenina principle can be extended to understanding much about life besides marriage. We tend to seek easy, single-factor explanations for success, but for most important things, success requires avoiding many possible causes of failure. The Anna Karenina principle is on my mind now because it illuminates a question about animal domestication that has enormous significance for human history. Why have so many seemingly suitable, big, wild mammal species, such as zebras and peccaries, never been domesticated, and why were the successful domesticates almost exclusively Eurasian?

Geographic differences among the continents affected the domestication of plants, which, in turn, affected the eventual collisions between peoples (*see* "Spacious Skies and Tilted Axes," May 1994). The outcome of those collisions was that Eurasian peoples subjugated Native Australians, Native Americans, and sub-Saharan Africans, rather than vice versa. Yet at least as significant for human history were geographic factors affecting big domestic mammals. The most spectacular example was the military role of Eurasia's horses in the New World. Horses enabled Cortés and Pizarro, leading only small bands of adventurers, to overthrow the Aztec and Inca empires, respectively. Of equal importance, domestic animals were the ultimate sources of the germs that evolved into Eurasian human diseases such as smallpox and flu. Those diseases decimated the Aztecs, Incas, and many other non-Eurasian peoples lacking prior exposure.

Even in peacetime, big, domestic mammals bring enormous advantages to human societies possessing them—as sources of meat, milk, fertilizer, wool, and hides. Until the Industrial Revolution, they were the chief agents of land transport and power. Domestic animals led to denser human populations and made possible the food surpluses and transport required to support the non-food-producing specialists of stratified societies, such as full-time craftspeople, scribes, kings, and soldiers. Domestic animals, along with cultivated plants, ultimately explain why literacy, empires, and steel weapons developed earlier in Eurasia than in other continents. None of those three tools of conquest arose in aboriginal Australia, steel weapons were absent from pre-Columbian America, and writing did not develop independently in sub-Saharan Africa.

All those consequences for human history spring from the domestication of surprisingly few species of big, terrestrial, herbivorous mammals. If one defines "big" as "weighing more than 100 pounds," then only fourteen such species were domesticated before the twentieth century. Nine of those Ancient Fourteen—the Arabian camel, Bactrian camel, llama/alpaca (distinct breeds of the same ancestral species), donkey, reindeer, water buffalo, yak, banteng, and gaur—were important only in very limited areas of the globe. Five others spread worldwide. Those Big Five of mammal domestication are the cow, sheep, goat, pig, and horse.

At this point I hear shouts of reader protest: you forgot elephants! What about the African war elephants with which Hannibal's armies crossed the Alps, and what about the Asian elephants still used as work animals in Southeast Asia today? No, I didn't forget them, and that brings me to an important distinction. Elephants have been tamed, but never domesticated. A domesticated animal is defined as an animal selectively bred in captivity, and thereby modified from its wild ancestors, for use by humans who control the animal's breeding and food supply. To appreciate the resultant modifications, just compare such dog breeds as Pekingese, dachshund, or Great Dane with an ancestral wolf. All other domestic animals as

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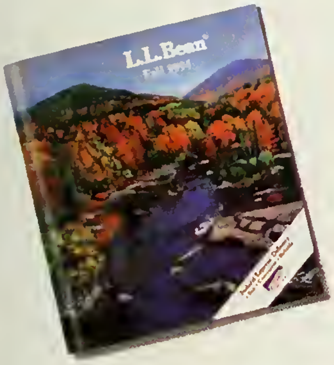

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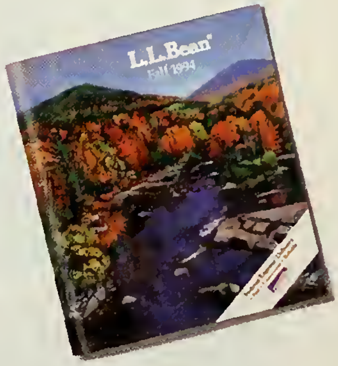

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well have been bred to differ from their wild ancestors—whether in size, color, wool, or milk output. In contrast, Hannibal's elephants were, and Asian work elephants are, wild elephants that were captured and tamed, not bred in captivity.

The wild ancestors of the Ancient Fourteen were distributed unequally over the globe. South America had only one such ancestor, which gave rise to the llama and alpaca. North America, Australia, and sub-Saharan Africa had none at all. The lack of domestic mammals indigenous to sub-Saharan Africa is especially astonishing, since a main reason that tourists travel to Africa today is to see its abundant and diverse species of big, herbivorous, wild mammals. In contrast, the wild ancestors of thirteen of the Ancient Fourteen (including all of the Big Five) were confined to Eurasia. (For the purposes of this discussion, in several cases "Eurasia" includes North Africa, which biogeographically and in many aspects of human culture is more closely related to Eurasia than to sub-Saharan Africa.) The very unequal distribution of wild ancestral species was an important factor in determining that Eurasians, rather than peoples of other continents, were the ones to end up with guns, germs, and steel. How can we explain that unequal distribution?

Part of the reason is simply that Eurasia has the largest number of big, terrestrial, wild mammal species, whether or not ancestral to a domesticated species. Let's define a "candidate for domestication" as any terrestrial herbivorous or omnivorous mammal species (one not predominantly a carnivore) weighing more than 100 pounds. As shown in the table below, Eurasia has the most candidates, seventy-two species, just as it has the most species in many other plant and animal groups. That's because Eurasia is the world's largest land mass. It is also very diverse ecologically, with habitats ranging from vast tropical rain forests to equally extensive tundras and deserts. Sub-Saharan Africa has fewer candidates, fifty-one species, just as it has fewer species in most other plant and animal groups, simply because it is smaller and ecologically less diverse than Eurasia.

The Americas may formerly have had as many candidates as Africa, but most American big mammal species became extinct about 11,000 years ago, when ancestral Indians first colonized the Americas. Among those now-extinct candidates were species, including North American horses and camels, that would probably have been domesticated had they survived. Unlike African and Eurasian mammals, which coevolved with humans and learned to fear us as we slowly developed our hunting skills over millions of years, most American big mammals suddenly encountered humans at a time when our hunting skills were already highly advanced. These mammals were probably fearless, as animals of remote islands colonized only recently by humans still are today. They would have been easy prey, quickly exterminated by the first Americans.

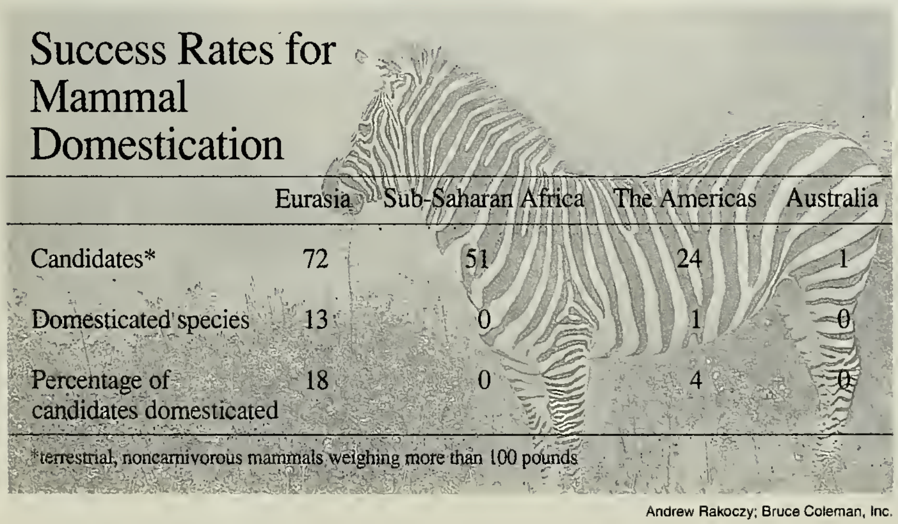
Australia, the smallest and most isolated continent, now has only one candidate, the red kangaroo. Australia once had other big mammals (giant kangaroos and rhinolike marsupials), but as in the Americas—and probably for the same reasons—they became extinct when the first humans arrived.

Although Eurasia was the continent with the most candidate species of wild mammals to start out with, that is not the whole explanation for the continent's edge in animal domestication. The *percentage* of candidates actually domesticated is highest in Eurasia (18 percent), and is especially low in sub-Saharan Africa (0 percent: no species domesticated out of fifty-one candidates!). Surprisingly, many species of African and American mammals that were never domesticated had close Eurasian relatives or counterparts that were bred for use by humans. Why were Eurasia's horses domesticated but not Africa's zebras? Why Eurasia's pigs but not American peccaries or Africa's three species of true wild pigs? Why Eurasia's five species of wild cattle (aurochs, water buffalo, yak, gaur, banteng) but not the African buffalo or American bison? Why the Asian mouflon sheep (ancestor of our domestic sheep) but not the North American bighorn?

Cultural anthropologists might wonder whether there were continent-wide differences among people themselves that somehow made Eurasians especially receptive to domestic mammals. Perhaps, for instance, Africans found it superfluous to tend domestic stock because of Africa's abundance of wild game on the hoof. That explanation is refuted by Africans' ready adoption of Eurasia's Big Five mammals when they were finally introduced to sub-Saharan Africa. African peoples who acquired those Eurasian mammals—notably the Bantu farmers, the Khoi herders of southern Africa, and people of medieval west African kingdoms—thereby gained a huge advantage over other African peoples and displaced them. Similarly, aboriginal Tasmanians immediately adopted European dogs, and Patagonian and Great Plains Indians immediately adopted European horses and used them to terrorize Indians without horses. Hence the explanation for the little or no domestication in the Americas or Africa lies with the locally available wild mammals themselves, not with the local people.

A first stage in the domestication of wild animals is taming and keeping them as pets. Virtually all traditional human societies have kept pets. The variety of wild animals thus tamed is far greater than the variety eventually domesticated and includes some species that we would scarcely have imagined as pets: young grizzly bears, kept by the Ainu people of Japan; kangaroos and cassowaries in the New Guinea villages where I work; ospreys in the Solomon Islands; and hyenas, cheetahs, giraffes, and gazelles kept by the ancient Egyptians. Why did so few species that became pets emerge as domestic animals? More than a century ago, Francis Galton offered a succinct answer: "It

Success Rates for Mammal Domestication



	Eurasia	Sub-Saharan Africa	The Americas	Australia
Candidates*	72	51	24	1
Domesticated species	13	0	1	0
Percentage of candidates domesticated	18	0	4	0

*terrestrial, noncarnivorous mammals weighing more than 100 pounds

Andrew Rakoczy; Bruce Coleman, Inc.

would appear that every wild animal has had its chance of being domesticated, that those few which fulfilled...[certain] conditions were domesticated long ago, but that the large remainder, who failed sometimes in only one small particular, are destined to perpetual wildness."

Three facts confirm Galton's view that early herding peoples quickly domesticated all big mammal species suitable for that fate. First, all big mammals whose initial domestication can be dated by archeological evidence were domesticated between about 8000 and 2500 B.C. The era of domestication began with the sheep, goat, and pig and ended with the Arabian and Bactrian camels and the water buffalo. Since 2500 B.C. there have been no significant additions.

Second, several of those ancient domesticates, including the pig and cow, were independently domesticated in several different parts of Eurasia. This reemphasizes that they really were the most suitable species and repeatedly attracted the domestication efforts of diverse peoples. Finally, not even modern geneticists, exercising far more draconian control over animal breeding than did ancient peoples, have been able to add to the Ancient Fourteen. Recent, well-organized efforts to domesticate the moose, elk, eland, and American bison have achieved only limited success, while efforts with zebras had to be abandoned.

In all, of the world's 148 big, wild, terrestrial, herbivorous mammals—the candidates for domestication—only fourteen passed the test. Why did the other 134 species fail? To which conditions was Francis Galton referring when he spoke of them as "destined to perpetual wildness"?

In accordance with the Anna Karenina principle, a candidate wild species must possess many different characteristics to be domesticated. Lack of any one requirement dooms efforts at domestication, just as it dooms efforts at building a happy marriage. Playing marriage counselor to the zebra–human partnership and other ill-sorted pairs, we can recognize at least six reasons for failed domestication:

Diet: Every time that an animal eats a plant or another animal, the conversion of food biomass into the consumer's biomass involves an efficiency of much less than 100 percent: typically about 10 percent. That is, it takes about 10,000 pounds of corn to produce a 1,000-pound cow. If you want 1,000 pounds of carnivore, you have to feed it 10,000 pounds of herbivore grown on 100,000 pounds of corn. As a result of this fundamental inefficiency, no mammalian carnivore has ever been domesticated as a food animal. (No, it's not because its meat would be tough or tasteless: we eat carnivorous wild fish all the time, and I can personally attest to the delicious flavor of lion-burger.) The nearest thing to an exception is the dog, which was raised for food in Polynesia and Aztec Mexico and still is in parts of Asia. However, dogs are not strict carnivores but omnivores, as you can confirm by reading the list of ingredients on any bag of dog food. Dogs reared for food are efficiently fattened on vegetables and garbage. Even among herbivores and omnivores, some species, such as koalas, are too finicky in their plant preferences to have been domesticated.

Growth rate: To be worth keeping, domesticates must also grow quickly. That eliminates gorillas and elephants, even though they are vegetarians with admirably nonfinicky food preferences and represent a lot of meat. What would-be gorilla rancher or elephant rancher would wait ten to fifteen years for his herd to reach adult size? Modern Asians who want work elephants find it much cheaper to capture them from the wild and tame them.

Problems of captive breeding: We humans don't like to have sex under the watchful eyes of others; some potentially valuable animal species don't like to either. That's what derailed efforts to domesticate cheetahs, the swiftest of all land animals, despite our strong motivation to do so for thousands of years. Tame cheetahs were prized by ancient Egyptians, ancient Assyrians, and modern Indians as hunting animals infinitely superior to dogs. One Mogul emperor of India kept a stable of a thousand cheetahs. But despite the large investments that many wealthy princes made, all their cheetahs were caught in the wild and tamed. The princes' efforts to breed cheetahs in captivity failed, and even biologists in modern zoos did not achieve their first successful cheetah birth until 1960. One reason is that in the wild a group of cheetah brothers chase a female for several days, and that rough courtship over large distances seems to be required to get the female to ovulate or to become sexually receptive. Captive cheetahs usually refuse to carry out that elaborate courtship ritual. A similar problem has derailed efforts to breed the vicuña, an Andean wild camel highly prized for its fine, light wool.

Nasty disposition: Some animal species are more vicious than others, and species that regularly try to kill their human caretakers do not make good livestock. That's what prevented the Ainus from domesticating grizzly bears, which they traditionally captured as cubs but wisely slaughtered within a year. Africa's buffaloes, hippos, and rhinos all represent a ton or more of meat on the hoof and would have been ideal livestock—had they not been the most dangerous and unpredictable of African mammals.

Few people would be surprised at the disqualification of those notoriously vicious candidates. But there are other disqualified candidates whose difficult and dangerous dispositions are not so well known. The eight species of wild equids, for instance, vary greatly in disposition. Two of them, the horse and the North African ass (ancestor of the donkey), were successfully domesticated. The closely related onager, or Asiatic ass, seems to have been used for cross-breeding and incipient domestication experiments in ancient times, but its evil temper caused those attempts to be abandoned. Africa's zebras proved even worse. They were tried out as draft animals in the nineteenth century in what is now South Africa, and eccentric Lord Walter Rothschild hitched zebras to his carriage on the streets of London. But zebras become impossibly dangerous as they grow older. They have the unpleasant habit of biting a person and not letting go until the victim is dead. As killers of zookeepers, zebras rank not far behind lions and tigers. As a result, it has been impossible to saddle or ride zebras, and South African enthusiasm for their domestication waned.

Tendency to panic: Big mammalian

herbivore species react to danger from predators or humans in different ways. Some species are nervous, fast, and programmed for instant flight when they perceive a threat. Other species are slower, less nervous, seek protection in herds, stand their ground when threatened, and don't run until necessary. Most species of deer and antelopes are of the former type, while sheep and goats are of the latter.

Naturally, the nervous species are difficult to keep in captivity. If penned, they are likely to panic, and will either die of shock or batter themselves to death against the fence in their attempts to escape. That's true, for example, of gazelles, which for thousands of years were by far the most frequently hunted game species of the Fertile Crescent, cradle of Western civilization. There is no mammal that the first settled people of the Fertile Crescent had more opportunity to domesticate than the gazelle. But no gazelle species has ever been domesticated. Just imagine trying to herd an animal that bolts and blindly bashes itself against walls, that can leap as much as thirty feet forward, and run at a speed of fifty miles per hour!

Social structure: Almost all species of domesticated large mammals prove to be ones whose wild ancestors share three social characteristics: they live in herds; they maintain a well-developed dominance hierarchy among herd members; and the herds occupy overlapping home ranges rather than mutually exclusive territories. For example, herds of wild horses consist of one stallion and up to a half dozen mares and their foals. Mare A dominates mares B, C, D, E; mare B is submissive to A but dominates C, D, and E; and so on. When the herd is on the move, its members maintain a stereotyped order: in the rear, the stallion; in the front, the top-ranking female, followed by her foals in order of age, with the youngest first; and behind her, the other mares in order of rank, each followed by her foals in order of age. In that way, many adults can coexist in the herd without constant fighting.

Such social structure is ideal for domestication, because humans in effect take over the hierarchy. Domestic horses of a pack line follow the human leader instead of the top-ranking female. Herds or packs of sheep, goats, cows, and ancestral dogs (wolves) have a similar hierarchy. As young animals grow up in such a herd, they imprint on the animals that they regularly see nearby. In the wild, those are members of their own species, but captive young herd animals also see humans nearby and become imprinted on them. Because herd members tolerate one another in the wild, they can also be bunched up and penned.

Solitary territorial animals cannot be herded. They do not tolerate one another, they do not become imprinted on humans, and they are not instinctively submissive. Who ever saw a line of wild cats following a human, or allowing themselves to be herded by one? Every cat lover knows that cats are not submissive to humans in the way that dogs instinctively are. Cats and ferrets are the only solitary, territorial mammal species that were domesticated, because our motive for domesticating them was not to herd them in large groups raised for food, but to keep them as hunters or pets.

While most solitary territorial species have not been domesticated, it is not conversely the case that most herd species can be domesticated. Most can't, for one of several additional reasons.

First, herds of many species do not have overlapping home ranges but instead maintain exclusive territories against other herds. It is no more possible to pen two such herds together than it is to pen two males of a solitary species. For instance, vicuñas live in herds of up to ten animals, consisting of one male, his harem, and their young. But each herd has an exclusive feeding territory and also an exclusive sleeping territory. This behavior, as well as finicky mating habits, prevented domestication of vicuñas.

Second, many species live in herds for only part of the year, becoming combative and territorial during the breeding season. Most deer and antelope species follow this pattern, a crucial factor that disqualified all of Africa's social antelope species.

Finally, the social systems of many herd species, again including most deer and antelope, are not well-defined dominance hierarchies, so the animals are not instinctively prepared to become imprinted on a leader (and hence to become misimprinted on humans). Although many deer and antelope species have been tamed (think of all those true Bambi stories), one never sees tame deer and antelopes driven in herds like sheep. That problem also derailed domestication of North American bighorn sheep, which belong to the same genus as Asiatic mouflons, ancestor of our domestic sheep. Bighorns are similar to mouflons with one crucial exception: they lack the mouflon's stereotyped submissiveness to dominant individuals.

Bighorns illustrate the paradox that close relatives of domesticated species often are not themselves domesticable. Other examples are the zebra and onager (closely related to the horse and donkey), the African buffalo (cow and water buffalo), and the vicuña (llama/alpaca). A final example can be found in Perissodactyla, the order of odd-toed hoofed mammals that includes horses, rhinos, and tapirs. The two perissodactyls that have been domesticated—the horse and the North African ass—belong to the same genus. No species of tapir or rhinoceros has ever been domesticated, although domestic tapirs would have been great assets to Native Americans and domestic rhinos would have been great assets to Africans. Just picture what a charge of African cavalry mounted on rhinos would have done to the ranks of would-be conquering European soldiers! Alas for Native Americans and Africans, all tapir species are solitary, and rhinos are territorial (at least males are in the breeding season) and dangerously nasty, disqualifying them as domesticates.

In short, Eurasians' advantages—guns, germs, and steel—were in large part the luck of the draw: Europeans happened to inherit many more species of domesticable, large, wild, mammalian herbivores than did people of the other continents. Small and isolated, Australia had few candidates to begin with, and all but one of them became extinct (were exterminated?) when the first human hunters reached Australia. The Americas initially had many candidates, but most of them also disappeared when human hunters arrived. Only Eurasia and Africa escaped massive late-Pleistocene extinctions of big mammals because mammals of those continents had coevolved with humans for a long time. Unlike their Australian and American counterparts, they weren't suddenly exposed to humans late in our evolutionary history, when our hunting skills were already highly developed.

On all continents, most candidates for domestication were eliminated by the Anna Karenina principle. Humans and most animals make an unhappy marriage, for one or more of the many possible reasons cited: animal diet, growth rate, mating habits, disposition, tendency to panic, and social organization. Tolstoy would have approved of the insight offered by an earlier author, Saint Matthew: "Many are called, but few are chosen."

Jared Diamond is a physiologist and evolutionary biologist at UCLA Medical School.

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Lucy on the Earth in Stasis

Ethiopian hominids were in no hurry to become human—and an evolutionist is not surprised

by Stephen Jay Gould

Queen Victoria, just a bit behind the times as usual, took her first journey by railroad in 1842—from Windsor to London (by 1840, the United States already had 2,816 miles of track in operation, while England boasted 1,331 miles). Beyond this royal symbol, 1842 was a good year for change in general. Darwin composed his first sketch of the theory of natural selection (followed, in 1844, by an expanded draft and finally, in 1859, by a published version, *The Origin of Species*). And in *Locksley Hall*, Alfred, Lord Tennyson, wrote the most famous of all Victorian lines about the inevitability of change: "Let the great world spin forever down the ringing grooves of change."

I unite Tennyson's line with Victoria and rail transport for several reasons, most literally because Tennyson himself later wrote that his striking, though peculiar, metaphor for change (both visual and aural) arose from a misperception during his own first journey by rail: "When I went by the first train from Liverpool to Manchester (1830), I thought that the wheels ran in a groove. It was a black night and there was such a vast crowd round the train at the station that we could not see the wheels. Then I made this line."

We are beset by dualities, perhaps because nature favors pairings, but more, I suspect, because our mind works as a dichotomizing machine: night and day, sun and moon, male and female, life and death (*the* question, as Hamlet told us). Among the organizing dualities of our consciousness, change and constancy stands out as perhaps the deepest and most pervasive. Heraclitus said that we can't step twice into the same river, while his contemporary Pythagoras tried to extract invariance from the world's overt complexity by discovering simple regularities in number and geometry—a scholar's dream still pursued, as by Bertrand Russell in our day, when he included among the three passions of his life, "I have tried to apprehend the Pythagorean power by which number holds sway above the flux."

These deep dualities cannot be analyzed in terms of truth and falsity, for the two sides are both and neither. In our struggles to comprehend this immensely puzzling and amazingly intricate universe, both themes of change and themes of constancy yield crucial insights for different questions and different scales. Since the two sides of this duality are equally true and useful, the favoring of one or the other at various, fluctuating times in the history of science becomes our best illustration of social impact upon a process that mythology regards as free of personal preference and driven exclusively by observation—for no organizing construct of the mind can be more socially and politically influenced than our transient preference for either change or stability as the essential nature of the universe.

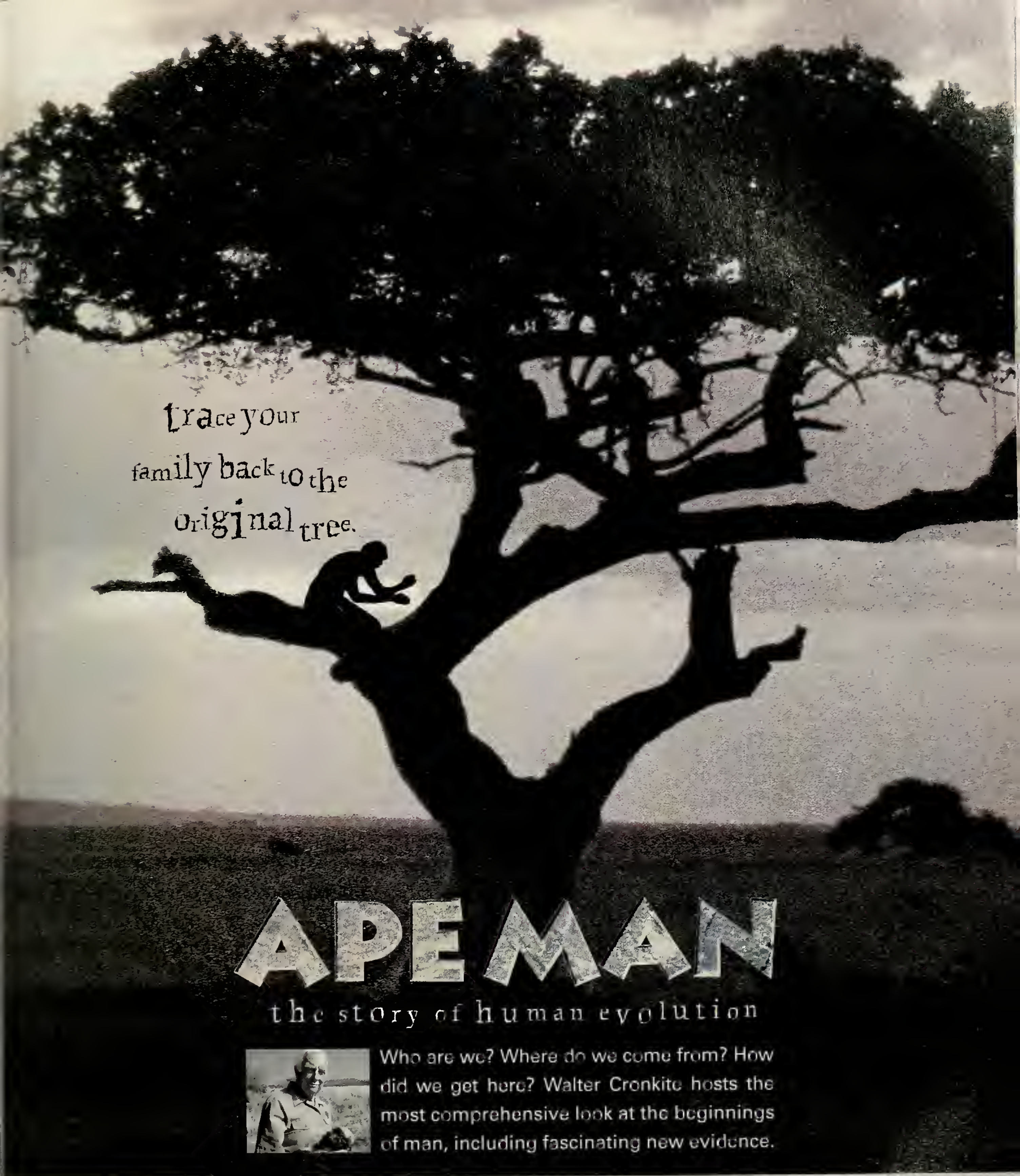
Many periods of Western history have favored stability if only as a supposed natural buttress to a ruling political hierarchy of monarchs and nobles or popes and bishops. But a fundamental tenet of Western life, at least since the late eighteenth century, has proclaimed change as natural and constant. Social conservatives may rail and moan, visionaries and romantics may dance and sing, but the ringing grooves have dominated our view of the world for the past two centuries at least. Belief in change as nature's essential way blossomed in the eighteenth-century age of revolutions, with America and France leading a sometimes ambiguous way, flourished with the subsequent wave of romanticism in the arts, and reached an apogee (for Tennyson chose his metaphor wisely) with the even more ambiguous Victorian triumph of industrial and colonial expansion.

Evolution is a fact of nature—one that could probably not have been perceived, and certainly not widely promulgated, before preference for change in this cardinal duality swept the Western world. But evolution also enjoyed a much easier path to acceptance in Darwin's century because its central theme of change meshed so well with prevailing social context. Biological evolution, with its unbeatable combination of empirical truth and social fit, therefore became the quintessential theory of change within Western science.

Obviously, I do not write this essay to challenge evolutionary change because one side of its popularity has a social root. But I do wish to stress the importance of acknowledging social influence as the best possible antidote to overconfidence about our perception of truth and the best spur to healthy skepticism and self-examination. Much of what we regard as empirically proven, or logically necessary, may only be a contingent reflection of transient social preferences. And if notions of change as nature's essence rank among the strongest of these social preferences, then we need to be especially skeptical when we weigh our assumptions about the character of change.

Social preference extends beyond a simple belief in change as essential to a set of assumptions about the nature of change. In particular, we usually view change as intrinsic and continuous, not rare and episodic. That is, we wish to conceptualize change as its own form of constancy, to define systems by their changes, and to view continuous alteration as a normal state—particularly of systems undergoing biological evolution.

But other theories of change are just as consistent with the general view of a universe driven by alteration. For example, stability might reign most of the time, and change might be a rare event, usually of



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substantial magnitude and occurring only when stresses impact a system beyond its capacity to absorb without substantial modification. In this alternative view, stability is the norm for most systems most of the time—and change, while driving the universe in the fullness of vast scales and long times, is absent at almost any given moment.

This conflict between change as continuous and steady versus rapid and episodic underlies many debates in the history of science—the great late-eighteenth through early-nineteenth-century struggle (when general theories of change had just become dominant and were therefore flexing muscles and dividing turf) between uniformitarianism and catastrophism for the physical history of the earth and the biological alteration of faunas, or (to cite a contemporary skirmish of much smaller scale) the debate between punctuated equilibrium and gradualism for the process of speciation in biological lineages.

I shall not hide my preferences and biases. I helped to devise the theory of punctuated equilibrium with Niles Eldredge in 1972, and we rejoiced last year in the majority of our child (now able to drink, in addition to driving and voting—but not, we pray, at the same time). I have cheered from the sidelines (and occasionally given a boost in these essays) as catastrophic theories of mass extinction make their comeback in the virtual proof now available for extraterrestrial impact as the trigger of the Cretaceous–Tertiary dying.

I am not a foe of gradual change; I believe that this style of alteration often prevails. But I do think that punctuational change writes nature's primary signature—and I am convinced that our difficulty in conceptualizing this style of alteration arises from social and psychological bias rather than from any shyness of nature in printing its John Hancock (so conspicuously that the king might read it without his spectacles—although we poor ordinary mortals often seem blind, however prominent the signature).

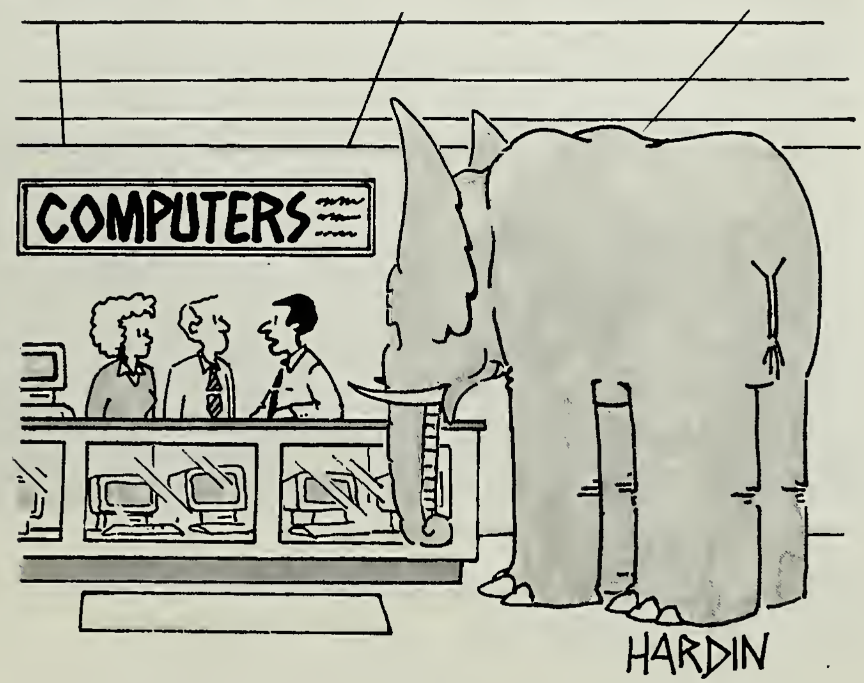
I have come to understand, in a different and personal way, that an equation of evolution with a belief in continuous change as nature's norm sets the most pervasive misconception of life's history in the general culture of intelligent and well-educated lay audiences. At this point in my mid-career as a writer and lecturer, I have given so many hundreds of talks, and received so many thousands of letters, that I have a good sense of recurring themes and their relative frequencies. Some questions arise rarely; a few are unique and wonderfully idiosyncratic or challenging. But other questions occur with such predictable regularity that they inspire such clichéd comments as, "If only I had a dollar for each time I've heard that one, I could retire to a life of indolent luxury."

I do not regard these inevitable questions as stupid in any sense. Quite the contrary: I hear them every time I speak because they are good questions coming from the heart of human concern, interest, and puzzlement. But such questions are often based on deep misconceptions about the nature of evolution. In fact, people get stuck on these questions precisely because they grasp (however dimly) an inconsistency between the empirical world and a formulation that seems exclusive or inevitable according to their understanding of evolutionary theory. The solution does not lie in revising facts, but in forcing a conceptual reformulation that switches the facts from anomaly to expectation.

My two most common questions (really less and more sophisticated versions of the same concern) are rooted in the fallacy of assuming that evolution means continuous change, and that stability must therefore count as the most puzzling of anomalies. The first, less sophisticated version simply asks: "Where is human evolution going in the future?"

Questions are not neutral; they presuppose a list of assumptions that may be quite long and complex. This query begins with a belief that evolution is always going somewhere and that we would especially like to know where such a universal process will lead parochial little us. I feel that I can only respond with a question of my own: "Why do you think that we are or ought to be going anywhere?" I then try to explain that human bodily form has been stable for tens of thousands of years (during which everything that we call civilization has been built without substantial alteration in any physical aspect of brains or bodies that the fossil record might preserve). I then add that stability on scales of hundreds of thousands to millions of years is a norm and expectation for large, successful, geographically widespread populations. Evolution tends to be concentrated in events of branching speciation, and such events usually occur in small and isolated populations. Humans live all over the world, move vigorously from place to place, and maintain an apparently unstoppable habit of interbreeding everywhere they go—therefore we permit ourselves no opportunity for isolation and speciation (unless you want to construct a science fiction scenario about space colonies). Thus, I can only answer this most inevitable of questions by saying that we are unlikely to be going anywhere in the ordinary course of things (all bets are off with such culturally devised phenomena as genetic engineering), and that evolutionary theory predicts and expects such stability.

The more sophisticated version comes from listeners who already know the facts of long-term recent stability, regard the sit-



"He wants a system with lots of memory, but without a mouse."

uation as strongly anomalous, have thought about it, and have devised a potential explanation (which would be quite sensible if the misconceived equation of evolution with continuous change were valid): "Does the recent stability of human bodily form arise because culture has suppressed the ruthless action of natural selection and halted the process of weeding out the unfit, thus blocking adaptive evolutionary change?"

I try to answer this version in two parts. I first identify this question as a vestigial holdover from old-style eugenics and its false assumption—the bastion of the misnamed and discredited doctrine of "social Darwinism"—that human "progress" requires a relentless struggle in the overt gladiatorial mode, with victors rising to positions of power and inferior folks either put to the wall or precipitated into the lower classes. In this view, culture stymies nature by permitting the unfit to survive (through such derailments of Darwinian order as manufacturing eyeglasses, hearing aids, and wheelchairs). "Bad" genes accumulate and evolutionary toughening grinds to a halt.

I confess that I do get cross in noting the astonishing persistence of such a badly formulated and socially pernicious argument. Genes leading to eyes that require corrective lenses are not "bad" in any absolute sense; they do increase our dependence upon culture (to supply the needed assistance), but human life is now so inextricably dependent upon culture for a thousand other reasons that I cannot imagine why we would choose to lament this additional link. As the only evolutionary consequence that I can imagine, such a cultural "softening" of natural selection may slightly boost our genetic variability as a species, but I cannot regard such an increase as anything but neutral or favorable.

But I then point out that the initial question rests upon what logicians label an "unarticulated major premise" and we ordinary folk call a "hidden assumption"—the same one that motivated this essay. If we suggest that cultural softening caused human stability, then we imply a prior (though unstated) belief that evolutionary change is a natural norm—and that any failure to note such change requires a special explanation. But if the norm for species like ours is really stability, then the anomaly vanishes, and the question resolves itself into a nonissue.

As another cultural test of the prejudicial hold imposed upon our understanding of evolution by the doctrine of continuous change as a defining norm, we might consider press reporting of discoveries that affirm substantial intervals of stasis on the human family tree. Are such findings reported as affirming an expectation or presenting a strong surprise? I have long noted that surprise always dominates, and I decided to write this essay because such a fine example has just appeared in newspapers and magazines throughout the world.

"Gosh. You really do eat like a bird."

The March 31, 1994, issue of *Nature*, Britain's leading professional journal of science, featured a strikingly apelike human fossil skull on its cover, above the heading "Son of Lucy." The technical article within, by William H. Kimbel, Donald C. Johanson, and Yoel Rak, bore the less titillating title, "The First Skull and Other New Discoveries of *Australopithecus afarensis* at Hadar, Ethiopia."

The human lineage branched off from the clade of our closest cousins, chimpanzees and gorillas, about 6 to 8 million years ago—a date inferred from genetic distances among living species, not from direct evidence of fossils. The first well-dated and clearly accepted human fossils are 3.9 million years old and come from strata in Ethiopia. All fossil humans spanning the first million years of our recorded history (3.9 to 3.0 million years ago) belong to the single species *Australopithecus afarensis*, named by D. C. Johnson, T. D. White, and Y. Coppens in 1978. (The name *Australopithecus* means "southern ape" and honors the first discoveries of later species in this genus from South Africa in the 1920s; *afarensis* refers to the Afar region of Ethiopia, where this earlier species was found.)

During the 1970s, nearly 250 fossils of this species were recovered from the main site at Hadar by a team led by Don Johanson. This trove included a 40 percent complete female skeleton now famous throughout the world by its field name, Lucy, given to honor the Beatles' famous and somewhat cryptic song about a hallucinogenic substance once popular in certain segments of society. (The coining of informal and irreverent field names is a hallowed pastime among paleontologists, although few find their way into popular speech; I will not bore you with the names of various snails I have collected.)

Nature often plays cruel jokes on us if only to keep this little evolutionary twig in its proper place. Johanson's 250 fossils constituted one of the richest finds in the history of human paleontology. Our skeleton includes about 100 bones, and many fossilize poorly. We are intrigued and informed, above all, by skulls—not only for prejudicial reasons of traditional overemphasis upon brainpower (or lack thereof in our earliest ancestors) but also for the more legitimate reasons that skulls are so complex and therefore so informative and diagnostic. With so much material, we might have expected a good skull or two. But, alas, not a single skull, or even a really good fragment, arose from this mag-

nificent collection. Lucy remained headless. (Johanson and his team did try to piece a skull together from numerous fragments found in distant places, but this reconstruction was too partial and conjectural to win much approval.)

Moreover, this rich material provoked as many puzzles and controversies as it provided new and clear information. In particular, the large difference in body size between two groups of bones included within these fossils sparked a lively debate between two interpretations. Do these groups represent males and females of a single species? Or might two species be hiding under the single name *Australopithecus afarensis*? Modern humans average about 11 percent difference in length of arm bones between males and females, while the two groups included in *A. afarensis* average 22 to 24 percent for the same measures. Proponents of the "two species" theory argue that this difference is too great for sexual dimorphism in a single species, but proponents of the "two sexes" theory (I will not hide my allegiance with this school) reply that many primates, including gorillas, equal or exceed this degree of sexual dimorphism, and that other species of the genus *Australopithecus* also exhibit nearly as high a degree of difference between groups accepted as sexes of a single species.

Obviously, the best way to resolve such controversies demands an exit from armchairs and the polemic factory of academic publication, and reentry into the field to search for more fossils. Johanson and colleagues have been following this excellent strategy for several years, and have been richly repaid with fifty-three new specimens from the Hadar region, including the best possible reward of an excellent skull—a large male dubbed, unsurprisingly, "son of Lucy."

I was delighted to note the theoretical emphasis that Kimbel, Johanson, and Rak chose to place upon their skull and related finds. Of all the issues raised by these important fossils, the three authors emphasized evidence for prolonged stasis within *A. afarensis* as their primary and most interesting conclusion. This evidence includes two parts: first, the further affirmation that only one species, with strong dimorphism between sexes, lived in this region (and perhaps anywhere on the human family tree) during this formative interval of nearly a million years; second, the strong evidence for morphological stability in *A. afarensis* throughout this long time. The three authors roll both conclusions into the final sentence of their abstract: "They [the new fossils] confirm the taxonomic unity of *A. afarensis* and constitute the largest body of evidence for about 0.9 million years of stasis in the earliest known hominid species."

The new finds provide evidence for prolonged stasis in *A. afarensis* by extending the geological range of this species in both directions. Heretofore, firmly identified specimens occupied the short interval between 3.18 million years old (the best date for Lucy herself) to 3.4 for the oldest material from Hadar. (At 3.5 million years old, the famous footprints at Laetoli, presumably of a male and female walking in tandem, probably represent *A. afarensis* as well, but however stunning, footprints are impressions, not bones.) The new skull, at 3.0 million years old, represents the youngest known material of *A. afarensis.* Since the bones are indistinguishable from skull pieces found earlier among the older specimens, Lucy's "son" demonstrates nearly half a million years of stasis in the first distinctive species of our distinctive evolutionary bush.

Extension to older times rests on more tenuous inference, but still represents our best tentative conclusion on limited evidence. In 1987, B. J. Asfaw described a large fragment of the diagnostic and taxonomically important frontal region of the skull (including brow ridges) from substantially older rocks at the nearby site of Belohdelie. He tentatively attributed this 3.9-million-year-old skull piece to *A. afarensis,* but could not be sure because Johanson's main trove of younger material from Hadar included no well-preserved frontal bone for comparison. The Belohdelie frontal has therefore rested in limbo for several years. But the new skull of Lucy's son includes a complete frontal region—and it is indistinguishable from the 0.9-million-year-older material at Belohdelie. Admittedly, identity in the frontal region is not proof of stasis throughout the skeleton, but Belohdelie is all we have of Lucy's earliest years, and stasis does prevail for the information available.

Thus, strong evidence from much of the skeleton indicates stasis in *A. afarensis* for nearly half a million years (quite a good chunk of time already), from the oldest Hadar specimens at 3.4 million years to the skull and associated bones of Lucy's son at 3.0 million. Limited material from part of the skull also shows no change in recorded morphology right back to the earliest specimen of *A. afarensis* at 3.9 million years.

The first specimens on the hominid bush therefore persisted in stasis, as illustrated by all available positive evidence, for its entire recorded range of nearly a million years. (Some people have a false impression that claims for stasis rely on negative evidence or absence of demonstrated changes. On the contrary, stasis should be a positive conclusion based upon hard anatomical evidence of nonchange through substantial time. We must also remember that the oldest and youngest specimens are only the first and last so far found, not the full range of the species. *A. afarensis* might have lived even longer in stability—but now I am speculating with negative evidence, and I had best shut up.)

Nature had put a press embargo on the story of Lucy's son until its official publication date of March 31, and journalists do respect these fair conventions. Thus, press reports of the discovery all appeared in a single whoosh (for reporters had enjoyed ample lead times to prepare their stories) in newspapers for March 31 or April 1 (no joke)—thereby enhancing the force of a global "experiment" to test whether reported stability surprises even well-informed people because they equate evolution with continuous change.

I was delighted to note that two articles did describe Lucy's son in the light of punctuated equilibrium, therefore recognizing stasis as the prediction of this theory, rather than as a surprising anomaly, disconnected from any proposed explanation. The *Miami Herald* wrote: "Experts in human origins...said the new skull is a compelling argument for the theory that the evolution of human life on Earth proceeded in fits and starts, with long periods of stasis punctuated by sudden periods of change." Giles Whittell, writing in the *Times* (London) under a headline "Skull Find Backs Evolution Leap," stated: "The 3 million year old skull...lends weight to the view that evolution was not gradual but sporadic, involving long periods of no progress at all.... *A. afarensis* flourished unchanged for almost a million years."

But the great majority of stories professed pure surprise that our evolutionary adventure should have begun with a million years of stability. "Remarkable" surely led the pack as an adjective to modify stasis (J. N. Wilford in the *New York Times,* and R. C. Cowen in the *Christian Science Monitor,* who wrote: "What's remarkable about this 3 million year old fossil is not that it is so old but that it's so young. It is 200,000 years younger than the famous Lucy...and a million years younger than the oldest specimen. Yet it looks like those ancestors"). Among other adjectives, Tim Friend in *U.S.A. Today* favored "unexpected," while Mr. Cowen also proclaimed the new skull "astonishing" in its demonstration of stasis.

Most revealing are the more subtle, linguistic clues that betray an expectation (or even a belief in the higher virtue) of continuous change. Do you not, for example, sense disparagement in Keay Davidson's description of Lucy's stasis (from the *San Francisco Examiner*), as though our earliest ancestor didn't quite cut the mustard in delaying progress so long: "The skull strengthens scientists' belief that Lucy was part of a single species that puttered around Ethiopia, evolving very little, over at least 900,000 years." In an even more revealing passage, Boyce Rensberger, writing in the *Washington Post,* expressed surprise that Lucy's brain may be no larger than an ancestral ape's, even though she lived nearly a million years after the split of our lineage from the ape bush. For here we encounter the unstated implication (another "unarticulated major premise") that a million years damned well ought to be enough time for accumulating notable change in a world of continuous alteration—although no such expectation arises in a world of stasis and punctuation, for such an interval may well lie within a period of stability. Rensberger wrote: "The newly found skull's brain capacity has not yet been measured. But it is not expected to be much more than that of a large ape, even though the creature lived at least 900,000 years after its ancestors diverged from the ape lineage."

Obviously, for a revised view about the general tempo of evolutionary change, stasis can only provide one side of a story, lest we be left with no evolution at all! The opposite and integrated side (the punctuation in punctuated equilibrium) proposes a concentration of change into relatively short episodes—jabs of reorganization in a world of generally stable systems. Enter this world at any random moment and, as an overwhelming probability, nothing much will be happening in a history of change. But survey the totality over millions of years and these episodes of punctuation, though they may only occupy a percent or two of time, build the signature of historical alteration. Scale is everything in history and geology.

The punctuations in evolutionary change are usually events of branching speciation, generally occurring in small and isolated populations within an interval (many thousands of years) that appears glacially slow at the inappropriate scale of a human lifetime, but resolves to a moment at geology's proper scale of millions. (Remember that 10,000 years—a period that encompasses all of written human history—equals only one percent in Lucy's million year epoch of stasis.)

In this light, I am gratified to see that continuing studies on the million-year period following Lucy's tenure point more and more, as data on bones and dates accumulate, to a veritable forest of rapid speciation events, leading to several additional members of the genus *Australopithecus,* and also to the first representative of our own genus, *Homo*. A chart distributed by Johanson's Institute of Human Origins to accompany their find of Lucy's son proposes as many as seven branching events within a restricted interval following Lucy's demise—a period shorter than that of Lucy's own stasis.

This flowering may correspond to a time of rapid and strongly fluctuating environmental change coincident with the beginnings of glaciation at higher latitudes. My colleague Elisabeth Vrba, of Yale University, has used such evidence to unite the pattern of punctuated equilibrium with the idea that events of speciation are not evenly distributed through time, but concentrated into episodes accompanied by substantial environmental change—the "turnover-pulse hypothesis" in her formulation. Nearly all the news reports of Lucy's son also emphasized this complementary side of copious branching following the stable reign of *A. afarensis*. Many of these stories quoted W. H. Kimbel, first author of the *Nature* article: "There is no obvious sign of evolution in this pre-human species for about a million years. Yet later, within only a fraction of that time, it gave rise to a great branching of the family tree."

I began with the most famous poetic metaphor about change from Victorian England. Let me end with an even more celebrated verse about leaping, from Tennyson's predecessor as poet laureate, William Wordsworth:

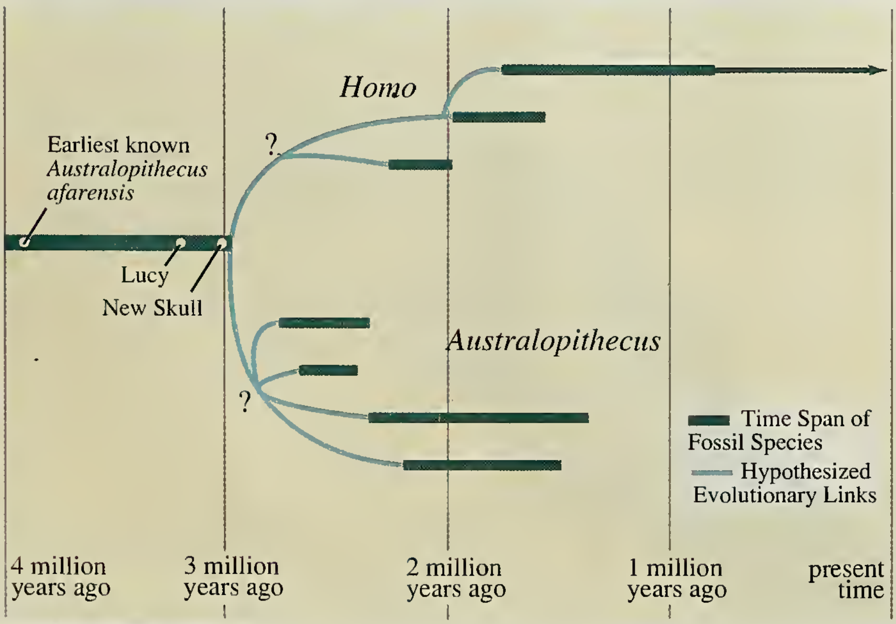
My heart leaps up when I behold
   A rainbow in the sky:
So was it when my life began;
So is it now I am a man;
So be it when I shall grow old,
   Or let me die!
The child is father of the man;
And I could wish my days to be
Bound each to each by natural piety.

If you are puzzled, I did intend this implied contradiction. Wordsworth's leap is only metaphorical; the poem expresses a hope for lifetime stability in aesthetic perception and moral value. Try his contemporary William Blake for the other side of life as rupture:

My mother groan'd! my father wept.
Into the dangerous world I lept.

Duality may be a conceptual prison, but if we must live with such a mental strategy, we might maximize our opportunity to grasp some of nature's complexity by hitching our star to the dyad of change and constancy. Slow and steady does not always win the race.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.



Adapted from Institute of Human Origins

The Fast Trek

by Lory Frame

At a symposium in Calgary in 1971, my husband, George, and I, a couple of green graduate students in wildlife science, joined a group gathered around George Schaller—the man who had studied mountain gorillas in Uganda and gone on to found the Lion Project in Tanzania's Serengeti National Park in 1966. Perched on the edge of a table and casually tapping one foot in the air, Schaller looked as fit and graceful as one of his lions. To us he was a star. He had been back from the field for a couple of years and must then have been correcting the proofs of his book *The Serengeti Lion.*

My husband and I thought we would soon go to northern India to study the one-horned Indian rhinoceros, but already the Indian government was imposing intolerable conditions on the research. (In fact, the project later fell through, and we went instead to the Serengeti to study hunting dogs and cheetahs.) We talked with Schaller of the difficulties of wildlife research in third world countries.

"Get yourself a pair of binoculars," he said, after listening to stories of bureaucrats seizing title to a car and politicians using a grant for something else. Setting down his empty coffee cup, he added, "Just go in, get the data, and get out."

Schaller's words came back to me as I read Craig Packer's new book, *Into Africa.* I can scarcely imagine two personalities more different than Schaller's and Packer's, yet Schaller's tersely stated objective is implicit throughout this book. Packer and his wife, Anne Pusey, are the latest and longest-lasting of Schaller's successors in the Lion Project. They have kept the project going since 1978, so they have had to go to Africa again and again. (Packer has been back recently to assess a distemper epidemic that has killed at least forty lions.)

My husband and I worked in the Serengeti from 1972 until just a couple of months before Packer and his wife arrived in 1978. We got out after a decade of socialism had reduced Tanzania's economy to shambles, and Packer started off at the bleakest possible time. One couldn't even buy toilet paper in Tanzania, and fieldwork there was definitely not glamorous.

Packer hangs his narrative on a trip he made in 1991 to Serengeti and Gombe National Parks, some 500 miles apart. Gombe is the steamy mountain rain forest where, in the early 1960s, another star scientist, Jane Goodall, discovered that chimpanzees eat meat and use tools. Packer had started his career there as one of Goodall's assistants and was now returning to initiate some new research. The entire trip lasted fifty-two days, but of that time, Packer spent all or part of twenty-two days en route. Hold on to your hat.

From the very first lines of the book we know Packer isn't thrilled to be going back to Africa (his sixteenth trip). But as the boxes and bottles in the car shake and tip over, as the passengers stop to repack the car and have some binoculars stolen, as the texture of dirt, noise, delay, and frustration is developed, we begin to understand what it is really like—for Packer anyway—and we know he did not come to Africa for this.

After spending four days traveling and meeting the necessary people, Packer finally reaches the heart of the Serengeti National Park—the Serengeti Research Institute (SRI), where Schaller did his work. He spends only eight days there and another eight after returning from his trip to Gombe. Packer recounts his first sighting of lions in an oddly matter-of-fact and unadorned manner, considering the trouble he had getting to the Serengeti. He is preoccupied. He has a very angry assistant at SRI who won't hand over forty lion scat samples. And his attempts to worm some lions for his graduate student are unsuccessful. (She longs for some adult worms to take home to her laboratory in Oxford.)

INTO AFRICA, by Craig Packer. *University of Chicago Press, $24.95; 288 pp., illus.*

Go in, get your data, and get out. But in only sixteen days?

Packer takes us through the process of hypothesizing, testing, and revising prior assumptions about lions. For example: Female lions nurse one another's cubs. Would a female ever short her own cubs to let others drink? Test it. Do cubs get more to eat in "crèches" than they would if their mothers raised them separately? Test it. Do the mothers eat better, for that matter, if they hunt in large groups? Test it. As Packer ponders, tests, and rejects one hypothesis after another, we feel ourselves drawn closer and closer to why he keeps coming back here.

"I study the darkness," Packer says, by which he means that animals often behave appallingly toward one another. Why do males kill cubs (that are not their own offspring) after they take over a new pride? Because the mothers won't cycle again until the cubs are two years old, and the

males that have just taken over a new pride cannot afford to wait that long: the average sojourn of males in a pride is only about two years. Get those genes into the next generation. Kill the cubs, and bring the mothers into estrus immediately. "Every lion in the world has a father who is a murderer," Packer says. (Oddly, he does not explain why nomadic females also kill cubs, a phenomenon Schaller observed.) His essays on the self-interest that underlies all animal behavior are lucid, unsentimental, and intellectually compelling. *Into Africa* serves up animal behavior correctly: as a savory dish that would be ruined by sugar. Those with immature palates may not like it, but grown-ups will.

In Part II, Packer flies to Dar es Salaam and then to Kigoma, where he gets a boat to Gombe:

> In the murk, even after all these years, I can recognize each valley: Kahama, Mkenke, now Kakombe. We draw closer to land, chugging past square concrete buildings shrouded by trees and shrubs, past the sheet metal house where I used to live. Anthony cuts the engine, and we are engulfed in sudden silence. The boat grinds on the gravel beach in front of Jane's veranda. Warm lake water laps at our legs as we drag the hull onto the silver shore. I walk a few yards away and stare into the empty night, nervous of the shadows in the dark. Even after all these years.

Maybe his description of Gombe is so vivid because a terrible thing that happened there still haunts him. One dark night in 1975, a boatload of Marxist rebels motored across the lake from Zaire and kidnapped four young researchers. Packer and his wife were fortuitously away on holiday or they would have been taken too. When they returned, they were given a half-hour to collect their things and get out. This event was not only a personal disaster for the captives and their families but also the death of Gombe as a research center for the next fifteen years. Now, with a grant from the National Science Foundation to initiate new research, Packer is back, but he is not entirely comfortable in this unhealthful place. After setting up a method for weighing chimps, hurriedly mapping the palm groves in the chimp community, and waiting for his student to get samples of baboon feces, he is glad to leave. Go in, get the data, and get out.

In Part III, Packer stops briefly at the Ngorongoro Crater on the eastern edge of the Serengeti, camping at Lerai Cabin, where my husband and I lived for a time. (Fortunately, he didn't notice the ghastly—but only available—color of paint we'd used on the inside walls.) The crater's lion population was nearly exterminated by a plague of biting flies in 1961. A few surviving females founded the population that lives there today, and Packer is interested in the effects of this loss of genetic variability.

Soon Packer is back at SRI to attend a meeting organized by Anthony Sinclair, one of the original SRI scientists of the 1960s and now a professor at the University of British Columbia, and Peter Arcese, who studies ungulates in northern Serengeti National Park. They want to devise a computer program of the entire Serengeti ecosystem that could generate predictions of the park's condition if this or that variable (such as rainfall) were to change. Naturally, the effects of the various predator species on the prey and on one another would be important. Serengeti's current predator specialists are at the meeting but appear to be unhappy about it, like children who have been told to play nice and share their toys. "Participation," Packer comments dryly, "has not been wholehearted."

The scene brings back a memory of the mid-1970s when my husband and I worked at SRI. Tony Sinclair breezed into Seronera and encouraged us to do a survey of predator numbers on the plains. Everyone working at SRI was drafted, and there were one or two who resented it.

Packer senses similar recalcitrance fourteen years later. Scientists get to SRI with their own grants, so the interests of the "SRI community" may not rank as high as one's own research. The computer model was obviously not of equal value to everyone. Self-interest exists in humans as it does in lions or chimps or any other creature. The darkness in our hearts, as Packer thinks of it, is what gets in the way of productivity and the common good.

Into Africa is a new kind of animal behavior book. Prior authors have dwelt contemplatively on the minutiae of an animal or a place; Packer doesn't pause very long anywhere and this gives the book an engaging briskness. Another difference is that readers don't have to love animals to find this book engrossing; all they need is curiosity. Packer himself is intrigued, not by animals themselves, but by the things they do. At random, I opened the book at twenty places and found only six pages on which animals were even mentioned. This book is really about someone who studies lions, what he thinks of his fellow humans, what he notices about modern Africa, and what he gets done in spite of difficulties.

Packer is introducing us to his Africa, giving us pithy, gossipy (in spots), occasionally whimsical descriptions of its people, history, researchers, bureaucrats, politics, shops, journeys, sounds, and smells.

I especially like the credit he gives to Barbie Allen, a woman whose father settled in Kenya after World War I. She had raised her own family of four there, and then extended her beneficence to include itinerant scientists. Since the 1970s she has operated what we call the "other SRI" from her home in Nairobi. Given the difficulty of living and working in Tanzania, Barbie's support was not just appreciated, it was critical. Many a sick scientist—sick in body or maybe just sick at heart—got well again under her roof, instead of having to repair all the way home to Europe or the States.

I remember one afternoon on the plains when I was hot, dusty, and exhausted after four days on safari. I saw a little dust cloud coming closer and closer until the dark spot of a vehicle could be seen at the bottom of the plume. Finally, as the car pulled up and some people got out, I recognized Barbie. She had loaded the car with fresh vegetables and the cooler with meat, none of which we had seen in three months. "We just thought we'd take a drive," she said, casually introducing us to her companions. A "drive" of eight hours. Not everybody acts out of self-interest, and Barbie is proof.

What keeps Packer coming back again and again into unhealthful, inconvenient, frustrating Africa? To get his data and get out. What does he do with his data? "I would like to believe that by understanding the nature of selfishness," he says, "we may someday understand the best way to divert that selfish energy to the common good." All right, but here is another reason, and most scientists will recognize it:

> Everything kept falling into place...the lions fit the same pattern, a pattern no one had ever noticed before.... To feel that you have discovered something important about nature is intensely exciting. When the feeling hits, I can hardly sit still. My mind is on fire; the excitement sustains me over these rough, dusty roads, illuminates my cold winter days in Minneapolis.

Lory Frame studied African hunting dogs in the Serengeti and warthogs in Burkina Faso. With her husband, George Frame, she coauthored and illustrated Swift and Enduring, *an account of their hunting dog and cheetah studies. When not in Africa, she writes from her home in Grassy Sound, New Jersey.*

Rough Rookeries

Baby sea lions soon discover that their adult neighbors can be killers

Text and photographs by Fred Bruemmer

In Rudyard Kipling's story "The White Seal," a mother fur seal warns her pup:

You mustn't swim till you're six weeks old,
Or your head will be sunk by your heels;
And summer gales and Killer Whales
Are bad for baby seals

That is good advice for most seals. But in four out of the world's five sea lion species, the most common danger to pups comes from their adult kin. Infanticide, accidental or intentional, is a major cause of pup mortality.

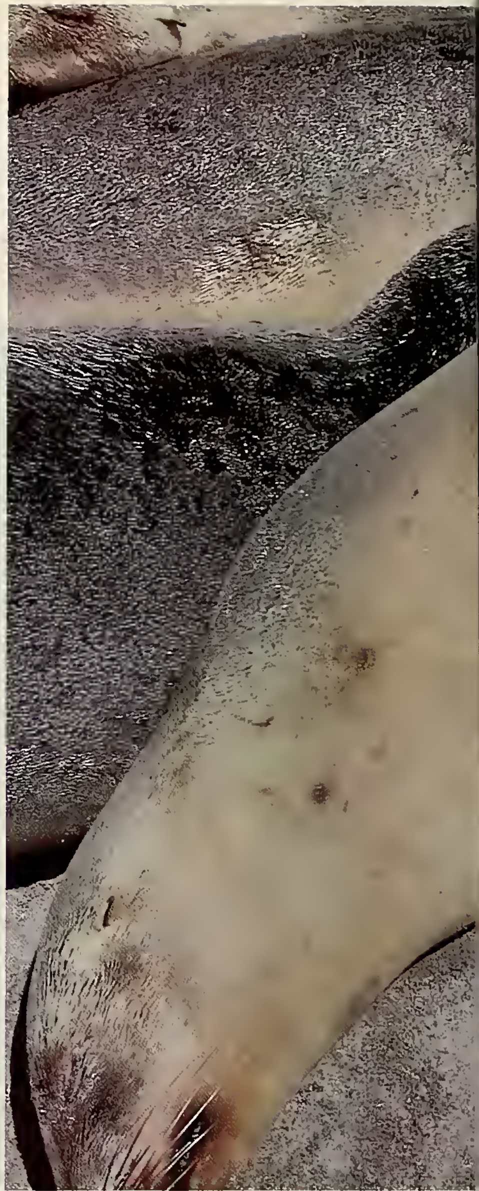
Eight-hundred-pound Hooker's sea lion bulls will galumph blithely across just-born twelve-pound pups or absent-mindedly sit on a pup and squash it. Young male southern sea lions sneak in among females on a beach, kidnap pups, use them to practice herding and harem keeping, and sometimes kill them. Steller's sea lion cows can be fierce toward pups other than their own; they bite, shake, and toss "alien" pups that come too near. And Australian sea lion bulls attack pups with concentrated, lethal fury, biting and shaking them as a terrier shakes a rat, and leaving them mangled on the beach. In this species, about 20 percent of pup mortality is due to attacks by adult males.

The Hooker's is the rarest and probably the most mild-mannered of all sea lions (seal scientists refer to them fondly as "the gentle Hookers"). Most breed in the Auckland Islands, 300 miles south of New Zealand. I observed them for several months on Enderby, the northernmost island of this group where, during the austral summer, about 600 sea lions mass on the broad, half-mile-long breeding beach.

The males arrive in early November and after some violent fights, the strongest bulls divide the beach among themselves. For nearly a month they all are males-in-waiting, each jealously guarding his empty circle of sand. The females come to the beach in early December, settle upon the territories of the waiting bulls, and a few days later give birth to pups that were conceived the previous year.

Hooker's sea lion bulls fight on Enderby Island, off New Zealand, while a pup scurries out of harm's way.

After herding pups into a "harem," below, a subadult Hooker's sea lion bull rests on the beach. A sleeping female Hooker's sea lion, right, nurses her own pup, as well as an orphan that has settled in to feed.



Shortly after the birthing season, with many females about to reenter estrus, the bulls are most excitable and the just-born pups most vulnerable. The bulls I watched were not actively hostile to pups and never attacked them. They completely ignored them; for all they cared, the pups might have been lumps of sand upon the beach. In their jealousy-prodded charges, however, the bulls simply trampled any pups that got in their way. While the females did their best to shield the youngsters, they were rarely fast enough or strong enough to deflect a charging 800-pound male.

The sand is soft, and the pups are amazingly resilient; most survived being steamrollered by the great bulls. The greatest danger to pups was not a passing bull, but one that halted abruptly right on top of the pup. It would sit there, a massive hulk, totally oblivious of the tiny creature squirming beneath it. Most females tried frantically but ineffectually to free their pinned pups: if a small flipper protruded from beneath the bull, they pulled it, usually without success. They never bite the bulls, but New Zealand sea mammal expert Martin Cawthorn watched a female use a shrewd stratagem to free her pup. She moved provocatively in front of the bull and presented herself for mounting. The bull moved instantly to the female, who repelled him, nuzzled her freed pup, and led it to safety.

Three percent of all pups born on Enderby Island are accidentally crushed to death by rampaging bulls. The pups are quick and precocious, however. Within three or four days of birth they know the danger of a big bull and quickly scramble out of the way when one comes barging along. Within ten days, the surviving youngsters leave the dangerous regions of the beach and gather in safer areas.

Female pinnipeds (sea lions, seals, and walruses) usually nurse only their own pups and repel all others. The placid Hooker's sea lion cows generally adhere to this rule, but with certain exceptions. When females go to sea to feed, for instance, their pups, hungry after a day or two, shuffle off in search of milk. Typically, a hungry pup sidles up to another suckling pup to drink quietly from a sleeping mother's teat. When the female awakes, she growls at the intruder, the pup backs off, the cow goes back to sleep, and the pup resumes its interrupted meal. Cows snarl and snap but do not hurt the milk moocher; the youngster's risk is minimal and the reward worth it. I once saw a female nurse four pups.

Immature Hooker's sea lion bulls are a nuisance to the pups, but they do not attack them. These three- to five-year-old males are the restless ruffians of the beach, constantly play-fighting with one another. Sometimes they try to mount adult cows, are noisily repelled, and have to flee from charging territorial males—thereby endangering any pups in their path. Young males may also use pups as female substitutes: they herd them, try to form and keep pup "harems," and occasionally attempt to mate with squirming, protesting pups. But they are not brutal, and when pups are really fed up, they quickly escape.

Southern sea lion pups are less fortunate. During a four-year study conducted at Peninsula Valdés in Argentina, by Claudio Campagna, of the University of California, and his colleagues, immature male

where the females will cluster. The females arrive about two weeks later, and also claim spaces according to their places in the social hierarchy, with the most sought-after spots going to the older cows.

A few days after their arrival at the rookeries, the females bear pups that face a rough initiation into the world. The moment a pup is born, its mother raises it a few feet above the beach and drops it onto the rocks—the sea lion version of a slap on the bottom. She repeats this behavior (one scientist observed a female picking up and dropping her newborn pup fifty-two times in a row) until the pup is crying and crawling. Then the female sniffs her pup and listens intently to its voice; from this moment on she can pick out her baby from all others on the beach. The hardy, forty-pound pups easily survive this rough handling, but some face another danger. At times, the previous year's pups overwhelm the mother with their importunate nuzzling and crying for attention. Distracted, she may fail to bond properly with the newborn, and might even attack it as if it were a stranger. In some cases, where 150-pound yearlings monopolized a mother's attentions, the newborn pup died in a day or two.

sea lions seized pups on 285 occasions. Some were individual kidnappings, while other incidents were raids carried out by several subadult males acting together. While adult male and female southern sea lions do not injure pups, the subadult males "appear to use pups as female substitutes to redirect their frustrated sexual and aggressive motivations," according to Campagna. During his study, 5.6 percent of the abducted pups and 1.3 percent of the pups born each year died from injuries caused by subadult males.

Among Steller's, or northern, sea lions, the female is a threat to pups. I studied the behavior of this species during two seasons in the early 1980s on Marmot Island, off Kodiak Island in Alaska. The largest of all sea lions, adult males grow up to twelve feet in length and weigh more than 2,000 pounds, and adult females can be nine feet long and weigh nearly 800 pounds. Sadly, the Steller's sea lion populations have drastically declined in Alaska. In 1961, the total Steller's sea lion population was thought to be between 240,000 and 300,000. Thirty years later, in 1991, only an estimated 40,000 were left. Lack of food fish due to overfishing by humans seems to be a major reason for this rapid decline.

During my field studies at Marmot Island a decade ago, more than 10,000 sea lions crowded the seven rookeries and each season about 5,000 pups were born. Now many beaches are empty; fewer than 3,000 sea lions were counted during recent summer breeding seasons there.

At Marmot Island the bulls arrive in May and after many fights divide the beaches among themselves, top territories going to "beachmasters"—eight- to ten-year-old males in their prime. Their choice of sites seems to accurately anticipate

The main danger to Steller's sea lion pups, however, is not from their mothers, which are intensely maternal and protective, but from other, unrelated cows. Most females are fiercely hostile to all pups that are not their own. During its first week of life, a pup does not recognize its mother's voice and may crawl hopefully toward any calling cow on the crowded beach—a move that can be fatal. If a female, upon sniffing the pup, decides it is not hers, she snarls and tosses it yards away. Landing in the private space of another cow, the pup may be grabbed and flung again, then thrown back and forth by hostile females, like a screaming, flippered rag doll. Most survive this brutal treatment and learn to recognize their mother's voice, for there is no milk-mooching in this species.

Even more dangerous for a pup than a run-in with the wrong mother is an encounter with a female that has lost her own youngster. On Marmot Island, I watched several cows seeking and calling for their lost offspring. Such a female rushes eagerly toward any pup that responds and sniffs it hopefully. If it turns out to be the "wrong" pup, the frustrated female bites and flings the pup, rushes after it and bites it again, and may maul it until it is dead.

In size and appearance, Hooker's sea lion, of subantarctic and New Zealand waters, and the neighboring Australian sea lion are similar. In temperament, however, they are totally different. Hooker's are placid and pacific, while Australian sea lions are excitable and belligerent. The Australian scientist B. J. Marlow, in the first comparative study of these two species, published in 1975, characterized the social behavior of the Australian sea lion as extremely aggressive in both sexes of all ages. In contrast, the Hooker's appeared "extremely benign."

Australian sea lions differ in another, vital way from other pinnipeds. Most pinniped species have a twelve-month reproductive cycle, during which adults return to their ancestral breeding grounds at a specific time of the year. Females give birth shortly after arrival and mate again a few days later. Within weeks, adults and young leave the rookery sites and return to the sea to follow their favorite prey.

Only the Australian sea lion has an asynchronous, eighteen-month breeding cycle. Females can come to breeding beaches and give birth at any time of the year. In a recent paper, Australian scientists Nicholas J. Gales, Peter D. Shaughnessy, and Terry R. Dennis speculate that the Australian sea lion's irregular reproductive cycle is an adaptation to an equitable climate and a depauperate sea. By staggering births, the lactating females' demands on the local seas' limited food resources is spread over the entire year.

Among other sea lions, top bulls have harems, while each high-ranking Australian male usually keeps only one female. If a subordinate male approaches, the guardian bull quickly chases him away and then, huffing and snorting, returns to his post near the female. When an equal-

On Australia's Kangaroo Island, a male Australian sea lion bull, left, top, pounces on a pup that has emerged from hiding among the rocks. The male shakes the pup violently, center, then flings it away. Finally, after several fierce attacks, the bull has killed the pup, bottom.

Although devotedly maternal to her own pup, a Steller's sea lion cow on Marmot Island, Alaska, attacks and bites any "alien" pup that comes too near.

sized male encroaches on the female, a violent, often bloody fight ensues. The huge males face each other, hacking and parrying. Often one may grab a thick fold of skin on the neck or flank of his adversary, jerk and heave and—like a sumo wrestler—try to lift the opponent off the ground. Fights last until the lighter, weaker animal turns and flees.

Wrestling and intimidation among mature males is normal sea lion behavior. But biologists are puzzled by what seem to be aberrant attacks by bulls upon pups. Australian sea lion females, unlike females of other sea lion species, will bite bulls that come dangerously close to their pups. As B. J. Marlow has observed, however, this defense is usually ineffectual. Some females may even attempt to defend pups that are not their own from rampaging bulls. Australian sea lion pups have come to fear all adults, except their mothers, and flee at their approach. Before a female goes to sea to feed, usually ten days to two weeks after parturition, she hides her pup in a niche or crevice or beneath piled boulders where a bull cannot reach it. As Marlow observed in 1975, this strategy favors meek pups that obediently remain concealed, while the curious, venturesome pup that comes out and explores is most likely to be caught and killed by a bull. "It is difficult to visualize the adaptive advantage of a social system which causes high pup mortality from adult aggression," Marlow wrote, "and which would appear to favor timid and nonexploratory behavior in pups."

Before the season at Seal Bay on Kangaroo Island off southern Australia, I had read the scattered reports about such attacks, but nothing in the dry, detached scientific literature had prepared me for the malefic ferocity of a bull intent on killing a pup. Here is one sequence of behavior that I witnessed during the austral summer of 1992–93.

A female about to give birth had come from the sea and picked a spot near the cliff that rose at the back of the beach. Another female, now at sea, had hidden her three-week-old pup among the boulders at the base of this cliff. Within a few hours of her arrival, a top bull had found the pregnant female, guarded her with possessive vigilance, and fended off the attentions of several encroaching males. Three days later, a young male tentatively crossed into the exclusive sphere of the resident bull, only to be attacked. For a moment the ri-

After feeding at sea, a female Steller's sea lion sniffs a pup to be certain it is her own.

vals faced each other, then the young bull turned and fled. The huge bull, seething with unspent fighting spirit, his mouth wide open and vibrissae abristle, waddled back to his post.

At this moment, the long-hidden pup emerged from its refuge among the boulders. Probably hungry, it may have mistaken the pregnant female for its mother. When the bull saw the movement, he immediately lunged forward and grabbed the pup before it could flee. The pregnant female attacked and bit the bull, but to no avail. He shook the pup, flung it ten feet, rushed after it, grabbed it, and shook and tossed it again. Each movement of the desperate youngster incited the bull to new attacks, until the pup lay dead.

Eventually, the beach's resident Rosenberg's goanna, a five-foot-long monitor lizard that patrolled the area for carrion, fed on the carcass. Leslie V. Higgins, of the University of California, who studied Australian sea lions at Seal Bay in 1986–87 and again in 1988, recorded eight attacks by bulls on pups, four of which were fatal, and felt that "misdirected aggression" by bored bulls is the most likely explanation for the behavior.

Harem bulls of other sea lion species defend extensive territories, fight frequently with rival males, and mate often. In contrast, the Australian sea lion male has a much smaller territory to defend, and it is occupied by only a single female. Days may pass without a fight, until anything that moves—and that is usually a pup—becomes a target and victim of the bull's pent-up aggression.

Other attacks on pups followed a similar pattern but not all resulted in death. I observed one large male that came upon an older pup playing in a shallow rock pool. He pounced on it and bit it, but as he tried to get a firmer hold, the pup twisted free and escaped.

Interestingly, the "ferocious" Australian sea lion males kill about 3 percent of the pups born in their rookeries—the same percentage destroyed by the "gentle" Hooker's bulls, with their proclivity for accidental tramplings. □

A king vulture in Costa Rica adopts a threat posture. These birds are the largest and most powerful of the New World forest vultures.
Erwin and Peggy Bauer

To the Vultures Belong the Spoils

In New World rain forests, scavenging specialists win the carrion sweepstakes

by David C. Houston

The carcass of a howler monkey, half buried by leaves and debris, lay in the darkness of the forest floor in northern Venezuela. Homing in on the corpse, a turkey vulture landed beside it. Within minutes, another touched down, keeping its distance as the first nosed the prize and scratched the earth around it. Two more turkey vultures remained airborne near the treetops. They were, perhaps, warned away by rapid changes in the hue of the bald red heads of the birds on the ground, which can signal dominance within their species. A couple of black vultures, however, were less inhibited and soon took their place next to the carcass.

Work on the dead monkey was barely under way when a king vulture easily exerted its dominance over the other birds and took charge. While the black vultures squabbled in the background, the king grasped the monkey with both feet and tore through its skin and into the tendons. Now the softer tissues of the dead animal were exposed, making access for the other species easier. The black vultures unraveled the intestines, while the turkey vultures, more dainty feeders, poked within the carcass for small bits of meat, often using one foot as an anchor. Gradually, scraps clinging to bone or scattered on the ground were plucked and devoured, completing the cleanup. The turkey vultures were the last to leave.

In a grassy area on the edge of the forest, the ample corpse of a domestic cow was attracting scavengers. Once again, turkey vultures were the first on the ground, followed closely by black vultures. Because they often hunt in family groups, black vultures quickly draw in more of their kind. (The record for this area is more than 200 black vultures at a single carcass.) Their gathering numbers easily displaced the turkey vultures, which waited on the sidelines. The cow's body, its hide softened by decomposition, was ready for the black vultures. They began to feed on muscle and viscera that could be extracted with little force. Any suitable hole in the skin was an invitation for the black vultures to climb right into the roomy carcass, full of meat that could not be reached from the outside. Again the turkey vultures polished off small, remaining bits of carrion.

No less an observer than Charles Darwin, who had seen the turkey vulture in South America in the 1830s, described it in *The Voyage of the Beagle* as a "disgusting bird, with its bald scarlet head formed to wallow in putridity." But the features that struck Darwin as repellent are the hallmarks of a supremely efficient scavenger. The ways in which vultures make their living from death, and the ecological roles they play in tropical forests, have been the focus of my research for the past few years. This work has taken me to rain forests in Brazil, Venezuela, and Panama.

While extremely similar in appearance to Old World vultures, New World vultures are not related to them. The vultures of Africa, Asia, and Europe are descended from the same ancestor as are eagles and hawks. New World vultures, including the California and Andean condors, share a common ancestry with the storks. The two major vulture groups are thus textbook examples of convergent evolution: two unrelated groups of animals that resemble each other closely because they have developed the same adaptations for a similar way of life. In the case of vultures, these adaptations include bald skin on the head and neck, which helps to prevent feathers from becoming soiled and also aids in heat regulation. Vultures are also superbly adapted for soaring flight, having large, broad wings. All vultures make their living by scavenging dead animals. While black vultures do sometimes kill weak animals, the other species have virtually lost the ability to kill their own prey and survive only by finding carrion.

The Old World vultures differ from their Western Hemisphere counterparts in that they live exclusively in open areas—grasslands, savannas, and deserts. New World condors inhabit mountainous regions, and some other New World vultures range into a variety of landscapes. However, the greatest diversity of New World vultures—five species—is found in Central and South American tropical rain forests. Of these, the turkey vulture is the most widespread; in winter, the resident tropical race is joined by migrant turkey vultures from North America. The lesser and greater yellow-headed vultures are close relatives of the turkey vulture; the lesser is a denizen of open areas near the forest edge, while the greater is strictly a forest bird. Black vultures range throughout South America, usually inhabiting forest edges and the outskirts of villages and towns. Finally, the king vulture, the most spectacular and powerful of the forest scavengers, is still widely found in undisturbed areas. In and near forests, these vul-

Their long, broad wings allow vultures to soar and glide over great distances, right. Such effortless flight is an advantage when carcasses—their source of food—are few and far between. Below: A young turkey vulture in Panama lingers by the picked-clean bones of a chicken.

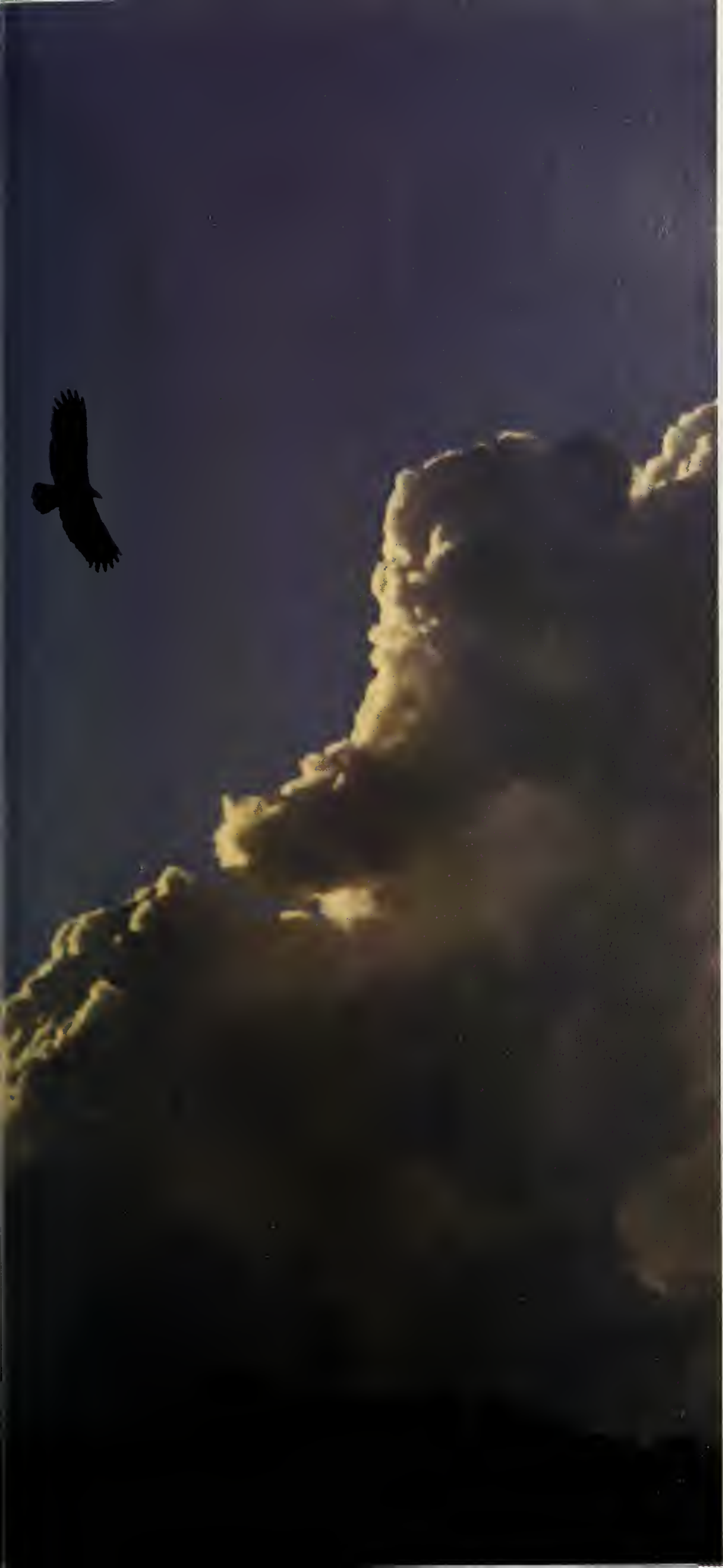
David C. Houston

tures are abundant. They average up to two birds per square mile, a density probably greater than that of any other carnivorous bird.

The tropical forest would appear to be a difficult place for high-flying birds to spot a potential meal. Virtually all plant growth is in the lush treetops. In some places, the dense canopy allows less than one percent of sunlight to reach the ground, so relatively few plants and animals thrive in the dark understory. Sloths and monkeys, the most abundant forest mammals, live in the canopy. Apart from an occasional snake and monkey-eating eagle, big predators find treetops a risky place in which to pursue prey, and most canopy-dwelling mammals probably die of disease, parasites, accidents, old age, or food shortages, rather than predation. On average, in healthy forests with thriving mammal populations, one animal dies in each square mile every day.

When a monkey or sloth dies, it falls, crashing down perhaps some seventy feet through the dense canopy foliage, then through the shrub layer, to land in the deep shade of the forest floor. Often covered by leaves and debris thrown up on impact, the body, if it can be located, represents a windfall of protein for other members of the forest community. A dead animal will attract typical ground predators, such as jaguars, ocelots, and tayras, as well as armadillos, opossums, and coatis; even forest tortoises relish a meat meal when they can find one. Carrion flies and beetles, which lay eggs or even live maggots on carrion and rely on it as a source of food for their larvae, constantly scour the forest floor for corpses. Maggots pour digestive enzymes into soft tissue, breaking it down into a fluid that they then suck into their gut, absorbing the nutrients. Aided by the heat and humidity of the rain forest, they can reduce most of a small monkey carcass to a skinful of mush within three days. From a vulture's point of view, finding a carcass is a race against time. Not only do vultures have to beat mammalian scavengers, already on the ground ready to follow a scent trail to the prize, but they also have to find the body before insects render it an inedible, maggot-ridden soup.

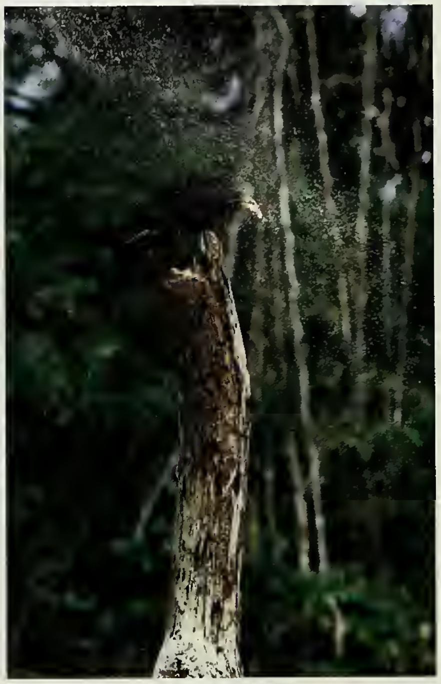
To find out more about the competition for carrion, I conducted a series of experiments at seven different forest sites in South America, putting out chicken car-



Aldo Brando

A large snag in a Brazilian forest serves as a perch for a greater yellow-headed vulture, below. These vultures, and their close relatives the turkey vultures, have a keen sense of smell.

Luiz Claudio Marigo

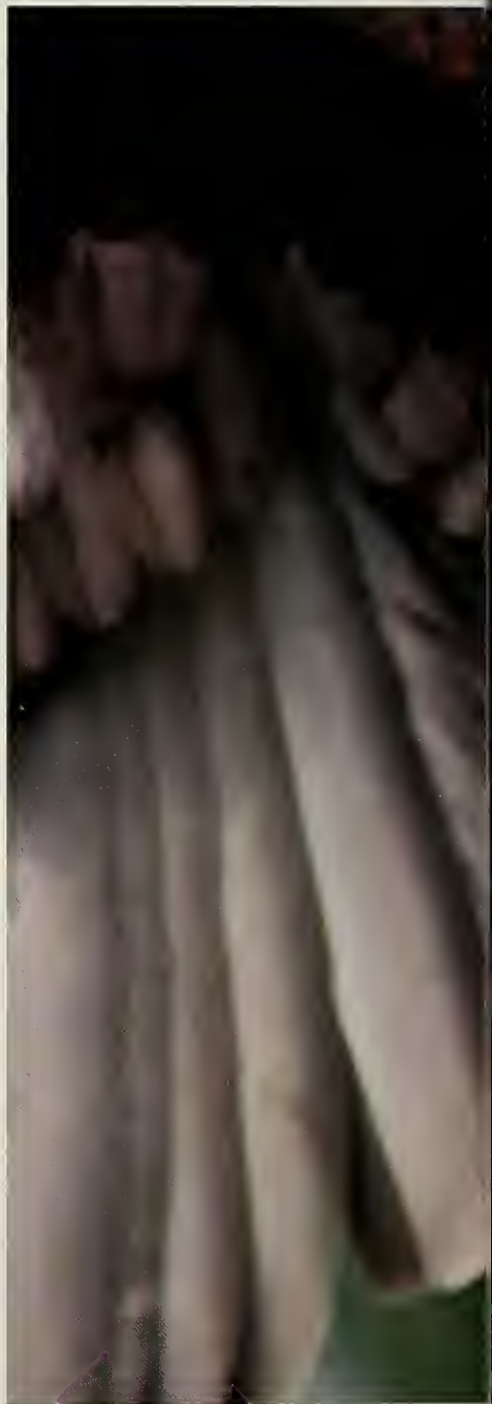


casses and then monitoring which animals came to feed from them. Between 60 and 95 percent of all the carcasses I provided were taken by forest vultures. Yet, unlike their insect and mammalian competitors, vultures have to search from above the tree canopy. How do they home in on carrion so swiftly?

Birds are often assumed to have no sense of smell at all, and in most birds, this sense is indeed poorly developed. In a few species, however, olfaction is acute. The kiwis of New Zealand, for example, nose out earthworms in the soil, and the ocean-going shearwaters are able to detect fish and plankton shoals by faint traces of fish oils in the water. Kenneth Stager, of the Natural History Museum of Los Angeles, was the first researcher to carry out carefully controlled experiments that demonstrated that turkey vultures were attracted by the scents given off by carrion; and Betsy Bang, of Johns Hopkins University, has shown that the brain and olfactory region in the skull of these birds is exceptionally well developed.

The turkey vulture's total dependence on its sense of smell to find food in the forest can be easily demonstrated by putting

Thomas Kitchin; First Light



If the hide is too tough to penetrate, a carcass, such as that of a steer, below, can present a problem to black vultures. The birds tend to take advantage of any available opening or exposed soft tissue.
Kevin Schafer and Martha Hill

out carcasses, some left uncovered and some hidden completely by a pile of leaves. The birds find the hidden carcasses just as quickly as those in the open. Turkey vultures hunt by flying just above the level of the tree canopy, sniffing the air all the time. As soon as they get a whiff of rotting meat, they start to circle to determine where the aroma is strongest. They then fly down into the forest, following the scent trail from tree to tree, until they are led to their reward on the forest floor. Because an airborne bird on the scent is usually within sight of many others that are quick to follow, good numbers of vultures of various species can congregate at a carcass within minutes.

A dead animal takes some time before it begins to smell strong enough for a turkey vulture to detect it. To find out how long, and to test the smelling ability of vultures, I placed a series of dead chickens in the forest in Panama: some were freshly killed, others were a day old and smelling slightly, still others were several days old and really stinking. Turkey vultures could not detect carrion less than about twelve hours old. A carcass twenty-four hours old, however, emits a sufficient stench to attract vultures readily.

These birds have a reputation for savoring stinking, rotting meat, but when offered a choice of relatively fresh or rotting meat, they strongly preferred the fresh. This is probably why the earliest investigations into whether turkey vultures had a sense of smell reached the wrong conclusion. In 1826, John James Audubon published the results of a series of feeding trials that he had carried out on turkey vultures, from which he concluded that they had no sense of smell at all. But Audubon had based his experiments on the assumption that vultures would be particularly attracted to foul-smelling food, so he had sought out the most rancid old fish and dead dogs to use for his baits. Not surprisingly, vultures failed to arrive. I am sure that they could smell his rank baits perfectly well but preferred to keep on searching for more wholesome fare.

Badly decayed meat contains unpleasant bacterial compounds that either impede digestion or are actively toxic. Dan Janzen, of the University of Pennsylvania, has suggested that many of the products of bacterial and fungal growth in foods have evolved specifically to render the food inedible to larger animals, so that microorganisms do not have their food supply stolen from them. Vultures will eat rotten meat if they are extremely hungry—as would any starving animal—but if they are not short of food, they will give bad meat a miss and wait for the scent of something more palatable.

Turkey vultures can tell from the smell coming through the tree canopy how long an animal has been dead, probably because the smells given out by the bacteria that develop in meat change with the age of the carcass. Thus, vultures do not even bother to fly down to old carcasses as often as they do to day-old carrion. Even the human nose can detect the level of decay. I soon learned to tell the age of a chicken carcass from its smell—fortunately not a skill I need to use very often at home. But our ancestors, who probably

Like all other vultures, the turkey vulture, above, has a bald head. Bits of carrion do not adhere to the skin as they would to feathers. When a king vulture is present, left, even a crowd of black vultures will defer to it. Here a king, using its superior strength and more formidable beak, rends a carcass.
F. Köster; Survival Anglia

Patricio Robles Gil; Bruce Coleman, Inc.

Faced with the armor on the back of an armadillo carcass, a king vulture attacks the underbelly and entrails, below. A turkey vulture, right, sunbathes on a palm tree in the Yucatán Peninsula.

Carol Farneti; Planet Earth Pictures

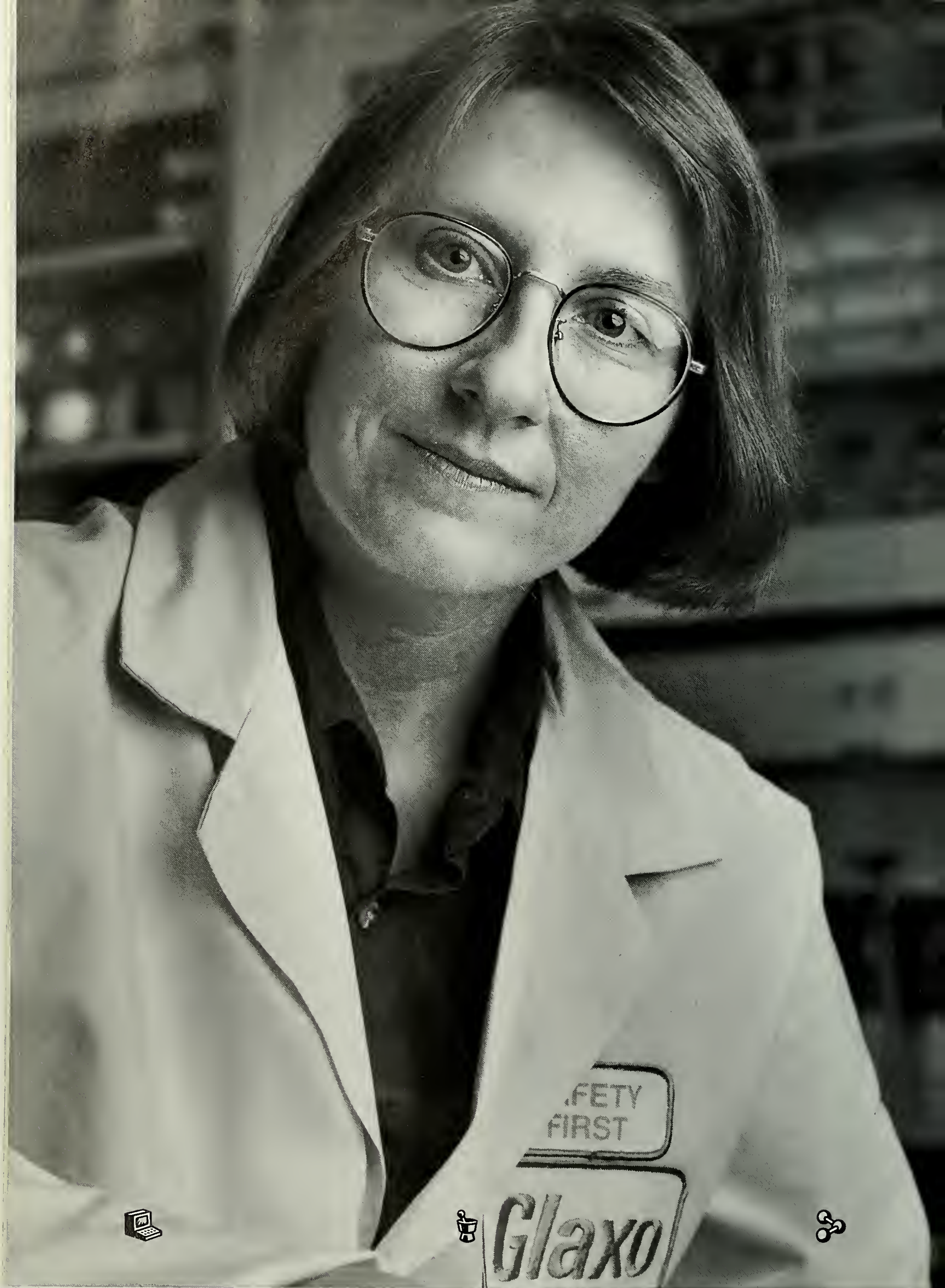
scavenged as well as hunted for their food, may have found this ability useful.

Only turkey vultures and lesser and greater yellow-headed vultures can locate food by smell; black and king vultures (and, incidentally, the condors) lack this ability completely. Their technique is to fly at high altitude and keep an eye on the turkey and yellow-headed vultures flying below them, just at the level of the tree canopy. As soon as they see these birds circling and starting to congregate, they descend and join in the feeding party.

Because both black and king vultures dominate other vulture species, they tend to take over the carcass for a while. The presence of different species at the same carcass poses little problem, however, because each species specializes in a method of feeding. King vultures are the only ones powerful enough to tear through tough skin and open up a carcass for others. Black vultures tend to concentrate on the blocks of viscera and muscle, while turkey and yellow-headed vultures feed more slowly and can tear off the last scraps of meat from the bones.

At first I was surprised at how few of the carcasses I set out were discovered by scavenging mammals. Yet the vultures' dominance as South American forest scavengers makes sense when considered from the standpoint of energy expended versus energy consumed. Dead animals are scarce and ephemeral, and their whereabouts are unpredictable. Even with an acute sense of smell, mammals have to search by walking or running—energetically expensive ways to travel, particularly if a food supply is irregular. No species of mammal has ever evolved as an exclusive scavenger, while many bird species have done so. Birds' traveling costs are minimal. All vultures, for example, are supremely adapted for soaring flight. Many species scarcely flap their wings in the course of a day; instead, they glide, taking advantage of rising air currents to stay aloft. They can cover long distances at high speed, using little energy. A soaring vulture can afford to spend much of the day airborne, covering hundreds of miles in search of scarce carcasses.

The most successful of New World tropical forest scavengers, vultures are also the major meat-eating animals in the forest community, consuming more than all mammalian predators put together. The job of recycling the animal riches of the rain forest falls mainly to them. Although they may not win any beauty contests, vultures carry on their roles in the rain forests with quiet efficiency, and to my eye, with a certain adaptive elegance. □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No Pain, No Game

For the Mayoruna and Matses of the Amazonian forest, preparing for the hunt can be an ordeal

by Katharine Milton

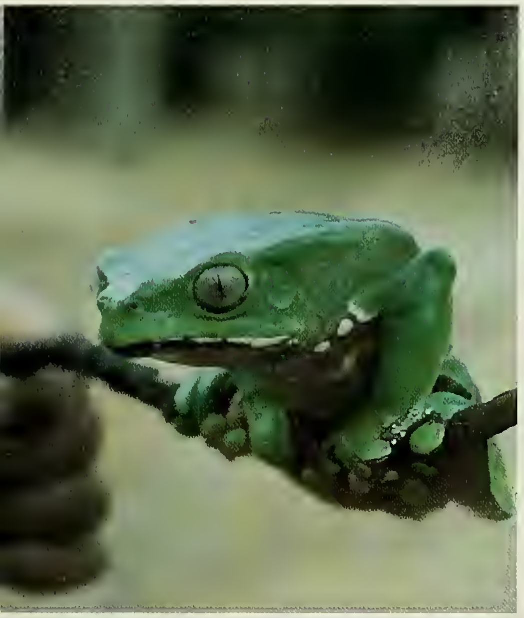
Early in my study of diet and ecology in Lobo, a village of 110 Mayoruna Indians in Brazil's Amazonian forest, I noticed that the men and adolescent boys had neat rows of small scars on their upper arms and chest. At first I thought these might be the result of cigarette burns, and although this seemed a bit odd, I didn't really question my interpretation until it dawned on me that the Mayoruna had no cigarettes. Not conversant in Panoan, the Mayoruna language, I finally pointed to the scars and indicated that I wanted to know what had caused them. Several youths smiled at me and then ran into the forest. After twenty or thirty minutes, they returned bearing a leafy branch on which sat a large, handsome, green frog.

I thought it very kind of the boys to show me this wonderful frog, but I had no idea that it was connected to my question about the burn marks. I wondered if the boys thought I was hungry and were offering the frog to me for my supper. They allowed me to admire it for some minutes as it sat calmly on the branch and then on the shoulder and arm of one young man. It was a vivid green, with striking yellow mottling on the underside of its limbs and body, and it moved with an exaggeratedly slow gait, similar to that of the African chameleon. But then the boys took the frog and began to prepare it for some kind of procedure. I finally realized that the frog did have something to do with the burns after all.

Without touching the animal, the boys looped slender cords made of vines around all four of its limbs. They then drove small stakes into the ground and stretched the frog out, firmly attaching the cords to the stakes. At that point, several of them picked up wooden splinters and began to harass the frog, poking it particularly around the eyes and nostrils. In response, the terrified frog began to exude a clear, glossy secretion from its skin that began to settle in a cloudy, mucuslike film around its feet. I had no doubt that this was some kind of potent substance that the frog used for defense. Did contact with it cause burns? Using a splinter, the boys

A Matses hunter in Peru, an expert with bow and arrow, displays a common piping guan he has shot.
Jeff Rotman

Katharine Milton



scraped the secretion off the head, back, sides, and limbs of the frog.

After the frog had been poked and scraped for some minutes, its ability to produce the secretion evidently was exhausted. At that point, the captors carefully removed the cords from the frog's limbs and permitted it to walk away. The frog was not physically damaged, only frightened. One boy who briefly touched the frog while removing the cords ran to the nearby river to wash his hands.

The secretion had been collected on a clean, flat piece of wood, which was placed near a fire to dry. The wood with the dried secretion—which looked like shiny glue—was then wrapped in cloth and stored in a secure, dry area in the thatch of a nearby house. On four occasions I observed how the frog's secretion was used in a type of hunting magic.

Traditionally, the Mayoruna live by horticulture (sweet manioc, plantain), hunting (tapir, peccary, woolly monkey, spider monkey), and some supplementary fishing. The men's skills with bow and arrow are impressive: "I pity the animal that crosses the path of a Mayoruna," remarked a visitor who had done considerable hunting with them. Yet hunting game in the forests of the Amazon Basin is always an unpredictable venture, a hunter never knowing whether on any given day he will have good luck, moderate luck, or no luck at all. Anthropologists have long noted that important activities with uncertain outcomes are the most likely to be surrounded with magical practices.

Detailed cave paintings, animal figurines, and stylized caches of animal bones found in Europe suggest that more than 30,000 years ago, human hunters were carrying out a wide variety of magical practices, possibly to improve hunting success. Ethnographic accounts of many past as well as present-day hunter-gatherer groups throughout the world describe a rich array of magical practices involving smoke, blood, bark, leaves, roots, and other substances, which the hunters believe improve their hunting prowess and luck, increase the numbers of prey, or propitiate animal spirits.

The Mayoruna use the frog secretion as a drug and regard its effects as a potent form of hunting magic. On two occasions when I observed the procedure, the drug was taken on a day of heavy rain—perhaps a bad day to hunt but a good day to practice hunting magic in preparation for more opportune conditions. I never saw a hunter take the drug by himself: two, three, or more men took it together.

To get the frog secretion into the body, the hunters heat a vine twig on a burning log until the twig is white hot. One man then takes the twig and applies it to the arm or chest of a person wishing to take the drug. The white-hot twig is allowed to rest on the surface of the skin for less than a second, then removed and reheated; each individual ultimately receives three to six burns, placed in a neat row, one under the other. At this point, the frog secretion is taken from its storage site and unwrapped.

Gorman/Lavalle

When disturbed, a tree frog of the species Phyllomedusa bicolor, *far left, secretes a noxious substance, presumably a defense against predators. Amazonian Indians deliberately harass a frog, left, and collect the secretions on a stick for use as a ritual drug in hunting. (They will then let the frog go.) Small scars, below, show where the secretions have been introduced through the skin.*

Jeff Rotman

One hunter mixes his saliva with it, stirring it with a splinter to make a whitish, soft paste. The individual receiving the drug then uses his fingernail to carefully scrape away the small burned patches of skin, leaving open wounds. A small mound of the paste is then applied to each open burn.

Before receiving the burns, participants drink an impressive amount of manioc, banana, or other gruel. The first time I witnessed this, I didn't know why they did it, but I soon found out. The drug apparently enters the bloodstream through the open wounds very rapidly; within minutes it induces heavy, repeated vomiting. The Indians told me, through an interpreter, that the gruel lessens the pain. Another visible result is swelling of the lips and face; other rapid effects are headache and a burning sensation in the anal mucosa.

After vomiting several times, each participant sits quietly, often holding his head in his hands. Later he gets into his hammock and falls into a "sleep," during which he may babble and make other sounds. The sleep was described to me as exciting, rather than restful. Men say they think of "nothing" while in this sleep; that it is very similar to being very drunk. If they take the secretion about eight in the morning, they are recovering from its effects by five or six in the evening of the same day, although they may still lie about in their hammocks and act somewhat groggy. I was told, however, that if someone who is under the influence of the drug is thrown in the river or forced to bathe, he will rapidly shake off his somnolence.

I asked various Mayoruna why they took the drug since it appeared to be so unpleasant. The men replied that taking the frog secretion "made them hunt better." Taking it was said "to get rid of bad luck, help you to keep good luck, and help your arrows find the game animals." Men also stated that taking the secretion made them physically much more powerful—their senses keener, their stamina greater, their aim with the arrow more precise.

I was told that Mayoruna boys are first given the frog secretion when they are about seven or eight years of age "so that they will become accustomed to taking it." Women occasionally take the frog secretion so that "they will work harder." I estimated that most or all adult male hunters in Lobo take the frog secretion at least once a month.

The Mayoruna Indians in Lobo have another type of painful hunting magic. Men seek out large "fire" caterpillars, whose three-inch bodies are covered with long, white, stinging hairs. My one contact with one of these caterpillars produced such immediate, excruciating pain that for months afterward I flinched at the mere thought of white, fuzzy objects. As caterpillars are soft-bodied, small organisms, they apparently require a very rapid-acting chemical defense against potential predators that would crush or ingest them.

Some Mayoruna keep these white caterpillars on banana plants in their gardens so they will be readily available. To use them for hunting magic, they pick up the caterpillar on a twig and rub it on the bare upper arm. This practice, which is supposed to make a man a better hunter, leaves additional areas of scar tissue on the Mayoruna men and boys who take the frog secretion.

The Mayoruna I visited live in western Brazil, near the border with Peru. Steven

Jeff Rotman

The articles of manufactured clothing worn by young Matses, right, indicate their group's outside contacts. A Mayoruna boy, below, holding his family's catch from the river, and a Mayoruna teenager with his pet fawn, below right, belong to a much more isolated group.

Katharine Milton

Romanoff, an American anthropologist, has spent some fifteen months living with the Mayoruna of Peru, where they are referred to as Matses. His description of how the frog secretion is used for hunting magic matches what I saw almost completely, but he also mentions that the drug is sometimes administered to individuals (men, women, or children) who are lazy or are having problems or even as a punishment. Among the Matses, a dab of the paste may even be placed on the nose of a favored hunting dog to improve its hunting abilities.

Romanoff also observed a number of other energy-inducing rituals among the Matses. In these, an older man, respected for his knowledge or energy, blows tobacco smoke or uses stinging nettles or other painful materials to magically imbue younger individuals, usually men, with energy, strength, or knowledge.

While working with the Amahuaca Indians in a Peruvian headwater area of the Rio Inuya near the Brazilian border, anthropologist Robert Carneiro of the American Museum of Natural History also observed similar hunting magic. The Amahuaca, like the Mayoruna, are Panoan-speakers, and the two groups may be closely related. The Amahuaca men take a frog secretion (almost certainly from the same species of frog used by the Mayoruna) and place it in burns using the same technique. Carneiro, however, reports that in their case the effects last for some three days rather than a single day, and that Amahuaca men claim to experience vivid hallucinations while under the effects of the drug.

Amahuaca men also deliberately seek out wasps' nests and let numerous wasps sting them, believing that they will emerge from this ordeal better hunters. Youths may have strips of highly caustic tree bark tied around their wrists or forearms to insure that when they are hunting "no animal will escape."

Some years ago, Delvair Montagner Melatti, a Brazilian anthropologist, began to work with another Panoan-speaking group in Brazil, the Marubo, who live to the south of the Mayoruna and are one of their traditional enemies. The Marubo used the frog secretion extensively during her earlier visits, giving it to children as young as three years of age. Children typically did not like to take the secretion, which is unpleasant for anyone and which, in a small child, can produce very powerful effects. According to Montagner, taking the frog secretion appeared to be a daily or even twice daily ritual; however, the Marubo bathed very shortly after the secretion was administered. In some manner, the shock of the cold water and action of the bath curtailed much of the effect of the secretion, so the Marubo did not spend the rest of the day lying in a hammock but rather were able to hunt, work, or carry out other activities with vigor.

The Marubo stated that they used the secretion for two principal reasons—to rid the body of harmful impurities, including such things as bad luck, and to imbue the body with power, energy, and good luck. Children were given the secretion not only for these reasons but also as a punishment to correct improper behavior. In the past, the area of the body on which the burns were placed was apparently related to the type of effect desired. To cure laziness, for example, burns would be placed on the back of the neck, while to rid oneself of weakness and become powerful and quick, burns were placed on the stomach or upper arms. To improve hunting success, burns were placed on the chest and upper arms. To kill people in warfare, they were placed near the sternum. Painful, stinging herbs were also rubbed on the skin to augment the effects of the frog secretion. In her later visits, Montagner noted far fewer scars on the bodies of the Marubo and concluded that the practice was gradually dying out owing to the influence of missionaries and other outside forces.

The Mayoruna and others obtain the secretion from *Phyllomedusa bicolor*, a large tree frog that lives high in trees near rivers

Katharine Milton

and streams. Curious about the chemical composition of the frog secretion, I obtained a dried sample and brought it back to the United States for analysis. I sent it to the laboratory of John Daly, a chemist at the National Institutes of Health, who along with his associate Charles Myers, a herpetologist at the American Museum of Natural History, is well known for studies of the chemical compounds in secretions of the so-called poison dart frogs.

Poison dart frogs of the genus *Phyllobates* produce among the most potent of all naturally occurring, nonprotein toxins—the batrachotoxin alkaloids. Some Indian groups smear the secretions from these frogs on blowgun darts in order to kill game. The poison leads rapidly to car-

Art Wolfe

A Matses woman, below, cuts up a tapir, a favored game animal. Bottom: A pot of tapir meat cooks over the fire. Opposite page: A Mayoruna mother wears straw whiskers to evoke the image of a jaguar. This adornment has now fallen out of use, but facial tattoos are still in fashion.
Photographs below by Jeff Rotman

diac failure in wounded game, but the meat of such animals is safe for humans to consume.

The secretion from the hunting magic frog, *Phyllomedusa bicolor*, is very different from those of poison dart frogs. Daly and his colleagues were able to isolate a previously unknown peptide, which they named adenoregulin. Earlier work by Vittorio Erspamer had shown that the skin of the frog contained a variety of vasoactive and opioid peptides. All these peptides presumably interact to produce the variety of symptoms and sensations noted in individuals who take the frog secretion. When some of the frog secretion was administered to mice at the National Institutes of Health, the mice fell into a drowsy trance. When the mice were stimulated, however, the effects of the trance could be rapidly dissipated—the same pattern of behavior noted in the Marubo, who bathe in the river after taking the secretion and then are able to carry out their daily activities with increased enthusiasm.

No one knows how tropical forest-dwelling people first acquired knowledge about the plant and animal compounds they use as medicines, stimulants, and magic. Most such discoveries were probably the result of some chance observation of the effect of contact with, or ingestion of, some leaf, bark, insect, or animal. The observer may have noted this effect on himself or on another person or animal. A series of trial-and-error experiments may then have helped determine how best to administer and use the chemical substances involved. To the best of my knowledge, the Mayoruna, and related Panoan-speaking groups among whom the procedure has been observed, are the only Amazonian Indians who introduce a drug into their bloodstream through a deliberate break in the skin. Elsewhere, such chemical substances are generally inhaled or swallowed.

Why many hunting magic procedures are painful or unpleasant is another mystery. Perhaps, as practitioners claim, the experience leaves them feeling energized and refreshed. The pain or stimulation brought on by frog secretions, wasp stings, stinging caterpillars, and caustic bark conceivably causes the release of brain peptide endorphins that ultimately lead to enhanced alertness, physical strength, and endurance.

Or more simply, hunters may believe that by subjecting themselves to some form of ordeal or discipline they are earning favor or investing themselves with extra power derived from animal spirits, deities, or ancestors. This added confidence and determination could enhance their hunting success. The limits of the human mind's influence over physical reality, at least over the body and health, are far from settled. Whether through a prayer, a fetish, or a frog, people throughout the world find ways to harness this resource. □

Photographs by Mike Severns

A male common house gecko feeds on a moth. Large eyes help this nocturnal insectivore in its search for food.

Gecko Power Play in the Pacific

Ever since they hitched a ride to Hawaii, competition between these little lizards has been driving them up the wall

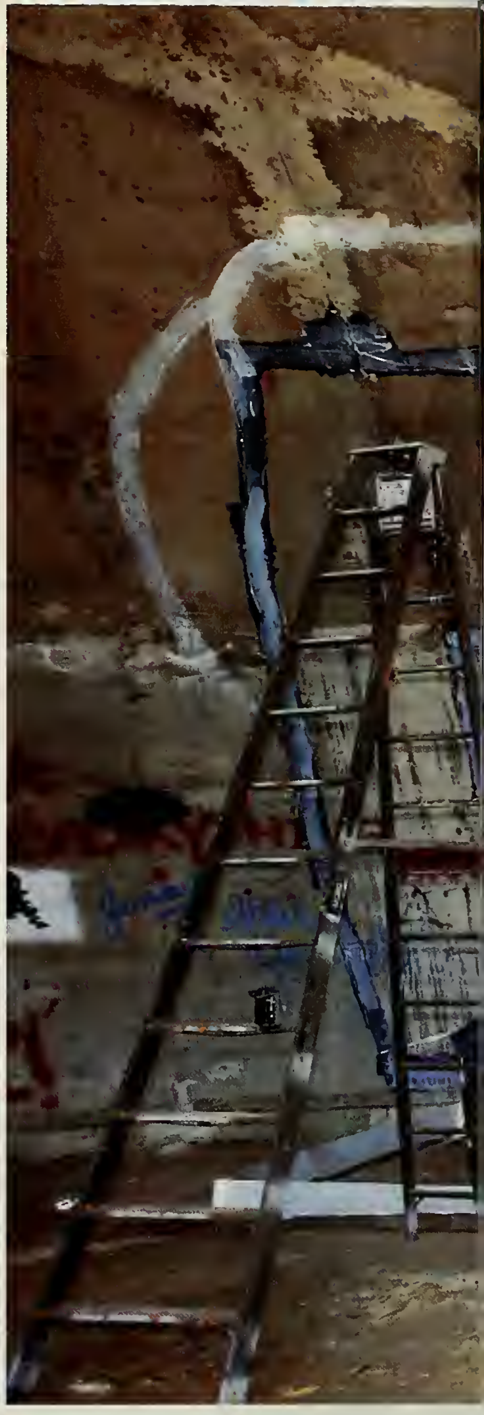
by Kenneth Petren and Ted J. Case

After sunset on a South Pacific island, gentle trade winds sway the pandanus trees on the grounds of a local school. As day gives way to night, clouds of insects form around lights in the empty schoolyard. This is our cue to get down to work: collecting geckos, little lizards best known for the pads on their toes that enable them to perform Spiderman-like feats of climbing on almost any surface. Armed with powerful headlamps and long brooms, and with plastic bags dangling from our necks, we sprint to the first light. Holding our brooms aloft, we poke around the light, brushing geckos from the wall with frenzied actions. Then we move rapidly along the side of the building, sweeping under the eaves and pouncing on any lizards trying to escape through the grass. Once we have collected a few dozen of the finger-sized geckos, we catch our breath and decide to call it a night.

During the course of four years, we spent many nights, together with Douglas Bolger (formerly at the University of California, San Diego, and now at Dartmouth), in pursuit of common house geckos on Viti Levu, an island in the Fiji archipelago. Our goal was to monitor their numbers and study their interactions with other gecko species found in Fiji and on other South Pacific islands.

Many gecko species thrive in urban environments throughout the Pacific. All originated either in Southeast Asia or in the larger islands of the western Pacific, but they dispersed eastward by hitching rides with human colonists to the most remote islands. Geckos began their trans-Pacific trek thousands of years ago, stowed away in the cargo of Polynesian canoes. Some of the earliest stowaways belonged to asexual species, in which all individuals are females capable of laying viable eggs without male fertilization. Such species have an advantage over sexual species, as there is no need for both a male and female to start a population; a single individual or egg will do. Two asexual species that reached many of the Pacific islands by stowing away are the four-inch-long fox gecko (*Hemidactylus garnotti*) and the

Concrete aircraft hangars from World War II proved a good environment in which to study Hawaii's urban geckos. A fence kept predators out, and a strategic coating of blue Fluon (a suspension of Teflon particles the geckos can't cling to) kept the lizards in.



three-inch-long mourning gecko (*Lepidodactylus lugubris*). But since World War II, the increased volume of shipping in the Pacific has also enabled the common house gecko (*H. frenatus*), a sexual species, to colonize these islands.

All these geckos are nocturnal and insectivorous. Like tiny tigers stalking prey, they creep along, keeping their bodies pressed close to whatever they're walking on, and finish off the hunt with a final pounce and snap of the jaws. They may forage for insects on trees, plants, and buildings, requiring little more than a loose piece of bark or a wall mirror to hide behind during the day.

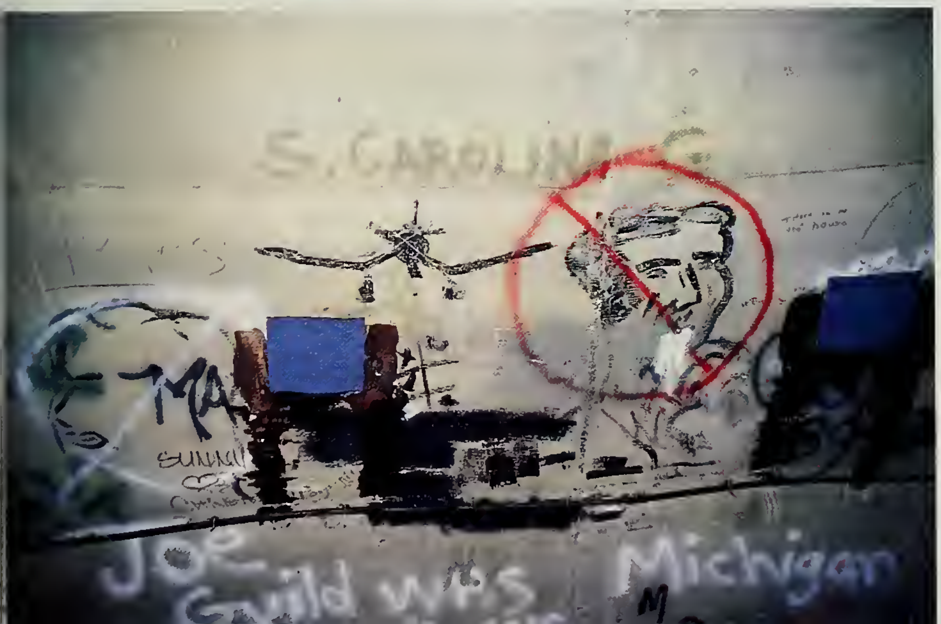
Flat walls, windows, and ceilings present no obstacle to these remarkable climbers. In fact, walls with overhanging eaves are a boon to the lizards: by impeding the insects' horizontal and vertical flight paths, the walls concentrate flying prey. These flat surfaces also generally make the insects more conspicuous than they are on cylindrical tree trunks. And with the advent of electric lights, the benefits of living near people became even more striking, for the lights attract a smorgasbord of flying fodder for the geckos.

But not all gecko species have fared equally well. Typically, once the common house geckos have established themselves in and around port towns, they quickly spread to other inhabited parts of an island and displace many of the earlier arrivals, including the fox and mourning geckos. The fox gecko, which is similar in size, shape, and habits to the common house gecko, is now very rare and simply can't be found in many of the places we see the other two species.

Our Fiji study demonstrated that as the common house gecko invaded, resident mourning geckos grew more slowly and their numbers decreased. Gecko skin is so thin and transparent that eggs can easily be counted and measured while still inside the female, enabling us to determine that the mourning geckos were producing fewer eggs as common house geckos took over. But what made the house gecko more successful than the mourning gecko? Was it simply its larger size?

To find out, and continue our investigations into the role of competition in determining the makeup and structure of a community of animals, we decided to expand our experiments with the geckos. Several aspects of the situation made us optimistic. The geckos are abundant and tolerant of handling by humans; the house gecko invasion tends to be rapid and have immediate, clear-cut effects; and given the geckos' penchant for urban environments, we could easily mimic a "natural" situation. All we needed were enclosures supplied with insects, hiding places, water, and egg-laying sites. With these ingredients, we thought we had the right mix to look for the actual mechanism of competition as it occurs on a relatively large scale, something that is not often observable during the lifetime of your average ecologist.

Hawaii was the logical place for this next phase of our research. The house gecko invasion is still in progress in some parts of the islands, and there are many small, abandoned buildings and bunkers left over from World War II. Our first task



The authors also set up four small enclosures, above, in one of the hangars. This enabled them to make detailed observations of all interactions between the common house and mourning geckos. Left: The space between a carpet-covered piece of thin Plexiglas (blue rectangle) and the graffiti-covered wall it is attached to provides a daytime hiding place for the lizards.

was to find a site with enough identical structures for us to set up experimental populations. Local residents sometimes hinted at the existence of such structures, but no one seemed to know just where they were. In our search for the appropriate site, we contacted more than twenty military bases and government agencies in Hawaii. Because we had few contacts at these installations, we had to start from scratch. The first phone calls went something like this:

"Hello, I'm looking for abandoned structures—maybe ten to twenty of them. Can you help me?"

"Well, I'm not sure. What do you want to use them for?"

"We want to do an ecological experiment with geckos."

"What? Did you say geckos?"

"Yes, geckos. Little lizards."

From the other end of the line came sounds of uncontrollable laughter, as colleagues were being told, followed by more laughter, and the reply, "I don't think so, but I heard that there were some old bunkers somewhere. I'm not sure exactly where, though." One military representative replied, "Sir, do you have any idea how the military works?"

Undeterred, we began to ascend the learning curve, amassing a huge network of phone contacts. We considered structures of all sizes and shapes, but eventually settled on the concrete aircraft hangars at Barbers Point Naval Air Station

Geckos are master climbers. Microscopic hairs on the white, oval toe pads of this common house gecko, left, enable it to cling to almost any surface. Two eggs are clearly visible in the mourning gecko below, photographed through glass. Under ideal conditions, she may produce a new clutch in as little as three weeks.

on Oahu. The hangars are solid concrete half-domes, sixty feet across, seventeen feet high, and forty feet deep, with one end completely open. They were built to protect small aircraft from the machine-gun strafing that devastated planes on the old Ewa airstrip during the attack on Pearl Harbor. The inner walls are often covered with graffiti, some of it nearly as old as the structures themselves, which gives the hangars a distinctly urban atmosphere.

The scrub forest around Barbers Point, like much of Hawaii, also shows abundant signs of human influence. The dominant tree is the kiawe, a mesquite introduced from North America. The leaf litter is densely populated with roaches (mostly nonnative) of all sizes, a food source that supports large numbers of common house geckos. The geckos, in turn, are fed upon by mongooses and feral cats, both introduced species that reach extremely high densities in these forests. Many of our initial experimental subjects fell prey to cats at night and mongooses during the day, until we constructed small fences to keep the predators away.

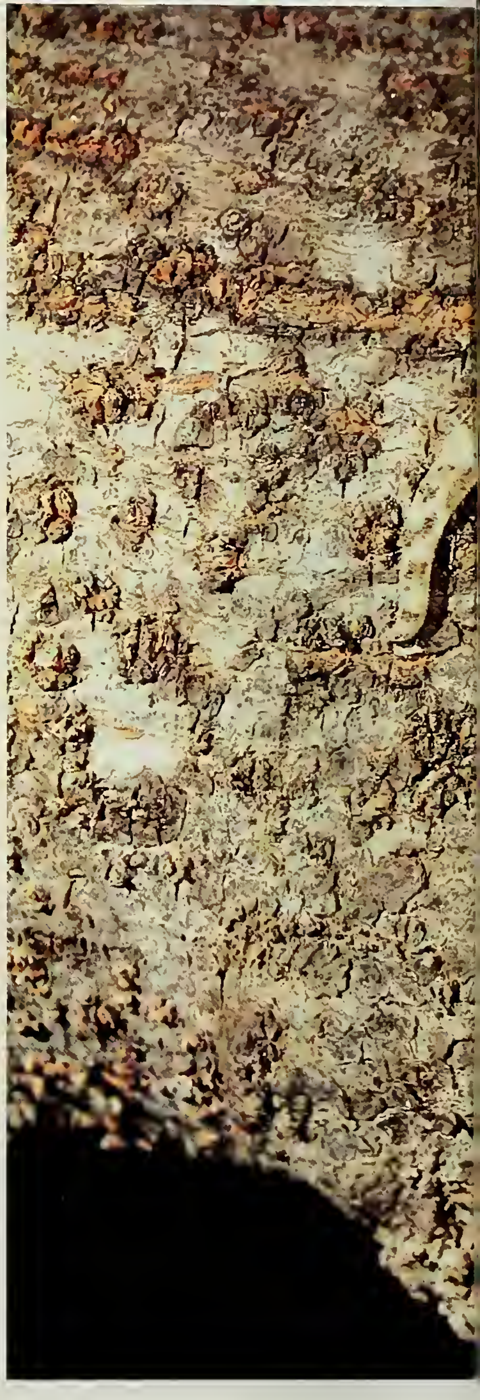
Three other introduced inhabitants pretty much round out the ecological picture at Barbers Point: termites, which eat kiawe and are eaten by geckos; scorpions; and centipedes. The centipedes are large and abundant. They eat the roaches but also prey on weak, lethargic geckos, consuming the entire body without leaving a trace. One of our less enviable maintenance duties was "centipede patrol," an attempt to reduce the numbers of centipedes trapped in our enclosures.

Our foray into urban ecology took on a distinctly military flavor when our area was periodically surrounded by armed troops decked out in full camouflage and face paint. During training exercises, they stalked and raided neighboring camps, using our hangars for cover. Particularly unsettling were the grenades, smoke bombs, and battle helicopters hovering below tree level, which would suddenly pop up and dart over the study site to deliver their armaments a stone's throw away.

Despite these distractions, we began making plans to convert eighteen hangars into separate, enclosed populations so that we could monitor the geckos closely and periodically conduct censuses. In the laboratory, we had confined geckos to their terrariums by smearing petroleum jelly along the tops of the tank walls. Gecko-proofing the huge hangars in this way would have called for hundreds of feet of the Vaseline barrier, spread by hand from fifty-five-gallon drums. Much to our relief, we learned of Fluon, a substance the entomological community uses to contain colonies of insects. A suspension of Teflon particles (the same Teflon—a product of NASA re-

A native of the Comoro Islands, near Madagascar, the gold dust gecko is a recent addition to Hawaii's already vast collection of introduced species. It is too early to tell if this new arrival will flourish and have an effect on native animals or other introduced geckos.

Mourning geckos, right, reproduce asexually. Different lineages of such clones can be recognized by the patterns on their backs.



search—that keeps your eggs from sticking to the pan), Fluon goes on like paint, and two coats will defeat even the most sticky-footed gecko.

With a satisfactory way to keep our gecko colonies intact, we began the painstaking task of renovation in the fall of 1991. We quickly learned that the skills of the urban ecologist may include painting, sweeping, hammering thousands of nails into concrete, and gaining an extensive knowledge of spray foam (to fill holes so the geckos could not escape the census). We used a variety of adhesives to secure our custom-designed gecko condominiums to the walls to provide daytime refuges for the geckos. Through a blend of creative electronics and laborious hauling of fifty-pound batteries for periodic recharging, we equipped half the hangars with a light, powered to turn on automatically at night.

There were plenty of common house geckos already inhabiting the hangars, but we decided to get all the geckos for our experiments—both mourning and common house varieties—from the same place, which meant gathering them at the few sites where mourning geckos are still abundant. (Mourning geckos continue to do well in many nonurban environments, especially in cooler, wetter, higher-elevation areas, where there may not be enough food for the larger common house geckos.) With our proven broom-and-bag technique, we collected hundreds of geckos and introduced them to the hangars. Many promptly escaped, which led to a frustrating period of design modification, more hammering and gluing, and restocking.

Eventually our efforts yielded a stable experimental system that was both gecko-proof and gecko-friendly. Now we could control all aspects of the experiment and take a completely new census of all populations (twenty geckos per hangar) every eight days. Some hangars had only one species, while others had equal numbers of both species. On census days, I moved from one end of an enclosure to the other, capturing, identifying, and measuring all geckos as they were caught fleeing their refuges. The design of the enclosures enabled daytime census taking, so a headlamp wasn't necessary, but a small broom proved indispensable for the roundup.

After a few weeks of settling in, we had results that agreed with our Fiji findings: mourning geckos became thinner and produced fewer eggs when common house geckos were around. This effect was seen, however, only in revetments with electric lights. Since insects concentrated near the lights, we theorized that the larger house geckos were monopolizing these insect-rich patches. The real excitement began when we placed a blind near the light and started to observe the geckos' interactions on the vertical wall near the light.

To our surprise, the all-female mourning geckos were very aggressive toward one another, something not seen in our earlier studies of captive individuals in terrariums. Long-drawn-out battles raged over positions near the light. Opponents made clicking and growling noises, arched their backs, turned side-to-side, and then—clamping their jaws down on each other's head or body—locked into a wrestling position. At this point, one gecko usually let go and retreated, although sometimes the fight continued, with one gecko suspending the other in midair and the dangling gecko avoiding the fall to the floor only by keeping its jaws tight on the other's head. Often both would fall to the ground—sixty body

lengths or more—and immediately begin the long climb back up to the light.

While aggressive interactions between mourning geckos were almost constant, the situation with the common house geckos was less clear. Males spent much of their time patrolling for other males and would drive them off instantly in battles similar to, but much swifter than, those of the asexual mourning gecko. In contrast, females, which are smaller than males but still larger than mourning geckos, simply foraged side-by-side at the light, feasting on their favorite foods—winged termites and moths. Males would essentially ignore females except when feeling amorous; then a brief tail-wagging, followed by copulation, would take place, often directly on the light in the middle of the feeding frenzy.

Our biggest surprise was discovering that the common house gecko was not aggressive toward the mourning gecko, even when ten to fifteen geckos of both species were crowded within three feet of the light. In fact, the most dominant mourning gecko would often attack and bite a larger common house gecko, which appeared unimpressed and seldom retaliated. Further, our censuses revealed that members of the two species commonly shared refuges during the day as well, so there appeared to be little or no direct aggression day or night. Why then does the mourning gecko fare so poorly in the company of its larger relative?

At least part of the answer was revealed in a small-scale experiment constructed solely for nighttime observation. We set up four enclosures, placing eight mourning geckos in each of the first two, and eight common house geckos in each of the remaining two. All enclosures had an electric light. After a couple of weeks, we removed the four least active mourning geckos and replaced them with four active common house geckos and watched to see what happened. The results depended on the social status of the individual mourning geckos: in each enclosure there was a dominant individual that never lost a fight with another mourning gecko and that usually sat right on the light, where insect foraging was best. These dominant

A common house gecko, below, hugs the wall as it stalks a moth. Right: The mourning gecko gets less to eat when its larger, faster relatives are around.

mourning geckos actually spent more time at the light in the presence of common house geckos, while the subordinate mourning geckos moved even farther from the light to forage in less productive areas. Foraging even a few inches from the light can make a huge difference, as insect numbers drop off dramatically with distance from the light. Since this experiment, we have learned that this subtle displacement is still evident months after the introduction of common house geckos.

We have also learned that even dominant mourning geckos are worse off in the presence of common house geckos. In spite of having access to the best seat at the insect smorgasbord, they get less to eat. This may be partly because mourning geckos spend so much time fighting with one another: time spent fighting is time not spent eating. The male common house geckos not only end their fights quickly, but they are also larger and faster than the mourning geckos and thus better at catching insects. Meanwhile, because female common house geckos forage peacefully side by side, they may be able to catch more insects. In this way, the different roles of males and females in the sexual species may give them an overall advantage over the asexual mourning gecko.

Although the aggregations of insects around lights appear to be the key feature giving the common house geckos a competitive edge, long hours of observation may ultimately lead us to conclude that there is no single dominating mechanism of competition, but many interacting mechanisms. And as the story continues to unfold, new questions come up. Can a subordinate mourning gecko, for example, eventually overcome its fear of house geckos and rise to replace a dominant individual that has died or moved on? We also hope to learn more about juveniles, which may have an especially strong incentive to stay clear of house geckos: under extreme circumstances, they themselves may become dinner for one of the large male common house geckos. We expect it will be a while before we have answered all the questions raised by these little lizards. In the meantime, we are perfecting our skills with hammer and glue. □

Broadcast Blues

I hear America singing

by Roger L. Welsch

There are some questions for which there are no answers, problems for which there are no solutions, science or not. Take that periodic, pandemic dreariness that seems to invade the human condition. We have a literary phrase for it—*mal de siècle*—but it remains generally unexplored and unexplained by science. Psychology is into its second century and yet the human mind, not to mention the cat's, is like a sealed book with uncut pages.

This morning I was still in my pajamas when I walked past our upstairs bathroom, where my daughter Antonia was getting ready for the day. "How's it going, Honey?" I asked. She didn't hear me because her radio was blaring the latest tune by Billie Bob Clintstone, " 'Despair' Ain't Quite the Word for the Misery I Feel":

> You done left me here, a cowboy broken-hearted,
> So's I done gone over to the Wal-Mart and carted
> Enough Ding-Dongs and Ho-Hos to ease my ruint ego;
> Cowgirls like you ought to be illegal...

I turned down the radio and greeted her again: "Good morning, Antonia. Nice day, huh?"

"Oh, I guess so, Dad. It's just that I'm feeling kind of down."

"Problems at school?"

"No, I don't know what it is. I just don't feel very spunky."

"Well, sorry, Hon. Hope things go better when the sun comes up."

I went downstairs and kissed Linda good morning. "Mind if I turn down your tape deck so I can watch the morning news?" She was listening to her current favorite, Rita Mae Hardtime, singing "You're a Rotten, Stinking Puke and I Don't Gotta Take It No More":

> You're ugly and you know it,
> You're a degenerate and you show it;
> You've betrayed me, lied, and ran,
> But I love you, my beer-guzzlin', womanizin', snooze-chewin' man...

"You look like you've been crying. Are you okay?"

"Yes, I'm just feeling a little blue this morning. I think maybe it's the bad weather. I just can't seem to shake it. Maybe I'll feel better once I get some coffee."

"Antonia's feeling a little down this morning too. Well, I'm going to run up to town for the mail. Be back in about a half hour."

I stepped out into a beautiful spring morning. The sun was shining and the birds singing. Down beyond the trees I could hear the sound of the river running strong and deep. I leaned up against my pickup truck and admired the morning's warmth and calm for a moment before I jumped in and started her up. Linda must have been driving the truck the day before because she had set the radio to her favorite country-western station, MZRY. Whining steel guitars. Even my amateur ear could hear that the guy who was singing needed adenoid work pretty seriously:

> I knowed that you was cheatin', but why with my best friend?
> Think I'll take my old .44 and put this all to an end;
> I'd throw myself off a bridge, end the worry and fritterin',
> But with my luck I'd get picked up by the EPA and throwed in jail for litterin'.

The dogs always howl like a fire siren when they hear songs like that, so I turned off the radio and drove into town about half speed, enjoying the day. The rattles of the loose frame and the whine of the bad steering pumps on my battered Ford seemed a major improvement over anything I could find on the radio. I was feeling pretty good by the time I got to the post office. "How's it going, Fred? Nice day, huh?" I said to the postmaster.

He turned down his radio, and I'm glad he did, because he was listening to yet another country-western station, DWNR. Darlene Dourndrear was sobbing something about

> We was beaten, starved, and flailed,
> Specially when Pop was jailed;
> Mom tried her best, but had to work us
> So hard, we didn't even get to go to the circus.

"I like Darlene," Fred said. "She sings about real things from her own life. Like me. Even though I have a great family, a good job, and live in a lovely town, I'm not feeling so good about life myself these days."

"Fred, I was reading in *Newsweek* last month that Darlene Dourndrear's real name is Margot DuPont, she attended Bryn Mawr, was a debutante, and inherited enough money to buy Poughkeepsie. Singing country music is only her hobby."

"Yeah, I heard that too, but the thing is, she sings about real things that are probably happening to other people. Like me."

"Right, Fred."

Yvonne Buchanan

"About half your mail today is from folks trying to raise money for charities, Rog. Here's the National Depression Hotline, and the Fund for the Generally Down on Their Luck, the Malaise Society for the Prevention of Cruelty to the Bummed Out, and…."

I tossed the flyers into Fred's wastebasket and drove home the long way, taking the gravel road down by the creek. As cheery as I was feeling, I couldn't help wondering what the heck was going on in the world to make everyone so troubled and beset—that mystery that science may never solve. I took the turn over toward Beecher's Pond so I could take a look at how the muskrats were coming along with their spring work.

I tried the radio again and with great good fortune found a public broadcast station buried between two high-watt country-western stations. Ah, Beethoven's Ninth, right at the point where the chorus sings Schiller's "Ode to Joy" (in German, of course, but roughly as follows):

> Joy, sweet balm of the gods, daughter
> of Elysium,
> Intoxicated with your fire, we enter
> your divine sanctuary—
> Your magic heals even the most angry
> divisions of our time.
> We are all brothers and sisters beneath
> your gentle wings…

I got into the music pretty good and pushed the pickup a little hard, but I backed off again when I got close to Beecher's Pond because there was a nice bunch of canvasback ducks sitting on the still water and I didn't want my whistling to scare them off. Finally, I couldn't contain my enthusiasm in the face of Beethoven and Schiller, so I cut loose with my locomotive-loud whistle and darn near hyperventilated myself.

The canvasbacks didn't budge—the Beethoven didn't bother them at all.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

On the Matter of Smallpox

Long before a safe vaccine became widely available, people took the risk of inoculating themselves with the smallpox virus

by Samuel M. Wilson

In April 1806, a package containing dried scabs and a vial of pus, taken from the open sores of a child in Mexico City, was sent by messenger to Manuel Antonio Cordero y Bustamante, governor of the Spanish provinces surrounding the missions of San Antonio, in what is now Texas. Governor Cordero's physicians lanced the skins of several hundred European-Americans and Indians living in the area and smeared the diluted pus and dissolved scabs into the wounds. As a consequence, these residents contracted cowpox, a disease closely related to smallpox. The antibodies they developed from the infection were to protect them from smallpox for the rest of their lives.

Distribution of the vaccine to this outpost of the Spanish Empire was due largely to the efforts of Francisco Xavier Balmis, a physician who sailed around the globe between 1803 and 1807 visiting settlements of the Spanish Empire. He was among the most courageous of souls not only because of the magnitude of his undertaking—more than 100,000 people in Latin America were vaccinated directly or indirectly through his efforts—but also because he struggled, along with many others, against the popularly held, intuitive sentiment that one did not preserve people's health by making them sick.

In a 1941 article in *The Journal of the History of Medicine*, S. F. Cook related how the Spanish king Carlos IV, terrified when his daughter contracted smallpox, had the rest of his family vaccinated after she recovered. Then, at his government's expense, he mounted the "philanthropic expedition of vaccination," putting Balmis in charge of getting the vaccine across the Atlantic to North and South America, and if possible, on to the Spanish Philippines. At the time, it was by far the largest vaccination program ever attempted. On the first leg of his journey, Balmis sailed from Spain to the Canary Islands and then to Puerto Rico.

Carrying the vaccine across the Atlantic was not easy. To vaccinate others, Balmis needed the "matter" of cowpox from the open sores of infected people—what we now know to be the active virus. That meant that he needed the pus and lymphatic fluid from people who were at just the right stage of the disease. Once infected, a victim showed no symptoms for more than a week. Aches, fever, and delirium set in about the ninth day, and at the beginning of the third week after exposure, blisters and pustules erupted.

So from the orphanages of Coruña, Spain, and surrounding areas, Balmis recruited twenty-two young boys who had never had either cowpox or smallpox. He then saw to it that they were infected with cowpox one by one as they crossed the ocean and traveled through Latin America, insuring that there would always be one person whose infection was at the right stage to pass on the disease. These twenty-two children were rewarded with the Crown's commitment to care for them until they were grown and to pay the costs of their schooling in the New World. Although little is known about how these children fared in the Americas or whether any of them ever returned to Spain, none of them died from their exposure to the disease, and they saved thousands.

Balmis's expedition was inspired by the work of the English physician Edward Jenner, who demonstrated that a patient could gain immunity against smallpox relatively safely by being infected with cowpox, a less dangerous disease that rarely proved fatal. In 1796 Jenner inoculated a child with pus taken from a cowpox sore on the hand of a milkmaid, who had caught it from an open sore on the udder of a cow. As Jenner records in a letter to a friend: "But now listen to the most delightful part of my story. The boy has since been inoculated for the Smallpox which as I ventured to predict produced no effect. I shall now pursue my Experiments with redoubled ardor."

Jenner was not the first to notice that contracting cowpox could save a person from getting a fatal version of smallpox later. It was part of local knowledge in rural Britain. Milkmaids routinely caught cowpox; afterward, they almost never contracted smallpox. But Jenner's experiments convinced the medical community that immunization was the best way of fighting smallpox and made cowpox the method of choice.

For centuries people had known that if you survived a bout with smallpox itself, you could almost never catch it again. They believed, often mistakenly, that a person who contracted smallpox through the skin, in the same way that milkmaids caught cowpox through the cuts or callouses on their hands, had a good chance of survival. They also thought that those who caught the disease from close contact with an infected person (evidently by inhaling the virus) were more likely to die or to have their bodies pitted and scarred by the pox.

Inoculation with smallpox itself, also called variolation, appears to have been common for centuries among rural populations throughout Europe, Asia, and

Africa. Correspondence in the archives of the Royal Society of London shows that Englishmen had observed the practice in China before 1700. Several generations before Jenner's experiments, a furious debate had raged among physicians and town councils in Europe and America over whether inoculation with the "matter" of smallpox should be allowed. In the 1720s, in Boston and other New England towns, a war of pamphlets and posters was waged for and against the practice.

Inoculation was a chancy procedure. About 1.5 percent of those inoculated contracted severe cases and died of the disease, and sometimes recently inoculated people, who had not been kept in quarantine while they were contagious, spread the disease to others. But smallpox was such a ghastly disease that, to avoid it, people were willing to risk death for themselves and their children. In 1634, William Bradford provided an appalling description of what smallpox did to the Connecticut Indians:

> They fell sick of ye small poxe, and dyed most miserably; for a sorer disease cannot befall them; they fear it more than ye plague; for usualy they that have this disease have them in abundance, and for wante of bedding and lining and other helps, they fall into a lamentable condition, as they lye on their hard matts, ye poxe breaking and mattering, and runing one into another, their skin cleaving (by reason thereof) to the matts they lye on; when they turn them, a whole side will flea of at once, (as it were,) and they will be all of a gore blood, most fearfull to behold; and then being very sore, what with could and other distempers, they dye like rotten sheep.

Later, Bradford notes that seeing the Indians' "woefull and sadd condition, and hearing their pitifull cries and lamantations, [the settlers] had compastion of them, and dayly fetched them wood and water, and made them fires, gott them victualls whilst they lived, and buried them when they dyed" (*Of Plimoth Plantation*).

The Puritan minister and prolific writer Cotton Mather (1663–1728) learned of smallpox inoculation from a man named Onisemus, who had been brought as a slave from Africa. Mather asked other people from Africa about the practice and found that it was commonly done there. Given the tremendous threat of smallpox epidemics in the new American colonies, he became a strong proponent of inoculation with smallpox. In his small book entitled *An Account of the Method and Success of Inoculating the Small-Pox,* printed

in London in 1722, he gave a step-by-step description of the procedure:

They make a Choice of as healthy a young Person as they can find, that has the Small-Pox of the best Sort upon him; on the Twelfth or Thirteenth Day of his Decumbiture, with a Needle they prick some of the larger Pustules, and press out the Matter coming from them into some convenient Vessel, which is to be stopt close, and kept warm, in the Bosom of the Person that carries it to the intended Patient. This Person ought rather to be some other, than he who visited the sick Chamber for it; lest he should carry the Infection in the common way, which might prove dangerous. The Patient is to have several Small Wounds made with a Needle, or Lancet, in two or more places of the Skin, (the best Places are the Muscles of the Arm) and immediately let there be dropt out of a Drop of the Matter in the Glass on each of the Places, and mix'd with the Blood that is issuing out. The Wound should be cover'd with some little Concave Vessel, and bound over, that the Matter may not be rubb'd off by the garments for a few Hours.

The dedication to Mather's book, written by J. Dummer, affirmed that the idea that inoculation with smallpox could prevent the disease was not at all new:

This Practice of ingrafting the Small-Pox has been used from Time immemorial among the Circassians, and for many Years past in the Levant, yet it is a new Thing in these Parts of Europe, and still more so in America: And as all new Discoveries, however rational in themselves, and beneficial to Mankind, are receiv'd at first with Opposition, none has met with greater than this in New-England.

In the late 1600s the practice of inoculation with smallpox had been described in Turkey and the eastern Mediterranean, and seems to have been widely used throughout Europe. Peasants called the rather dangerous practice "buying the smallpox," and most contemporary accounts noted (with either praise or contempt) that old women were the ones who knew how to inoculate people. A highly respected London physician of the early eighteenth century, for example, wrote derisively that "posterity will scarcely be brought to believe that a method practiced only by a few Ignorant Women, amongst an illiterate and unthinking People should...be received into the Royal Palace" (cited by R. P. Sterns, "Remarks upon the Introduction of Inoculation for Smallpox in England," *Bulletin of the History of Medicine,* 1950).

Even though these practices existed, no one at the time understood why the disease spread or why inoculation seemed to work sometimes. Classical Greek physicians like Hippocrates based their treatments on the premise that diseases arose from imbalances in the four basic humors, a theory still current in the seventeenth century. The humors were blood, yellow bile, black bile, and mucus (the sanguine, choleric, melancholic, and phlegmatic humors, respectively). Disequilibrium among these humors was thought to cause the skin to erupt with the sores of smallpox, but just what caused the disequilibrium was unclear.

The celebrated Muslim physician Abu Bakr Muhammad ibn Zakariya Razi (better known as Rhazes) who lived from about A.D. 865 to 925, built upon the humoral theory of disease by suggesting that within each of us there is a case of smallpox (and many other maladies) waiting to boil out of our blood and erupt into open sores on the skin. His "innate seed theory" also involved the belief that changes in atmospheric conditions could trigger epidemics. Even into the nineteenth century this theory was probably the most widely accepted explanation for why people got sick (little wonder that Spanish conquistadors were so obsessed with the risks of staying in the "unhealthful airs" of the American tropics).

While these humoral and innate seed explanations were widely accepted, a remarkably modern theory was proposed as early as 1546 by an Italian from Verona, Girolamo Fracastoro (1478–1553). In his *De Contagione et Contagiosis Morbis et Eorum Curatione,* he argued that *seminaria*—in effect small seeds of disease—could be transmitted from person to person through a variety of means. Each disease (he addressed measles and smallpox specifically) had its own unique *seminaria*. Fracastoro also spent much of his career studying "the French disease"—syphilis.

After the Dutch businessman and amateur lens grinder Anton van Leeuwenhoek (1632–1723) refined the single-lens microscope in the seventeenth century, the existence of microscopic organisms was demonstrated, and Fracastoro's theory of *seminaria* was revived in a new form. About the same time, a theory attributing the spread of smallpox to animalcules (minuscule animals) was also widely discussed. The smallpox virus was so minute, however, that it was not detected with the early microscopes. Thus for a time such explanations remained in doubt. In some of his writings, for example, Cotton Mather called the agents of the disease "animalculae" of uncertain character, but in others he called them "miasms" (miasmas, or vapors).

"The venomous Miasms of the Small Pox," Mather wrote,

> entering into the Body, in the Way of Inspiration, are immediately taken into the Blood of the Lungs; and, I pray, how many Pulses pass, before the very Heart is pierc'd with them? And within how many more they are convey'd into all the Bowels?

In an elaborate discussion he compared the body to a fortress, and argued that if the miasms came in through the lungs, they were deadly, but if they had to fight their way through the "Out-Works of the Citadel," the person's skin and muscle, they could be defeated.

But where did the miasmas come from? In the early 1700s, no one knew. The English physician Thomas Sydenham (1642–1689)—whose opinions, so powerful in the inoculation debates in Boston in the 1720s, were well known to Mather—believed that "noxious miasms" issuing forth from the earth into the atmosphere were responsible for epidemics. Sydenham's 1666 treatise, *Methodus Curandi Febres,* was based on this "miasmic theory" and was the most influential reference available in its day.

The treatments that doctors used to treat smallpox, however, had little to do with the theories of how the patient got the disease: Rhazes believed that imperceptible atmospheric changes brought illness and advocated "heat therapy" to warn the body of an invisible threat and drive away the infectious humors. Fracastoro believed that *seminaria* had somehow entered the patient's body and went along with Rhazes in hoping that heat might drive them out again. Sydenham's theory did not contribute to the understanding of how people got smallpox, but rather to its clinical treatment. He argued that heat therapy with steam and blankets was the worst treatment since it exacerbated the sores and helped to spread the contagion.

From the idea that diseases were spread through microscopic seeds or animalcules, it was a small step to understanding that different diseases were brought about by very different animalcules. "The Pestilence can never breed the Small-Pox, nor the Small-Pox the Measles...any more than a Hen can a Duck, a Wolf a Sheep, or a thistle Figs," wrote physician Thomas Fuller in his 1772 *Pharmacopoeia Extemporainea.* Bacteriology and modern "germ theories" of disease were based on these concepts, and were further refined in the 1870s by pioneers like Robert Koch and Louis Pasteur.

Only in the twentieth century have scientists begun to leam how viruses invade the human organism and how the immune system can learn to identify and repel new threats. We now believe that vaccination with cowpox confers immunity to smallpox because the two are related members of a family of viruses, which also includes monkeypox, camelpox, buffalopox, and whitepox.

Although Jenner's method of vaccination became widespread, smallpox was extremely difficult to eradicate. Immunity cannot be passed on from one generation to another, so each new generation is vulnerable to smallpox epidemics. In a letter to Jenner, Thomas Jefferson wrote, "Yours is the comfortable reflection that mankind can never forget that you have lived. Future nations will know by history only that the loathsome smallpox has existed." He was right about the first part, but it took nearly two centuries to make the second part a reality (see *Smallpox and Its Eradication,* by Frank Fenner et al. [Geneva: World Health Organization, 1988]).

Just as Francisco Xavier Balmis needed a human chain of orphaned children to maintain an active cowpox infection during his Atlantic crossing, smallpox must spread from person to person in order to continue to exist naturally. By 1977, after a decade of intensive vaccination led by the World Health Organization, the virus was unable to find its next victim. Although a cure for smallpox had never been found, the disease was conquered.

Yet the virus is still maintained in laboratories for study. (In 1978, it escaped from a British laboratory, several people were infected, and one of them died.) Samples of the virus still sit in freezers in Moscow and at the Centers for Disease Control in Atlanta. Should we now keep it alive? The DNA sequences of several strains of the virus are known, and, if need be, the virus could be reconstructed using nucleotide sequences from other organisms. Thus, some argue that we should destroy the remaining samples. But if we keep them frozen, we may be able to learn more from them later. As one of the oldest and wisest of human adages says, keep your friends close and your enemies closer. The World Health Organization is expected to make the final decision in May 1995.

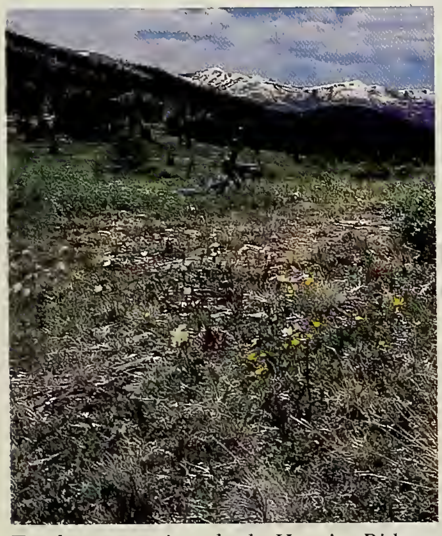
Samuel M. Wilson teaches anthropology at the University of Texas at Austin.

Hoosier Ridge, Colorado

by Robert H. Mohlenbrock

The Continental Divide, the Rocky Mountain watershed that separates westward- from eastward-flowing rivers, generally runs north–south. Locally, however, it may run in more of an east–west direction. One such place is Hoosier Ridge, in central Colorado, a 11,600- to 13,200-foot-high crest whose slopes support tundra vegetation—stunted, cold-adapted species characteristic of high altitudes and high latitudes. Located in Pike and White River National Forests, it is most easily reached by taking Colorado Highway 9 to Hoosier Pass and hiking eastward.

To the west of Hoosier Pass lies the Mosquito Range, consisting of calcareous rock, or limestone. Hoosier Ridge, to the east, is essentially granitic. The most abundant vegetation lies on the moister, north-facing slopes of the ridge, where depressions are snow covered even in late spring or early summer. Here the dominant plants are tufted hair grass, with its threadlike leaves, and golden avens, a wildflower in the rose family. Other plentiful wildflowers are sky pilot, which is a handsome, blue-flowered member of the phlox family, and the densely tufted, pink-and-white-flowered whiproot clover, a species confined to granitic soil. In small, sheltered areas where the most snow and



Tundra vegetation cloaks Hoosier Ridge, on the Continental Divide. Right: A view northeast from Hoosier Pass.
Christine S. Beck

Don Kurz

Hoosier Ridge
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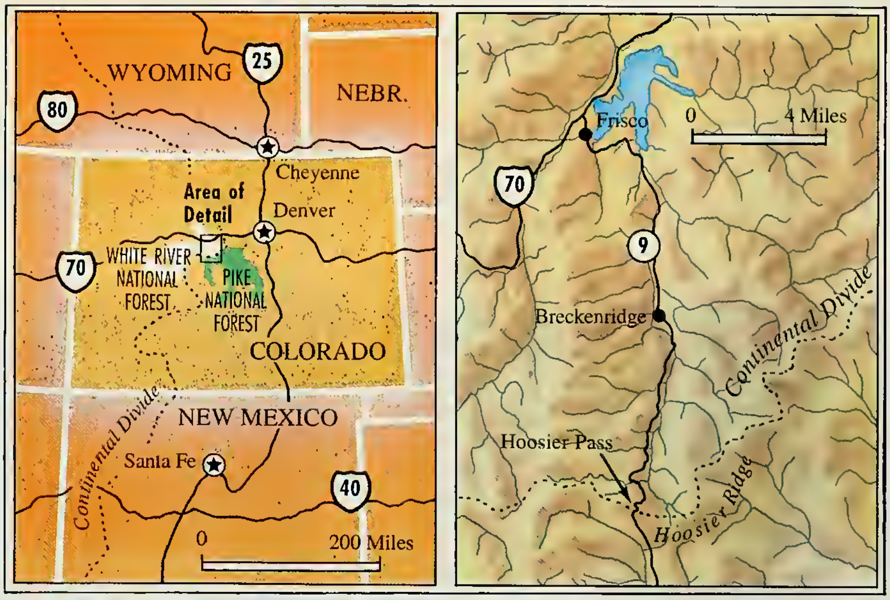

water accumulate, miniature, stunted trees of subalpine fir and Engelmann spruce grow alongside the equally diminutive gray willow.

South of the Continental Divide, on the warmer but drier south-facing slopes, the same golden avens and a grass known as kobresia prevail at the higher elevations, while tufted hair grass grows lower down, punctuated by shrubby, dwarf, gray willows and barren-ground willows. Scattered throughout the plant communities on both sides of Hoosier Ridge are areas of bare rock, bare soil, and permanent snowfields, where vegetation other than mosses and lichens cannot survive.

What makes Hoosier Ridge so significant botanically are some dozen rare alpine species that grow in isolation from their closest relatives. The most celebrated of these is Penland's alpine fen mustard, a three-inch-tall plant discovered on Hoosier Ridge in 1935 by botanist C. William Penland. Since that time, it has been found in a few other areas, all along a seventeen-mile stretch of the Mosquito Range crest. This rare plant grows in sphagnum-covered fens above 12,500 feet, habitats confined to small, flat ledges kept moist by surrounding, persistent snowfields. Such snowfields exist along the north slopes of this east–west portion of the Continental Divide; where the watershed runs north–south, the slopes are more exposed to the drying effects of the prevailing winds.

A tiny plant with minute, white flowers and shiny, heart-shaped leaves borne on slender stalks, Penland's alpine fen mustard is most closely related to Edwards' arctic mustard, found more than one thousand miles away in the Arctic Circle. Another species in the same genus grows in Asia. Because of its rarity, Penland's alpine fen mustard is being considered for the Federal Endangered Species list.

Other rarities include globe gilia, a sweet-smelling member of the phlox family, whose creamy white flowers form in a dense cluster at the top of a six-inch-tall stem. Although this species was first discovered in 1872, it has never been found anywhere in the world except on southern slopes along Hoosier Ridge and in the Mosquito Range.

Sea pink grows on rocky slopes in the Hoosier Ridge tundra at elevations above 12,000 feet. Its spherical clusters of pink flowers rise above a basal tuft of very narrow leaves. The only other places in the world where this species is found are in Canada's Northwest Territories and in Mongolia.

Weber's saussurea grows in the Beartooth Mountains of northeastern Wyoming and in the Belt Mountains of Montana, as well as in the tundra of Hoosier Ridge. It has purple flowers and is protected from the bitter conditions by woolly leaves and bracts. Its closest relative, another kind of saussurea, lives in Saskatchewan.

These and other rare wildflowers can be damaged or destroyed by trampling or other disturbance. Colorado has already acted to designate 925 acres of Hoosier Ridge as a State Natural Area. Since this zone falls within National Forest land, however, full government protection will not be assured unless the U. S. Forest Service designates this a Research Natural Area as well.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U.S. national forests.

Sea pink grows in northwest Canada, in Mongolia, and on Hoosier Ridge.
Wendy Shattil and Bob Rozinski

A Change of Scenery

by Gail S. Cleere

In Plato's *Republic,* Socrates asks Glaucon, "Shall we make astronomy our next study? What do you say?" Glaucon responds, "Certainly, a working knowledge of the seasons, months, and years is beneficial to everyone, to commanders as well as to farmers and sailors." Socrates replies: "You make me smile, Glaucon. You are so afraid that the public will accuse you of recommending unprofitable studies."

While Socrates was not overly concerned about the utility of astronomy, today these "unprofitable studies" depend upon public support. Without public funds, the space probes to the planets would never have been launched and the Hubble Space Telescope would not be sending back its remarkable images of the distant stars and galaxies. There is, however, a very practical reason for spending tax dollars on astronomy. At the United States Naval Observatory in Washington, D.C., and the Royal Greenwich Observatory in England, the precise determination of the seasons, months, and years is the order of the day—not to mention a few other fundamentals such as the positions of the stars. This month, the Naval Observatory's *Almanac* tells us that the autumnal equinox will occur at 2:19 A.M., EDT, on September 23, and with that the season changes and fall begins.

You won't actually *see* anything at that moment. The nighttime constellations won't suddenly shift positions, and the leaves on the trees won't all suddenly fall down. But what will happen that morning (and this is something you can see) is that the sun will rise exactly in the east and set later that day due west. The equinoxes are the only two days of the year when this occurs. And if you happen to be on the equator, the sun will appear directly overhead at noon.

The equinoxes seem to have great appeal to the general public. An enduring legend—one that causes phones to ring incessantly at observatories across the country—is that at the precise moment of the equinox an egg can be made to stand on its end. It's not true, but the *St. Louis Post-Dispatch* reported one year that "hundreds of New Yorkers gathered at Ralph J. Bunche Park across from the United Nations at the moment of the spring equinox to sings songs, smoke controlled substances, chant slogans and balance eggs—all in the cause of world peace."

England's Stonehenge, rising majestically on the Salisbury Plain, draws mobs not only at the solstices but also at the equinoxes. Cullen Murphy, editor, essayist, and creator of the Prince Valiant cartoon series, described the regular contingent of neo-Druidic types that gather there for these occasions as a good-sized horde of "crank antiquarians, hardy perennials on the British scene, with their exotic opinions, their ample supplies of stationery, and the propinquity to a free press," as well as "trailer-based itinerants, of questionable cleanliness and with no visible means of support, whose purpose in life appears to be (in the words of press accounts) to alarm local authorities." Ancient sites in Egypt and South America also have monuments aligned to the equinox, and they, too, attract their astronomical enthusiasts.

Besides the phases of the moon, equinoxes and solstices are perhaps all that most people know about cyclic patterns of the sky. The changing sky, however, is repetitive and therefore easy to comprehend. Because the earth rotates on an axis that points almost directly toward Polaris, all the constellations move counterclockwise around the North Star, taking one full day to complete a circle. This means that when we are looking south at night, the constellations move from east to west by about 15° an hour. And, because the earth also revolves around the sun, the night side of our planet is facing a slightly different direction each night. This causes the scenery to change constantly, albeit slowly. The constellations rise about four minutes earlier each day, so new ones are always appearing on the horizon as the seasons advance, bringing us the diversity of the night sky throughout the year.

Earth's orbit around the sun also means that on the autumnal equinox, from our perspective, the sun moves to a place in the sky (in the constellation Virgo) that is 180° away from the fundamental reckoning point for all objects in the sky—the vernal equinox, which it reached six months earlier. Together, the equinoxes and the solstices are the four great events that shape the year.

Because our system of celestial coordinates is based on these points in the sky, knowing precisely when and where the equinoxes and solstices occur is vital. Without this information, we couldn't figure the exact positions of the stars, large telescopes could not be aimed, ships could not use celestial navigation, and spacecraft could not be launched with any hope of reaching their destination.

THE PLANETS IN SEPTEMBER

Mercury is visible very low in the western sky and sets within about forty-five minutes of sunset throughout September. A very thin crescent moon will be well to the left of Mercury and slightly higher in altitude on the 7th. On the 20th, Mercury will be just below and to the right of Spica in Virgo, and on the 21st, the two will appear side-by-side, with Mercury just off to the star's left (Mercury will appear twice as bright as Spica). You'll get a better glimpse of Mercury if you use a good pair of binoculars. On the 26th, it will arrive at greatest eastern elongation, or angular distance from the sun (26°).

Venus, too, is in the west at sundown, not far behind the planet Mercury, standing about 9° above the horizon at midmonth. It reaches its brightest magnitude (–4.6) on the 28th, shining with a brilliance unequaled by any other planet. On the evening of the 8th, look for a striking conjunction of Venus with a slender crescent moon low in the west–southwest sky soon after sundown.

Mars rises after midnight not far from the twin stars Castor and Pollux in Gemini. Mars rides well above and to the left of the gibbous crescent moon during the predawn hours of the 1st. On the 30th, the orientation will be similar, but the separation between the moon and planet will be even greater.

Jupiter is nearing the western horizon at sunset, setting about two hours later. On the 9th, look for bright Jupiter off to the right of the waxing crescent moon. Venus, a much more brilliant object, will be just below them.

Saturn finally reaches opposition on the 1st, which means that it will rise when the sun goes down and stay with us all night long. Saturn is currently in the faint constellation Aquarius and will be easy to pick out as the night progresses. On the 17th and 18th, the nearly full moon will pass Saturn. On the 17th, the moon will be above and to the right of Saturn, and on the 18th it will stand above and to the left of the planet.

Uranus and **Neptune** are just left of the 3d-magnitude star Albaldah in Sagittarius, a relatively dim area in this constellation. On the 14th, watch for the first-quarter moon passing overhead.

Pluto, which is currently in the constellation Libra, sets before midnight. At +13.7 magnitude, about a thousand times fainter than the faintest naked-eye star, the tiny planet remains invisible, except to those with very large telescopes.

The **Moon** is new at 2:33 P.M., EDT, on the 5th; first-quarter moon is at 7:34 A.M., EDT, on the 12th. The full moon occurs at 4:00 P.M., EDT, on the 19th, and is called the harvest moon because it is the closest to the autumnal equinox. The moon reaches last quarter on the 27th at 8:23 P.M., EDT.

Gail S. Cleere lives in Washington, D.C., and writes on popular astronomy.

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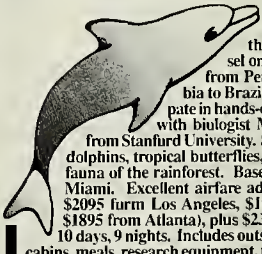

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Chaotic Cuddlers

What are downy, month-old emperor penguin chicks to do when the temperature drops to –30° F? To survive, they must maintain a body heat of 96° F, or 126° warmer than the air. Have they gone into a huddle to discuss the matter, or does misery want company? Neither, it turns out. Clumping in tightly packed groups of one hundred or more helps the birds stay warm, protects them against cold winds, and reduces an individual's rate of heat loss by 25 to 50 percent.

Emperors, the largest species of penguins, spend their entire lives at sea or on the antarctic sea ice, the world's coldest habitat. Yet the chick clusters, known as crèches, often generate sufficient heat to melt an oval depression in the ice. If a deeper hole forms near the center, some chicks may fall in or become trapped. Therefore, the crèche shifts its location often, pocking the ice with craters. Even later in life, as many as 6,000 emperors may crowd together during blizzards and severe winds—but adults huddle in orderly groups, while the chicks crowd together every which way.

Giant petrels may threaten young emperors that are left alone on the ice while their parents forage in the open ocean. Predators, however, tend not to bother chicks when they huddle in large crèches. During October and November, the antarctic summer, groups of chicks begin to congregate at the edge of the sea ice. Eventually, when a chunk breaks off to form a floe, the young penguins raft northward to warmer seas to begin their lives as adults.—*R. M.*

Photograph by Graham Robertson
AUSCAPE International

At the American Museum of Natural History

Empires Beyond the Great Wall

Opening Friday, September 16, in Gallery 77, a new exhibition, "Empires Beyond the Great Wall," traces 3,500 years of the history and culture of steppe empires, culminating in the reign of Genghis Khan. Among the exhibits are a gold funerary mask and more than 200 other works of art, including ornamental plates and vessels, porcelain, and gold saddle ornaments. Also featured are a full-sized re-creation of a recently excavated frescoed tomb, a yurt, and examples of Mongol women's traditional clothing. The exhibition will run through Sunday, November 27.

Genghis Khan: Hero or Villain?

Nearly 800 years after Genghis Khan's death, opinions about his character and history vary. Was he a warrior-king who promoted cultural and commercial interchanges between East and West, a brilliant military commander, or a bloodthirsty barbarian? Morris Rossabi, professor of history at City University of New York, visiting professor at Columbia University, and author of *Kubilai Khan: His Life and Times,* will talk about the life and career of Genghis Khan and his successors. The lecture, in conjunction with the exhibition "Empires Beyond the Great Wall," will be presented on Thursday, September 22, at 7:00 P.M. in the Kaufmann Theater. Call (212) 769-5606 for ticket availability.

Stories and Songs of the Jewish New Year

On Tuesday, September 13, at 7:00 P.M. in the Main Auditorium, rabbi and folksinger Shlomo Carlebach and master storyteller Diane Wolkstein will celebrate, with story and song, the Jewish New Year, a ten-day period that concludes with Yom Kippur, the Day of Atonement. Call (212) 769-5606 for information.

American Museum: The Inside Story

The American Museum of Natural History celebrates its 125th anniversary this year. Two-hour walking tours, highlighting aspects of the Museum's vast natural history collection of more than 30 million speci-

Museum visitors in 1937 admire a turn-of-the-century reconstruction of a Brontosaurus *sporting a* Camarasaurus *skull (which was found in a Wyoming quarry near the giant skeleton). The dinosaur—now renamed* Apatosaurus*—will be reunited with its correct skull in the new fossil hall scheduled to open next spring.*
AMNH

ens and artifacts, will take place on Friday, eptember 9, at 6:00 P.M., and Saturday, Sep-mber 10, at 4:00 P.M.

On Saturday, September 17, at 11:00 A.M. id 1:00 and 3:00 P.M., Randall Schuh, cura-r in the Department of Entomology, will ad a special tour for the hearing impaired of e department that contains the world's rgest insect collection. Free with admission, urs begin in the second-floor Rotunda near e information desk. Call (212) 769-5562.

IRTH CONTROL IN THE ANCIENT WORLD

According to Galen, the foremost physician classical antiquity, pomegranates, willow, id date palm were the most effective contra-ptives. On Thursday, September 29, John ddle, a professor of history at North Car-ina State University and author of *Contra-ption and Abortion from the Ancient World the Renaissance,* will speak on what has en recovered of these ancient botanical rth control practices. The talk will be given 7:00 P.M. in the Kaufmann Theater. For ore information, call (212) 769-5606.

ROYAL TOMBS OF SIPÁN: A LECTURE SERIES

From the richest pre-Columbian royal tomb ever discovered, archeologists have been able to determine the sophistication of the Moche people's metallurgy. Two Tuesday-evening lectures will be given in conjunction with the exhibition, "Royal Tombs of Sipán." On September 27, Craig Morris, curator of South American Archeology at the Museum, will place the Sipán exhibition in historical and scientific context. On October 4, Heather Lechtman, professor of archeology and ancient technology at M.I.T., will compare the metallurgy practiced in Andean South America with that of the Old World. The talks begin at 7:00 P.M. in the Kaufmann Theater, and tickets for both lectures are $20. For more information, call (212) 769-5310.

These events take place at the American Museum of Natural History, Central Park West at 79th Street in New York City. The Kaufmann Theater is located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

Naturalist-author-photographer **Fred Bruemmer** (page 26) has studied the people and wildlife of the Arctic for thirty-seven years. A native of Latvia, he emigrated to Canada in 1950, at the age of twenty-one, and eventually settled in Montreal. Soon after, he began his forays to the north, traveling in an umiak, a skin boat of ancient design (*see* "Last of the Umiaks," *Natural History,* October 1992). His insatiable curiosity has led him to investigate ancient Eskimo ruins, the hunting habits of skuas, and the behavior of narwhals. But his greatest, most long-standing interest has been observing the lives of the seal clan. "Pinnipeds fascinate me," says Bruemmer, "and to study them, I have traveled extensively, from Lake Baikal in Siberia to Namibia, Antarctica, and Australia." *Natural History* has published the results of several of these studies, including those of walruses (November 1977), Hooker's sea lions (July 1983), Cape fur seals (November 1988), and hooded seals (July 1990). Among Bruemmer's many books on the natural history of the north, the most recent are *The Narwhal: Unicorn of the Arctic Sea* and *Arctic Memories: Living With the Inuit,* both published in 1993 by Key Porter Books, Toronto. For additional reading on seals, he recommends Judith King's *Seals of the World* (Ithaca: Cornell University Press, 1983).

For **David C. Houston** (page 34), the sight of a vulture probing the eye sockets or entrails of a carcass is as notable as that of an owl silently homing-in on a furtive rodent or an eagle swooping down on a rabbit. Specialists in locating and devouring the dead, vultures are adept at earning their living. Their feeding habits and ecological roles within various habitats have intrigued Houston since 1969, when he began a field study in the Serengeti. He has since studied Old World vultures in many parts of Africa and in India. For the past decade, his work on the forest vultures of Central and South America has enabled him to compare the dynamics of scavenging in New and Old World vultures. Houston, who received his doctorate in zoology from Oxford University in England, is now a senior lecturer in zoology and a member of the applied ornithology unit at Glasgow University in Scotland. His interest in the ecology of scavenging birds extends to part-time scavengers closer to home—ravens, crows, and hawks. Living in the west of Scotland, Houston often does fieldwork in the highlands, conveniently located right on his doorstep. For more information on vultures, readers can consult *Vulture Biology and Management,* edited by Sanford R. Wilbur and Jerome A. Jackson (Berkeley: University of California Press, 1983). Houston's chapter, "The Adaptations of Scavengers," in *Serengeti: Dynamics of an Ecosystem,* edited by R. E. Sinclair and M. Norton Griffiths (Chicago: University of Chicago Press, 1979) deals with African vultures.

Although she originally went to Amazonia to study howler monkeys, **Katharine Milton** (page 44) has returned again and again to Brazil to record the lives of little-known groups of human inhabitants. She is especially concerned

with how different indigenous peoples use the forest's resources, and with the nutritional components of their tropical plant foods and the significance of local food taboos. She continues to be interested in howler monkeys, conducting research in Panama on their interactions with a host-specific parasite, the howler monkey botfly. Among her side interests are neotropical parrots, in whose social nature, elaborate communication system, and high-quality plant food diet she perceives a parallel with primates. Milton is a professor of physical anthropology at the University of California at Berkeley. For additional reading she recommends "Hunting and Hunting Magic Among the Amahuaca of the Peruvian Montaña," by Robert L. Carneiro (*Ethnology,* vol. 9, no. 4, October 1970); "Frogs That Sweat —Not Bullets But a Poison for Darts," by J. S. Bainbridge (*Smithsonian,* January 1989); and "Making Magic," by Peter Gorman (*Omni,* July 1993).

Australian seabird ecologist **Graham Robertson** (page 78), says he considers the emperor penguin "the most remarkable animal I have experienced in twenty years as a wildlife biologist." He admires the bird's behavioral and physiological adaptations to the Antarctic, and "its wonderfully phlegmatic nature in the face of such extreme cold." Athletic as well as scholarly, Robertson represented Australia in the world championship pentathlon during the mid-1970s, then spent fourteen years studying red kangaroos and zone vegetation for the New South Wales National Parks and Wildlife Service. He recently completed his doctoral thesis on emperor penguin ecology based on a fourteen-month study at Australia's Mawson Station in Antarctica. To photograph the chick crèche at the Auster emperor penguin colony for this month's "Natural Moment," Robertson used a Nikon FM 2, with a 105mm f 2.5 lens and Kodachrome 64 film. "I had to be fast," he recalls, "because if I stayed too long, my presence would have caused the crowd of chicks to break apart and lose precious heat." When not in the field, the forty-five-year-old Robertson lives in Hobart, Australia, with his wife, two young daughters, and "a mob of horses."

Ken Petren (page 52) is a postdoctoral researcher in the Department of Biology at the University of California at San Diego. Coauthor **Ted J. Case** (left) is a professor in the same department. Case has studied ecological invasions in many parts of the world, including much of the South Pacific. Petren's initiation into the urban ecology of the introduced geckos came after he had spent three years studying birds in the pristine rain forests of southeast Peru. Both men believe that ecological research in urban areas may lead to insights not obtainable in wilder ecosystems and that, with human influence now penetrating all corners of the globe, such insights may prove especially valuable in any discussion of how to manage or repair "natural" systems. They hope, however, that all ecological work in the future will not by necessity be urban ecology. The two have traveled extensively between islands in the Sea of Cortés, investigating the evolution of body size in iguanine lizards. Petren, when not caught up at Gecko Central (their Hawaiian headquarters), pursues another passion: "Elvis biogeography," the study of the Elvis phenomenon in order to predict where and when the King will next be sighted. For more on some of the theory behind the authors' research, readers can take a look at *Community Ecology,* edited by Jared Diamond and Ted J. Case (New York: Harper and Row, 1985). Readers thinking of heading to Hawaii might want to get ahold of Sean McKeown's *Hawaiian Reptiles and Amphibians* (Honolulu: Oriental Publishing Company, 1979).

NATURAL HISTORY

10/94

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COVER: Do high levels of a protective enzyme help the Pacific tree frog survive under conditions that threaten other amphibians? Story on page 32. *Photograph by Kerry T. Givens; Bruce Coleman, Inc.*

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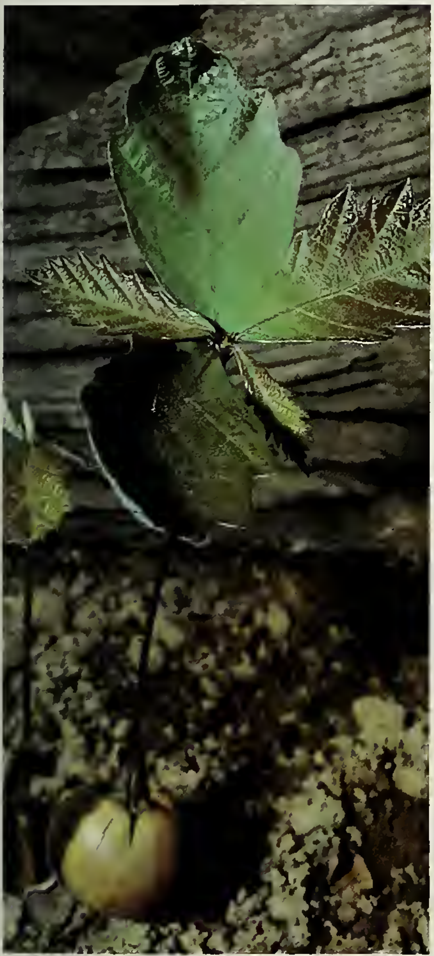
Vol. 103, No. 10, October 1994



UNIVERSAL'S FRANKENSTEIN

In "The Monster's Human Nature" ("This View of Life," July 1994), Stephen Jay Gould quite wrongly describes the portrayal of the monster in the 1931 film *Frankenstein*. Karloff's monster is, as Mary Shelley intended, "susceptible of love and sympathy." The monster's tragedy is the ignorance of those around him, not a "genetic" predisposition to evil. If Gould sees differently, that's understandable. The film's prologue, in which a "host" tells us that Frankenstein is creating evil, was intended to placate church and civic groups. Although the film soon contradicted its own stated theme, the dodge worked and apparently is still working sixty years later. Copernicus and Galileo on occasion tried similar diversions (which fooled no one) and are given points for cleverness. Let's give the same nod to Universal Studios, which at least succeeded in its subterfuge.

FRANK J. DELLO STRITTO
Bensalem, Pennsylvania

FIVE GIANTS

Edwin Colbert, in "Four Giants of Paleontology" (May 1994), omits any mention of Walter Granger, who was a key, but often unheralded, member of the Department of Vertebrate Paleontology during Henry Fairfield Osborn's reign at the American Museum.

Granger provided the department with an endless stream of mammal and dinosaur fossils, along with superb field notes—data that formed the basis of the research Colbert writes about.

Granger, with William Diller Matthew, worked to produce the famous Bridger Basin studies that led to Matthew's monograph on ancient carnivorous and insectivorous mammals. Their collaborative studies on the evolution of fossil horses and Lower Eocene mammals are paleontological classics. Granger also directed the posthumous completion of Matthew's San Juan Basin monograph, which Colbert cites as Matthew's "crowning work."

After his death in 1941, the American Museum eulogized Granger as "one of the great paleontologists...and a field collector [without] peer."

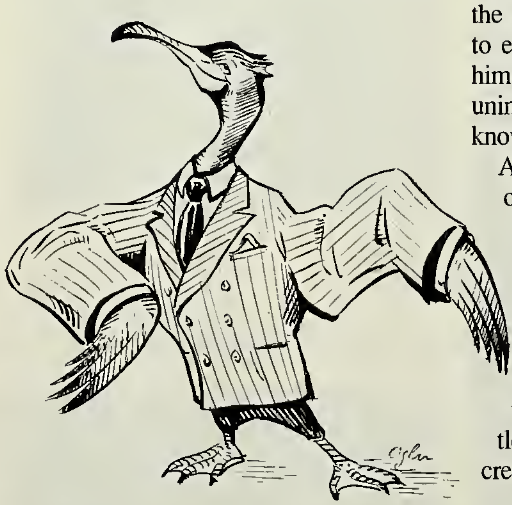
VINCENT L. MORGAN
KATHERINE R. MORGAN
The Granger Papers Project
Durham, New Hampshire

DOUBLE *What*?

We note with interest the mention of a new bird species, "the double-breasted cormorant," in Robert H. Mohlenbrock's "Bonaventure Island, Quebec" ("This Land," May 1994), but we were disappointed that it was not illustrated.

May we inquire whether it looks something like this?

WENDY SHADWELL, *Birder*
LAIRD OGDEN, *Artist*
New York, New York



The "double-crested cormorant" became "double-breasted" through an editorial error.—*Ed.*

GOD'S SCIENTISTS AND OTHERS

I very much appreciated Christopher Toumey's piece ("God's Own Scientists," July 1994) for its revealing but respectful view of a creation science discussion group and for his personal observations at the conclusion. I am both a Christian of Lutheran flavor and a scientist firmly convinced of evolution and teaching its mechanisms. I know I am one of many similarly inclined, faithful Christian lay people.

So much discourse on antievolution (including in your pages) runs roughshod over the very real needs of people to make an organic unit of their spiritual and physical lives. It is refreshing to find a kindred spirit in Toumey.

STUART A. SMITH
Ada, Ohio

Eugenie C. Scott, in "The Struggle for the Schools" (July 1994), mentions that evolved forms of the creationist argument continue to assault the courts of our land. Stephen Jay Gould, in his wonderful essay "Justice Scalia's Misunderstanding" (October 1987), pointed out that Justice Antonin Scalia, one of the dissenters from the 1987 Supreme Court decision striking down the Louisiana equal time act, holds the mistaken belief that evolution claims to explain the origin of life. Gould asks himself how Justice Scalia could "be so uninformed about the basic state of our knowledge?"

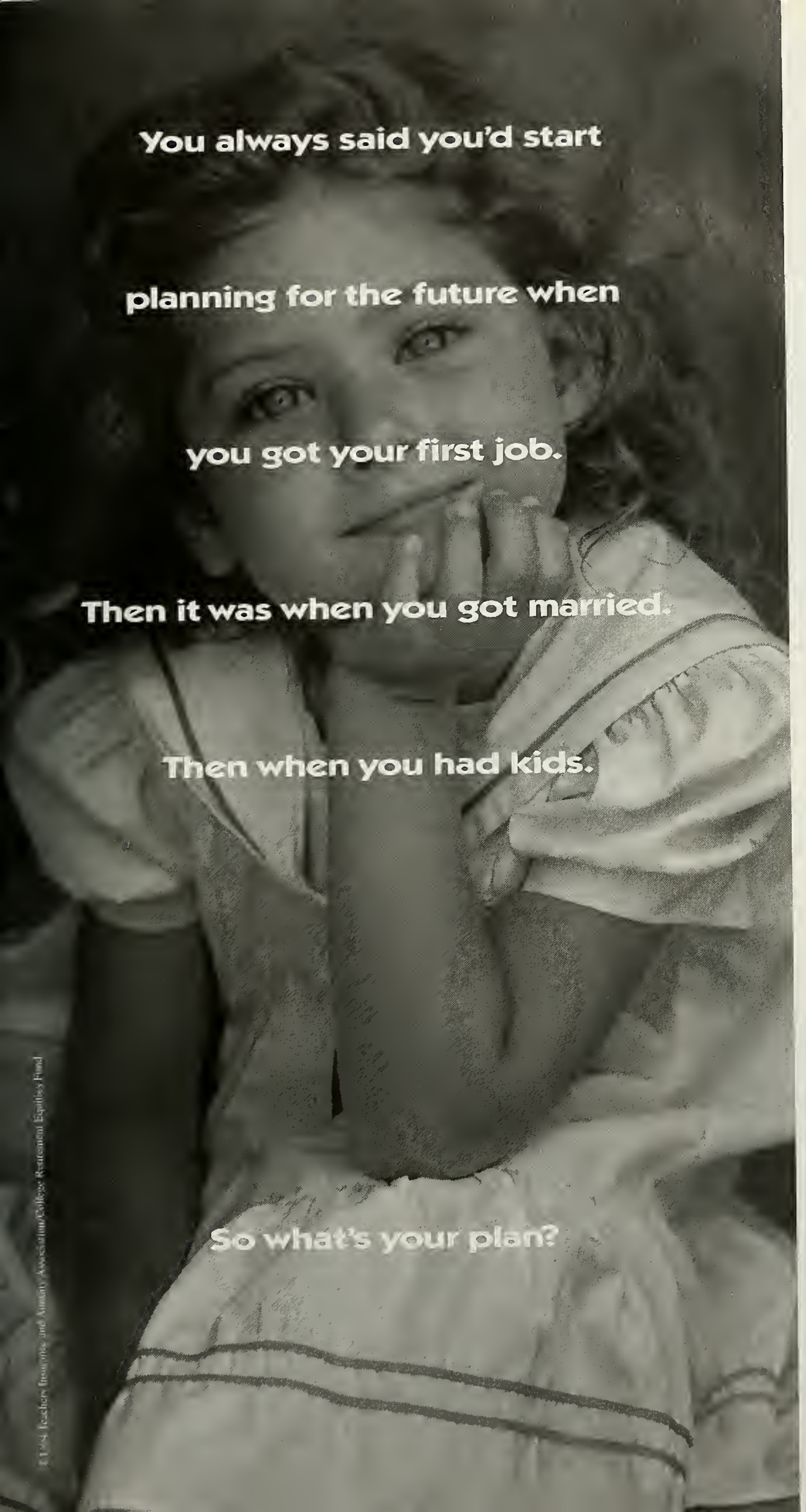
As scientists, we should do a better job of explaining that evolution is the study of how life changes *after* it originates. If a United States Supreme Court Justice doesn't understand evolution, then what chance does a public school teacher have of producing a generation of educated people who will not have to go to court to battle the next evolutionary stage of the creationist argument?

MATTHEW MACISAAC
Mahwah, New Jersey

GLANCING AT AN ECLIPSE

Stephen Jay Gould's August 1994 essay ("Happy Thoughts on a Sunny Day in New York City") was as delightful and thought provoking as we have come to expect, but I have an important cavil. It is dangerously untrue to say that we can "look directly at the sun for a moment without danger." Whether a "moment" is a minute or a few seconds doesn't matter; we will simply burn holes in our maculas.

EDWARD J. PRENNER, M.D.
Forest Hills, New York


You always said you'd start
planning for the future when
you got your first job.
Then it was when you got married.
Then when you had kids.
So what's your plan?
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Jove's Thunderbolts

Comet Shoemaker-Levy 9 was a pat on the back for science

by Stephen Jay Gould

One night in 1847, and partly to escape her parents' noisy dinner party, Maria Mitchell of Nantucket lugged her telescope to the roof of the Pacific National Bank (where her father worked as chief cashier) and discovered a comet five degrees from Polaris, the North Star. For this discovery, the first comet found by an American woman, Mitchell received many honors, including a gold medal from the king of Denmark and election, as the first woman ever so recognized, to the American Academy of Arts and Sciences in Boston.

(Mitchell's certificate of election still hangs on the wall of her birth house in Nantucket, and it is a painful and ambiguous thing to see. Two statements are crossed out: the printed salutation "Sir" has been altered to "Madam" by hand, and the designation of "fellow" has been replaced by "honorary member," meaning that Mitchell had not been granted voting privileges. The document is signed by Harvard's great professor of botany Asa Gray, later one of Darwin's stoutest supporters. More than ninety years would pass before another woman won election. Today, I am happy to report, for I am a member and the Academy's house lies just around the corner from my own, people of all shapes, sexes, colors, and backgrounds cavort in one of the oldest intellectual societies of our land with liberty and justice for all.)

A few other women excelled in astronomy during this age of nearly total exclusion for one sex from science, but most, like Caroline Herschel, gained access as sisters, wives, or daughters of male astronomers. Maria Mitchell, however, succeeded on her own. Her father, William, was an amateur astronomer, and he did rate ship's chronometers for part of his living (a vital activity in the great whaling port of Nantucket at a time when ships measured longitude by maintaining extremely accurate clocks on board). But William Mitchell was not a professional scientist, and he worked primarily as head cashier of a bank when Maria discovered her comet.

Maria Mitchell, who earned no college degree for want of opportunity, became the first female professor of astronomy in America, serving from 1865 to 1888 at Vassar College, where she vigorously promoted scientific education at America's premier college for women. She received honorary doctorates from Columbia, Hanover, and Rutgers. Maria Mitchell died in 1889. In 1902, family members and former students established the Maria Mitchell Association in Nantucket, an organization dedicated to astronomical observation and science education.

I gave the annual address at the Maria Mitchell Association on July 21, 1994. In lieu of an honorarium, I made one strong request: after my evening talk, I wanted to see Jupiter through Maria Mitchell's own telescope (not the original instrument of her 1847 discovery, for this machine resides in the Association's museum, but through the still-functioning five-inch refractor made by Alvin Clark of Boston and given to Mitchell in 1857 by an organization called the Women of America).

Call me foolish if you wish, but a professional lifetime as a paleontologist and evolutionist has led me to view connectivity and return to original sources as imbued with the highest value, both intellectual *and* ethical (or aesthetic). I wanted to see Jupiter that night through Maria Mitchell's telescope because she had been the great American pioneer in cometary discovery, and Jupiter, at that very moment, was being bombarded by a succession of more than twenty fragments from Comet Shoemaker-Levy 9. I was unable, I must confess, to make out the scars on Jupiter's surface through Maria Mitchell's telescope, for Jupiter had already set behind a clump of trees. But I waited patiently and finally saw the flicker of Jupiter among the leaves. Mission accomplished. Meanwhile, all the astronomical enthusiasts of Nantucket crowded around the adjacent computer, watching the latest information about Shoemaker-Levy 9 coming in on Internet from all over the world.

In March 1993, my friend and colleague Gene Shoemaker (world's expert on the geology of impact structures), along with Carolyn Shoemaker and David Levy, discovered a linear array of about twenty cometary fragments stretched out in a trail nearly 125,000 miles long near Jupiter. They determined that Jupiter's gravity had pulled the entire comet apart when it had passed within 60,000 miles of the giant planet's surface. They also recognized—and now the excitement started—that all these fragments would inevitably crash into Jupiter in July 1994.

What a show, and what timing—precisely at the twenty-fifth anniversary of Neil Armstrong's first step upon the lunar surface. But an epidemic of cold feet then gripped the astronomical community, and the spin doctors of diminished expectation raised their voices high. The impact would yield results of great scientific value to be sure, they said, but viewers shouldn't expect to see much of any visceral interest. The fragments would probably be pulled farther apart and burn into nothingness in the high reaches of Jupiter's atmosphere. Or, given our ignorance of cometary composition, perhaps the fragments contained little more than dust and ice—not the right


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(True or False)*
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* False. The Dimetrodon was actually an early relative of mammals that lived in North America some 280 million years ago.
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stuff to punch holes in a planet's surface. One commentator predicted impact flashes so small and fast that each would appear in no more than a single camera pixel from the *Galileo* spacecraft, poised near Jupiter. The semiofficial report in the July 14 issue of *Nature*, just a week before impact, went forth under the headline: "Comet Shoemaker-Levy 9: The Big Fizzle Is Coming."

I certainly understand the reasons for toning down expectations. The general ethos of science tends toward caution, especially before the fact—and astronomers had been badly burned twice in recent years, both times by comets, as Halley and Kohoutek truly fizzled relative to most people's expectations. In addition, scientists are still reluctant to grant much of a role to catastrophic agents as major players in the recent history of the solar system, and particularly the earth and its life. A whimper from Shoemaker-Levy 9, rather than a bang, would surely reinforce this old prejudice.

All the world now knows that Shoemaker-Levy 9 put on the show of shows, vastly exceeding all publicly expressed expectations, both in stunning visual terms and in a plethora of scientific data that will keep us busy for years to come. I am writing this essay on the weekend after the bombardment and cannot begin to make any sensible assessment of causes and reasons, but we need no more than a quick review of phenomena to illustrate the difference between a rave and a fizzle.

All twenty-one fragments of Shoemaker-Levy 9 hit Jupiter along a single latitude of the southern hemisphere. Impacts occurred during the Jovian night and were not directly visible from the earth. But Jupiter rotates in about nine hours, rather than our twenty-four, and the sites of impact moved quickly into our view, forming a chain of circular scars, some larger than the entire earth! We do not know how long the scars will last, or even whether their darkness records shadow or substance (blackened carbon or some forms of sulfur, have been suggested). We do not know how far the fragments penetrated Jupiter, or even what penetration means on a gaseous planet that has no discrete rocky surface—but white-hot gasses, presumably from the planet's interior, erupted through holes of impact "in great fireballs as if from cosmic cannons" (to quote Malcolm W. Browne, the *New York Times*, July 26).

The largest chunk of comet, called Fragment G, hit Jupiter at 3:30 A.M. on July 18, producing a flash and fireball that briefly exceeded the entire planet in brightness (so much for single pixels!). Fragment G may have plunged nearly forty miles into Jupiter's atmosphere. A plume of superheated gas then erupted and rose to a height of 1,300 miles above the impact site, yielding some of the most spectacular pictures of the entire week.

I have read various estimates of the size and power of this largest strike, but taking the most conservative figure reported in major scientific journals and newspapers (*USA Today*, July 22), Fragment G measured some 2.0 to 2.5 miles in diameter and hit with an explosive energy of about 6 million megatons of TNT. Taken all together, the twenty-one fragments, by this same estimate, released an equivalent of about 40 million megatons of TNT—or some 500 times the power of all the earth's nuclear weapons combined.

This comparison to the megatonnage of our entire nuclear arsenal sent shivers up my spine and brought forth from my memory a similar figure, which recalled the key debate within paleontology during the past decade, and also crystallized the various themes for this essay. In 1979, Luis Alvarez and his collaborators first published their theory that a large extraterrestrial object, a comet or an asteroid some six miles in diameter, struck the earth at the end of the Cretaceous period 65 million years ago, thus triggering one of the five great mass extinctions of life's history—the latest and, parochially for us at least, the most important, as this event wiped out dinosaurs and gave mammals their opportunity.

I knew nothing about the physics of impact at the time, and I remember harboring some strong initial doubts about the efficacy of such an event. I did understand how a crashing body might be decidedly unpleasant for a *Tyrannosaurus* caught directly in the path of descent, but why should an object only six miles across wreak such havoc upon a planet with a diameter of 8,000 miles? I expressed my naïve skepticism to Alvarez, a Nobel Prize-winning physicist who had worked on the Hiroshima bomb and certainly understood such matters, and he shut me up with the following estimate: a bolide six miles in diameter would strike the earth with 10,000 times the megatonnage of all the earth's nuclear weapons combined. Fragment G, in comparison, was a pipsqueak—yet this object tore an earth-sized hole in Jupiter and produced a fireball equal in brightness to the entire planet. If Fragment G could so impact giant Jupiter, shall we doubt the catastrophic effect of a much larger strike upon our much smaller planet?

When Alvarez and company first proposed their radical hypothesis of catastrophic extinction, paleontologists almost to a person rejected the idea with ridicule and vehemence. (Both for the decent purpose of allowing you to judge my argument more fairly, and for an utterly base motive of bragging in retrospect, I must confess my biases and place myself among the "almosts" as one of Alvarez's rare paleontological supporters from the start.) Since then, however, evidence for impact has accumulated to virtual proof—first the initial discovery of iridium at high concentration in strata marking the extinction (for iridium is almost absent in indigenous sediments of the earth, but present at normal cosmic abundances in comets and asteroids); then the finding of shocked quartz in the same sediments (for this unusual form of a common mineral can be generated, so far as we know, only by high pressures associated with impacts, and not by any internal process known to act at or near the earth's surface); and finally the apparent "smoking gun" itself, a massive crater of the right age, and up to 200 miles in diameter, off Mexico's Yucatán Peninsula.

In the light of such overwhelming support for impact, opponents of catastrophic extinction have generally retreated to the fallback position that a comet or asteroid did indeed strike our planet, but that the extinction had other earth-based and more gradualistic causes (granting, at most, the terminal and ineffective role of *coup de grâce* to the great explosion). This argument fails no logical test, but I would be mighty surprised if it succeeds. Coincidences do occur, but we should not seek their complexities as favored modes of explanation. Why argue that a bolide hit the earth just when a great extinction happened to be occurring for other, unknown reasons, when the bolide itself can do the work required?

When such strong hostility greets such an interesting theory, and continues with substantial vigor even after the theory has been effectively validated, we must seek deeper causes rooted in general philosophies and methodologies. No theoretical preference has been so strong and dominating in the earth sciences as Charles Lyell's doctrine of uniformitarianism—a complex set of ideas centered upon the notion that current and observable causes, acting at characteristically minute and gradual rates, can produce all the grand effects of the earth's history by accumulating their tiny increments through the immensity of geological time. To produce the Grand Canyon over time's vastness, erode the Colorado River valley grain by grain. To populate the earth with novel fauna, extirpate old species and evolve new forms one by one, so that any observer at a moment in time would notice nothing. At most, under the uniformitarian perspective, climates and topographies might occasionally alter at especially high rates, promoting more species deaths than usual over a relatively short interval—but never a truly catastrophic mass extinction. Both Lyell and Darwin strenuously argued that so-called mass extinctions must spread out over several million years (with the appearance of suddenness arising as an artifact of an imperfect geological record) and that the causes of such episodes could only reside in an intensification of ordinary processes.

This issue of uniformitarian versus catastrophic change stands as one of the grand questions of science, for the debate pervades so many disciplines and bears so strongly upon some of the most profound puzzles of our lives. Consider just two of the deep issues. *The nature of change itself:* Is human culture, life, the physical universe indefinitely mutable and subject to continuous and usually insensible change (the uniformitarian view), or does stable structure characterize most forms and institutions, with change therefore concentrated in rare and rapid episodes of transition between stable states, often initiated by catastrophic disturbances to which existing systems cannot adjust? *The nature of causality:* Do large effects arise as simple extensions of small changes produced by the ordinary, deterministic causes that we can study every day, or do occasional catastrophes introduce strong elements of capriciousness and unpredictability to the pathways of planetary history?

William Glen, a distinguished geologist and historian of science at the United States Geological Survey in Menlo Park, California, has spent the last fifteen years working in the interesting area of scientific revolutions in the making. He first wrote a fine book on what most people have judged as the greatest revolution in geology since the discovery of time's vastness in the late eighteenth and early nineteenth century: the development of the theory of plate tectonics and the consequent validation of continental drift (*The Road to Jaramillo*, Stanford University Press, 1982). During the past decade, Glen has been tracing the movement of Alvarez's asteroid from heresy to orthodoxy, and chronicling the regrowth of catastrophist thinking in general, particularly in the context of discussion about mass extinction (see his recent book *The Mass Extinction Debates: How Science Works in a Crisis*, Stanford University Press, 1994).

Glen surprised the hell out of me one day by saying that he regarded the debate over catastrophic mass extinction as potentially more important in the history of science than plate tectonics. Much as I might like to accept such an argument, I initially cringed and strongly objected, for I had so long accepted the virtual mantra among geologists that no reformulation could be more profound than plate tectonics—the earth's surface broken into thin plates in motion, with new crust welling up at oceanic ridges, spreading out to form and push the plates and eventually descending back into the earth at subduction zones.

But Glen reminded me of the famous statement by Freud that I have often quoted in these essays: the most important scientific revolutions have, as their only common feature, the dethronement of human arrogance from one pedestal after another of previous convictions about our own cosmic importance. At the very least, great revolutions must alter some central concept about our lives or the workings of the universe. Plate tectonics radically changed the physics of the earth, but few fundamental tenets of human life or physical causality were altered thereby. We believed, before, that the earth's crust could move up and down to form mountains and ocean basins; we know, after, that planetary real estate flows laterally as well.

But catastrophic impact theory, as Bill

Glen argued with great force, has much broader implications if it can be established as a generality in the mechanisms of planetary history, and not just as an explanation for a few peculiar events, including the Cretaceous–Tertiary extinction. For if impacts shape much that matters in geological time, then catastrophism becomes at least coequal with a previously dominant or nearly exclusive uniformitarianism—and all our views on the nature of change and causality must be revised. Moreover, these potential revisions speak to the tensions that Freud identified as both scary and liberating—for catastrophism supports themes that many of us would rather not acknowledge about chance and unpredictability in the evolution of all lineages, including our own. No random bolt from the blue 65.3 million years ago, no extinction of dinosaurs, no mammalian dominance, no human life today—whereas the uniformitarian perspective harmonizes much better with traditional ideas of a gradual rise to inevitable success by mammals.

As a believer in connectivity with initial sources, as illustrated earlier by my tale of Maria Mitchell's telescope, I decided then to excavate the original definition of geology's great dichotomy in an attempt to understand the importance of catastrophism's resurgence and the role of Shoemaker-Levy 9 as a contribution to the argument. The terms "uniformitarian" and "catastrophist" were coined by William Whewell, England's leading philosopher of science, in a review of the second volume of Lyell's *Principles of Geology* (published in the *Quarterly Review,* vol. 47, for March and July, 1832). Whewell wrote:

> Have the changes which lead us from one geological state to another been, on a long average, uniform in their intensity, or have they consisted of epochs of paroxysmal and catastrophic action, interposed between periods of comparative tranquility. These two opinions will probably for some time divide the geological world into two sects, which may perhaps be designated as the *Uniformitarians* and the *Catastrophists.*

G. P. Scrope, one of Lyell's leading geological colleagues, read Whewell's review and wrote to Lyell suggesting that the dichotomy might easily be resolved or compromised:

> As to the dispute he speaks of, which I know has now and then raged pretty warmly between you as a Uniformitarian and the Catastrophists I do not see any but an imaginary line of separation between you. It is only a dispute about degree, a plus or minus affair; a little concession on either side will unite you in perfect cordiality.

"I think this may explain the disappearing frog population."

But Lyell firmly rejected this mediation and stuck by Whewell's division. He wrote to Whewell, quoting Scrope's opinion and then adding his own support for a dichotomy of principle:

> On this point I cannot budge an inch for reasons to be developed in v. 3 [that is, the third volume of his *Principles of Geology,* published the next year in 1833]. It is of course a question of probability to some extent in the present state of our knowledge, but I consider it a most important question of principle, whether we incline to the probabilities as seen in the last 3000 years or possibilities which I hold to be uncalled for by any overwhelming evidence.

In other words, Lyell writes, why invent unseen (and catastrophic) forces when slowly acting present causes, observed for more than 3,000 years, suffice to render all geological events in the fullness of time.

The intensity of Lyell's rhetorical support for uniformitarianism may best be judged in the famous first chapter of volume 3, composed in the light of Whewell's review and its codified dichotomy (later editions of the *Principles of Geology* dispersed the material of this short, seven-page chapter into earlier parts of the book). Catastrophism, Lyell argues, must be rejected as a speculative system that will degrade geology to a playground of untestable conjecture, whereas uniformitarianism, firmly grounded in observation of present causes, will establish geology as a rigorous, empirically based, mature science. Lyell was a lawyer by profession and a brilliant writer by avocation. No one has ever matched him for persuasive prose:

> Never was there a dogma more calculated to foster indolence, and to blunt the keen edge of curiosity, than this assumption of the discordance between the former and the existing causes of change. It produced a state of mind unfavorable in the highest conceivable degree to the candid reception of the evidence of those minute, but incessant mutations, which every part of the earth's surface is undergoing.... We hear of sudden and violent revolutions of the globe, of the instantaneous elevation of mountain chains, of paroxysms of volcanic energy.... We are also told of general catastrophes and a succession of deluges, of the alternation of periods of repose and disorder, of the refrigeration of the globe, of the sudden annihilation of whole races of animals and plants,


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and other hypotheses, in which we see the ancient spirit of speculation revived, and a desire manifested to cut, rather than patiently to untie, the Gordian knot.

I have long regarded Lyell's argument as deeply unfair in principle, however brilliant in rhetoric—yet he prevailed for nearly 150 years, thus restricting the range of geological hypotheses. He argues that we should prefer direct observation to any form of inference (labeled as "speculation" in his rhetoric). Catastrophism then loses by unjustly blinkered definition, rather than by fair test. If the catastrophic model has any validity, then natural forces of paroxysmal intensity occasionally impact the globe to great and sudden geological effect, but at very infrequent intervals. If the waiting time between such events usually amounts to millions of years—as must be the case for large impacts producing global mass extinctions—and if human observation of present processes has been limited to only a few thousand years, what chance do we have of ever observing such catastrophes over the course of human history?

We cannot reject plausible forces because we do not see them directly. Most of science relies upon ingenious and rigorous inference, not passive observation alone. We were quite confident about many phenomena—atoms and black holes among them—before we developed technologies for their visualization. How can we ridicule a force that we have not seen for 3,000 years, when good theory predicts that its momentary episodes of operation should be separated by many millions of years? Why are we so loath to accept global catastrophes as major actors in the history of the earth and life when we have seen the commoner events of smaller scale that occur so much more frequently? The Tunguska object, the cometary fragment that exploded 28,000 feet above Siberia in 1908, flattened a thousand square miles of forest and would have produced the greatest disaster in human history had it struck anywhere near a population center. The Tunguska object, by best estimate, measured about 300 feet in diameter. Such small particles hit the earth with waiting times of hundreds to thousands of years and can therefore be studied as rare historical events. May we not extrapolate from these to the much rarer giant bolides, with diameters measured in miles, that must strike the earth with waiting times of tens to hundreds of millions of years, but with massive global effects and with sufficient frequency to shape much of planetary history in a half dozen or so good strikes during the tenure of multicellular animal life?

Lyell had lobbied hard to secure Whewell's review in the most prestigious of British journals. But Whewell, while praising the book and fairly describing Lyell's system, then argued that Lyell had been unduly restrictive in his uniformitarian rigidity and that the case for catastrophism remained open in principle. In other words, the issue must be settled by scientific study (observation *and* inference), not by a priori definition. Whewell wrote in defense of catastrophism, and in the next paragraph following his definitions:

> It seems to us somewhat rash to suppose, as the uniformitarian does, that the information which we at present possess concerning the course of physical occurrences, affecting the earth and its inhabitants, is sufficient to enable us to construct classifications, which shall include all that is past under the categories of the present. Limited as our knowledge is in time, in space, in kind, it would be very wonderful if it should have suggested to us all the laws and causes by which the natural history of the globe, viewed on the largest scale, is influenced—it would be strange, if it should not even have left us ignorant of some of the most important of the agents which, since the beginning of time, have been in action; of something, in short, which may manifest itself in great and distant catastrophes.

We didn't need Shoemaker-Levy 9 to validate catastrophism by the most direct route of overt observation. We were fortunate indeed to witness any event at such a scale during the few hundred years that technology and enlightened understanding have combined to give us tools of comprehension. The Cretaceous bolide had pretty much proved itself through inferences based upon fossilized results a few years before Jupiter fractured Shoemaker-Levy 9 into its twenty-one murderous bits.

Shoemaker-Levy 9 must therefore represent an indulgence of nature—a gift to us, a reward for our proper use of scientific inference to validate at least one global catastrophe (the terminal Cretaceous bolide) against all the prejudices of our unformitarian training. Nature almost seemed to be saying to her wayward and insignificant child on earth: "You did it the right and hard way, by difficult inference; well done, thou good and faithful servant; now I will show you a cosmic catastrophe directly, and for free, even though such an event might plausibly not occur for many thousands of years."

All this, of course, is metaphor. I have not become an addlepated New Ager, and I do not believe that nature operates by anything akin to our notion of intent. We just caught a break with Shoemaker-Levy 9. But do consider two more truly wondrous events in closing. Shoemaker-Levy 9 hit Jupiter precisely to the day of the twenty-fifth anniversary of our first human landing on the moon. Is nature returning the compliment of our respectful foray into her realm by teaching us something fundamental about her ways at such an auspicious moment? Let us also, and finally, thank nature for setting this display on a distant and giant planet that can easily bear the shock, and not closer to home where a similar event might relegate us to the fate of the dinosaurs.

"I understand there's a newt in the House of Representatives."

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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Adiós, Locos?

An ancient mollusk is disappearing—and not at a snail's pace

by Louis H. DiSalvo

Along the 3,000-mile coastline from mid-Peru to southern Chile lives a gray marine snail, with a flattened, bowl-shaped shell about as big as your hand. It lives on rocks that may be just below the water's surface or as much as ninety feet down. Known to science as *Concholepas concholepas,* the snail is commonly referred to, for obscure reasons, as the "loco." Humans are the loco snail's only serious predator; they wade, swim, and dive in hordes to capture every visible specimen. In 1980, loco divers were selling more than 26,000 tons of these mollusks annually. During the past decade, however, the catch has dwindled to a small fraction of its former tonnage. As the snail becomes rarer, the value of its meat keeps rising. Now snail hunters will risk arrest and even the disappearance of the species in their quest to satisfy the market's demands.

I first saw a loco a little more than a dozen years ago when I first arrived in Chile. It was on a plate in a restaurant in Santiago; nearby on the table sat a loco-shell ashtray. Since a moratorium on collecting them was imposed in 1985, locos are not listed on restaurant menus. However, if you whisper to the waiter, you can probably get two illegally obtained, undersized prizes on a bed of lettuce with mayonnaise ("locos mayo") for about ten American dollars. Illegal trade is brisk. In late 1991, a clandestine packing operation was raided near Santiago and more than 70,000 locos were seized. When the ban on taking these snails was lifted for fifteen days in 1988, several fishing ports in southern Chile experienced a brief "gold rush." Loco divers and their boatmen made and lost fortunes in a few days. Some had sailed more than a thousand miles to the last richly productive loco grounds. During those two weeks, more than 12,000 tons of locos were exported.

Tons of discarded loco snail shells litter the shores of a coastal bay in Valdivia, Chile. Despite the mollusk's protected status, poaching remains common.
Ricardo Carrasco-Stuparich

Apparently, divers had been at work for months establishing underwater stockpiles in anticipation of opening day.

Locos constituted the world's largest gastropod fishery in the early 1980s, when they were being exported as "Chilean abalonelike shellfish" to Asian markets. This label arose only from commercial necessity; locos may taste somewhat like abalone, but the resemblance is superficial. Although both are flat-shelled gastropods, abalone shells have perforations and pearlescent colors that locos do not. The loco's shell is drab inside and out and is usually covered with barnacles.

A much older evolutionary group, abalones have diverged into numerous species around the world, while the genus *Concholepas* has only one living species, the loco, which lives only on the South American temperate west coast. Nor do locos behave like abalones. The latter are tranquil grazers on marine algae, whereas locos are persistent carnivores that attack barnacles, several species of mussels, and tunicates (sea squirts). Years ago, I found that locos would even attack and consume California abalones, which were being tested for introduction to Chile. Predation by locos is one possible explanation for the inability of abalones to colonize temperate South American waters.

The loco thrives in nutrient-rich local waters, where phytoplankton proliferate. Barnacles, mussels, and tunicates thrive on these microscopic plants and are in turn consumed by the locos. When unmolested, the locos become populous. Older fishermen remember when they were plentiful everywhere, but today large numbers can be observed only in specially protected research reserves.

Abalone larvae hatch from yolk-filled eggs; they settle to the bottom of the sea in a few days and begin to feed. In contrast, locos reproduce by depositing hundreds of white, inch-long capsules on subtidal rocks; each capsule contains thousands of fertilized eggs, which develop into tiny shelled larvae, or veligers. After about one or two months' incubation in the capsule, the veligers are released into the ocean where they swim about freely, using their swimming organ (velum), which also serves as an efficient device for trapping phytoplanktonic food. A few months after the larvae have left the capsules, miniature locos begin to appear on wave-swept rocks. Although Juan Carlos Castilla, of the Catholic University in Santiago, and his associates had described the later phases of the loco's natural history in numerous papers published from 1976 to the present, little was known about the animal's free-swimming planktonic stage or its life as a tiny bottom feeder.

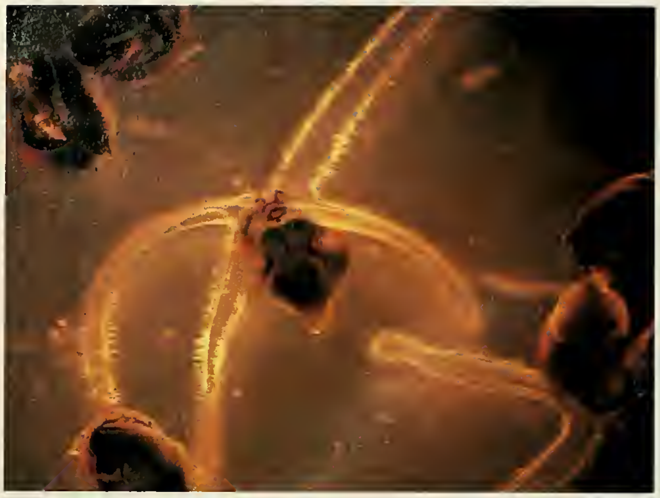
Widely dispersed in the plankton, maturing loco larvae seek surface waters, and are difficult to capture or study. They apparently move to varying depths as they react to light and food—which also makes them a difficult target for predators. Laboratory observations suggest that when the tiny larvae are getting ready to settle, they swim near the ocean floor, out of reach of plankton nets. Before my lab studies, no one could recognize loco veligers among the other molluscan larvae, since no one had cultured locos to obtain reference specimens. Two-millimeter-sized snails are not easily spotted on boulder-strewn shores carpeted with marine life and pounded by waves.

During the mid-1980s, I was able to culture locos in the laboratory for the first time and watch the larvae grow from three-tenths of a millimeter into ready-to-settle specimens nearly two millimeters in length. To raise them took about a hundred days of patiently changing water, feeding the larvae with microalgae, and treating them with antibiotics to prevent bacterial diseases from killing them. Out of half a million larvae, I was able to shepherd seven into settling, but only one grew into an adult loco.

Now I had reference specimens that allowed me to recognize the loco larvae in mixed plankton samples taken from the ocean. Also, I learned that the older, ready-to-settle larvae migrate to the sea surface, and are probably blown ashore by spring winds, as are other planktonic larvae of shore-dwelling invertebrates. From the top of their foot, advanced loco larvae produce a byssal thread that they use to suspend themselves from the water surface much as spiders hang from a ceiling. They can also abandon the thread and crawl upside down on the surface film, as do many freshwater snails. In strongly agitated water, where the swimming organ could be damaged or the byssal thread lost, larvae envelop an air bubble with their foot to keep from sinking. Such behavior may allow planktonic larvae to travel great distances and survive rigorous wave action. Although feeble swimmers, they need only move up or down to catch an ocean current or wind-driven surface slick that may carry them for hundreds of miles. Myriads have been lost at sea, leaving only the best evolved navigators to float to shore.

Based on my laboratory observations, I designed a net for collecting surface plankton and was surprised and pleased to find three ready-to-settle loco larvae among my first catch. Although the larvae were normally scarce (averaging only one for each half mile the net was towed), I soon had enough to observe their metamorphosis in the laboratory.

I set up some aquariums with naturally encrusted stones and a strong water current vigorously agitated with compressed air to simulate a wave-swept coastline. The larvae drifted around, trailing byssal thread "lassos," which soon caught on the rocks or even on actively bubbling air stones. When pulled to a rock by its elastic thread, a larva would adhere to the surface using the suckerlike extension of its foot, made sticky by mucus. Because their small size allows them to anchor within a clinging microlayer of water, they could then crawl around on the rock, unaffected by wave motions. If the rock surface was biochemically attractive for an extended stay, they would absorb the parachutelike velum in as little as two hours. When they found the surface noxious or uncomfortable, however, they extended the velum and were lifted away on the currents to seek a different settlement site. Many molluscan larvae are capable of delaying their



Two eyes and a mouth are positioned near the center of a drifting loco larva, from which four armlike lobes radiate. Blown to shore by winds, loco larvae eventually settle on rocks.

Photographs by Louis DiSalvo

An adult loco, its shell covered with barnacles, perches on an intertidal rock. Two white "teeth" on the shell's right edge are used to harvest rock-bound barnacles for food.

metamorphosis until they have found an appropriate surface.

A few years ago, Daniel Morse, of the University of California at Santa Barbara, demonstrated the intricate biochemical interactions between abalone larvae and their settlement surfaces. Although the loco is not closely related to abalones, some of the same principles probably apply. Larvae of several invertebrate species are known to be attracted by chemical substances emitted by their own species or by prey. Following such chemical trails enhances their chances of finding food or mates.

Recently metamorphosed locos begin their postlarval lives scraping microalgae off the rocks, as do abalone. Later, however, they will become carnivores. Also, in contrast to abalone, which begin to enlarge their shells shortly after they settle and begin feeding, the locos pass through a further set of changes. During their algal feeding period, which lasts from one to several days, the young loco's shell changes from transparent to a deep chestnut brown. This pigmentation leaves the shell at least five times more resistant to breakage than it was during the loco's planktonic odyssey; this added strength enhances its chances of surviving the rough surf.

Once pigmented, the tiny locos become carnivorous, attacking prey with exquisite precision. Their exclusive prey at this stage are barnacles their own size, which they neatly drill with a special scraping organ, the radula. Aided by a slightly acid secretion to soften the prey's shell, the radula is used both to drill and to extract meat. Like other predatory gastropods, such as the cassids (*see* "Murder and Mayhem in the Miocene," *Natural History*, August 1991), they bore a hole a few tenths of a millimeter in diameter and then insert a trunklike proboscis and rasp to scrape out the prey from the inside. Only after they have begun to feed in this manner do they begin to deposit a white fringe of definitive adult shell.

During the first sixty days, the insatiable little locos grow to ten millimeters long, eating their way through as many as five barnacle species on the rocks, without discriminating among them. The little brown larval shell remains embedded in the larger, permanent adult one as a relic of the snail larvae's oceanic voyage and rocky landing. As long as the young locos feed on barnacles, the shell remains white. If they are fed mussels, which they accept with gusto upon reaching ten millimeters in length, the new shell turns black.

Many young locos I have collected in the field have white shells, while older ones are dark—suggesting a history of first feeding on barnacles, then switching to mussels or other prey. Upon settling onto rocky bottoms, the postlarval snails have pitch-black body tissues, but change to almost pure white during their first two weeks of bottom dwelling. Two months later, the body begins to take on the gray pigmentation of adults. Their inconspicuous coloration helps protect the elusive young; in addition, many of them often hide within empty barnacle shells.

My long-term research goals in Chile include learning how to save locos from extinction and perhaps one day reseeding their natural beds for managed commercial harvesting. Although many people are tempted to buy the banned loco meat, I sense a rising concern for conservation among the Chilean people. Recently, the Chilean legislature passed a new fisheries law that should begin to protect the country's coastal resources. In the Caribbean, parallel efforts are being made to protect and culture the queen conch (*Strombus gigas*), a once-plentiful mollusk that has suffered similar declines in population in recent years.

There is a certain enchantment in imagining the tiny loco larvae floating on their "gossamer wings" for hundreds or even thousands of miles, surviving the multiple perils of their frail life in the planktonic soup, as they have for millions of years. Loco fossils have been found in South Africa, and remains of related, extinct *Concholepas* species are known from other widely scattered sites around the world. But *C. concholepas* has existed essentially unchanged on the Chilean coast for about two million years. We are only now beginning to appreciate its cycle of reproduction, dispersal, and return to its favored habitat. If my hopes are realized, our work here with the Chilean National Fisheries Service will enable the loco to continue its ancient cycle into the future.

Louis H. DiSalvo earned his Ph.D. in environmental science from the University of North Carolina and now specializes in marine microbiology and aquaculture. He is a consultant to government agencies and fisheries in Chile, where he operates an independent marine laboratory.

TECHNOLOGY UPDATE

500 miles from nowhere, it'll give you a cold drink or a warm burger...

NASA space flights inspired this portable fridge that outperforms conventional fridges, replaces the ice chest and alternates as a food warmer.

By Charles Anton

Recognize the ice cooler in this picture? Surprisingly enough, there isn't one. What you see instead is a Koolatron, an invention that replaces the traditional ice cooler, and its many limitations, with a technology even more sophisticated than your home fridge. And far better suited to travel.

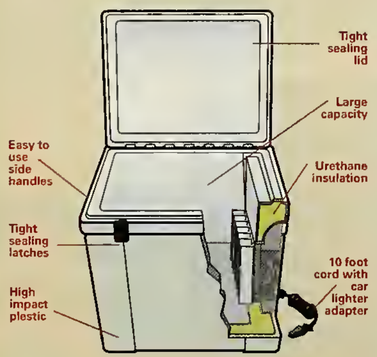
What's more, the innocent looking box before you is not only a refrigerator, it's also a food warmer.

NASA inspired portable refrigerator. Because of space travel's tough demands, scientists had to find something more dependable and less bulky than traditional refrigeration coils and compressors. Their research led them to discover a miraculous solid state component called the thermo-electric module.

Aside from a small fan, this electronic fridge has no moving parts to wear out or break down. It's not affected by tilting, jarring or vibration (situations that cause home fridges to fail). The governing module, no bigger than a matchbook, actually delivers the cooling power of a 10 pound block of ice.

The refrigerator from outer space.

The secret of the Koolatron Cooler/Warmer is a miniature thermo-electric module that effectively replaces bulky piping coils, loud motors and compressors used in conventional refrigeration units. In the cool mode, the Koolatron reduces the outside temperature by 40 degrees F. At the switch of a plug, it becomes a food warmer, going up to 125 degrees.



From satellites to station wagons. Thermo-electric temperature control has now been proven with more than 25 years of use in some of the most rigorous space and laboratory applications. And Koolatron is the first manufacturer to make this technology available to families, fishermen, boaters, campers and hunters– in fact anyone on the move.

Home refrigeration has come a long way since the days of the ice box and the block of ice. But when we travel, we go back to the sloppy ice cooler with its soggy and sometimes spoiled food. No more! Now for the price of a good cooler and one or two seasons of buying ice, (or about five family restaurant meals), all the advantages of home cooling are available for you electronically and conveniently.

Think about your last trip. You just got away nicely on your long-awaited vacation. You're cruising comfortably in your car along a busy interstate with only a few rest stops or restaurants. You guessed it... the kids want to stop for a snack. But your Koolatron is stocked with fruit, sandwiches, cold drinks, fried chicken... fresh and cold. Everybody helps themselves and you have saved valuable vacation time and another expensive restaurant bill.

Hot or cold. With the switch of a plug, the Koolatron becomes a food warmer for a casserole, burger or baby's bottle. It can go up to 125 degrees.

And because there are no temperamental compressors or gasses, the Koolatron works perfectly under all circumstances, even upside down. Empty, the large model weighs only 12 pounds and the smaller one weighs just seven. Full, the large model holds up to 40 12-oz. cans and the smaller one holds six.

Just load it up and plug it in. On motor trips, plug your Koolatron into your cigarette lighter; it will use less power than a tail light. If you decide to carry it to a picnic place or a fishing hole, the Koolatron will hold its cooling capacity for 24 hours. If you leave it plugged into your battery with the engine off, it consumes only three amps of power.

Limited time offer. Because Comtrad is bringing this offer to you directly, you save the cost of middlemen and retail mark-ups. For a limited time only, you can get this advanced, portable Koolatron refrigerator at the introductory price of $99. Call today to take advantage of this special promotional pricing. Most orders are processed within 72 hours.

Try it risk free. We guarantee your satisfaction with any product from Comtrad Industries. With the Koolatron you get our complete "No Questions Asked" 30 day money-back guarantee. Plus you get a full one year manufacturer's limited warranty. If you are not satisfied for any reason, just return the product for a complete refund.

The versatile Koolatron is available in two sizes. The P24A holds 30 quarts and the smaller P9 holds seven quarts. An optional AC adaptor lets you use them in your rec room, patio or motel room. They plug into any regular outlet.

Koolatron (P24A) holds 30 quarts	$99	$12 S&H
Koolatron (P9) holds 7 quarts	$79	$8 S&H
Optional AC Adapter (AC 10)	$39	$6 S&H

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A Texas Powwow

The Alabama and Coushatta Indians make no apologies for their eclectic traditions

by Samuel M. Wilson

It is pouring rain outside the Inn of the Twelve Clans on the Alabama-Coushatta reservation in east Texas, and no one is eager to leave. Because of the rain, the afternoon's gourd dances, which were to have been held in the powwow arena at the community center baseball field, have been moved into the gymnasium. Whenever the restaurant door swings open, the drum can be heard in the distance. The dancing last night had gone on until after midnight, and there was a five-mile run at seven this morning, so more than a few are willing to linger over lunch, saving their energy for the evening's dances.

Jack B., a member of the Alabama tribe, sits at a formica table and counts through his children and grandchildren. One of his seven children married a Pawnee, one an Omaha, a few married non-Indians. Everything he says is accompanied with quick, strong gestures. "He went away, became an outsider," he says, sweeping his arm toward the restaurant door. (I look.) "But he might come back, maybe to retire," he continues, pointing to his chest. Speaking of an aunt, he presses three fingers hard against his left palm and tells us, "She came back here a couple of years ago, but she died."

As we sit in the inn, the people at the table are constantly coming and going. Jack's son needs car keys. Jack's sister stops by (but is soon called away by a relative). A young woman who lives off the reservation and works for the *Houston Post* drifts by a couple of times. Her T-shirt has a raccoon on it, and several people make the connection—her nickname is Sawa, "raccoon" in the Alabama language. John Humano, Sr., one of the powwow (dance ceremony) officials, sits for a while. Someone mistakenly introduces him as a Kiowa Apache and is corrected by a chorus; he is Comanche and his wife is Kiowa. He likes to say he's a "Kiowa captive." As people come and go, the joke is repeated a few more times.

Drummers ride in the powwow parade.
Samuel M. Wilson

The conversation drifts somehow to languages. English is not Jack's first language or probably his second, since he speaks both Alabama and Coushatta. Maybe it is not even his third, since his mother was half Choctaw and he speaks that tribe's language, too. All of these are languages in the Muskogean family, which includes Creek, Chickasaw, and others spoken by the Native Americans of the Southeast. Jack counts from one to ten in Alabama and then in Choctaw and observes that the number eight is practically the same (*ontotchiina* in Alabama, *untuchina* in Choctaw). He notes that knowing one of the languages makes the others easier, although in his opinion, things in Choctaw are sometimes said backward.

Thirty years ago, someone notes, none of the kids entering first grade spoke any English, so they were often held back a year or two. Jack nods. Now most children know English well by the time they enter school. They also understand Alabama or Coushatta, but many will not use these languages unless they have to when speaking to older people. Even so, much of the discussion taking place at surrounding tables is in Alabama or Coushatta.

At the time of first European contact, the ancestors of the Alabama-Coushatta lived along the major rivers of central Alabama—the Coosa, Tallapoosa, and Alabama. Hernando de Soto must have met some of them in his meandering expedition through the Southeast in the early

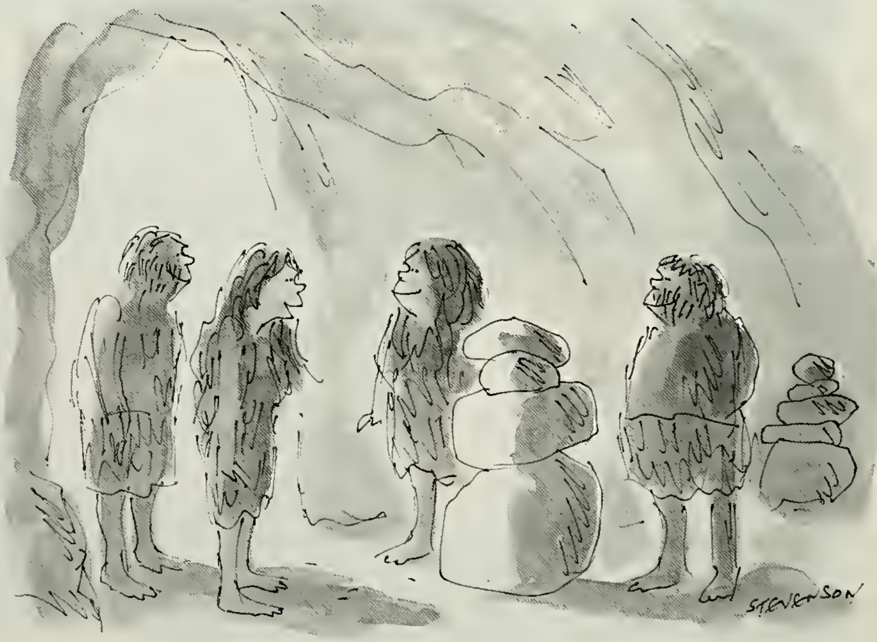
1540s. Documents and maps from the early 1700s show the location of "Alibamu" and "Kosati" villages still in this territory. But under increasing pressure from British and other European colonists moving west in the mid-1700s, the Alabama and Coushatta moved to lands in Louisiana and east Texas.

Thus the Alabama and Coushatta were settled in Texas in the late 1700s, before Anglo-American colonization of the region (the battle of the Alamo was in 1836). By the late 1820s, they had asked the Mexican government for permanent possession of their lands, and after Texas became an independent republic in 1836, the well-established and prosperous Alabama and Coushatta were the only groups to be exempted from a purge of Native Americans. They again escaped the fate of so many Indians of the southeastern woodlands, who were forced to move to the Oklahoma Indian Territories in the 1830s (the Cherokee "trail of tears" was just one such forced relocation). As a result of their unusual history, the Alabama-Coushatta reservation is somewhat isolated from other areas with large Native American populations.

Next to the gymnasium where the dance drum is beating lies the Alabama-Coushatta cemetery, surrounded by the tall pine and oak forest of the Big Thicket, as this part of east Texas is called. Some of the headstones date back to the mid-1800s. Back in the woods is the grave of subchief Colabe Sylestine, who in the nineteenth century helped lead the Alabama and Coushatta to their present home in Polk County and who signed the agreement with the state of Texas granting his people their land. Elsewhere in the cemetery, the short flagstaffs of long-since-dissolved flags lean against the headstone of McConico Batisse (1875–1951), a former chief of the Alabama. A razor, a tin coffee cup, and the shell of a flashlight sit along the line of the grave. The rain has washed away some of the gray sand around them, creating little pedestals for these characteristic possessions of the deceased.

Henry Steel, a Kickapoo from Oklahoma, was master of ceremonies for the first night of dances at the powwow last night. He may have been asked because of his "gift of gab," and rightfully so. He delights in intertribal jokes and camaraderie: "We're going to have three intertribal songs; in my language that's *niiswikwaa*, for you Comanches that's *tres*, and for you Cherokees"—holding up three fingers—"it's this many."

For an hour or more before the "grand entry," men, mostly older ones, performed the gourd dances. In front of the improvised benches that enclosed the dance circle, they danced slowly in and out to the music from the singers and drummers; some occasionally paused to shake hands and talk with one another in groups of two or three. They wore different versions of "traditional dress," some simply jeans and a western-cut shirt with a long, narrow sash tied around the waist and another sash over the shoulders. Each carried a



"Oh! I love Precambrian."

feathered fan in his left hand and shook a gourd rattle in his right.

Sitting at the center of the dance circle on metal folding chairs stenciled ACIR (Alabama-Coushatta Indian Reservation), a half dozen men sang and beat a large skin drum. Around them sat three or four women, also singing, and a few restless children who had to stay beside their parents or grandparents. Known collectively as the Drum, the people who sing and beat the drum are the soul of the powwow; they can carry on for hours without breaks.

Meanwhile the dancers for the evening's main ceremonies were getting ready. Some of the powwow dances involve competition in costume and dancing, putting personal status, skill, and grace to the test. For the mostly younger participants in these competitions, the dances also carry overtones of courtship and romance. Some of the evening's most impressive choreography took place in the parking lot as parents, often while dressing themselves, helped their restless children into elaborate outfits with headpieces, moccasins, and other components. The M.C. chastised everyone for the delay in the grand entry: "We're running late. We're twenty-two minutes into Indian time."

Miraculously—at a time determined by them and not by the M.C.—the milling horde became an ordered procession. An honor guard of war veterans entered the dance circle first, carrying the flags of the United States and Texas and a flag commemorating MIAs. The head gourd dancer, John Dart (another visitor from Oklahoma), came next, followed by the princesses of the Alabama and Coushatta tribes, both high-school seniors. Some other "royalty" followed. The women in buckskin regalia entered next, then women wearing "southern shawl costume," or "southern cloth dress"—silk or satin dresses in muted blues and reds, with bonework or beadwork draped over their shoulders and hanging down in front and back, a tasseled shawl over their left arm, and a feather fan in their right hand. Next came women in "northern shawl costume," a similar dress, but with the tasseled shawl unfolded and draped over their shoulders, a style more suited to exuberant dances favored by the younger women. Others wore "jingle dresses" covered with hundreds of shiny metal bells.

The men followed in "traditional dress," a diverse category of regalia that usually included a three-foot circle of tail feathers worn behind the hips. They wore moccasins, a breechcloth, a headdress of fur or a few upright feathers, bonework or colored beadwork, breastplates, armbands, legbands, and face paint, and usually held a short, ornate staff in the right hand. One man wore a wolfskin cape, with the wolf's head coming out over his forehead. His face was painted with wide, vertical white stripes, and he danced in a distinctive crouching, staccato step.

Then came the "fancy dress" dancers, whose costumes were flamboyant elaborations on the men's traditional dress. Their dance was the most athletic of all, and their regalia was designed to amplify every movement. In addition to the bustle of tail feathers, they had another circle of feathers around their shoulders, all of them tipped with streamers. The feathers and other parts of the costumes were dyed in brilliant colors. Sequined shoes, neon colors, and chromed bonework showed that innovative decorations were not discouraged.

Now, dyed feathers, beadwork, bone chest-plates, and huge bustles of feathers were admittedly not part of Alabama or Coushatta dress in centuries past. Some of the tedious cognoscenti of the powwow circuit lament this loss of tradition and deride the incorporation of Plains Indian dress as well as completely novel styles. But so what if these are not the sorts of clothes the ancestors of the Alabama and Coushatta wore? People of European ancestry no longer wear powdered wigs, knee breeches, or big-buckled shoes. Why should the distinctive powwow costumes, one of the most exuberant expressions of Native American creativity, be held to any different standard?

After the grand entry came the "tiny tots" competitions. Their regalia was something like that of the older participants, but with Mickey Mouse disposable diapers instead of breechcloths. Things slowed a bit, with feathered headpieces slipping down over eyes, and armbands and sashes being shed as fast as parents could put them on.

Quite a few of the spectators wandered over to the booths to get something to eat. Frybread is a staple on the Alabama-Coushatta reservation. It is bread dough formed into a thin slab about five inches across, then slipped into a frying pan of hot oil. The result is something like a chewy, unsweetened doughnut without a hole. Topped with beans, cheese, and lettuce, it becomes an "Indian taco."

After a few other competitive classes came the ladies' southern shawl dance, a subtle exercise that lacks the spinning and shaking of the fancy dancers. This contest had the most dancers, spanning the greatest range of ages, with women in their fifties and sixties competing with those in their teens. The drum started and the dancers moved slowly forward, clockwise, as if walking carefully through the dark, trying to see who was there or to find something they lost. The tassels of the folded shawls draped over the dancers' left arms raked back and forth, and the beadwork down their backs swept back and forth to the same rhythm. In her motionless right hand, elbow bent, each dancer held a feather fan. After three great beats on the drum they danced lower, the fringes of their shawls nearly touching the ground. Two songs were needed for all the southern shawl dancers to compete.

Among the evening's dances, the most exciting was the Tracy Batisse Memorial Competition for male fancy dancers. At smaller powwows during the year, the dancers had competed to get into the finals for this competition, whose prestige far exceeds the $1,000 cash, silk jacket, and other things that come with winning. The four finalists all seemed to be about eighteen to twenty years old. They had been wandering around behind the bleachers for the previous half-hour, stretching, looking up in the air, turning away friends who wanted to talk, and shaking their shoulders and fingers like sprinters waiting for their call to the blocks.

About 2,000 people were watching the dances, the majority of them Indians. About 500 were Alabama and Coushatta living on the reservation; perhaps another 1,000 lived away but had come back for the annual powwow. Other Native Americans present included Chickasaw, Cherokee, Choctaw, Seminole, and Creek from Oklahoma and, from farther away, Sac, Fox, Comanche, Kiowa, Lakota, and Shoshone. Many non-Indians had also come, some from neighboring towns and some from great distances, to enjoy the dancing and the welcoming atmosphere of the powwow.

No one was getting frybread now. The M.C. called for a "contest dance," and the Drum started off at an exhilarating pace. The fancy dancers shook the tassels streaming from their shoulders and hips, spinning the tasseled batons looped around their wrists. Leaping and turning, they looked like a flurry of feathers. They danced the same dance, but each added his own new moves. Girlfriends and family sat around the dance arena, arched forward, clenching their fists.

The Drum's rapid pace slowed for three intense beats, and with them the dancers all flew downward into a low crouch, jumping three times. The participants' passion, and the focused hush of the crowd, made it plain that this was no show for tourists. The annual powwow is the event all the Alabama and Coushatta try to come home for, and this dance is its centerpiece. The dancers are competitive, to be sure, but together they reflect a commitment to Alabama and Coushatta identity and tradition.

The Drum then launched into a furious tempo, taking the dancers with it. Finally the Drum ended the song with a great flourish, leaving the four finalists reaching for the sky, dripping sweat and exhausted, feathers quivering and tasseled batons twirling high above from both wrists. A storm of applause burst from the crowd, as the M.C. quipped, "Well, gentlemen, that was a good warm-up song—now let's start the competition!"

Samuel M. Wilson teaches anthropology at the University of Texas at Austin.

Caroni Swamp, Trinidad

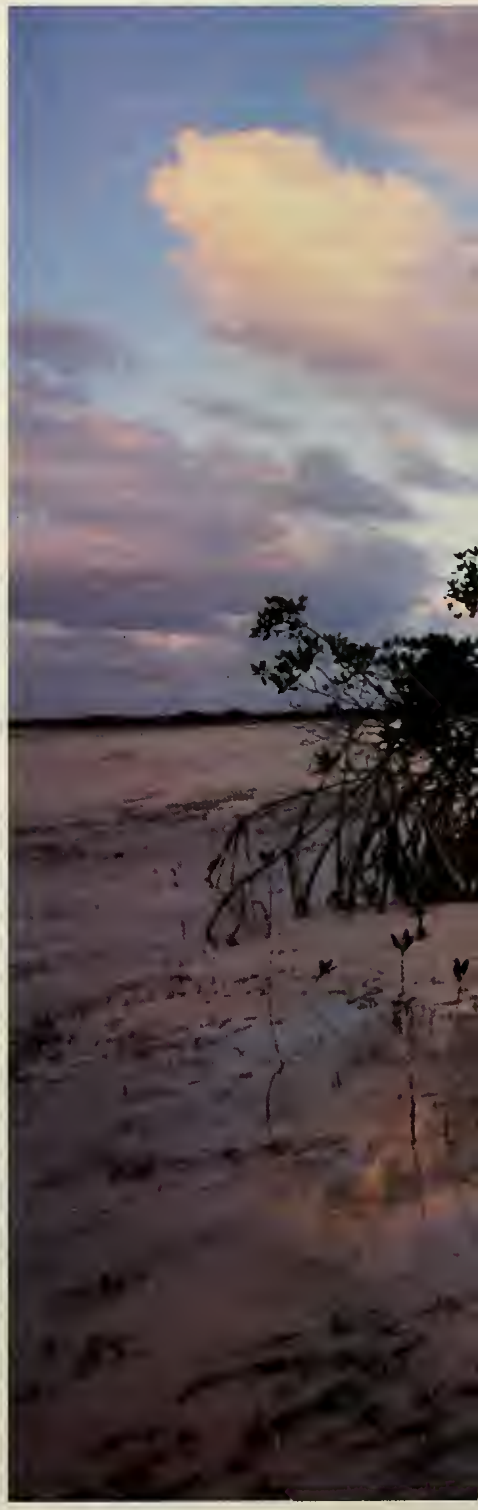
by Robert H. Mohlenbrock

On Trinidad's western coast, about five miles south of the capital city of Port of Spain, lies Caroni Swamp, a forty-square-mile stretch of swampland intersected by numerous water channels. Fed by freshwater that drains down from the island's Northern Range and Central Hills, this wetland is also bathed by seawater from the Gulf of Paria, which separates Trinidad from the mainland of Venezuela. Twice every twenty-four hours, the tide brings in saltwater, which mixes with the fresh. The major estuary is the Caroni River, which receives water from its mountain tributaries and flows westward through the Northern Basin before dividing into a number of distributaries that meander through the swamp.

The salinity of the swamp is especially high during the dry season, from January to April, when there is little rainfall. The salt content in the water may reach twenty-five parts per thousand, compared with about thirty-five parts per thousand for seawater. During the rainy season, from June to December, the ratio may drop to as little as six parts per thousand. Very different circumstances prevail in Nariva Swamp, on Trinidad's eastern coast, where the steady supply of water from the Nariva River maintains a freshwater swamp forest (*see* "This Land," October 1993).

With its mangrove stands and open areas dominated by grasses and sedges, Caroni Swamp presents an impression of wilderness, but it has been altered by occasional disturbances. As part of a 1921 land-reclamation scheme, various drains and sluices were excavated. The Princess Margaret Highway, which is now Caroni's eastern border, was constructed on reclaimed land. Seven canals were subsequently cut east to west, to increase water circulation.

Tour companies provide boat trips into Caroni Swamp, and I was fortunate to obtain the services of Winston Nana, one of the boat operators who also happens to be a knowledgeable naturalist. In a large, flat-bottomed boat, we meandered through continuous stands of mangrove trees, following an intricate network of estuaries and lagoons.

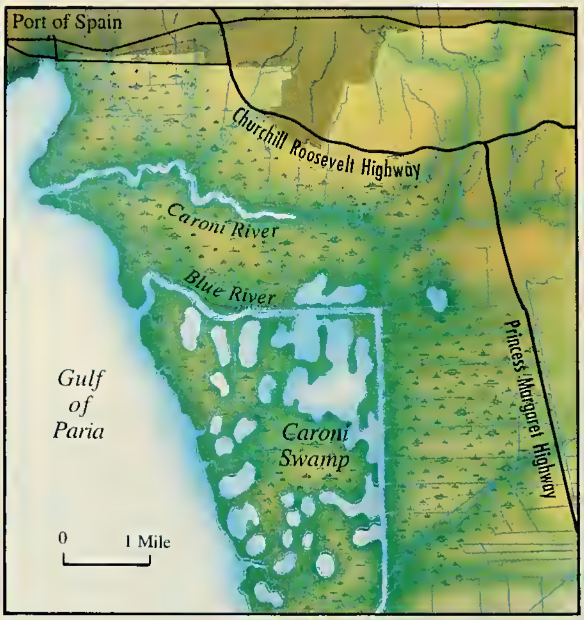


Kevin Schafer

Red mangroves grow along the seacoast of Caroni Swamp, below. Opposite page: A tricolored heron is one of 150 bird species that frequent the swamp.
Gerry Ellis

Caroni Swamp
For visitor information write:
Director
Forestry Division
P. O. Box 30
Long Circular Road
Port of Spain, Trinidad

Joe LeMonnier



Winston Nana showed me how to distinguish between the seven different species of mangroves that grow in Caroni Swamp. The most numerous are three species of red mangroves, which tend to form the borders of the waterways. Red mangroves are unusual in the plant kingdom in that they are viviparous—that is, they disperse growing young instead of dormant seeds. Following flowering, pollination, and fertilization, the mangrove produces long, spindle-shaped seedpods, each containing a single seed. While still on the tree, the seed within the pod germinates, and the pod splits open, exposing the young leaves. When the young plant is sufficiently developed, the pod with the seedling finally falls from the parent tree, the pod's pointed end burrowing into the mud. Spongy roots soon grow from this buried point.

Each evening, scarlet ibises return from their feeding grounds to roost in Caroni's mangroves.
Art Wolfe

By a process called reverse osmosis, the roots take up water and needed nutrients while excluding much of the salt. If excess salt enters the plant, it can be stored in the leaves. In this way red mangroves can tolerate a high degree of salinity. The trees also send down hundreds of prop roots that provide anchorage in the murky, watery soil.

Particles of soil and silt that get caught on the prop roots may, over time, form a thick deposit of soil. For this reason, botanists have long regarded red mangroves as pioneer species that build land along tropical coastlines. More recently, however, researchers have noticed that seedlings of black mangroves and white mangroves may also colonize new sites. And ecologist F. E. Egler has even shown that red mangroves sometimes spread landward instead of seaward. Thus some ecologists prefer to regard red mangroves as land stabilizers, rather than land builders.

Two kinds of black mangroves grow in Caroni Swamp, usually on firmer ground than the red mangroves. Beneath the black mangroves are dozens of slender, woody, straw-shaped outgrowths from the root system. Called pneumatophores, these projections store nutrients as well as provide additional support and anchorage for the plants. The triangular pods containing single seeds of the black mangroves are not viviparous, but fall to the mud beneath the tree and are transported by tides to other muddy areas where the seeds may germinate. A white mangrove and a buttonwood mangrove complete the array of mangrove species at Caroni Swamp.

Animal life abounds in the swamp. At low tide, the mudflats are alive with fiddler crabs, blue crabs (a delicacy Trinidadians make into callaloo soup), and a purplish crab that grows to a length of sixteen inches. The purplish crab feeds on the many oysters and barnacles found on the mudflats. Many of the red mangrove's prop roots are covered with tree-climbing crabs, which consume the algae that periodically inundate parts of the swamp. Raccoons stealthily make their way around the prop roots, looking for a meal of crabs. A small crocodilian known as the spectacled caiman may haul itself out of the water to bask. The silky anteater, nearly two feet long at maturity, roams about to forage at night but spends the day up in a tree, curled around the branches.

About 450 acres within the swamp have

been set aside as the Caroni Bird Sanctuary. The star attractions are the 3,000 scarlet ibises that, near sunset, fly from adjacent Venezuela into Caroni Swamp and perch or nest in the tops of mangrove trees. The pink birds that accompany them are juveniles, whose colors will intensify after three years.

Scarlet ibises have a wingspan of thirty-one inches and are thirty-seven inches long from the tip of the bill to the tip of the tail. There are six nesting and roosting colonies at Caroni, much fewer than existed twenty-five years ago, when 10,000 scarlet ibises lived in the swamp. The birds build their nests in the crowns of mangrove trees, cementing together pieces of twigs with their own droppings.

Another bird that nests in the mangroves is the yellow-throated spinetail, named for its relatively long, slender tail. Spinetails feed on insects and spiders, sometimes jumping into the air to catch flying insects.

Altogether some 150 kinds of birds visit Caroni Swamp. Other birds that Winston Nana helped me identify on my excursion included snowy egrets, great blue and tricolored herons, lesser yellow-legs, black-bellied plovers, whimbrels, willets, and a green-rumped parrotlet. But perhaps the most peculiar was the potoo, which has very short legs and a tail about as long as its body. A nocturnal bird related to nightjars, the potoo spends its day sitting erect on a branch, with its head and bill pointing upward. In this posture, it looks like a twig. At night, the potoo flies from its perch to capture insects, returning to the perch to devour them.

More than eighty kinds of fish have been found in Caroni's estuaries and lagoons. One of the most amazing is the four-eyed fish *Anableps*, which can see both above and below the water surface. I saw a school of them swimming, and their eyes looked like bubbles on the water. *Anableps* actually has only two eyes, but they are divided by an epithelial line into upper and lower portions, each with its own cornea and retina. When the fish swims with its eyes at the waterline, it can see objects in focus both above and below. Apparently the above-water view enables the fish to keep an eye out for predators; it seeks its own prey underwater.

This month, Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, takes a break from his usual beat, the 156 U.S. national forests.

Sticker Shock

Beware the ties that bind

by Roger L. Welsch

I collect and repair old tractors—to be exact, Allis Chalmers WC tractors from the late 1930s. It's more than an avocation: dismantling and reassembling old Allises is my therapy, my retreat, my obsession. At this point I have...well, I have more orange Allises than I would like my wife to know about.

The thing is, parts for old tractors are hard to find, and therefore expensive, so I am always looking for another Allis WC, mostly to cannibalize for parts. Every now and then someone tells me he has an old one sitting back in the wood lot and he'll let me have it for a hundred dollars or so.

As you can imagine, any piece of iron that has been sitting back in the trees for a couple of decades develops a good case of rust; in fact, most of the tractors I acquire have over the years become a ton and a half of solid rust. Pistons are stuck (in contrast to automobiles, which have "engines" that "seize up" or "freeze," tractors have "motors" that "stick"), valves are stuck, crankshafts are stuck, transmissions are stuck...carburetors, magnetos, steering assemblies, throttles, controls, plugs, pumps, bearings, seals, gears, lugs, screws, bolts, nuts...all stuck. Rare is the day, therefore, that I am not occupied with the process of getting something *un*stuck.

I'm not alone. My conversations with friends in town often focus on exactly the same sort of problems. Farmers, mechanics, plumbers, electricians, bartenders, cooks—all trying to get things unstuck. And I am amazed at the variety of techniques that have been devised for getting things unstuck.

Tractor restorers and mechanics often have "secret" recipes for unsticking motors—blends of fine-grade olive oil, brake fluid, transmission oil, vinegar, kerosene, even Coca-Cola. I have listened in on endless conversations arguing the merits of one formula or another. I pretty much adhere, so to speak, to commercial unstickers like WD-40 or Liquid Wrench, which I would buy in 60-gallon drums if I could find a source. Anything to get rid of whatever it is that sticks motors. And in addition, of course, one wants some reliable substance to keep them unstuck.

Mine is the quest that drives a good part of modern technology and warfare, and that drove ancient technology and warfare as well—how to keep your own stuff unstuck and how to get the other guy's stuff stuck. Tank treads let your army move without getting stuck; tank traps snarl up the enemy's tank treads so they do get stuck. Oil, grease, graphite, bearings, exotic "slick" materials—all have been developed to keep chariots, catapults, guns, airplanes, and rockets rolling and sliding. The Allied bombing effort against Germany, on the other hand, was concentrated on the ball bearing plants at Rostock, to keep the blitzkrieg from rolling along smoothly—and at Ploesti, to deny the Axis the oil to lubricate whatever bearings they did get made. Sticking, unsticking, sticking, unsticking. That's the true dialectic of history.

If this sounds like the sort of simplification an outsider to military thinking might come up with out of ignorance, please note: (1) I am not exactly a novice at military tactics, having been a staff sergeant in the Nebraska Air National Guard at one time; and (2) military researchers acknowledge my thesis in their own nomenclature. They speak of "slick'ems" and "stick'ems," further classified as NLWs, or "nonlethal weapons." No kidding. Slick'ems slow things down by making them *too* slippery: they render roads, bridges, and railroads so slick that both motor traffic and foot traffic are stopped dead—it's like trying to move on ice.

A new stick'em, on the other hand, was recently described in *Newsweek* (February 7, 1994) as "a sticky foam that slimes.... Fearsome gunk, it quickly turns to taffy when exposed to air.... Bad guys would be stuck until sprayed with solvent." The

Rand Corporation's Bruce Hoffman described the stuff as "a polymer adhesive that you drop from a plane or spray on a road, and things just stick. If you glue down the Serbs' artillery, what are they going to do, just throw their guns down and walk away? And could they? The problem is, people stick to it too."

Some folks outside of the military are already licking their chops at the idea of getting their hands on this technology. For example, police want to stop miscreants dead in their tracks by zapping them with a canister of super stick'em or greasing the skids into the slammer with a good dose of slimy slick'em. I love the idea of a bunch of muggers wadded up in a ball of goo for a couple of days; just the company should be punishment enough, not to mention the, er, inconvenience, if you catch my drift.

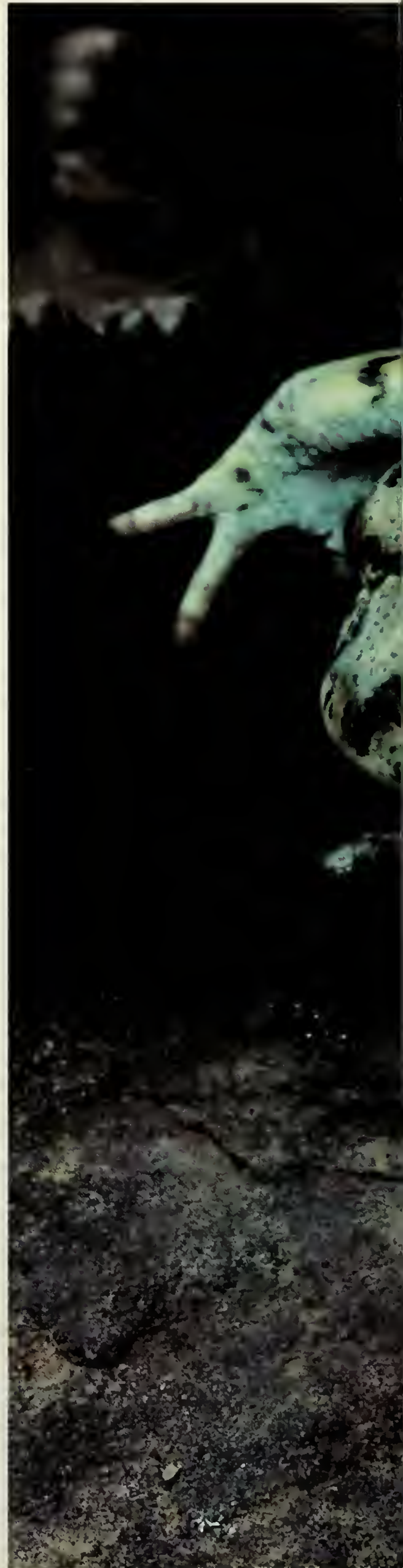
Before long, of course, whatever advantage the good guys have will wind up in the arsenal of the crooks. Police would have to carry not only cans of stick'em to nail crooks caught red-handed but also a can of *un*stick'em in case the situation deteriorated into a running goo battle and an officer was gooed by hostile or even friendly fire.

As for us civilians, the world could definitely become a less friendly place if this stuff fell into the wrong hands. I would fight to the death to defend my right to bear slick'em in well-regulated tractor repair but is there really an argument for public, over-the-counter access to stick'em? Will the NRA say, "When stick'em is outlawed, only outlaws will have stick'em"?

If the terrible potential of all this is not dealt with seriously, and I mean now, the words, "Stick 'em up," may take on a whole new importance.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

Phil Dotson; Photo Researchers, Inc.



Amphibians in a Bad Light

What is killing the eggs of Oregon's western toad?

by Andrew R. Blaustein

Each spring, two or three times a week, my graduate students and I travel eighty miles east, from Oregon State University to Lost Lake in the Cascade Range. Surrounded by snow-capped peaks and volcanic debris, the lake, at an altitude of about 4,000 feet, is the lowest in the area and consequently the first to lose its ice covering. And when the ice goes, western toads (*Bufo boreas*) immediately begin breeding by the hundreds. Because this can happen any time in May or June, frequent visits insure that we catch them in the act. But it is not easy; some years, when the snowpack is great, we have to snowshoe several miles around the lake to get to the breeding site.

This year, however, the snow around the lake melted by early May, so we could drive close to the small section of the lake that these amphibians seem to prefer. Toads began to emerge on May 6, the earliest date we had ever seen them arise from their six-month winter sleep. We donned our waders, picked up our pails, nets, scales, and notebooks, and ventured into the cold, clear water. After some searching, we found hundreds of toads.

To obtain a long-term record of their reproductive patterns and changes in their population size, we had been weighing, measuring, and marking western toads at Lost Lake since 1979. Nevertheless, we were still amazed at how the toads, in their quest to mate, scrambled over snow and ice and into near-freezing water. Close to the surface, where the toads congregated, violent winds and snow, accompanied by

Before the snow has completely melted in Oregon's Cascade Range, toads, frogs, and salamanders breed in the clear waters of Lost Lake, above. The western toad, right, is in decline throughout most of its range.
D. Grant Hokit

Edward R. Degginger; Bruce Coleman, Inc.

In shallow water, a single strand of western toad eggs, below, lies exposed to the sun's ultraviolet rays. Most salamanders, however, lay their eggs in deep water or other protected places. Inside their eggs, right, embryonic salamanders have already developed their feathery external gills.

Alan Blank; Bruce Coleman, Inc.

pelting hail, continued to buffet them while they bred.

Males arrived first, followed by females, and in a seemingly haphazard manner, hundreds of toads searched for mates. Because the males outnumbered females, the competition for access to females was intense and shoving matches often erupted. Soon after the pairs formed, the females began laying eggs and the males fertilized them by releasing sperm directly into the water. On average, each female produced some 12,000 eggs in long strips surrounded by a protective, jellylike covering. The individual strings stretched for more than twenty feet and often became intertwined with the shallow vegetation and with eggs deposited by other females. Three days after the toads began to converge on the lake, egg laying was complete and they disappeared into the forests to feed and fatten up before hibernating again in the early fall.

During peak years at Lost Lake, we have seen more than 500 pairs of toads, several hundred unpaired males, and several million eggs strewn about the lake, but this year we counted only 147 breeding pairs and about 100 unpaired males. Almost two million eggs were laid. As usual, the eggs, with their jet-black embryos, began to develop normally, but two days after they were laid, we began to see the same ominous pattern we had observed for the past several years at lakes throughout the Cascades. Many embryos began to turn white as they started to die in wavelike fashion from one end of the enormous egg mass to the other. Soon they became a putrid, decaying mess, attracting flies and other insects—a potential feast that lured Pacific tree frogs (*Hyla regilla*) to the site. Opportunistic garter snakes arrived next to dine on the frogs. A week after the toad eggs had been laid, only half of them were viable. After the normal developmental period of about two weeks, even fewer hatched as tiny tadpoles. And this was only a small part of a much bigger problem.

By the mid-1980s, we began to notice that the frogs and toads we had been studying were becoming more difficult to find. Some populations of the most common species, such as the Cascades (*Rana cascadae*) and red-legged (*R. aurora*) frogs and the western toad, were nowhere to be found. Through the grapevine, I learned that amphibians were disappearing in many parts of the world, from North and South America, Asia, Africa, and Australia. Some species were even reported to have become extinct. To add to the mystery, in some areas populations of certain species were doing fine, while others were disappearing. In Oregon, for example, Pacific tree frog populations were thriving in lakes and ponds where western toad and Cascades frog populations were dwindling.

Biologists proposed many possible causes for the declines, including habitat destruction, pollution, and natural population fluctuations, but no single reason was apparent. In many areas, including our study sites, declines were occurring in relatively undisturbed habitat with no apparent pollution. Yet by the late 1980s, a pattern began to emerge that gave us some clues to the puzzling egg deaths—and perhaps to the shrinking populations—in the Cascades.

A significant number of the troubled species were mountain-dwelling amphibians that laid their eggs in the open, in shallow water—the same way in which the declining Oregon species did. Throughout development, these relatively unprotected eggs would be exposed to sunlight and potentially harmful ultraviolet (UV) radiation. The middle portion of the UV spectrum, known as UV-B, is especially dangerous. In humans it can cause sunburn and skin cancer and weaken the immune system. UV-B can also damage amphibians. In the mid-1970s, a labora-

tory study conducted by Robert Worrest, at Oregon State University, showed that western toad embryos developed abnormally when subjected to UV-B radiation. Since then, several reports have documented a gradual increase in UV-B radiation hitting the earth's surface as the protective ozone layer thins. Were increasing levels of UV-B radiation responsible for the high rate of egg mortality in the Cascades? And if other declining amphibians had a similar vulnerability at the egg stage, could increasing exposure to UV-B radiation each spring be responsible for shrinking their populations over time?

In the late 1980s, when I first suspected UV-B radiation caused the toad eggs to die, I began a series of simple experiments to see if this was possible. I brought some newly laid western toad eggs to my laboratory and reared them in the absence of sunlight in aquariums filled with lake water. I followed the eggs' development until they hatched. Several months later the tadpoles metamorphosed into young toads. I was excited to see that almost all of the laboratory eggs survived, while eggs from the same clutches left to develop in the lake had died at unprecedented rates. Whatever the problem was, it did not seem to be in the eggs themselves.

After hearing about my ideas on UV-B radiation and amphibian declines, John Hays, a molecular geneticist at Oregon State University, called me to discuss how he might get involved. To learn how plants and animals repair UV-B damage to DNA, Hays had been studying the process in the eggs of African clawed frogs (*Xenopus*)—the amphibian equivalent of the well-studied laboratory rat.

When a cell is exposed to UV-B radiation, the energy can be absorbed by a number of biologically important molecules, including proteins and DNA. When this happens, the bonds between atoms and molecules can be altered, causing the cell's chemical machinery to malfunction. Such changes are particularly disruptive when they occur in DNA; if the genetic code, which carries the instructions for life, is misread, mutations and cell death can occur. Many plants and animals, however, are able to repair a certain amount of DNA damage. Photolyase, an enzyme found in the cells of many organisms, can remove the harmful defects. Hays reasoned that the eggs of different amphibian species may contain different amounts of photolyase. Therefore, we predicted that species with the greatest quantities of the enzyme would be more resistant to damage by UV-B than species with less photolyase. This could explain why the eggs of some amphibians were dying while those of others were unaffected.

The first step in testing our hypothesis was to collect eggs from a number of amphibian species with different egg-laying behaviors. We also made sure to include eggs from species that were in decline and from species that were doing well. Once eggs were collected, Hays and his chief technician, Peter Hoffman, measured photolyase levels, using the same techniques they had perfected while studying African clawed frogs.

The results of the molecular tests were compelling. The eggs of the nine species we examined showed enormous differences in the amount of photolyase they contained. Eggs of the Pacific tree frog (which are laid in open, shallow water) had the most photolyase: three times as much as the Cascades frog and six times as much as the western toad. The eggs of the six salamanders we tested had less than any of the frogs, with the least amount being found in Dunn's salamander, *Plethodon dunni* (Pacific tree frog eggs had eighty times more photolyase than these amphibians).

The correlation between levels of photolyase and egg-laying behavior was striking. The salamanders, whose eggs have little photolyase, generally lay their eggs under logs, in crevices, or in deep water—all places where little UV-B radiation will penetrate—while species that lay their eggs in the open, exposed to sunlight, had the highest levels of the enzyme. The egg-laying behavior of salamanders may not have evolved specifically to afford them protection from UV-B radiation; other selective pressures, such as predation and temperature requirements for development may have been more important. Nevertheless, the protection from UV-B

may be a secondary benefit. Those species that laid their eggs in the open, however, needed high levels of photolyase to minimize the damage to their DNA caused by exposure to direct sunlight.

Although the results of the enzyme studies were suggestive, we still needed to know if UV-B radiation was damaging eggs in nature. We began tackling this question even before we had the results of the DNA repair study. With field experiments in lakes and ponds where amphibians naturally lay eggs, we could compare the hatching success of eggs exposed to UV-B with that of shielded eggs. We gathered freshly laid eggs from four species that deposited them in the open: Cascades frogs, Pacific tree frogs, western toads, and northwestern salamanders (*Ambystoma gracile*). We placed the eggs in the bottom of screened, boxlike enclosures that allowed water to flow freely through them. Over some of the enclosures, we placed plastic filters that blocked UV-B. We left a second set of enclosures uncovered, exposing the animals in them to the rays. A third set, which had a plastic filter that allowed transmission of UV-B, provided a control to insure that any variation we found under the UV-B-blocking model was not due to the presence of a plastic cover.

We placed the enclosures randomly in the shallow water of lakes or ponds where natural breeding sites were located. By using four enclosures of each type, we insured that our results were not caused by some bias in our procedure or by a small sample size. Setting up the experiments at several different sites helped assure that any results we obtained were not unique to a particular area.

Although we only had to follow the development of the eggs until they either hatched or died, the experiments took two years to complete. Like most fieldwork, the project ran into some unexpected trouble. During the first year, we could not get enough viable eggs to set up our experiments because the animals did not breed at all sites. Spring storms with high winds destroyed some of our enclosures. Under the same harsh spring weather encountered by the toads, we had to count and measure each egg, in every enclosure, every day. And then there was vandalism, both by humans and smaller mammals. So someone had to guard each site, twenty-four hours a day, until the experiments were done, which often took two weeks. By the end of the second year, however, we had results that were both dramatic and foreboding.

More than 40 percent of the western toad and Cascades frog eggs exposed to UV-B radiation died, compared with 10 to 20 percent of those that were shielded. Northwestern salamanders did not fare better; more than 90 percent of their exposed eggs died. The Pacific tree frog, however, was unscathed, with almost all of its eggs surviving under all lighting conditions.

These results, together with those from the DNA repair study, convinced us that the link between UV-B radiation and the egg deaths was real. Natural levels of UV-B were killing amphibian eggs in the field. Pacific tree frogs—which had the highest levels of photolyase and whose populations were doing fine—seemed more resistant to UV-B than did western toads and Cascades frogs, two species with less photolyase that are in decline throughout their ranges. We do not know the status of northwestern salamander populations, but given our results, they too could be in jeopardy.

We had found one small piece of the amphibian decline puzzle. But many questions remain. Is the egg mortality in the Cascades caused solely by UV-B exposure or are other factors involved? We had observed the growing presence of a pathogenic fungus in the lakes. Is the UV-B radiation compromising the defense systems of embryos, making them more susceptible to disease? Another question is, how much mortality during the egg stage can a population endure before it crashes? Western toads, for example, live for twenty years or more, so the results of their reproductive troubles in recent years may not become apparent for many years.

Finally, could we settle on a universal explanation for amphibian declines? In-

Unlike most salamanders, the northwestern salamander often deposits its eggs in shallow water where ultraviolet rays penetrate.
D. Grant Hokit

creasing levels of UV-B radiation are obviously not the only reason these animals were disappearing. It cannot explain, for example, why species that live under dense forest canopies, protected from UV-B, are also in trouble. Perhaps other organisms, such as plants, fish, insects, and even humans will provide us with more information on the damaging effects of increasing levels of UV-B. We know, for example, that certain crop plants have reduced growth, photosynthetic activity, and flowering when exposed to UV-B radiation. In the Antarctic, severe ozone depletion and increased UV-B have been associated with reduced growth in phytoplankton.

If projected increases in UV-B occur, over evolutionary time there may be increased selection pressure on amphibians and other organisms to evolve efficient repair mechanisms or to alter their behaviors and thereby minimize their exposure to UV-B. Unfortunately, changes wrought by human disturbance occur at such rapid rates that many organisms may not have time to adapt. □

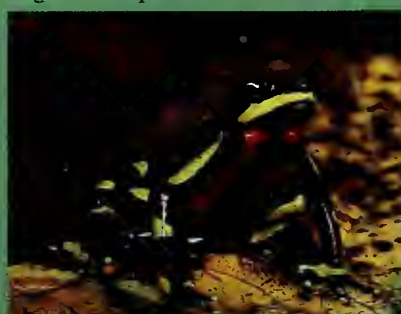
Here Today, Gone Tomorrow?

The impact of human activities on amphibians is difficult to gauge. Natural fluctuations in their populations and the lack of long-term data on their numbers have led to some uncertainty about their status. Nevertheless, an alarming number of amphibians are on the endangered list. Their semiaquatic life styles make amphibians particularly vulnerable to change; habitat destruction, which is probably the single most important cause for the decline of most species, affects amphibians both on land and in the water where they breed. Their permeable skin readily absorbs waterborne pollutants, they have no hair or feathers for protection, and their eggs are not encased in hard shells. In addition to habitat loss, a host of other factors—disease, water acidification, increased UV-B radiation, and introduced species in ponds and lakes—may be contributing to dwindling amphibian populations.

Golden toad (*Bufo periglenes*)
Gregory G. Dimijian; Photo Researchers, Inc.

Red-legged frog (*Rana aurora*).
Frank Schneidermeyer; Oxford Scientific Films

Some of the more attractive and interesting toads and frogs are among the amphibians that are disappearing. Populations of the red-legged frog (*Rana aurora*), found from British Columbia to northern Baja California, have dwindled drastically in California and Oregon, but the cause of the decline is unknown. Australia's gastric brooding frog (*Rheobatrachus silus*) is one of the most fascinating amphibians because of its habit of brooding its offspring in its stomach and then expelling them as tadpoles or young frogs. This species was discovered in 1973 and has not been seen in nature since 1979. The golden toad (*Bufo periglenes*), seen here mating, is found only in Costa Rica's Monte Verde Cloud Forest Preserve; its range is a few miles along the crest of the continental divide. This diminutive toad was abundant in 1987, but is now extremely rare. The harlequin frog (*Atelopus varius*) has vanished from the same area.—*R. A.*



Harlequin frog (*Atelopus varius*)
Michael Fogden; Oxford Scientific Films

Australian gastric brooding frog (*Rheobatrachus silus*)
R. W. G. Jenkins; NHPA

A Pacific tree frog rests on a leaf. Although this species deposits its eggs in shallow water, high levels of photolyase, an enzyme that repairs UV-B damage from the sun, seem to protect them.
Art Wolfe

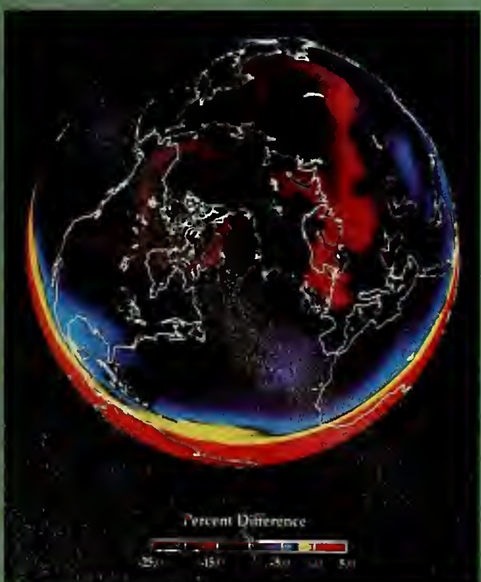
The Ozone Connection

The ozone layer is thinning, but how much is being lost over any particular part of the globe varies according to latitude and season. The computer-generated image below shows that significant losses have occurred over populous regions of Asia, Europe, and North America (demonstrating that the ozone hole over Antarctica is not our only problem). The image shows the change between the level of ozone in March 1993—a particularly bad year—and the average March level between 1979 and 1990. At midlatitudes, ozone levels (blue areas) are between 10 and 15 percent below the previous average, and nearer the pole they are as much as 20 percent below normal (purple). The red band over the Tropics shows a slight increase. The small black circle at the North Pole represents polar night, where no measurements are made.

Ozone is vital because it is the only component of the atmosphere that absorbs damaging ultraviolet radiation (UV-B) from the sun. The depletion of this protective layer, even by small amounts, may therefore have dire consequences for many organisms, including ourselves. Ozone, a blue-tinged gas that is a form of oxygen with three atoms instead of the usual two, is easily broken down by the chlorofluorocarbons and other pollutants that humans have dumped into the atmosphere. Despite international efforts to phase out the manufacture of the most destructive chemicals by the end of this century, some of those already released will persist in the stratosphere for many decades, eating away the ozone layer faster than it can be naturally replenished.

Quantifying the rise in UV-B radiation that accompanies the loss of ozone is complex, due to variable cloud cover and a host of other factors, but even a small loss of ozone can have large effects. One United Nations report calculated that even a one percent loss of ozone results in an extra 50,000 skin cancers and 100,000 cataracts worldwide.

A recent study of UV-B levels conducted by James B. Kerr and C. Thomas McElroy, of Environment Canada in Downsview, Ontario, gives some idea of how much more ultraviolet radiation is reaching the earth's surface. Their measurements, taken from the Toronto area (the same latitude where Andrew Blaustein conducted his field experiments on amphibian eggs), showed what a small change in ozone can mean. Between the winter of 1989–90 and the winter of 1992–93, ozone in the stratosphere dropped by 11 percent, but the amount of UV-B radiation reaching the ground climbed by 90 percent. Between the summer months for roughly the same period, ozone loss was 7.4 percent, while UV-B radiation increased by 30 percent. These increases may seem large, but because the ozone layer is so effective at blocking UV-B radiation, a doubling of the low natural levels still represents a relatively small exposure.—*R. A.*



NASA

Rob Simpson

What Are Squirrels Hiding?

Their half-eaten acorns are clues to a complex relationship with oaks

by Michael Steele and Peter Smallwood

Naturalists and casual observers alike have been struck by the special relationship between squirrels and acorns. As ecologists, though, we cannot observe these energetic mammals scurrying up and down oak trees and eating and burying acorns without wondering about their complex relationship with the trees. Are squirrels dispersers and planters of oak forests or pesky seed predators? The answer is not a simple one. Gray squirrels may devour many acorns, but by storing and failing to recover up to 74 percent of them (as they do when seeds are abundant), these arboreal rodents can also aid regeneration and dispersal of the oaks.

Their destructive powers are well documented. According to one 1908 report, squirrels destroyed tens of thousands of fallen acorns from an oak stand on the University of Indiana campus. A professor there estimated that each of the large white oaks had produced between two and eight thousand acorns, but within weeks of seed maturity hardly an acorn could be found among the fallen leaves.

Deer, turkeys, wild pigs, and bears also feed heavily on acorns, but do not store them, and are therefore of no benefit to the trees. Flying squirrels, chipmunks, and mice are also unlikely to promote tree dispersal, as they often store seeds in tree cavities and underground burrows. Only tree squirrels—whose behavior of caching below the leaf litter often promotes successful germination of acorns—and perhaps blue jays, important long-distance dispersers (see *Natural History,* October 1986), seem to help oaks spread and reproduce.

Early in our study, we observed one particularly puzzling behavior pattern. Squirrels would pry off the caps of acorns, bite through the shells to get at the nutritious inner kernels, and then discard them half eaten. Moments later, they would seize another acorn and repeat the routine. The ground under the towering oaks was littered with thousands of half-eaten acorns, each one bitten only from the top. Why would any animal waste so much time and energy and risk exposure to such predators as red-tailed hawks only to leave a large part of each acorn uneaten?

Gray squirrels are generally opportunistic in their feeding habits, but at other times they are picky. They often eat a variety of budding leaves, flowers, and spring twigs, and even the pupae of giant silk

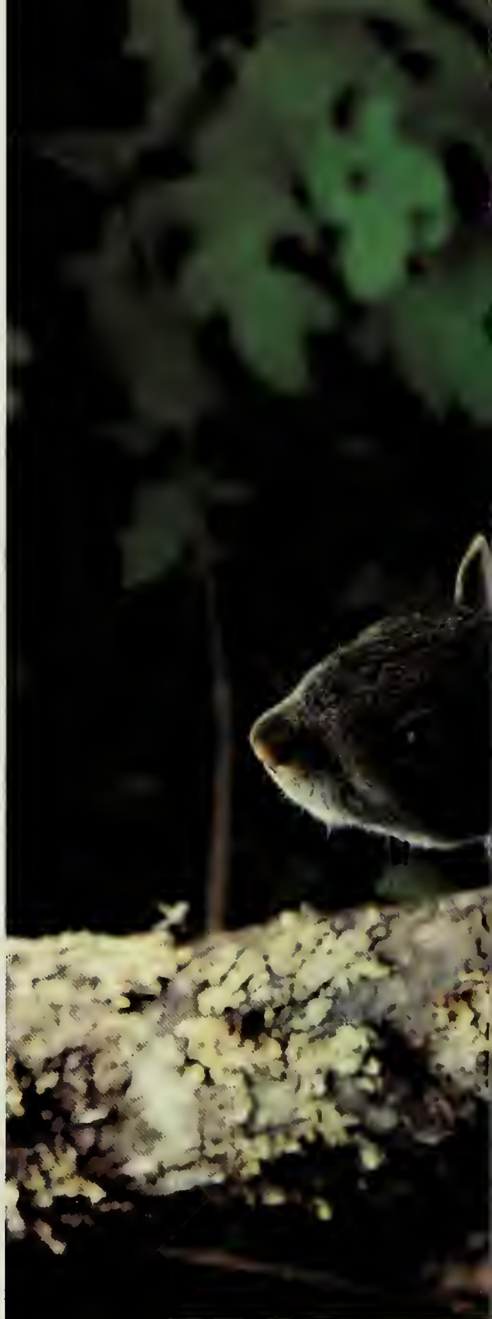
After sprouting from acorns, red oak seedlings produce their first leaves, above. Acorns of red oaks are more often cached by squirrels, while those of white oaks are immediately eaten. Right: Before caching it for use in winter, a gray squirrel nips an acorn's tip, killing the oak embryo so the seed cannot sprout.

E. R. Degginger; Bruce Coleman, Inc.

An acorn weevil feeds on oak seeds, below. Female weevils may deposit their eggs in them, and squirrels will frequently eat such infested acorns, larvae and all. Right: Two young squirrels venture from their natal nest in the spring or early summer. Within days they will be weaned and left by their mother to forage for themselves.

Mark Moffett; Minden Pictures

Rob Simpson



moths, carrion, a bird's egg or two—and, rarely, nestling chicks. During the autumn and winter months, however, their main diet consists of nuts and seeds, and at this time squirrels readily distinguish between various species, and even parts, of acorns. Active throughout the year, the squirrels store large quantities of seeds and nuts to see them through the winter. These caches usually include acorns of some of the thirty-two oak species that grow in the squirrel's range in eastern North America.

An oak seed, or acorn (really a fruit), consists of an outer shell enclosing two young, energy-rich seed leaves (or cotyledons) that meet to surround a tiny embryo at the apex, or tip. To a squirrel, the acorn is a package of energy (between five and twenty kilocalories) that can be easily opened and eaten in less than half the time needed for other, harder nuts or stored for use up to ten months later.

Not all acorns are the same. The two major groups of oaks—red and white—have seeds that differ generally in chemical makeup. Red oak acorns are rich in fats (18 to 25 percent of dry weight) but are laced with 6 to 10 percent tannins (the bitter-tasting, water-soluble compounds used to tan hides). White oak acorns are less fatty (5 to 10 percent) and lower in tannins (less than 2 percent). The two groups of trees also differ in when they germinate. Red oak acorns lie dormant in winter and sprout in spring; white oak seeds usually sprout soon after falling to the ground in autumn.

We knew that more fat enhances the seeds' energy value, but we also suspected that high tannin levels make them less palatable and digestible to squirrels. Tannin in oak leaves repels many insects, and some trees may even increase their tannin concentrations as a natural pesticide. Do these chemicals also repel squirrels or do the squirrels rely on them to protect their own acorn caches from insects and other pathogens? How do tannins and other acorn chemicals influence the squirrels' feeding and caching decisions? And do these behaviors, in turn, affect the distribution of oaks? These were but a few of the questions we sought to answer with a series of field experiments.

In 1980, zoologist Alan R. Lewis studied the dietary preferences of squirrels in the winter by identifying the remains of acorns left behind after squirrels had eaten from their caches. Lewis demonstrated that squirrel preferences depend not only on the energy content of the acorns but also on their relative abundance. Sometimes as many as six species of oaks grow within the range of a single gray squirrel. Lewis found that when faced with these choices, the squirrels ate more fatty acorns, except when the lower-energy acorns were more numerous. Other researchers have shown that squirrels are generally efficient in their feeding habits, expending the least amount of energy to obtain the most nutritious foods (see *Natural History,* October 1989). Ecologist Christopher C. Smith, of Kansas State University, and others had shown that given a choice, squirrels preferred to take mostly the high-fat red oak acorns.

To further analyze the squirrels' preferences, Peter Smallwood and David Peters, of Ohio State University, created "artificial acorns" with measured chemical additives. After shelling and processing white oak acorns into a dough, they added various levels of tannin and fat to simulate those in real acorns. The squirrels consistently chose to eat the acorns with lower tannin levels, particularly in autumn—even those acorns with low fat content.

These results seemed to contradict such earlier studies of squirrels' food preferences as Smith's. After wrestling with this inconsistency, however, Smallwood and

Peters realized that squirrels may exhibit different preferences for caching and eating. Perhaps squirrels use one kind of acorn for immediate consumption and another for storing. When white oak acorns germinate in the fall, they concentrate much of their nutrients in a taproot, which squirrels find unpalatable. We wondered whether squirrels might eat white oak acorns immediately because their early germination renders them unsuitable for caching, and store the red oak acorns, which germinate later, for consumption in winter and spring.

To test this idea, we presented gray squirrels in Ohio and Pennsylvania parks and campuses with both red oak and white oak acorns. In each of more than 1,200 feeding trials, we recorded whether the acorn was eaten or stored, the distance it was dispersed, and the amount of time the animal took to eat or bury the acorn. Unambiguously, squirrels cached more red oak acorns (60 percent) and consistently ate those of the white oaks (more than 85 percent).

In a second group of experiments we attempted to determine the squirrel's role in dispersing trees—this time in mature oak forests in Pennsylvania's Pocono region. But we often failed to find the buried acorns, even after watching a squirrel only ten feet away shove a nut into a shallow hole, cover it, and brush debris over the top. Clearly, we needed a more sophisticated approach. Following the lead of botanist Victoria Sork, we tagged thousands of red and white acorns with small metal labels and, after the animals dispersed the seeds, used metal detectors to recover them. Again, the results were clear. Squirrels either ate white oak acorns on the spot or carried them only short distances before eating them. Red oak acorns were generally carried farther away and cached intact.

Other factors besides germination schedules and seed chemistry affect the seeds' perishability. Might squirrels also respond to these in deciding whether to cache? Many acorns become infested with insect larvae, particularly weevils of the genus *Curculio*. During spring, females of several species of these beetles bore into acorns to deposit their eggs. By early fall, the maggot-sized larvae have often destroyed more than 60 percent of the crop of single trees. Would squirrels avoid wormy acorns as less suitable for storing?

We identified batches of infested acorns

Preparing to cache an acorn, a gray squirrel excavates a hole in the soil. Often squirrels go through the motions of burying acorns, only to store the seeds elsewhere.
E. A. Janes; NHPA

by having them X-rayed at a local hospital, then offered them to the squirrels. Consistently, they selected noninfested seeds for caching, but opened and consumed the infested ones, eating the weevils as well. In nearly 300 tests, the squirrels readily ate the high-protein larvae.

Sometimes squirrels kill the early-sprouting white oak acorns by excising the seed embryos just before burying them, as John Fox reported in 1982. If an acorn germinates before the squirrel can recover it, up to half its stored energy goes to the seedling rather than the squirrel. A few quick scrapes of the squirrel's incisors across the bottom of the acorn kills the embryo and preserves the seed's nutrients intact.

While this notching behavior underscores the importance of seed perishability, it does not explain the habit of biting and discarding acorns that so intrigued us at the beginning of our study. Those squirrels ate only from the acorn's top half—the end farthest from the embryo. And the acorns were of red oaks, not white. As we moved our research from parks and campuses to rural woodlands, from the scrub-oak forests of the southeastern coastal plain to the oak-hickory forests of the Middle Atlantic States, we saw the same pattern. Squirrels bit off the tops of acorns of at least seven red oak species. We also found that blue jays and common grackles did the same. Squirrels, jays, and grackles each employed a different technique to open an acorn, but all consumed only 30 to 60 percent of the kernel—and always from the top of the seed. Later we discovered that weevil larvae were found in the top of the acorn two to three times more often than in the bottom.

Our first guess, that higher levels of noxious tannins are located near the bottom of the acorn, where the embryo is located, was borne out by chemical tests. But we also found, in more than seventy-five trials, that squirrels frequently cached partly eaten seeds, which raises the possibility that the acorns may have become adapted to withstand such attacks. Because their embryos were not destroyed, these seeds germinated about as often as undamaged ones. Perhaps for the oak, the half-palatable acorn is an effective strategy for survival. Maybe acorns benefit from being chosen by squirrels for burial and dispersal, as long as they are not totally destroyed.

We still wondered what factors other than tannin content influenced the squirrels' choices. What about the acorn's shape, for instance, or the toughness of its shell? In pursuit of these questions, we offered gray squirrels their choice of whole acorns, shelled acorns, and shelled acorns in which the bottom and top ends were carved to resemble the opposite ends. Squirrels ate just the top portion of both whole and shelled seeds, indicating that the shell was not the determining factor. But when we presented squirrels with carved seeds, we found that they were fooled into eating in reverse, feeding only on the disguised bottom half. Next we presented squirrels with artificial acorns that contained varying amounts of tannin. Consistently, when given those seeds with the highest tannin concentration, squirrels ate from the top half but consumed only a small amount.

Ecologist Joseph Grinnell, in a 1936 paper, pondered how oaks could colonize hilltops, since acorns are too heavy for wind dispersal and do not roll uphill. He concluded that animals must carry them to such sites. Although we are only just begining to grasp some of the complexities of the squirrels' relationship with oak forests, we agree with Grinnell's early assessment. By dispersing red oak acorns more often and farther than white oak acorns, by excising the embryo of white oak acorns and storing primarily sound acorns, we suspect that gray squirrels can strongly influence the distribution and range of various oak species. Indeed, evidence is accumulating that along with jays, squirrels are crucial in regenerating second-growth oak forests and may even have been responsible for spreading the vast stands of oak throughout North America after the last retreat of the glaciers 10,000 years ago. □

All the Khan's Horses

"Empires Beyond the Great Wall," an exhibition documenting 3,500 years of the history and culture of steppe empires, will be at the American Museum of Natural History through Sunday, November 27.

With fresh mounts in reserve, Genghis Khan's warriors could outlast any enemy

by Morris Rossabi

In August 1227, a somber funeral procession—escorting the body of perhaps the most renowned conqueror in world history—made its way toward the Burkhan Khaldun (Buddha Cliff) in northeastern Mongolia. Commanding a military force that never amounted to more than 200,000 troops, this Mongol ruler had united the disparate, nomadic Mongol tribes and initiated the conquest of territory stretching from Korea to Hungary and from Russia to modern Vietnam and Syria. His title was Genghis Khan, "Khan of All Between the Oceans."

Genghis Khan and his descendants could not have conquered and ruled the largest land empire in world history without their diminutive but extremely hardy steeds. In some respects, these Mongolian ponies resembled what is now known as Przewalski's horse (see page 54). Mongols held these horses in highest regard and accorded them great spiritual significance. Before setting forth on military expeditions, for example, commanders would scatter mare's milk on the earth to insure victory. In shamanic rituals, horses were sacrificed to provide "transport" to heaven.

The Mongols prized their horses primarily for the advantages they offered in warfare. In combat, the horses were fast and flexible, and Genghis Khan was the first leader to capitalize fully on these strengths. After hit-and-run raids, for example, his horsemen could race back and quickly disappear into their native steppes. Enemy armies from the sedentary agricultural societies to the south frequently had to abandon their pursuit because they were not accustomed to long rides on horseback and thus could not move as quickly. Nor could these farmer-soldiers leave their fields for extended periods to chase after the Mongols.

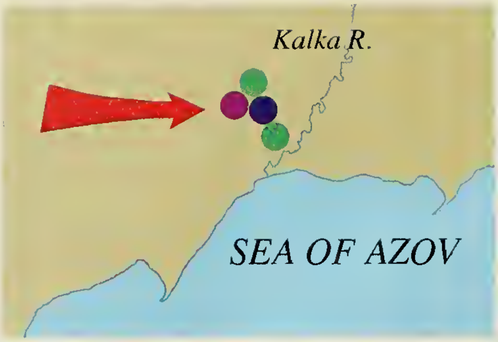
The Mongols had developed a composite bow made out of sinew and horn and were skilled at shooting it while riding, which gave them the upper hand against ordinary foot soldiers. With a range of more than 350 yards, the bow was superior to the contemporaneous English longbow, whose range was only 250 yards. A wood-and-leather saddle, which was rubbed with sheep's fat to prevent cracking and shrinkage, allowed the horses to bear the weight of their riders for long periods and also permitted the riders to retain a firm seat. Their saddlebags contained cooking pots, dried meat, yogurt, water bottles, and other essentials for lengthy expeditions. Finally, a sturdy stirrup enabled horsemen to be steadier and thus more accurate in shooting when mounted. A Chinese chronicler recognized the horse's value to the Mongols, observing that "by nature they [the Mongols] are good at riding and shooting. Therefore they took possession of the world through this advantage of bow and horse."

Genghis Khan understood the importance of horses and insisted that his troops be solicitous of their steeds. A cavalryman normally had three or four, so that each was, at one time or another, given a respite from bearing the weight of the rider during a lengthy journey. Before combat, leather coverings were placed on the head of each horse and its body was covered with armor. After combat, Mongol horses could traverse the most rugged terrain and survive on little fodder.

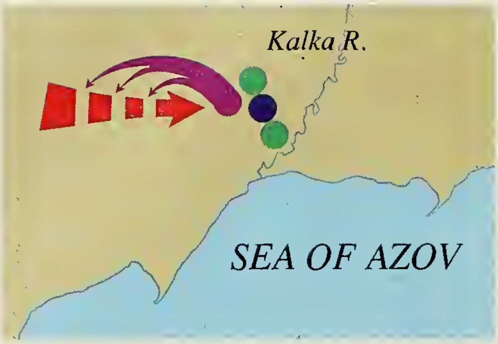
According to Marco Polo, the horse also

Mongol cavalrymen engage the enemy, facing page, in an illustration from an early-fourteenth-century manuscript by Rashid al-Din, a Persian-Jewish historian and an important minister at the Mongol court in Tabriz.
Wan-Go H. C. Weng; Bibliothèque Nationale

For almost ten days before the Kalka River battle on May 31, 1223, more than 20,000 invading Mongols (colored dots) feigned retreat before a Russian force (red arrow) of 80,000 men. At the Kalka River, the Mongols finally re-formed their ranks.



After pursuing the Mongols for days, the exhausted Russian troops were spread out along a twenty-mile line. The Mongols charged, with 5,000 mounted archers (violet arrows) in the lead.



Once the leading Russian detachments were separated from their support columns and thrown into disarray, 5,000 Mongol heavy cavalry troops (dark blue) engaged them in close combat. Ten thousand light cavalry troops (light green) followed the retreating Russians, capturing or slaughtering most of them.

provided sustenance to its rider on long trips during which all the food had been consumed. On such occasions, the rider would cut the horse's veins and drink the blood that spurted forth. Marco Polo reported, perhaps with some exaggeration, that a horseman could, by nourishing himself on his horse's blood, "ride quite ten days' marches without eating any cooked food and without lighting a fire." And because its milk offered additional sustenance during extended military campaigns, a cavalryman usually preferred a mare as a mount. The milk was often fermented to produce kumiss, or *araq*, a potent alcoholic drink liberally consumed by the Mongols. In short, as one commander stated, "If the horse dies, I die; if it lives, I survive."

Mobility and surprise characterized the military expeditions led by Genghis Khan and his commanders, and the horse was crucial for such tactics and strategy. Horses could, without exaggeration, be referred to as the intercontinental ballistic missiles of the thirteenth century. The battle of the Kalka River, now renamed the Kalmyus River, in southern Russia is a good example of the kind

Overleaf: The painter of this somewhat inaccurate depiction of a Mongol bridling a horse was probably a Persian city dweller eager to ingratiate himself with his Mongol patrons.
Topkapi Palace Museum, Istanbul

An illustration from History of the Moghuls, *a seventeenth-century Indian text, depicts Genghis Khan's army in battle against the Jurchen rulers of China in about 1214. The Mongols' horses appear to be well protected by leather and armor.*
Gulestan Palace Library, Tehran; Werner Forman Archive, Art Resource

A Horse of a Different Chromosome?

by Oliver A. Ryder

Although Genghi Khan's armies probably never numbered more than 200,000 troops, they may have had as many as 800,000 horses. Thirteenth-century sources, including *The Secret History of the Mongols*, give a tantalizing account of the training of Mongol horses. Captured in the wild and broken-in during the first two years of their lives, the young horses were then allowed to graze for three years.


Dominique Braud; Dembinsky Photo Assoc.

At the age of five they were once again ridden and prepared for combat. The Mongols depended on their horses so much, and gathered so many of them, that John of Plano Carpini, a papal emissary to the Mongol court from 1246 to 1247, noted with amazement that "they have such a number of horses and mares that I do not believe there are so many in all the rest of the world." What kind of horses were they?

A number of Mongol scholars, including historians James Chambers and Charles R. Bawden, have noted that the horses used by Genghis Khan and his descendants resembled Przewalski's horse, the species of wild horse that formerly inhabited the Gobi Desert and the steppes of Mongolia.

Przewalski's horse is named for Russian explorer and naturalist N. M. Przhevalsky, who first saw herds of the yellowish brown species in the central Asian steppes in about 1876. Both Przewalski's and the domestic horse are descended from the same lineage in the family Equidae, but Przewalski's horses differ from domestic horses morphologically, behaviorally, and genetically. All domestic breeds have 64 chromosomes, whereas Przewalski's have 66. (First-generation hybrids have 65 chromosomes and may interbreed with either domestic or Przewalski's horses.) Przewalski's horses have an erect, dark brown mane, no forelock, and white noses. Their coat has a distinctive dun color with a yellowish tinge on the back that becomes lighter toward the flanks and almost white under the belly. Their appearance is accentuated by bulky heads and, especially in stallions, stocky, well-muscled necks. Although their behavior has never been observed in wild populations, studies of herds kept in large enclosures and reserves suggest that, like feral domestic horses, stallions defend harems of mares from male competitors.

Przewalski's horses became extinct in the wild when the last survivors disappeared from the Dzungarian gobi of Mongolia in 1970, but were saved from total extinction by the existence of captive populations bred in zoos. Plans are now under way to return the only true wild horse to its ancient homelands in Mongolia, China, and adjacent regions of Russia. Experimental studies of herds of zoo-raised Przewalski's horses placed in new prairie and semidesert steppe environments suggest that adaptation to the wild environment can be rapidly accomplished. Perhaps one day they will repopulate their homelands and again roam freely in the wild.

Oliver A. Ryder holds the Kelberg Genetics Chair at the Zoological Society of San Diego's Center for Reproduction of Endangered Species. He has published extensively on the genetics of Przewalski's horses and other endangered species, and is particularly interested in the conservation of Asian arid steppe ecosystems and their wildlife.

of campaign Genghis Khan waged to gain territory and of the key role of horses.

After his relatively easy conquest of Central Asia from 1219 to 1220, Genghis Khan had dispatched about 30,000 troops led by Jebe and Sübedei, two of his ablest commanders, to conduct an exploratory foray to the west. After several skirmishes in Persia, the advance forces reached southern Russia. In an initial engagement, the Mongols, appearing to retreat, lured a much larger detachment of Georgian cavalry on a chase. When the Mongols sensed

In a fifteenth-century Ming Dynasty painting, a Mongol archer rides a horse equipped with sturdy stirrups and an elaborate saddle. An archer could shoot arrows accurately while riding at full tilt across the steppe.
Victoria and Albert Museum

that the Georgian horses were exhausted, they headed to where they kept reserve horses, quickly switched to them, and charged at the bedraggled, spread-out Georgians. Archers, who had been hiding with the reserve horses, backed up the cavalry—with a barrage of arrows as they routed the Georgians.

Continuing their exploration, the Mongol detachment crossed the Caucasus Mountains, a daunting expedition during which many men and horses perished. They wound up just north of the Black Sea on the southern Russian steppes, which offered rich pasturelands for their horses. After a brief respite, they first attacked Astrakhan to the east and then raided sites along the Dniester and Dnieper Rivers, inciting Russian retaliation in May of 1223 under Mstislav the Daring, who had a force of 80,000 men. Jebe and Sübedei commanded no more than 20,000 troops and were outnumbered by a ratio of four to one.

Knowing that an immediate, direct clash could be disastrous, the Mongols again used their tactic of feigned withdrawal. They

A late-fourteenth-century Persian painter depicted Mongols on a hunt. Falcons and dogs typically accompanied the horsemen.
The Topkapi Palace Museum, Istanbul

Opposite page: A seventeenth-century Indian miniature shows Genghis Khan praying to Tenggeri, the sky god, who, according to legend, entrusted him with the mission of uniting the world under Mongol control. The Mongol ruler is portrayed with Persian features and wearing Persian clothing.
Werner Forman Archive; Art Resource

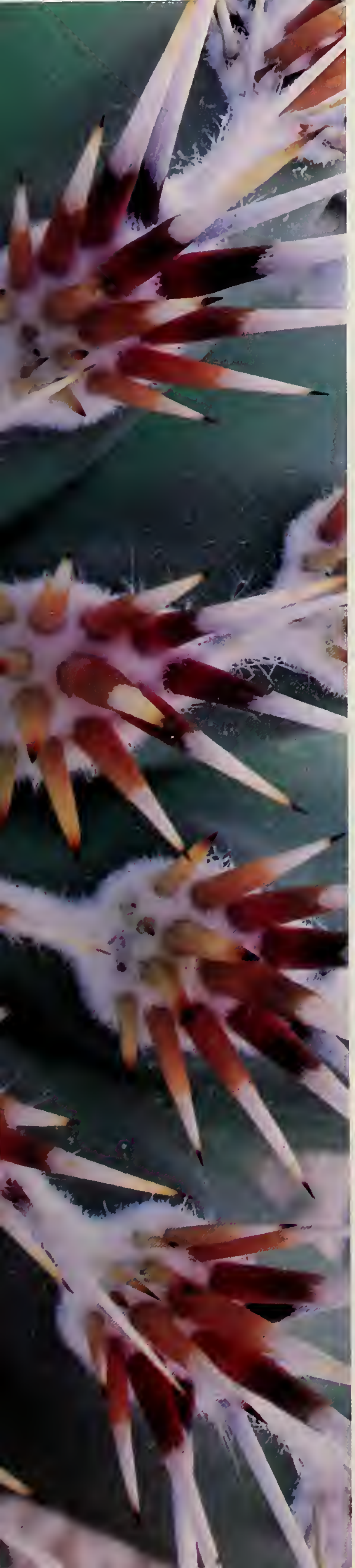
retreated for more than a week, because they wanted to be certain that the opposing army continued to pursue them but was spaced out over a considerable distance. At the Kalka River, the Mongols finally took a stand, swerving around and positioning themselves in battle formation, with archers mounted on horses in the front.

The Mongols' retreat seems to have lulled the Russians into believing that the invaders from the East were in disarray. Without waiting for the remainder of his army to catch up and without devising a unified attack, Mstislav the Daring ordered the advance troops to charge immediately. This decision proved to be calamitous. Mongol archers on their well-trained steeds crisscrossed the Russian route of attack, shooting their arrows with great precision. The Russian line of troops was disrupted, and the soldiers scattered.

After their attack, the archers turned the battlefield over to the Mongol heavy cavalry, which pummeled the already battered, disunited, and scattered Russians. Wearing an iron helmet, a shirt of raw silk, a coat of mail, and a cuirass, each Mongol in the heavy cavalry carried with him two bows, a dagger, a battle-ax, a twelve-foot lance, and a lasso as his principal weapons. Using lances, the detachment of heavy cavalry rapidly attacked and overwhelmed the Russian vanguard, which had been cut off from the rest of their forces in the very beginning of the battle.

Rejoined by the mounted archers, the combined Mongol force mowed down the straggling remnants of the Russian forces. Without an escape route, most were killed, and the rest, including Mstislav the Daring, were captured. Rather than shed the blood of rival princes—one of Genghis Khan's commands—Jebe and Sübedei ordered the unfortunate commander and two other princes stretched out under boards and slowly suffocated as Mongols stood or sat upon the boards during the victory banquet.

The battle at the Kalka River resembled, with some slight deviations, the general plan of most of Genghis Khan's campaigns. In less than two decades, Genghis Khan had, with the support of powerful cavalry, laid the foundations for an empire that was to control and govern much of Asia in the thirteenth and fourteenth centuries. He died on a campaign in Central Asia, and his underlings decided to return his corpse to his native land. Any unfortunate individual who happened to encounter the funeral cortege was immediately killed because the Mongols wished to conceal the precise location of the burial site. At least forty horses were reputedly sacrificed at Genghis Khan's tomb; his trusted steeds would be as important to him in the afterlife as they had been during his lifetime. □



Cardon and the Night Visitors

Bats pollinate a giant cactus—and may even determine its sex

by Theodore H. Fleming

Along a narrow belt in Mexico's western Sonoran Desert grows the cardon, the world's largest cactus. Widespread in Baja California and coastal Sonora, the cardon resembles the much more familiar saguaro because of its single trunk and multiple branches, but it is more massive. Like saguaros, young cardons grow slowly, most plants taking at least fifty years to attain sexual maturity. Large individuals may live well over a century and reach a maximum height of about sixty feet.

Like the saguaro and organ pipe cactuses with which they share their habitat, cardons provide food and shelter for many creatures. Elf owls make their homes in cactus cavities excavated by woodpeckers, as do violet-green swallows, ash-throated flycatchers, and even big brown bats. Ospreys and red-tailed hawks sometimes build their nest platforms on the cardon's highest branches. Yet, familiar as the cardon is to naturalists, no one realized that it also has the most enigmatic breed-

Left: Symmetrically patterned spines crown a cardon cactus, seen from above, in Mexico's Sonoran Desert. In Baja California Sur, above, sunrise over the Sierra Giganta illuminates a mixed forest of cardon cactuses and palos blancos, *or white-barked trees.*
Both photos by Jack W. Dykinga

ing system of any cactus—a puzzle that Sandrine Maurice, of the University of Paris, James Hamrick, of the University of Georgia, and I have been piecing together for the last few years.

Like most flowering plants, cactuses are usually hermaphroditic; that is, their flowers have both male and female organs producing pollen and ovules. Because their flowers appear to have fully functional anthers and ovaries, botanists assumed that the cardon, too, was a hermaphrodite. For a long time, they also assumed that the flowers were pollinated by wind, insects, or birds. But telltale signs pointed to another kind of pollinator. Cardon flowers are large (most wind-pollinated flowers are small) and white, so they are visible at night. In addition, they open at sundown (when birds aren't active) and produce large amounts of pollen and nectar. All these traits point to pollination by bats. Several years ago, Merlin Tuttle, of Bat Conservation International, and I began to investigate that possibility.

Bats pollinate a number of tropical trees, including the commercially valuable balsa, the fiber-producing kapok, and the durian, the source of a major fruit crop in Southeast Asia. Century plants, the basis of mescal and tequila, are also pollinated by bats. Since the 1890s, we have known that some specialized tropical bats, especially those living in drier areas, pollinate the flowers of certain shrubs, trees, and vines—and do so exclusively at night.

Cardons, we soon found, are visited by birds and by the occasional moth, but they are primarily pollinated by lesser long-nosed bats, a species that migrates from central Mexico to the Sonoran Desert each spring. Weighing just under one ounce, these mammals have a wingspan of about thirteen inches. We have radio-tracked their flights and found that the bats will fly at least fifteen to twenty miles, and possibly as far as fifty miles, from their roosts to feed on the nectar and pollen of various cactuses, including the saguaro and the organ pipe. Even more dependent on plants for food than are hummingbirds (which often supplement their diet of flower nectar with insects), these bats use the amino acids in pollen to make protein.

Merlin D. Tuttle, Bat Conservation International; Photo Researchers, Inc.

Lesser long-nosed bats, the principal pollinators of cardon cactuses, zero in on fruits, left, and flowers, below, during nocturnal forays of fifteen miles or more. The distance between the bats' roosts and the plants may influence the proportion of male, female, and hermaphroditic plants in the cactus populations.

Merlin D. Tuttle; Bat Conservation International

Foraging for about four hours each night, they carry pollen from plant to plant. When fruits mature, the bats also eat the pulp, dispersing seeds in their excreta.

Each spring, after mating with males on their central Mexican wintering grounds, pregnant females fly north, following the blooming schedules of columnar cactuses. Most of the males remain behind. The females assemble in maternity roosts in caves or abandoned mines, each giving birth to a single young in May. Such roosts may contain from a few thousand to 100,000 female bats.

When we began our study of the cardon at Bahia Kino, on the Gulf of California, we didn't realize that it had a rare and complicated breeding biology. We discovered this complexity by accident while trying to determine the importance of bats as cactus pollinators. The ephemeral cardon flowers bloom for only one night, opening at sunset and closing before noon the next day. In our earliest experiments, we placed bridal-veil netting over the flowers to separate the effects of bats and moths from those of birds and diurnal insects. We covered some flowers only during the day and others only at night, then recorded the percentage of flowers that developed into mature fruit. Our control group consisted of flowers that were not covered with netting and were visited by both nocturnal and diurnal pollinators.

We were disappointed to find that very few of our flowers (whether covered or uncovered) produced any fruit, and we thought the experiment had been a failure. When we examined many of the flowers more carefully, however, we were surprised to discover that all of the flowers on some plants produced pollen but lacked ovules; these plants were males. Other plants, we found, produced flowers that lacked pollen but *did* have ovules; these were females. Still other plants—the hermaphrodites—produced flowers with both pollen and ovules. No wonder most of the cardons in our experiment failed to produce fruit; we had inadvertently used mostly male plants! Once we recognized their gender system, we performed the experiments again and eventually demonstrated that because bats carry much larger amounts of pollen than do insects or birds, they were the superior pollinators.

The very presence of male and female plants in populations that also contain hermaphrodites raised an interesting evolutionary question. How can a male or female plant, which must somehow connect genetically with another, perhaps distant, plant of the opposite gender, reproduce as successfully as a hermaphrodite, which has flowers of both sexes on each plant? The hermaphrodite, with two ways of perpetuating itself (through pollen and seeds), would appear to have competitive superiority. Furthermore, hermaphroditic cardons are "self-compatible," that is, their pollen can successfully fertilize ovules on the same plant, or even within the same flower. Hence they sometimes produce fruit and offspring without the aid of bird, bee, or bat. With such advantages, why haven't the hermaphrodites simply overwhelmed the males and females and pushed them out of the population?

Jack W. Dykinga

A cardon cactus, left, blooms in the Sonoran coastal area near Puerto Lobos. The large, white flowers that open at sundown and produce large quantities of nectar and pollen are signs of coevolution with bat pollinators. The cardon, which grows in the Baja California desert, below, is the world's largest species of cactus. Some individuals may be sixty feet tall and live more than a century.

Jeff Foott; DRK Photo

We reasoned that, to have remained in the population, the single-sex plants must have had a compensatory feature that allowed them to persist genetically. We hypothesized that the males were producing more pollen and the females more fruit and seeds than their hermaphroditic counterparts. To test this idea, we measured pollen and/or seed production in all sexes and found that male and female plants indeed outproduced hermaphrodites in both respects. Each year, males produced about 60 percent more flowers and pollen, and females produced about 60 percent more seeds than the average hermaphrodite. Given enough visits by bats and other pollinators, males might be able to fertilize enough ovules and females to maintain their presence in a cactus population.

Another question arose after we completed our pollination studies at Bahia Kino and had gone on to survey the proportions of sexes throughout the plant's range in Sonora and Baja California. The distribution of the sexes varied significantly from place to place. Some cactus stands contained all three sex classes, while others included only females and hermaphrodites. No males were present in the southern third of the plant's range in Sonora or in the northern quarter of the range in Baja California. Where males were missing, hermaphrodites outnumbered females by about two to one.

What factor or factors might produce this geographic pattern? We wondered if climate might be the reason that no males lived in extreme parts of the species' range, but we soon found male cactuses growing in a wide variety of climatic conditions.

Next, we questioned whether male plants, which, along with females, we presumed to be mutants of hermaphroditic ancestry, hadn't had time to spread throughout the cardon's range. Genetic tests, however, revealed that these cactuses, although spread over a wide geographic area, constantly exchange genetic material. We believe that the long-distance flights of the bat pollinators have kept local populations from becoming isolated and inbred.

Finally, we explored whether the clumped distribution of male plants might be correlated with the ranges of bats. When we mapped the locations of known maternity roosts against the distribution of male cardons, we found a close fit. With one distant exception, all of the known maternity roosts in Sonora are in the northern half of the cardon's range, while all of the known roosts in Baja are in the southern two-thirds of its range. Male plants are found only within those two areas that are within about a fifty-mile radius of known bat roosts.

To make sure it was the distribution of bats rather than of some other pollinator that influenced the distribution of the cardons' sexes, we observed the behavior of cardon-visiting animals at four sites with males and four that lacked males. The most frequent avian visitors to cardon flowers during the day were gila woodpeckers, but these and other birds visited only about 13 percent of the flowers, usually less than once per hour. In contrast, bats visited about 90 percent of the flowers, but sites containing males differed in the time of arrival of bats. Bats began feeding before 9:00 P.M. at sites with male cactuses, but arrived later—after 11:00 P.M.—at places that lacked males.

We know from our radio-tracking studies that the time that bats arrive in an area depends on its distance from a roost. We also know from our observations at Bahia Kino that the later bats arrive in an area, the fewer visits they make to each cardon flower. Thus, flowers farther from bat roosts probably receive fewer visits than do those closer to the roosts.

Why do male cactuses drop in and out of populations while females do not? We don't yet understand the cardon's reproductive genetics, but we think males may be eliminated in some local populations because they are in strong competition with hermaphrodites. Hermaphroditic plants, by fertilizing their own ovules with or without the aid of pollinators, significantly reduce the number of ovules available to a male plant's pollen. Thus, despite producing more pollen than hermaphrodites, a male's pollen can only reach the ovules of females and hermaphrodites when pollinators are abundant. Female plants are totally dependent on animal pollinators. But when pollinators are relatively scarce, females still produce as many seeds per season as hermaphrodites do. Hence, they can persist in locations where males cannot.

The lives of this desert bat and desert cactus appear to have coevolved. Cardon plants are an important source of nectar, pollen, and fruit pulp for the bat. The bat, in turn, helps determine the reproductive success of individual plants through pollination and seed dispersal. By carrying pollen or seeds long distances, it can also influence the genetic and sexual composition of cardon populations. □

Seeking nectar, a lesser long-nosed bat pokes its entire head into a cardon flower.
Merlin D. Tuttle, Bat Conservation International; Photo Researchers, Inc.

At the American Museum of Natural History

125 Years of Discovery

As part of the Museum's 125th anniversary, an exhibition of selected artifacts, specimens, and memorabilia from the Museum's collections will open on Friday, October 14, in the Birds of the World Hall. The displays will include a mounted lion purchased in 1869 from the collections of Paris taxidermist Edouard Verreaux; a specimen of the now-extinct great auk; the complete skeleton of *Oxyaena*, an early carnivorous mammal collected in Wyoming in the 1890s; a painting of this animal as it might have appeared in life, by Charles R. Knight; two shadow puppets acquired in the South Pacific by anthropologist Margaret Mead in the 1930s; dinosaur eggs discovered in Mongolia by paleontologist Walter Granger during the Museum's Central Asiatic Expeditions in the 1920s; and the recent discovery by Museum scientists in Mongolia of the remains of the dinosaurlike *Mononykus*, a possible link between birds and theropod dinosaurs.

Also on October 14, a photo exhibition, "People and Places," will open in the Akeley Gallery. Taken on Museum expeditions, the photographs range from those by Carl Lumholtz in Mexico and Adolph Bandelier in Peru and Bolivia in the 1890s to more recent ones by Stanley A. Freed in India in the 1950s and 1970s and Ross McPhee in Cuba and Vietnam in the 1990s.

Margaret Mead Film and Video Festival

Shamanism and familial relationships will be among the major themes of the sixty-two films presented at the 1994 Margaret Mead Film and Video Festival. The Festival will open on Wednesday, October 12, and run through Tuesday, October 18. This year's retrospective celebrates the works of Richard Gordon and Carma Hinton, whose films on China have appeared at the Festival since its inception in 1976. One of the opening-night films will be *Fearless—The Hunterwali Story*, featuring Nadia, India's legendary stunt actress of the 1930s and 1940s. Director Riyad Vinci Wadia will introduce the film and answer questions afterward.

Same-day tickets may be purchased after 5:00 P.M. on weekdays or 10:30 A.M. on weekends for $8 ($7 for members and students with I.D.). A Festival pass for $44 ($40 for members and students with I.D.) and daily tickets can be prepurchased with MasterCard or VISA by calling (212) 769-5310. Seating is limited. For a complete schedule, call (212) 769-5305.

Okavango: Africa's Last Eden

Photographer Frans Lanting spent two years photographing the diverse flora and fauna of southern Africa's Okavango Delta, a project culminating in his book

A photograph from the memorabilia exhibit shows a messenger from the Museum's Education Department delivering taxidermy specimens to a New York City public school, June 1932.
AMNH

Museum anthropologist Adolph Bandelier, on the Henry Villard expedition to Peru and Bolivia, 1892.
AMNH

Okavango: Africa's Last Eden. On Thursday, October 6, he will give a slide-illustrated talk on this region, a wetland oasis of more than 8,500 square miles in Botswana's Kalahari Desert. The talk will begin at 7:00 P.M. in the Main Auditorium. Call (212) 769-5606 for information.

JENNIE—A TALE OF A CHIMPANZEE

As a columnist for *Natural History* in the 1980s, Douglas Preston explored the Museum's vaults, storage rooms, and archives, and wrote about his findings in *Dinosaurs in the Attic* (1986). The tragic tale of Meshie, a chimpanzee raised by a Museum curator, has become the basis of Preston's novel *Jennie,* which raises ethical questions about the use of primates for research, as well as attempts to raise chimps among humans. On Tuesday, October 11, at 7:00 P.M. in the Kaufmann Theater, Preston will show film footage of Meshie from the Museum's archives and talk about the case histories of other chimpanzees such as Lucy, Nim Chimpsky, Viki Hayes, and Washoe. For more information, call (212) 769-5606.

HUDSON VALLEY CRUISE

On Sunday, October 23, a high-speed catamaran will leave from Wall Street at noon and cruise as far as West Point, returning to New York by 4:00 P.M. Sidney Horenstein, coordinator of environmental public programs at the Museum, will point out aspects of geological interest along the way, and William Schuster, director of the Black Rock Forest Preserve, will talk about local plant life and the relationship of Black Rock to the rest of the Hudson Highlands. For ticket availability, call (212) 769-5606.

YELLOWSTONE

The history, geology, and wildlife of Yellowstone National Park are the subjects of a new IMAX film. The Grand Teton Mountains, the Lower Falls of the Grand Canyon of Yellowstone, and the interior of a vent of Old Faithful will be among the places featured. Showtimes are 12:30, 2:30, and 4:30 P.M. *Africa: The Serengeti,* an IMAX film about the vast savanna ecosystem of Kenya and Tanzania, will be shown at 10:30 and 11:30 A.M., and at 1:30 and 3:30 P.M. daily. For information, call (212) 769-5650.

DANGEROUS WINDOWS INTO THE EARTH

The hazards of earthquakes, from New York to California, will be the subject of four Tuesday-evening lectures. On October 11, Barbara Romanowicz, head of the Berkeley Seismic Station and professor of geology and geophysics at the University of California at Berkeley, will talk on what earthquakes tell us about the earth. On October 18, Allan G. Lindh, chief of the U. S. Geological Survey's seismology branch, will discuss the seismic activity of the San Andreas Fault system. On October 25, Klaus Jacob and Leonardo Doherty, scientists at Columbia University's Lamont-Doherty Earth Observatory, will evaluate the possibility of earthquakes in "stable" continental areas. Finally, on November 1, Lloyd Cluff, president of the Earthquake Engineering Research Institute, will discuss what we can do about earthquakes. Tickets for all four lectures are $25 ($20 for students). For a complete schedule of fall lectures, call (212) 769-5310.

PLANTS OF THE WETLANDS

The plant diversity of lakeshores, floodplains, bogs, marshes, and seasides will be the subject of a five-part series by William Schiller, lecturer in botany in the Museum's Department of Education. The hour-and-a-half talks will be held in the Kaufmann Theater on consecutive Mondays at 2:30 P.M., starting on October 24, and on consecutive Thursdays at 7:00 P.M., starting October 20. Tickets for all five lectures are $40.

THE HERITAGE OF GENGHIS KHAN

Adam T. Kessler, curator of "Empires Beyond the Great Wall," will lead a gallery tour of the exhibition and will discuss the artifacts on display and the steppe culture of the Mongol people. Tours cost $12 and will be given on Monday, October 3; Wednesday, October 5; and Friday, October 7, starting at 7:00 P.M. Call (212) 769-5310 for details.

These events take place at the American Museum of Natural History, Central Park West at 79th Street in New York City. The Kaufmann Theater is located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

Born to Talk?

by Peter Marler

The behaviorist B. F. Skinner viewed most human behavior as quintessentially cultural and structured by individual experience, with genetic factors playing a minimal role. His book on verbal behavior, published in 1957, struck a chord with a generation of like-minded anthropologists, linguists, philosophers, and psychologists. In the same year, Noam Chomsky's book on syntactic structures launched a direct confrontation with these behaviorists, arguing forcefully that we cannot begin to explain the complexities of language development without first recognizing the innate mechanisms unique to the human brain. Behaviorist dogma acknowledges that certain distinctive attributes of the human brain are required for the development of language, but these are thought to be merely the underpinnings for learning in general, with no direct bearing on the specific details of how language develops. A corollary of this empiricist view of language development, popular in the seventies and eighties, has been that concepts of innateness were not only scientifically questionable but perhaps even intellectually dangerous.

PATTERNS IN THE MIND: LANGUAGE AND HUMAN NATURE, by Ray Jackendoff. *Basic Books, Inc., $25; 246 pp., illus.* THE LANGUAGE INSTINCT: HOW THE MIND CREATES LANGUAGE, by Steven Pinker; *William Morrow and Co., Inc., $23; 494 pp.*

We have had to wait until the nineties for a more balanced view of the mechanisms underlying behavioral development. This new, more integrative position, appropriate for the era of the Human Genome Project, is well expressed in two creative and thought-provoking books, one by Chomsky's ex-student Ray Jackendoff and the other by Steven Pinker, a faculty colleague of Chomsky's at M.I.T. Both authors believe that genes play a much more dominant role in the development of human behavior than the behavioristic generation would have thought possible.

Jackendoff's *Patterns in the Mind: Language and Human Nature* and Pinker's *The Language Instinct: How the Mind Creates Language* accomplish more than a simple restatement and clarification of Chomskyan concepts, and their writings are most exciting when departing from the party line. Their approach is an exemplary illustration of how behavioral scientists can come to grips with the complex nature–nurture dilemma.

Jackendoff's lean, precise prose, blessedly free of jargon, launches us into these thorny issues. In the best tradition of an introductory text, *Patterns in the Mind* begins with a deceptively simple statement of purpose, setting forth a series of basic premises and then exploring their implications in more and more detail. Almost without realizing it, the reader is drawn into increasingly profound and complex topics as the book progresses.

Expanding on the theme of innateness, Jackendoff takes us through the basic tenets of Chomskyan insight. To account for the human ability to speak and understand novel sentences, we have to ascribe to the speaker's mind an innate mental grammar that specifies possible sentence patterns. That this specialized brain machinery drives a child to develop language is nowhere more forcefully manifest than in the signing behavior of the congenitally deaf. Deaf children deprived of access to a fully competent signing tutor often create their own private, so-called home-signing systems and invent some of the organizational features characteristic of spoken language. The parallels between speech and signing extend to the underlying brain mechanism. Studies of sign-language aphasias reveal that damage in Broca's and Wernicke's areas of the brain has the same effects on the comprehension or performance of signing that it does in speech, even though sign-language aphasics can use their hands perfectly well for other purposes.

Another compelling parallel between speech and signing (which also applies to the acquisition of a second spoken language) concerns sensitive periods of development when children learn most rapidly. Children who have acquired language before the age of seven achieve the greatest perfection in accent and are the most sensitive to vocabulary nuances. Jackendoff believes that

> nurture is maximally effective in language learning only when the proper elements of nature are in place—when a normal child is exposed to language during the critical period. If, for whatever reason, the proper elements of nature aren't in place, far more extensive nurture still doesn't produce performance at anywhere near the same level.

He puts it nicely when he writes, "Nature places its own stamp on nurture," and he believes that this imprint can be seen in other human behavior such as musical

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composition, where he contributes his insights as a concert clarinetist and horn player.

Some of the most stimulating ideas in *Patterns in the Mind* concern how meanings are actually encoded and used in the brain as a basis for thought and action. A child's brain accomplishes the phenomenal task of learning, on average, about ten words every day between the ages of two and five. That such a mind-boggling task could be achieved through learning by rote seems virtually inconceivable. Jackendoff argues, however, that if we think of the mind as full of elaborate machinery, actively and vigorously constructing concepts and associating those concepts with words, we can more easily grasp how such feats can be accomplished.

Pinker, in *The Language Instinct,* covers much of the same ground as Jackendoff, but more fully and in a different style. While Jackendoff writes with the relative austerity appropriate for what is essentially an advanced textbook on cognitive science and language, Pinker is clearly in love with language. The preface begins with a clear statement of intent: "to show that there is a world of elegance and richness in quotidian speech that far outshines the local curiosities of etymologies, unusual words and fine points of usage."

At times he writes as if he is intoxicated with the richness and diversity of languages and their content. In making a point, he is just as likely to quote from "All My Children" as from the Bard. Because the book is laced throughout with wit and humor, we might think that the entertainment is bought at the price of sacrificing scientific precision. But Pinker has a rare ability to express profound, original reflections in a way that is frankly entertaining. As a consequence, the book is a delight to read, even though it is packed with new ideas, often on difficult and challenging topics.

Although he is a follower of Chomsky and clearly reveres his mentor's intellect and insights, Pinker, like Jackendoff, departs radically from him in many respects. He points out that not all species universals—that is, attributes shared by all members of a species—are necessarily innate. He embraces a Darwinian approach to the evolution of language with an enthusiasm that one searches for in vain in the writings of Chomsky, who sometimes seems so bemused by the marvelous intricacies of language that he cannot imagine what the evolutionary antecedents might have been. Many of Pinker's insights are a direct consequence of his much broader approach to the biology of language. Pinker does not hesitate to criticize Chomsky's arcane style, whose technical analyses of word and sentence structure are often couched in "abstruse formalisms"—strict adherence to prescribed external forms. He characterizes Chomsky's discussions of flesh-and-blood speakers as "perfunctory and highly idealized." Perhaps as a reaction to Chomsky's predilection for formalisms, Pinker takes great pains to apply innateness arguments to language—with all of its colloquial blemishes and imperfections—as it is actually used. As a consequence, his case becomes all the more persuasive and compelling.

The emphasis in much of *The Language Instinct* is placed upon syntax, or the component of grammar that arranges words into phrases and sentences. Like Jackendoff, Pinker also believes that the creativity of the child's developing language only makes sense if an innate grammar exists (Chomsky's Universal Grammar). Much of the time, children's words, phrases, and sentences simply do not match anything they have actually heard. Some of the quirkiness of their speech makes sense if they are tenaciously adhering to rules that, in particular cases, may actually be inappropriate.

As compelling as the innateness argument is, it must not be overstated. At some organizational level, what children say must be determined by what they have heard. The underlying principles may be deeply hidden, but they are there and potentially available for the child to learn. These rules are often applied, even if (as happens so often in early speech) using them means violating some of the conventions of that particular language. Every parent can cite an example: "My teacher holded the baby rabbits and we patted them" or "I love cut-upped egg."

Neither Jackendoff nor Pinker will rule out the possibility that language is directly affected by an individual's genetic makeup. Linguist Myrna Gopnik studied a British family with thirty members, spanning three generations, that had a history of a particular grammatical speech defect that hinted strongly at a genetically based impairment. Once we have the idea that neuroanatomical abnormalities may be linked to linguistic behavior, postulating a genetic basis seems reasonable.

The many strange ways in which language can be disturbed by lesions resulting from stroke and other forms of brain injury (especially those involving Broca's and Wernicke's areas) are explored by both Jackendoff and Pinker. Pinker even develops a neural network model that would decode syntax. We have only to listen in on the lamentations of engineers trying to get their computers to process speech to appreciate the effortless ease with which the ears and brain of a baby accomplish the same task. Rarely do engineers seek inspiration from our understanding of how the brain does the job—or at least how we think it does it. Pinker presents his model, based on toy neurons, as a fun diversion, but he shows that, in principle, plausible networks can indeed be created. To determine whether they exist in the brain—and how the circuits are actually put together—is a daunting challenge for the next generation of neurobiologists. Pinker seems optimistic that they will be successful, perhaps soon.

Jackendoff, on the other hand, is more pessimistic. He gives what is, perhaps, a more realistic appraisal of the enormous gap between glimpsing a few aspects of how the linguistic machinery works (based on the observed effects of brain damage) and really understanding the microcircuitry that is responsible for normal function. Research at this level, although the subject of much theory, is a special art, only slowly being perfected by neurobiologists. Current targets are simple invertebrates, especially systems with small numbers of individually identified neurons whose physiological properties and interactions can be studied in great detail.

Direct investigation of the circuitry underlying language at this level of analysis in humans is not possible at present, but scientists thrive on such challenges. The battle is half won when researchers are convinced in principle that they have a meaningful set of hypotheses and models amenable to analysis at the cellular level. That is where we stand now in the study of the biology of language. The next step is up to the coming generation. Jackendoff and Pinker offer many pointers as to the direction that this research might profitably take.

Peter Marler, a professor in the Department of Neurobiology, Physiology, and Behavior at the University of California at Davis, specializes in animal behavior and is particularly interested in understanding how song dialects develop in birds. The author and editor of numerous papers and books about animal communication, Marler coauthored, with William J. Hamilton III, Mechanisms of Animal Behavior.


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EXOTIC
DESTINATIONS
By Andrew Bill

SALT WATER CROCODILES DOWN UNDER. PHOTO BY DAVID AUSTEN/TONY STONE WORLDWIDE
COVER: TOUCAN, BELIZE. PHOTO BY A & S CARY/ZEFA

EXOTIC DESTINATIONS

THE WORLD'S GREAT NATIONAL PARKS

In the midst of this frenetic, high-tech modern age, there are still quiet corners of the globe where nothing has changed— where days still open, unfold, and close according to the same natural rhythms they have followed for thousands of years.

Every country has at least one of these corners — a national park or protected area of outstanding natural beauty. No matter whether it's arid desert, deciduous lowland forest, or high mountain peaks, each preserve offers its visitors the key to the nation's unique natural identity, a glimpse of distinctive flora and fauna, of another world far removed from the twentieth century that hurtles past beyond its gates. In this issue of Exotic Destinations, *Natural History* Magazine's biannual tribute to outstanding vacation locales, we look at ten of the world's leading national parks.

Australia

Kakadu National Park

Ask any Australian naturalist which of that country's many parks captures most its incredible biodiversity and indigenous culture. He or she will no doubt talk of Kakadu, just east of Darwin on Australia's northern coast, which has been singled out by UNESCO as a World Heritage Site. Within its boundaries are woodlands, coastal fringes, wetlands, arid plateaus and southern hills — all in constant flux with the extreme seasons. These habitats are home to many of Australia's strange menagerie from dugongs (sea cows) and turtles on the beaches to crocodiles in the rivers, and goannas and kangaroos on land. Magpie geese, wandering whistle ducks, and ibises fleck the billabongs. Complementing this natural diversity, and an integral part of it, are the Aboriginal people who continue an unchanging lifestyle that they are happy to share with the modern visitor.

A careful study of pristine nature and accessibility, Kakadu has commercial tours ranging from the one day "rush-around" to a 15-day camp-out led by Aboriginal guides. Four-wheel drives are recommended for private parties. There are four eco-attuned resorts and lodges offering the highest level of comfort . Most visitors prefer the cooler temperatures of the dry season, May to September. For more information call (310) 645-9875.

Belize

Cockscomb Basin

Central America, the narrow land bridge between two continents, is renowned for its abundance and variety of natural wonders. Belize, on its Caribbean coast, can lay special claim to this distinction, for reasons best explained by its wildlife sanctuary of Cockscomb Basin .

Only increased to its present area of 100,000 acres in 1990, Cockscomb is ringed on three sides by high mountain ridges falling down to either side of the country's highest point, Victoria Peak. Within this dramatic amphitheater lives a remarkable concentration of fauna, most notably five species of feline — jaguar, puma, ocelot, jaguarundi, and, smallest of the lot, the diminutive margay — that prowl the forest by night in search of peccaries, Brocket deer, anteaters and tapir. Scattered through the canopy are more than 290 species of birds, ranging from the gaudy scarlet macaw and keel-billed toucan to the imposing king vulture. Armed with a comprehensive booklet, visitors can take self-guided walks along the forest paths, threading through the shadows of giant ferns and mighty mahogany trees, or may arrange for a tour by a member of the park personnel.

Rufus-tailed hummingbird, Belize

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The sanctuary headquarters is located on a six-mile entrance road that leads from the village of Maya Center, which, in turn, can be reached by driving south from Belize City along the scenic Hummingbird Highway. The dry season runs from February through May. June to October is the wettest period. For more information, call (212) 563-6011.

White-faced capuchin monkey, Costa Rica

TOM ULRICH, TONY STONE WORLDWIDE

Costa Rica

Corcovado National Park

Partly because 25 percent of the country is made up of wildlife refuges, and partly because of its incredible natural biodiversity, Costa Rica presents the naturalist with enormous choice. If forced to select one of its 20 national parks, try Corcovado, over 40,000 hectares of swamps and rainforest on the Osa Peninsula on the country's southern Pacific coast.

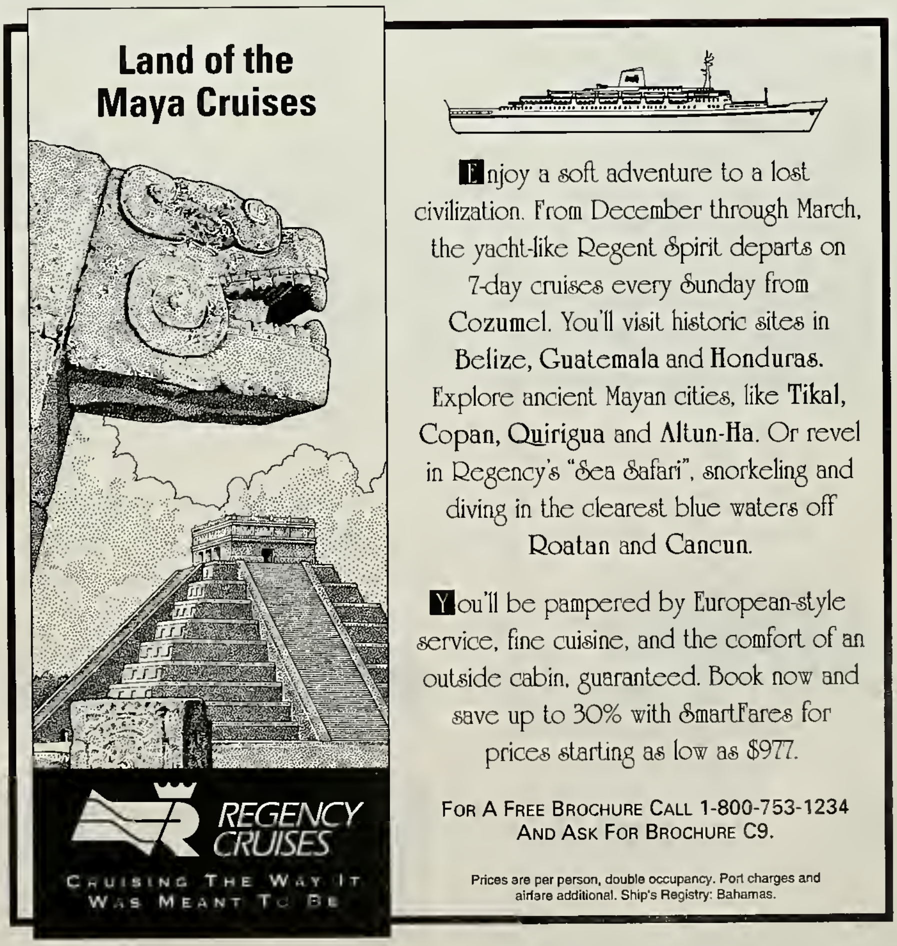
The broad range of habitats has spawned more than 140 species of mammals, from tapirs and crocodiles in the wetlands to silky anteaters, ocelots, and cougars in the low-altitude-cloud forests. As you walk the clearly-defined paths, crabwood and silk cotton trees suddenly shake as a family of capuchin monkeys with the faces of old men stops to stare down at the visitors. In quiet industry on the forest floor, leaf-cutter ants (just one of 6,000 insect species) march in endless and imperturbable columns. Looking skyward, bright scarlet macaws and the majestic wingspan of the great harpy eagle slash across the blue roofs of the clearings.

Despite its natural tranquillity, Corcovado is easy to reach by four-wheel drive vehicles cruise ship or light plane from Puerto Jimenez. Accommodations run the gamut, starting at the resort level — Albergue Lapa Rios (near Puerto Jimenez), Villas Rio Mar (Dominical). The season runs all year with light rains May to November. For more information: (800) 327-7033.

India

Corbett National Park

Opened in 1936, Corbett was India's first park. Sprawling across the foothills and plains, cut by the forest-flanked Ramganga River, Corbett has a breathtaking setting in the Patlidun Valley hard against the Himalayas in the north. Visitors traveling by park jeep — or in the shade of a how-



dah (6-person saddle) high on the back of an elephant — can see the terrain change from Sal forests to miles of open country dotted with only the occasional tree. As one of the first sanctuaries to come under the conservation scheme "Project Tiger," Corbett also offers the opportunity to see one of these rare cats stalking their prey of deer or wild boar.

A baby Indian elephant feeds on hay

MANOJ SHAH/TONY STONEWORLDWIDE

Other notable wildlife includes leopards, wild elephants, and sloths.

Just 230 miles from the major gateway of Delhi, Corbett is easy to reach by car. Visitors should stop in the town of Ramnagar (the entrance to the park) to arrange tours and accommodation in the Dhikala area of the park, where tented camps and forest rest houses can hold up to 150 people. Corbett is only open November to mid-May. For more about India's national parks, call the tourist offices at (212) 586-4901 (east coast) or (213) 380-8855 (west coast).

New Zealand

Kahurangi National Park

It's a mark of New Zealand's commitment to conservation that a country already known for its wide open expanses, low population, and pristine environment also has 38 parks. These mirror the country's diverse terrains from rain forest in the north to glaciers in the south.

New Zealand's newest addition to the list is Kahurangi National Park, opened in April of this year and located in the north-west corner of the South Island near the already celebrated Abel Tasman and Nelson Lakes national parks. Kahurangi is the nation's second largest (next to Fiordland) and, complementing the country's acclaimed flora and fauna, contains many natural attractions found nowhere else in the country. Visitors can hike from coastal terrain to high country following the Heaphy and Wangapeka walking tracks, enjoying more than half of the country's 2,270 plant species. Ornithologists can take this rare opportunity to find endangered species like the great spotted kiwi, blue duck, falcon and rock wren. Spelunkers can explore the country's longest cave system (22 miles) and deepest cave.

Paved roads from the Picton ferry connect the North and South islands, or visitors can take domestic airline flights to Nelson. Organized hiking tours complete with guide are available. Accommodations within the park are at designated camp sites. Rustic inns and deluxe hotels pepper neighboring towns. For more information call the tourist office at (310) 395-7480.

Panama

Soberania National Park

Soberania is one of the most accessible parks in Panama and one of the few places where you are guaranteed sightings of the larger fauna.

Just 16 miles out of Panama City, Soberania is a 54,000-acre rain forest preserve. Get there early in the morning and set off down the well-defined trails in search of the 100 recorded species of mammals, from the coy white-tailed deer to boisterous families of primates tumbling through the trees. One recommended trail in the western end of the

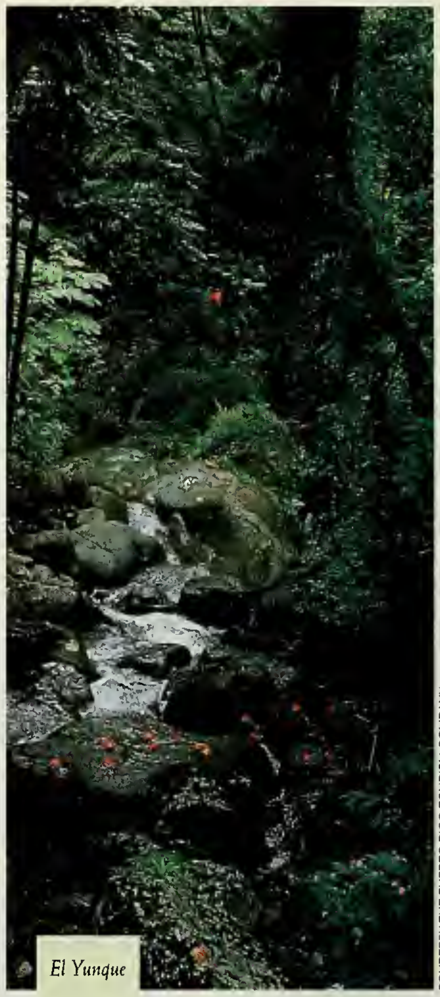
park ends, refreshingly, at the lush Agua Salud waterfall that flows into Lago Gatún. Another trail in the south, the Sandero el Charco, has the major flora clearly marked. Forest ranger guides are well-informed about forest lore. The Summit Botanical Garden and Zoo affords glimpses of those otherwise-elusive capuchin and howler monkeys, jaguars, and parrots.

To get to the park from Panama City, just drive northwest for 30 minutes to the town of Gamboa. Most visitors opt for the dry season, November to April, although the rainy season also has its merits. For more information call (800) 726-2627.

Puerto Rico

El Yunque National Forest

Remarkable in an island only 110 by 35 miles, Puerto Rico has over 20 designated forest reserves scattered across rolling hills, desert and rain forest. The finest example, both for its size, and long history, is El Yunque, an easy 45-minute drive east from the capital of San Juan.



El Yunque rain forest

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Its 28,000 rain forest acres cater to both the day-trip picnicker and the serious naturalist. For the latter, 13 trails lead off through four distinct forest types from rain forest to dwarf cloud forest, made up of over 240 species of tropical trees, 20 species of orchids, 50 varieties of ferns. As you walk through the shadows, you become aware of the forest's contradiction — silence and din — as thousands of tree frogs chirp "coqui," and birds, including the magnificent Puerto Rican parrot, call forward and back. At least 26 mammal species — such as the Puerto Rican boa — are unique to the island. One of the most rigorous trails winds up 3,523 feet to the top of the Pico El Toro, while Big Tree Trail, an easier alternative, ends at La Mina Falls. A tropical forest center, for better appreciation and study of the rain forest, is currently under construction.

If, after the hike, you want a more relaxing afternoon, bring a picnic and take the short drive down to one of the island's most spectacular beaches, palm-fringed Luquillo. Most hotels and resorts offer day trips. For more information call (800) 223-6530.

South Africa

Hluhluwe Game Reserve

All of South Africa's 17 national parks offer a variation on the big game experience. The best known is Kruger, with its many rest camps and large staff. One of the oldest of these reserves is Hluhluwe (pronounced shush-lui), located in Northern Zululand (north of Durban) and frequently linked with its sister reserve of Umfolozi. Here, amid a rare combination of forest, grasslands, and woodland savanna, visitors can expect to sight the oddly-graceful giraffe feeding on uppermost branches, cheetahs lazing in the sun, or hear the distant laughter of hyena. Crocs and hippos wallow in the rivers. This is the only park in Natal where you will see Africa's "big five" — elephant, lion, rhino, leopard and buffalo. An even rarer opportunity is to see the white rhino, once reduced to only 50 head but pulled from the brink of extinction in the early 60s. After driving the self-guided auto trails or taking a hike, guided by a game guard, across the varied terrain, visitors can head back to the comfort of the newly-renovated Hilltop Camp for cocktails and sunsets.

The best approach to Hluhluwe is by car either from Johannesburg (5 hours) or from Durban (3 hours). Otherwise special interest groups offer tailored tours. From May to August the shorter grass makes it easier to spot the game. Later, in the dry season, the game collects around the water holes. For information call (800) 822-5368 (eastern U.S.) or (800)-782 9772.

Thailand

Huai Kha Khaeng Wildlife Sanctuary

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United States

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Few national parks can compare with the sheer majesty and size of Glacier Bay. Outstanding even in a state with 15 national park areas, it encompasses 3.3 million acres of raw nature, untamed and untouched.

Most people experience its drama from the sea (see "Smooth Sailing"). At this level the two major attractions are the tidewater glaciers that abut the sea in blue ice walls that move with the slowness of millennia

COURTESY GLACIER BAY NATIONAL PARK

Margerie Glacier, Alaska

(occasionally releasing house-size chunks with a crack like a pistol shot) and the sea life from black and white guillemots to whales. Schools of orcas and humpbacks glide by oblivious of passing ships. But the park also extends beyond the coast rising from barren terrain left behind by retreating glaciers to the dank deep-greens of temperate rain forest. Its Mount Fairweather is the highest peak in southeastern Alaska. Those hiking its back country will come across many of North America's great land mammals including brown and black bears, mountain goats and moose.

There are no roads into the park. The easiest access is by scheduled boat and air service from Juneau, 65 miles away. Hikers planning in-land trips must arrange to be dropped by tour boat or float plane and should attend one of the twice-daily orientation talks at the park lodge (55 rooms) at Bartlett Cove. Guided hikes, kayak and rafting trips are also available. For more information call (907) 697-2230.

Andrew Bill is a free-lance journalist based in New York and specializing in travel and design.

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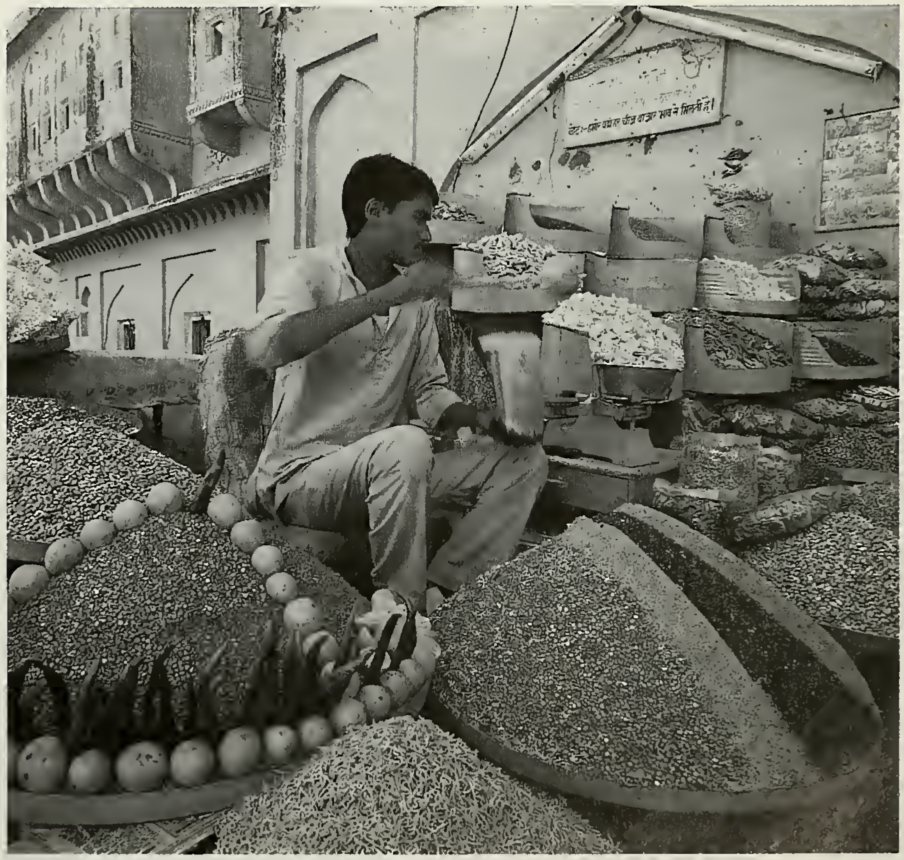

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A View Outside the Galaxy

by Gail S. Cleere

A quick look at a star map for early evening in October shows that one of the least interesting areas of the celestial sphere has now spread itself before us to the south. As always, the northern sky is occupied by Polaris and the Big Dipper, which circles the North Star throughout the year; but in the southern half of the sky, things have changed. The dense swath of the Milky Way that stretches across the sky on summer nights, has now sunk below the western horizon, and the glittering jewels of our winter sky have yet to rise in the east. In the hours after sunset, only a single first-magnitude star presents itself to us: Fomalhaut (which in Arabic means "mouth of the fish").

There is a reason for this dearth of bright stars in the autumn sky. On summer evenings, when we look toward the bright stars of Scorpio and Sagittarius to the south, we face the center of the Milky Way, with its concentration of stars obscured by a band of dark, interstellar dust. In October, however, when we look south past Piscis Austrinus (the Southern Fish) and Fomalhaut, we are facing the emptiness of intergalactic space.

Although Fomalhaut is almost twice the diameter of our sun and fourteen times more luminous—at a distance of twenty-three light-years, it is only the eighteenth brightest star in the sky. Because it is located in an area of the sky that is so sparsely populated by bright stars, it is sometimes called the Solitary One. Fomalhaut is surrounded by the faint stars of the water constellations: Aquarius (this month home to the planet Saturn), Delphinus, Pisces, Cetus, and Eridanus.

By midnight, however, our familiar winter friends—Taurus, Orion, Gemini, Canis Major—lumber up over the eastern horizon, recognizable, reassuring, and comforting. By midnight, Fomalhaut is nearly gone, and by midmonth it has set below the western horizon. By November, the winter Milky Way will rise over the eastern horizon, and our attention will be drawn toward the dense stars of the spiral arm of the galaxy that we live in.

THE PLANETS IN OCTOBER

Mercury is visible early in the month in the evening sky, but then passes between the earth and the sun, reaching inferior conjunction on October 21. By the end of the month, Mercury is again far enough away from the sun to be seen, and its best morning sky apparition of 1994 begins.

Venus is low in the southwest at sundown, disappearing on the western horizon by midmonth. If your southwestern horizon is very clear on the evenings of the 6th and 7th, look for the pretty grouping of Venus, Mercury, Jupiter, and the thin cresent moon just after sunset.

Mars rises just past midnight, well after the bright stars in Orion have led the charge across the October skies. At the beginning of the month, look for the red planet between the star Procyon, in Canis Minor, and Gemini's Castor and Pollux. On the morning of the 28th, Mars is 7° above the waning crescent moon.

Jupiter is low in the southwest at sunset, succumbing quickly to the solar glare. It remains in the constellation Libra.

Saturn is in the faint constellation Aquarius, well up in the southeast as the sun goes down, and does not set until after midnight. Enjoy it now, because next year this planet's magnificent rings will face us edge-on and will not be visible through telescopes. On the 14th and 15th, the waxing gibbous moon passes well north of Saturn.

Uranus and **Neptune** remain together in Sagittarius, following the summertime constellations as they dip below the western horizon in early evening.

Pluto and the giant planet Jupiter share the constellation Libra this month.

The **Moon** is new at 11:55 P.M., EDT,

on the 4th; first-quarter moon is at 3:17 P.M., EDT, on the 11th. The full moon, at 8:18 A.M., EDT, on the 19th, is called the hunter's moon. The moon reaches last quarter on the 27th at 12:44 P.M., EDT.

The Orionid meteor shower occurs on the evening of October 21–22, when the earth glides through the orbital path of Halley's comet. You will be treated to an average of 25 "falling stars" per hour. Last seen in 1986 and due back in 2061, the comet left behind small pieces of itself, blown off from its nucleus as it made close approaches to the sun.

The Orionids will peak two hours after midnight on the 22d for those in the eastern time zone. These are, coincidentally, the best hours to observe the shower from any location because the leading edge of the earth is rotating directly into the orbital path of the shower itself. Unfortunately, the moon is up for most of the night and may obscure some of the show.

Remember that on the last Sunday of October, at 2:00 A.M., you are to set your clocks back by one hour if your locality adheres to daylight saving time. This will put you back on standard time.

Gail S. Cleere lives in Washington, D.C., and writes on popular astronomy.

ERRATUM: In "Moonstruck" ("Celestial Events," April 1994), the distance to the moon at its April 11 apogee was misstated as 252,574 miles; the earth and moon were actually about seven miles closer together. In Gail Cleere's original manuscript, the distance was correctly given as 406,468 kilometers. For the reader's convenience, *Natural History* converts from metrics to more familiar units of measure. Apparently, the conversion factor in one of our calculators was not expressed to the necessary number of digits for accuracy where very large numbers are concerned. Hence the seven-mile discrepancy in the distance to the moon.—*Ed.*

Top Hat and Tails

Each winter, male white-tailed deer cast off their antlers completely and in spring must start a new set from scratch. Fed by a covering of living, blood-enriched "velvet," antlers grow rapidly throughout the summer. In early fall, the velvet is shed in bloody strips, revealing the beauty of the underlying bone. Only then is a buck ready for the rigors of the autumn rut—the hormone-fueled rites of intimidating his rivals and attracting mates.

Rutting whitetails often vigorously rub their heads against trees, and in the process may leave pungent, as well as visible, signs of their passage. This buck, photographed in early October in northern Minnesota's Tamarac National Wildlife Refuge, was thrashing around the forest edge when he began a battle with the low-hanging branches of a small maple. Then he indulged in a ritual seldom seen in whitetails. He made no effort to dislodge the leaves and limbs that clung to his antlers but carried them aloft as he strutted around the clearing. When this harvest eventually fell off, the buck again attacked the maple. He was last seen dissolving back into the woods wearing a cap of red-orange leaves at a rakish angle.

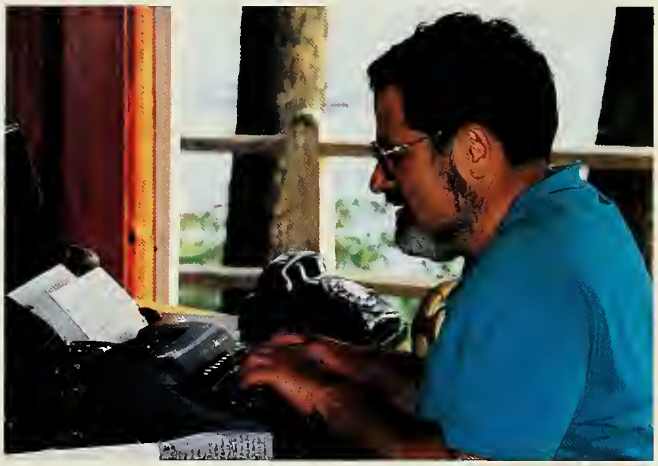
In whitetails, antlers serve not only as sparring weapons but also as identity badges and status symbols. According to Valerius Geist, of the University of Calgary, who has studied deer throughout the world, European red deer and the barasingha and rusa deer of Asia frequently resort to vegetative enhancement of this male attribute. At least one Minnesota whitetail is following such deer tradition, increasing its stature by behavior that Geist compares to putting on a hat.—*J. R.*

Photographs by Erwin and Peggy Bauer

Near the shore of Lost Lake in the Cascades, **Andrew R. Blaustein** (page 32) and Susan Walls, then a postdoctoral student, inspect toad eggs in experimental enclosures. Blaustein's study of amphibian population dynamics, which he has conducted for fifteen years, seems to have had its roots in his childhood. Although he grew up in New York City and Long Island, Blaustein remembers catching lots of toads and frogs while on family vacations in Maine and New Hampshire. His love of nature, reinforced by trips to the American Museum and a menagerie of exotic pets (which he still maintains), led him to study biology. After earning his B.A. from Southampton College in 1971, he headed west to pursue his master's degree at the University of Nevada at Reno and his Ph.D. in biology at the University of California at Santa Barbara. His thesis focused on the population dynamics of rodents, but after moving to Oregon State University in Corvallis, where he is a professor of zoology, Blaustein switched to amphibians because they were better for investigating the kinds of questions he wanted to answer. Now that he has established a link between the death of some amphibian eggs and increased UV-B radiation from the sun, Blaustein plans to continue studying how this and other factors might be contributing to the decline of many frogs, toads, and salamanders.

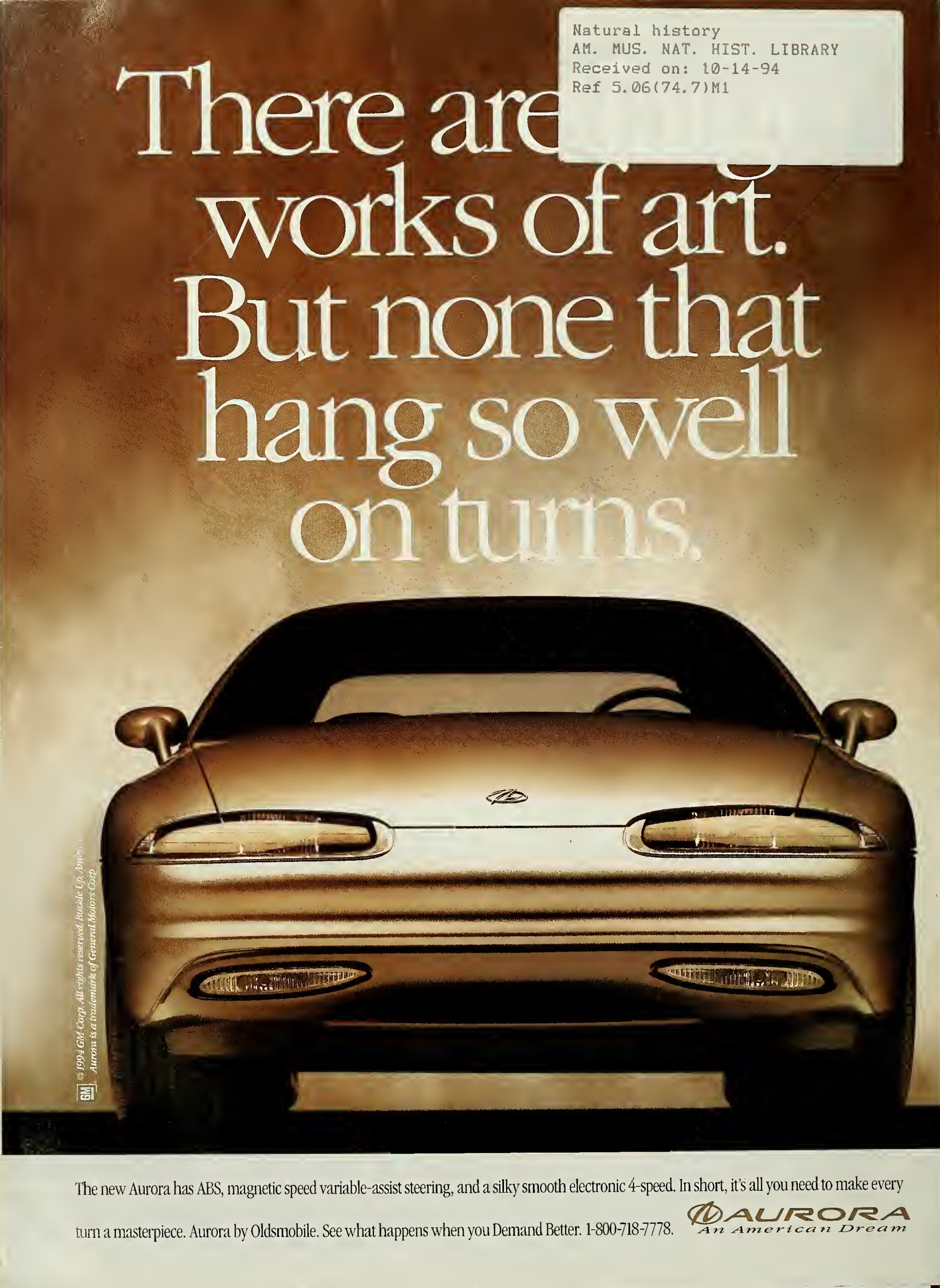
Ecologists **Michael Steele** and **Peter Smallwood** (page 40) first learned that they shared similar research interests in squirrels, oaks, and acorns nearly a decade ago, when they met at Highlands Biological Station in the southern Appalachian Mountains of North Carolina. But Smallwood, below right, was busy at night studying the foraging behavior of long-jawed spiders, while Steele, left, was gone during the day studying shrew and rodent community ecology. Collaboration had to wait until they met again in Pennsylvania, where they teach at separate colleges. (Steele is an assistant professor at Wilkes University, and Smallwood lectures at Bryn Mawr.) Steele's interest in natural history goes back to his early childhood, when he collected "butterflies, other insects, and a variety of reptiles and amphibians around Chesapeake Bay. Mammals were too hard to catch then." Smallwood, a self-defined "eclectic," is going beyond spiders and squirrels to investigate sex ratios in the Florida kestrel, or sparrow hawk. ("We've discovered that they raise primarily sons early in the breeding season, and primarily daughters later on. We're trying to understand why.") For further reading, the authors recommend *The Natural History of Squirrels,* by John Gurnell (New York: Facts on File, 1987), *Food Hoarding in Animals,* by Stephen Vander Wall (Chicago: University of Chicago Press, 1990), and *Faith in a Seed,* by Henry David Thoreau (Washington, D.C.: Island Press, 1993).

"I never laid eyes on a horse until my parents moved to Manhattan and I saw one in Central Park," says **Morris Rossabi** (page 48), who was born in Alexandria, Egypt, and lived there until the age of nine. "And my first glimpse of a yurt—in fact of any Mongol environment—was in a diorama at the American Museum of Natural History." Those early impressions captivated Rossabi, who earned his Ph.D. in Chinese and Inner Asian and Mongol history from Columbia University in 1970 and has taught and written on these subjects ever since. Formerly at Case Western Reserve University's China Institute, Rossabi is now a professor of Chinese and Inner Asian history at City University of New York (Queens College) and a visiting professor at Columbia University. The author of *Khubilai Khan* and *Voyager from Xanadu,* he is now halfway through a multivolume history of the Mongols and has almost finished a study of Roy Chapman Andrews's Mongolian expeditions. On frequent field trips, Rossabi has had many occasions to ride Mongol horses and to live in yurts. For more about these topics, Rossabi recommends *The Mongols,* by David Morgan (Oxford: Basil Blackwell, 1987), and *Genghis Khan,* by Paul Ratchnevsky (Oxford: Basil Blackwell, 1991).



Erwin and **Peggy Bauer** (page 88) make their home in Montana, but as full-time wildlife photographers, they have covered the globe. Truly a team, they are not certain which of them took the pictures of the white-tailed deer for this month's "Natural Moment." Erwin says, "We always shoot together and almost never know who did what." They photographed the white-tailed buck crowned with leaves using a Canon EOS1 camera and 600 mm lens. This month marks a record seventh time that the Bauers' work—from wart hogs to polar bears—has been featured as a "Natural Moment." The Bauers have numerous books to their credit. Their last was *Wild Dogs: The Wolves, Coyotes, and Foxes of North America,* published by Chronicle Books, and their next will be *Antlers,* to be published by Voyageur. More information on white-tailed deer can be found in *Whitetails* (San Francisco: Voyageur, 1993), with photos by Erwin and Peggy and text by Erwin. Whitetails are put in context with their relatives throughout the world in *The Natural History of Deer,* by Rory Putnam (Ithaca: Cornell University Press, 1989).

Theodore H. Fleming (page 58), his mathematician wife, Marcia, and their eighteen-year-old daughter, Cara, have traveled widely throughout Mexico for the past few seasons "chasing bats and cactuses." Fleming earned his doctorate in zoology from the University of Michigan in 1969 (for a thesis on tropical rodents) and is now a professor of biology at the University of Miami. He conducted several long studies of fruit bats in Central America (see *Natural History,* June 1985), and his interest in bats led him to investigate cardon cactuses, whose complicated sexual system he is still trying to unravel. Fleming is dismayed by recent changes in the cape area of Baja California and the coastal regions of Sonora, where developers are plowing under vast tracts of cardons to make way for new resorts, condominiums, and golf courses. "Cardons live in places that people now like to live in too," he says, "but it's a shame that this complex ecosystem, which we don't yet understand, is being disrupted." For further reading, Fleming recommends *The Cactus Primer,* by Arthur C. Gibson and Park S. Nobel (Cambridge: Harvard University Press, 1986), *The Evolution of Sex,* edited by Richard E. Michod and Bruce R. Levin (Sunderland: Sinauer, 1988), and Charles Darwin's *The Different Forms of Flowers on Plants of the Same Species* (Chicago: University of Chicago Press, 1986).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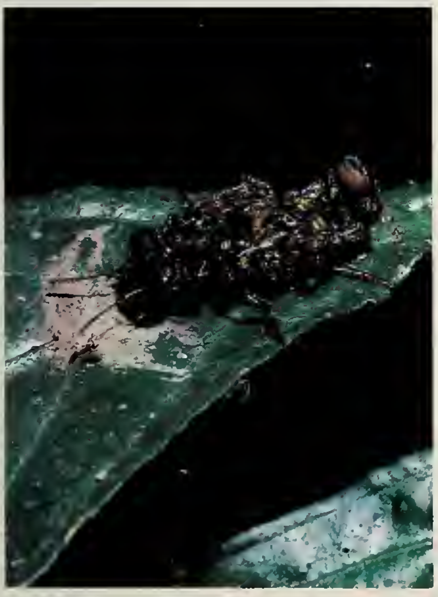
COVER: A northern river otter eats a brook trout. In Nevada, willow trees and beavers help hold the otter's fragile world together. Story on page 36. *Photograph by Stephen J. Krasemann; DRK Photo.*

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The Celestial Mechanic and the Earthly Naturalist

Where one Enlightenment scientist saw the world as an eternal machine, another perceived its unique history

by Stephen Jay Gould

During the San Francisco earthquake of 1906, a statue of Louis Agassiz fell off the front of a building at Stanford University and landed just as neatly as could be, but upside down—feet in the air and head buried in the pavement. Agassiz had been both the greatest ichthyologist of his day and the last serious creationist holdout against evolution when he died in 1873. David Starr Jordan, the president of Stanford, was the greatest ichthyologist of the generation after Agassiz and an early and fervent Darwinian as well. Thus, the two men shared a similar passion for the same group of organisms, but couldn't have disagreed more on theoretical issues.

According to legend, Jordan delivered one of history's greatest quips when he went out to survey the damage and saw the inverted statue: "Oh well, I always thought better of Agassiz in the concrete than in the abstract." A lovely story that surely deserves to be true. But, alas, it is not. In his own autobiography, *The Days of a Man,* written in 1922, David Starr Jordan felt duty bound to debunk this tale and admit that he had never uttered the famous line, while the originator had used a less quotable and opposite version. Jordan wrote:

> About the quadrangle the only touch of humor was furnished by the large marble statue of Agassiz, which had plunged from its place headfirst and waist-deep into the concrete pavement. Somebody—Dr. Argyll, perhaps—remarked that "Agassiz was great in the abstract but not in the concrete."

People are clever, but almost no one ever devises an optimal quip precisely at the needed moment. Therefore, virtually all great one-liners are later inventions—words that people wished they had spouted, but failed to manufacture at the truly opportune instant. Thus, the most famous scientific epithet of all is also, and alas, surely embellished if not downright phony.

We have all heard the story of Napoleon's meeting with the great astronomer Pierre-Simon Laplace (1749–1827), identified in the *Dictionary of Scientific Biography* as "among the most influential scientists in all history." Laplace, or so the story goes, gave Napoleon a copy of his multivolume *Mécanique céleste* (*Celestial Mechanics*). Napoleon perused the tomes and asked Laplace how he could write so much about the workings of the heavens without once mentioning God, the author of the universe. Laplace replied: "Sire, I have no need of that hypothesis."

The actual quip, well attested in a surviving letter, is mildly clever, but pretty insipid compared with the legend, and made by the general rather than the scientist. Laplace had first met Napoleon in 1785 when he examined the future emperor, then an artillery cadet, in mathematics at the École Militaire in Paris. In October 1799, three weeks before the coup d'ètat that brought Napoleon to power, Laplace did present the very weighty first two volumes of his work to his former student. Napoleon hefted them and then promised to read them "in the first six months I have free." He then invited Laplace to dinner the next day "if you have nothing better to do."

I suspect that this legend attached itself to Laplace because he does represent the best candidate for such a tale. Laplace is science's chief apostle of strict determinism and heavenly stability based on obedience of all bodies to laws of nature that damp out any perturbation to restore regularity of motion and position (Laplace coined the term "celestial mechanics").

Even Isaac Newton, so often cited as the apostle of such a view, happily invoked a little help from divine intervention either to get things going or to restore regularity at any time in subsequent celestial history when nature's usual laws could not rein in a perturbation. Newton, for example, sought to reconcile geological evidence for the earth's antiquity with the Genesis story of creation in six days by arguing that the earth then rotated very slowly, thus producing "days" of any desired length. But Newton could not then fathom how an acceleration of rotation to days of twenty-four hours could be accomplished under nature's laws, so he invoked a positive spin from God himself. He wrote to Thomas Burnet (a colleague who upheld universal constancy and sufficiency of nature's laws and who therefore favored an allegorical interpretation of biblical language about "days"):

> Where natural causes are at hand God uses them as instruments in his works, but I do not think them alone sufficient for the creation and therefore may be allowed to suppose that amongst other things God gave the earth its motion by such degrees and at such times as was most suitable to the creatures.

By contrast, the most famous quote genuinely attributed to Laplace vigorously defends a strict determinism that does make a conventional view of God's con-

tinuous role both irrelevant and unnecessary. (God may still be a clockwinder, an instigator of nature's immutable laws at the outset, but he has no need ever to intervene in subsequent history; after all, a truly omnipotent God can surely establish optimal laws right at the start, thus avoiding any necessity for direct miraculous correction should imperfect laws cause the heavens to go awry.) In an epigram that has defined strict determinism ever since, Laplace boasted: If anyone could provide a complete account of the position and motion of every particle in the universe at any single moment, then total knowledge of nature's laws would permit a full determination of all future history. Laplace's boast is usually cited from the introduction to his *Analytical Theory of Probabilities* (1812), but the *Dictionary of Scientific Biography* cites a much earlier and crisper version from a youthful article written in the seminal year of 1776:

> The present state of the system of nature is evidently a consequence of what it was in the preceding moment, and if we conceive of an intelligence which at a given instant comprehends all the relations of the entities of this universe, it could state the respective position, motions, and general affects of all these entities at any time in the past or future.

After his work in celestial mechanics, Laplace won most renown for his pioneering studies of probability. One might ask why the prophet of determinism and heavenly constancy should have focused upon probability, now so strongly associated with opposing ideas of randomness, but the solution is not far to seek. Laplace firmly believed that, in reality, every event is fully determined by general laws of the universe. But nature is complex and we are woefully ignorant of her ways; we must therefore calculate probabilities to compensate for our limitations. Events, in other words, are probable only relative to our knowledge.

Celestial mechanics is the most triumphant realm of deterministic predictability because our instruments are precise and the laws relatively simple (primarily Newton's principle of universal gravitation). But more complex terrestrial events are just as determined if only we knew the laws and conditions as well—as one day, perhaps, we will. Laplace wrote in his popular book of 1796, the one that shall be the focus of this essay:

> Everything in nature obeys these general laws; everything derives from them by necessity and with as much regularity as the cycle of seasons. The path followed by a light atom [*atôme léger*] that the winds seem to transport at random, is ruled in as certain a manner as the planetary orbits [my translation—by "atom," Laplace only means a tiny particle, not the invisible and chemically indivisible building block that later theory would identify].

"Hello, I'm Paul Bunyan. You've probably heard a lot of exaggerated stories about me."

Later in the book, he explicitly states that we will eventually learn the more complex laws for smaller terrestrial objects, and that earthly physics will then be as deterministic as celestial mechanics:

> Several experiments already made give us reason to hope that, one day, these laws will be perfectly known; then, by applying mathematics, we will be able to raise the physics of the earth to the same level that the discovery of universal gravitation has given to celestial physics:

In his 1776 article, Laplace explicitly links the need for a theory of probability to human ignorance of nature's deterministic ways, and he makes the same comparison between a simpler and well-known celestial mechanics and a much more difficult earthly physics:

> Man owes that advantage [in celestial mechanics] to the power of the instrument he employs, and to the small number of relations that [this field] embraces in its calculations. But ignorance of the different causes involved in the production of events, as well as their complexity, taken together with the imperfection of analysis, prevents our reaching the same certainty about the vast majority of phenomena. Thus there are things that are uncertain for us, things more or less probable, and we seek to compensate for the impossibility of knowing them by determining their different degrees of likelihood. So it is that we owe to the weakness of the human mind one of the most delicate and ingenious of mathematical theories, the science of chance or probability.

(I think that Laplace's view of probability is still commonly held by some scientists and, more widely, by well-educated people in general. Such is the allure of physical determinism, and our hope for a simple order of things—although I fear that nature contains much truly intrinsic randomness at all levels.)

In his study of celestial mechanics, the primary focus of his career, Laplace emphasized one theme above all others: the laws of nature, with Newton's principle of universal gravitation in the lead, decree a permanent stability that could only be disturbed by foreign causes (like God's miraculous hand—the unneeded hypothesis!). Laplace attacked this issue by studying all the classical and apparent exceptions that studies of planetary motion had accumulated over the centuries. These exceptions all took the same form: measurement of planetary orbits had detected a

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slight, but accumulating, irregularity, which if continued over eons, would destabilize the solar system. In each case, Laplace devised the same style of solution: these irregularities are not cumulative, but self-correcting. They are cycling oscillations that maintain the broader and permanent stability of the heavens. For this brilliant work, Laplace justly earned his common epithet as the Newton of France.

In 1773, Laplace took up the long-troubling problem of why Jupiter's orbit seemed to be shrinking while Saturn's expanded (a situation that, if continued, would destroy planetary alignment; the great Newton, in fact, had thrown up his hands and invoked occasional divine intervention to safeguard equilibrium). Laplace showed that these inequalities are periodic (with a cycle of nearly 1,000 years), and not accumulating. In the next phase of the cycle, Jupiter's orbit will expand, and Saturn's will shrink. Then, in 1786, Laplace developed a general proof that eccentricities and inclinations of planetary orbits must remain small and be fully self-correcting, thus maintaining the stability of the solar system.

Finally, in 1787, Laplace resolved the last major anomaly in planetary motion by relating the moon's orbit to changes in eccentricity of the earth's revolution about the sun. The moon's orbit had been expanding and our satellite would eventually escape, should the trend continue. Laplace showed that the moon's mean motion is accelerated when the earth's orbit be-

comes more circular, but will be retarded when the earth's eccentricity increases. He then argued that the earth's orbital eccentricity cycles with a period measured in millions of years; the lunar orbit will therefore be self-correcting, and the moon will not escape.

In 1788, with the fall of the Bastille and the great secular revolution just one year away, Laplace summarized his views on the fact and meaning of celestial stability:

> Thus the system of the world only oscillates around a mean state from which it never departs except by a very small quantity. By virtue of its constitution and the law of gravity, it enjoys a stability that can be destroyed only by foreign causes, and we are certain that their action is undetectable from the time of the most ancient observations until our own day. This stability in the system of the world, which assures its duration, is one of the most notable among all phenomena, in that it exhibits in the heavens the same intention to maintain order in the universe that nature has so admirably observed on earth for the sake of preserving individuals and perpetuating species.

All this quotation and argument properly leads us to view Laplace as the archetypal defender of a certain view of science, all too commonly equated with the entire varied enterprise: stability in the heavens, determinism of all events under the aegis of natural laws with clean, mathematical formulation—an almost antihistorical view that we might contrast with alternative models of complex unpredictability and dynamic change, often in accumulating and directional modes.

Fair enough, but we now encounter the anomaly that inspired this essay. Laplace is also the author of the first widely-credited historical theory for the origin of the solar system—the so-called nebular hypothesis of Kant and Laplace, first enunciated in 1796. (The great philosopher Immanuel Kant published a similar theory in the same year as Laplace; the two men were not in contact and surely developed their ideas independently.) How could the apostle of nonchange and antihistory also devise a theory that, according to the *Dictionary of Scientific Biography,* "has conventionally been cited as an early instance, perhaps as marking the introduction, of a historical dimension into physical science. That attribution, indeed, has been its chief attraction."

In 1796, Laplace published a wonderful book, honored and regarded as a prototype ever since, in a tradition that the French call *haute vulgarisation*, or high-class popularization (not at all an oxymoron, but the worthiest of all goals for scientific writers). The work, titled *Exposition du système du monde (Exposition of the System of the World)*, is suffused with the rationalistic spirit of a revolutionary France that had thrown off the shackles of past history. The title page, in fact, does not say 1796, but only "*L'an IV de la République Française*," since the revolutionary government had started time all over again on September 22, 1792, the day after the founding of the French republic.

In the opening *avertissement*, Laplace states that he will divide the circle into 400 degrees (100 for each quadrant), the day into ten hours, the hour into 100 minutes, the minute into 100 seconds, and temperature into 100 degrees from freezing to boiling of water (the only survivor, as the centigrade scale). (Do not infer that Laplace was a revolutionary zealot. Quite the contrary. He was shrewd and basically unpolitical. His major accomplishment, as the old quip goes about Talleyrand, was to serve every government from revolution to restoration, and die in bed. Laplace flourished by supporting any group in power, while not alienating the probable successors. His written dedication to Napoleon in his *Théorie analytique des probabilités* [1812] seemed so embarrassingly sycophantic to later editors that the semiofficial *Oeuvres complètes*, published after Laplace's death, left it out).

The *Exposition* is a two-volume work in five books—the first, on what may be seen by observing the heavens on a clear night; the second, on the "real" motion of planets, moons, and comets; the third, on laws of motion; the fourth, on Laplace's own work in celestial mechanics and gravity; and the fifth, on the history of astronomy. Laplace shows his distrust and discomfort for real history with all its messiness, its backings and forthings, by stating that he will not discuss astronomy as people actually developed the ideas, but will instead provide a rationally ordered chronological account of successes:

> The order in which I am about to discuss the principal results of the system of the world is not that which the human mind followed in its research. The march of the mind has been encumbered and uncertain; often it only reached the true cause of phenomena after having exhausted all the false hypotheses that imagination had suggested; and discovered truths have almost always been allied to errors that time and observation finally separated out. I will offer in a few words the tableau of attempts, and of successes.

The nebular hypothesis is undoubtedly

the most famous legacy of Laplace's *Exposition*, but it appears only as an afterthought in a few pages of a final chapter appended to the end of book 5—*Considerations sur le système du monde, et sur les progrès futurs de l'astronomie* (*Considerations on the System of the World and on the Future Progress of Astronomy*). This remarkable chapter also features a correct hypothesis that many "nebulae" (resolved in the best telescopes of the time as diffuse clouds) are actually distant galaxies of stars (with the Milky Way as an arm of our own galaxy), and that the universe is therefore vaster than we have ever conceived. In this section, Laplace even recognizes that some stars may be so dense that gravity precludes the escape of their own light—the phenomenon now recognized (in different form) as black holes. Thus Laplace argues (wrongly this time) that much apparent darkness in the night sky may really be occupied by enormous, dense stars. His figures and sizes are wrong by irrelevant modern standards, but his conjecture is fascinating:

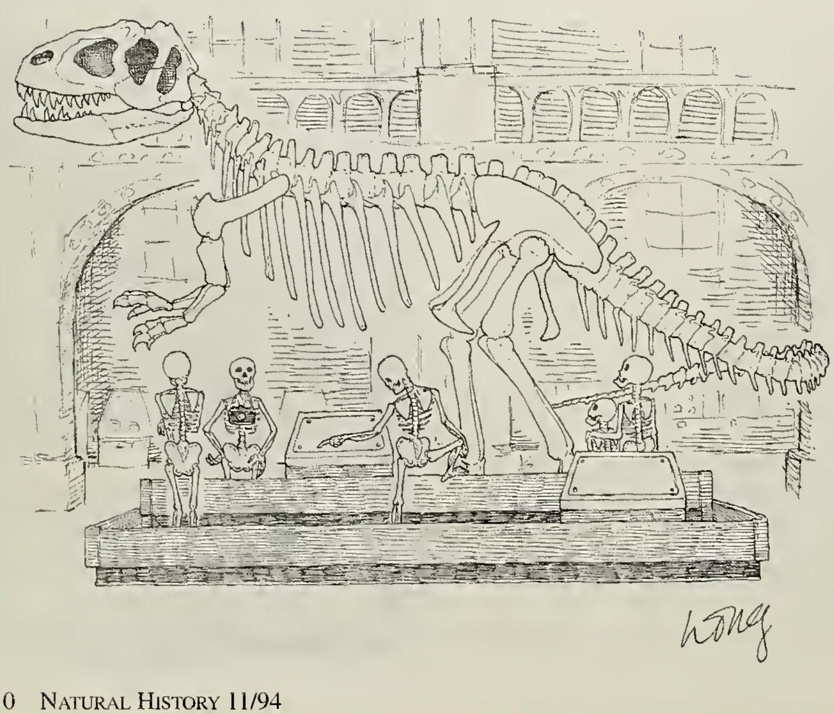
> A luminous star of the same density as the earth, but with a diameter 250 times greater than that of the sun, would not allow any of its light to reach us, by virtue of its own gravitational attraction. It is therefore possible that the largest luminous bodies in the universe are, for this reason, invisible.

According to the nebular hypothesis, the sun, early in its history, was surrounded by an atmosphere that extended well beyond the current planetary orbits. This atmosphere rotated with the sun. At successive intervals, large segments of this atmosphere broke off and coalesced in an equatorial plane at the periphery of this contracting mass; these segments also began to rotate on their own behalf and formed the planets at their centers. Satellites formed by a similar process, one fractal level down, of atmospheric rotation and spalling off around planetary cores. Laplace argued that no other mechanism could account for all the primary regularities of motion in the solar system—particularly, the revolution of all planets in the same direction and virtually in the same plane, the revolution of satellites in the same direction, and the rotation of all planets and satellites (not true, but Laplace didn't know) in the same direction.

How then can we resolve the paradox that the scientific apostle of stability, a man who seemed to distrust and reject any real history either for celestial objects or for his own profession, should also be godfather to the first important theory for the origin of the solar system? Part of the answer may simply be that Laplace only dedicated a few pages to the nebular hypothesis—and anyone might allow himself an uncharacteristic speculation, or a flight into a field usually considered alien, for such little dedicated space. (Until I read the *Exposition* after buying a copy last week, I had never realized how few pages the nebular hypothesis occupied, so the anomaly seemed greater to me. We so often make the silly mistake of equating later importance with length of original effort. Many of the most famous ideas in science began as paragraphs or footnotes in weighty tomes otherwise entirely forgotten. Have we not all been surprised and amused to find that some of the best known biblical stories only occupy a line or two among pages of begats and other dull lists?)

But the main reason is far more interesting and entirely conceptual, rather than practical. Most intellectuals never abandon their motivating belief; if they seem to write about something contrary, more careful reading usually reveals the passage as a form of support for the familiar central doctrine. Of course, the nebular hypothesis is a historical statement about the origin of planets, but as I read Laplace's conjecture and came to the last paragraph, I saw the evident solution and chuckled. Laplace invoked the nebular hypothesis in his customary interest of bolstering stability in the solar system! Planets must have some origin after all, and Laplace argues that this particular style of formation best guarantees permanence thereafter. The striking last paragraph, virtually cribbed from his 1788 article, triumphantly proclaims:

> Whatever one makes of this origin for the planetary system...it is certain these elements are ordered in such a manner that they must enjoy the greatest stability, if foreign causes never trouble them. Only by this means [formation by the nebular hypothesis] are the movements of planets and satellites almost circular, and directed in the same sense and almost in the same plane. This system can only oscillate about a mean state, from which it can only deviate by very tiny amounts. The average movements of rotation and revolution of these different bodies are uniform.... It seems that nature arranged all bodies in the heavens in order to assure the duration of the system, and by means similar to those so admirably followed on earth for the conservation of individuals and the perpetuation of species.



I was arrogant enough to think that I had made some sort of discovery when I read the *Exposition* last week and recognized the antihistorical basis for the hypothesis that made Laplace so famous as the first historian for the universe. But I soon discovered that others had followed the same path of argument. C. C. Gillipie, perhaps America's finest senior historian of science, put the point most forcefully in his long article on Laplace in the *Dictionary of Scientific Biography*: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> If the text is allowed to speak for Laplace, it will be altogether evident that evolutionary considerations in the 19th century sense formed no part of his mentality. The conclusions that he had reached concerned stability; the evidence for that he had calculated, many and many a time.... He again referred to it as a warranty for the care that nature had taken to ensure the duration of the physical universe, just as it has the conservation of organic species.... Clearly, it was not about the development of the solar system that he was thinking. It was about the birth.

We can, I think, best grasp the contrast between Laplace's antihistorical thinking and a truly historical approach by comparing the nebular hypothesis with the only serious contemporary competitor as a theory for planetary origins—the cometary collision hypothesis of the greatest of all eighteenth-century French naturalists, Georges Buffon (1707–1788). Laplace himself admitted Buffon as his only competition, writing in the *Exposition*: "Buffon is the only one I know who, since the discovery of the true system of the world, has tried to go back to the origin of planets and satellites."

Buffon argued that a comet had struck the sun, knocking out a large plume of solar material that then broke up to form the planets and satellites. Laplace rejected this alternative because Buffon's theory could not, in his view, explain all the regularities of planetary motion. Cometary impact would account for the common direction of planetary revolution with all planets in virtually the same plane (a result of the motion and orientation of the plume knocked from the sun). But Laplace argued that Buffon's theory could not account for the common direction of planetary rotation or for the origin of satellites.

Buffon and Laplace seem so different at first glance. Their generation or two of separation spans a world of change from Buffon's service to the last two King Louis before the revolution, to Laplace's work with various revolutionary governments and Napoleon. But their lives and studies include some striking similarities relevant to their joint interest in theories of planetary origin. Buffon was also a fine mathematician with two special interests that matched Laplace with uncanny precision. He was, first of all, a committed Newtonian who translated *The Method of Fluxions* into French from an English version of Newton's original Latin. Secondly, his greatest interest lay in probability, and he made a major contribution in first applying integral and differential calculus by extending the theory of probability to surfaces. (Interestingly, both Buffon and Laplace won admission to the French Academy of Sciences for monographs on probability; Buffon in 1734; Laplace in 1773.)

But the two men, in their scientific maturity, occupied opposite ends on the spectrum of professional activity, and the contrasting ethos of these termini set their profoundly differing attitudes to history, making Laplace indifferent and Buffon intrinsically committed. Laplace stuck to the mathematical bent of his youth and became the greatest celestial mechanic of his time. Buffon, on the other hand, changed course and devoted his career to botany and zoology; he became, in short, the greatest earthly naturalist of his day (only Linnaeus himself might have been granted higher rank).

Buffon's magnificent, multivolume *Histoire naturelle* took a lifetime (Buffon died before its completion) and fills a large library shelf. Students of the heavens may revel in constancy and precision. Students of earthly organisms also search for general patterns and frequently succeed; but naturalists must also take delight in the uniqueness of each creature, and they must be sensitive to the developmental histories of organisms, both in the courses of their lifetimes and (if they study the fossil record, as Buffon did) in the vastly larger domain of geological time. Good naturalists must be historians.

In 1749, Buffon introduced his cometary theory of planetary formation in his first work on geology, *Histoire et théorie de la terre* (*History and Theory of the Earth*). Much later, in 1778, Buffon published a much expanded and altered version entitled *Epoques de la nature* (*Epochs of Nature*). Most biologists and historians consider the *Epoques* to be Buffon's masterpiece and one of the finest examples of scientific prose ever written. The *Epoques* also includes an explicit de-

fense and exposition of historical methodology, thus providing a striking contrast with Laplace and helping us to grasp the criteria of proper history. In particular, two differences between Buffon and Laplace sharpen our understanding of the nature of historical inquiry.

Criteria of inference. Historians use and cherish the narrative methods of explanation by antecedent events and situations; current results are outcomes of the unique and contingent web of all that came before and all that bears continuity with a present world in need of explanation. Historians also know that records of the past must be imperfect, for many kinds of data are not recorded as material remains, and much that could be preserved in principle has not survived in actuality. We always mourn lost data and hope for greater completion, but we do not apologize for the necessarily fragmentary record of our past, and we may treat spotty information as a delicious puzzle and a challenge. Antihistorians, like Laplace, get very antsy when they must use narrative data; they often become downright apologetic when they base a claim on anything other than a calculation or a direct observation of a present event.

Laplace ended his discussion of the nebular hypothesis with just such an apology, speaking of "this planetary system, which I present with the mistrust that must accompany everything that is not the result of an observation or a calculation." Buffon, on the other hand, begins the *Epoques* with a paean of praise to the excitement and efficacy of digging into the archives of the past with narrative methods. Consider his opening words:

> In civil history, we consult titles, we research medals, we decipher ancient inscriptions in order to determine the time of human revolutions and to fix the dates of events in the moral order. Similarly, in natural history, it is necessary to excavate the archives of the world, to draw old monuments from the entrails of the earth, to collect their debris, and to reassemble into a single body of proof all the indices of physical changes which enable us to go back to the different ages of nature. This is the only way to fix points in the immensity of space, and to place a certain number of milestones on the eternal route of time [my translation].

Character of events. History must respect (and even love) the last two syllables of its name. Narratives must tell a story, a tale that captures our interest as a series of unique events with interesting causal connections. There is no history in Laplace's heavens, only a suite of bodies going nowhere as they cycle endlessly in obedience to simple laws. Any promising hope for directionality or accumulating instability is soon dashed by the self-correcting cyclicity of all perturbations. His nebular hypothesis is history, but only for the geological instant of the solar system's birth; ahistorical timelessness rules forever after. The thing that hath been, it is that which shall be; and that which is done, is that which shall be done; and there is no new thing under the sun.

By contrast, Buffon's *Epochs of Nature* is premised upon and titled by the opposite conviction that the time of our planet tells an engrossing story of accumulating change through several stages (called epochs by Buffon to set his title). He divided the history of the earth into seven directional epochs: first, the origin of the earth and planets by cometary impact; second, the formation of the solid earth and its mineral deposits; third, the covering of continents by water and the production of marine life; fourth, the retreat of waters and the emergence of new continents by volcanic action; fifth, the appearance of animal life on land; sixth, the fragmentation of continents and formation of the earth's current topography; and seventh, the appearance of humans and our accession to power. Could any contrast with Laplace's ever cycling heavens be more profound?

Buffon explicitly challenged the idea of constancy by noting that the narrative record of geology and paleontology proclaims a story of directional change:

> Although it may appear at first sight that the great works [of nature] do not alter and never change, and that its productions, even the most fragile and most evanescent, must be always and constantly the same...nevertheless, in observing more closely, we note that [nature's] course is not absolutely uniform, that it undergoes successive alterations giving rise to new combinations and to mutations of matter and form; and that, finally, however fixed nature may appear in its ensemble, so is it variable in each one of its parts; and if we embrace nature in its full extent, we cannot doubt that it is very different today from what it was at the beginning and from what it has become in the succession of time; it is these changes that we are calling epochs.

Lawful timelessness is awesome, but the pageant of history thrills us too, and in a different way that makes time sensible. Everyone needs a good mechanic, including the heavens, but give me an earthly naturalist any day, for humans are storytellers. In the nearly 250 essays of this series, I have tried to avoid repetition (if only to honor the principles of history cited above). But like a broken record (a metaphor from the last epoch of history, soon to be rendered unintelligible I fear), one quotation keeps recurring. I have used it to end nearly half a dozen essays (shameful in a way, but we all have our Laplacean side). This quotation also includes the masthead for the entire series "This View of Life" (I guess we all need our constancies). I love this quotation because it affirms the power of life and history by making the same contrast between Laplace's ever cycling heavens, always moving yet always the same, and the glorious tale of life, always different, always going somewhere, always telling a story. It is the last paragraph of Darwin's *Origin of Species:*

> There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms more beautiful and most wonderful have been, and are being, evolved.

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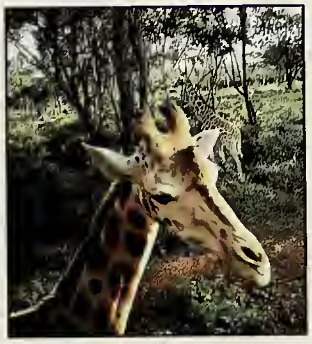

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Masters of Deception

Costa Rican rove beetles adjust to circumstances to fool both prey and rivals

by John Alcock and Adrian Forsyth

The distractions of the rain forest fill the air and trees above us as we follow a small mountain stream near the town of Monteverde, Costa Rica. Giant, iridescent blue butterflies flutter among the lianas overhead. In the canopy, keel-billed toucans proclaim their territories with a mechanical chorus of racheting calls. Howler monkeys rumble in distant treetops and a band of brown jays assail us with raucous jeers. But like most students of insect behavior, our eyes are focused downward as we search for our quarry among the dim understory vegetation.

Perhaps that's it ahead on a leaf, something that looks like a dab of mottled-brown plant debris or maybe a bird dropping. We step toward it slowly, hopefully, and bend down for a closer look. As we do, the organic miscellany transforms itself, sprouting legs and a head with huge, dark eyes and great, sickle-shaped mandibles. A long, yellow-tipped abdomen rears up and waves sinuously back and forth before the rove beetle whirs into flight. We are in luck.

The beetle flies only a few yards before plopping down on another streamside plant, where it settles into its humble bird-dung disguise. We wait an hour before the beetle finally rewards our patience. It abruptly turns 180 degrees on the leaf and wipes the tip of its abdomen across the surface, smearing a fluid secretion in a narrow arc. It then turns back to face the fluid, which gradually becomes pink, creating a half-moon of color in front of the beetle's large, sharp mandibles.

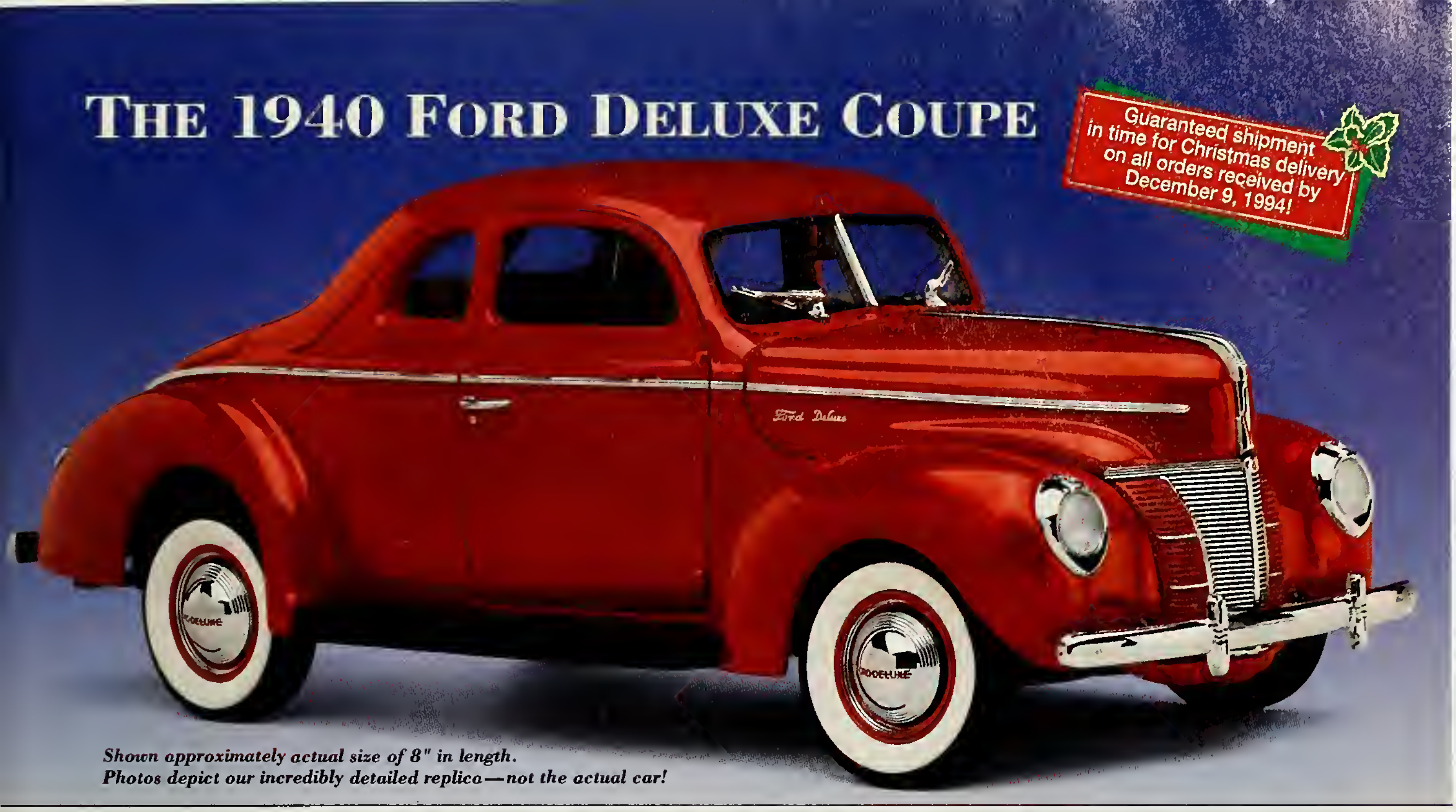
A rove beetle waits for flies to be lured to its pink secretion.
John Alcock

The beetle continues to sit on its perch, until a tiny fruit fly appears from nowhere and alights on the leaf. After a pause, the fly begins a crablike scuttle toward the beetle; then pauses again. The beetle raises its abdomen, arching it upward and twitching it slightly. A bubble of fluid appears from one of the two small tubes that extend from the abdomen tip. As the fly walks closer, the beetle curls its abdomen forward, waving it in front of the fly, which now faces the beetle head-on. The beetle's antennae line up to point directly at the smaller insect. The fly takes a few more steps and stops barely half an inch from the quivering beetle, which suddenly lunges forward, engulfing the fruit fly in its huge mandibles. In seconds, the beetle has crushed its prey and cut it to ribbons.

The beetle that we watched that day, *Leistotrophus versicolor*, will win no awards for beauty. Moreover, although often found on leaves, it also regularly frequents rotting carcasses, animal dung, and other thoroughly unsavory materials. If handled, the beetle smears a foul-smelling secretion on one's fingers and bites with some authority. Nevertheless, we have found that the behavior of this beetle more than compensates for its indelicate qualities. The only beetle known to prey exclusively on adult flies, it also executes its entertaining repertoire of deceitful tactics with considerable sophistication.

When the beetle hunts from ambush on leaves or rocks, for example, it uses chemical lures that draw its victims, particularly little fruit flies attracted to decaying fruits by their odors, close enough to be attacked and killed. On many occasions we have watched small flies approach abdomen-waving beetles and their aromatic pink smears. Perhaps distracted by the lure, the flies often continued to walk right up to their killers, even touching the beetle's hind legs or abdomen. The flies did not flee when the beetle twitched in response but even "cooperated" in their demise by moving slowly around until the predator had them directly in its sights.

In the course of our studies, however, we learned that the beetles also hunt flies in a very different place and manner. The beetles often wait, not on barren leaves or rocks but on dead sloths, well-rotted kinkajous, and the dung of mammals such



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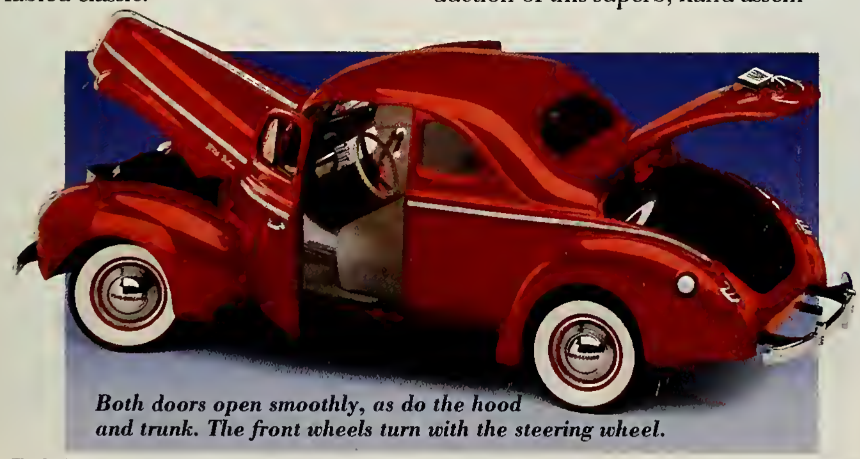

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as howler monkeys and coatimundis. These sites appeal to many species of flies, including some remarkably large, tropical blowflies, which are giants compared with the tiny fruit flies and phorids that the beetles can lure to their leaf perches. The blowflies provide a food bonanza for a beetle that can locate carrion or dung.

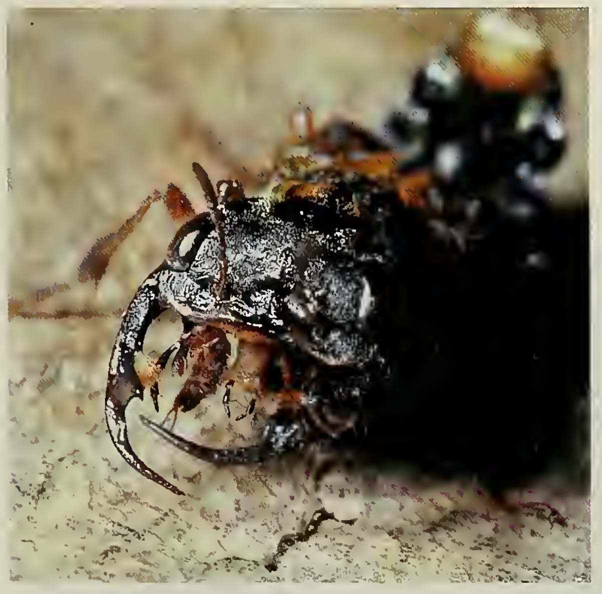
We discovered the beetle's alternative food source when we inspected the strongly scented carcass of an unfortunate sloth that had obviously succumbed some days previously. The dead animal had attracted a convention of rove beetles, some of which did not jump ship upon our approach. Despite the repellent state of the carcass, we stayed to see what, if anything, the beetles were doing as they rested on the dead animal's long hairs, on its shrunken paws, and on the ground immediately beside it. To our surprise and pleasure, the beetles were moderately lively in this environment, a point that one individual quickly made by capturing a big blowfly in midair. The predator managed this feat by using its elongate, sickle-shaped jaws to snap at the fly as it buzzed in for a landing on the sloth. The choice of landing site proved extremely unlucky for the fly but not for the beetle, which proceeded to convert the fly into pulp in short order.

We were impressed by the agility and speed with which the insect captured airborne prey. Later, at other carcasses and at dung and man-made compost heaps, we saw beetles performing this feat regularly, in addition to stalking their prey. A stalking beetle employs all the stealth of an experienced house cat, before lunging at its prey and embracing it with its lethal jaws.

The beetle clearly possesses two different hunting techniques. Since flies have little or no incentive to visit a streamside rock, sapling leaf, or fallen leaf litter, and will quickly leave if disturbed, the beetles resting at such sites must rely on their own devices to attract prey within striking distance. Under these conditions, the beetles offer scented secretions that induce their prey to visit and remain at their perches. At sites to which flies are naturally attracted, the beetles do not need chemical lures. Instead, they wait for flies to blunder into them, or they cautiously stalk flies distracted by the food surrounding them.

The caloric payoff for the two foraging methods differs considerably. The flies that visit perched beetles are tiny, few, and far between, whereas the blowflies that mill about by the dozens on dung are huge by comparison. So why do the beetles forage on leaves and rocks at all? We believe they do so because dung and carrion are relatively scarce commodities in the forest and ephemeral to boot. Countless numbers of dung beetles patrol such tropical environments and quickly find and remove animal droppings, which they use to feed themselves and their offspring. Carcasses also attract blowflies, but their maggot offspring quickly remove all the fly-attracting flesh from the deceased animals. Faced with a scarcity of easy foraging sites, the beetles make do in the interim by luring the occasional small fly.

But when dung or carrion is available, the beetles flock to it, creating small but dense communities of interacting individuals. These were the only sites, for example, where we saw rove beetles mating. This opportunity allowed us to discover how the beetles use deception of another kind to secure mates and territory.



The sickle-shaped jaws of a large male rove beetle are ideal for snaring flies in midflight.
Adrian Forsyth

As beetle newcomers fly in, tracking the odor trail upwind to the savory "bait," they land a short distance from their ultimate destination. After landing, they walk forward, waving their yellow-tipped abdomens vigorously from side to side. An arriving female may happen upon a male, already present and perched on top of a bit of dung or a part of a carcass. If she walks within an inch or two of the male, he will respond by following her. Courtship consists of the male's tapping the female's abdomen with the underside of his head, an activity that often causes the female to stop walking and to lower her abdomen, which is normally held aloft and waved from side to side. This signals her receptivity and prompts the male to twist his abdomen under his body to copulate. After mating briefly, the two separate and the male may walk back to his original perch while the female forages for flies nearby.

When two males chance to meet at a rich fly-hunting site, their behavior is quite different. They generally snap at each other with their formidable jaws, and if one of the combatants does not hurry off, the battle quickly escalates. They align themselves side by side so that each can bite the other's rapidly waving abdomen. In extreme cases, these bites lead one male to grasp the other firmly about the midsection and attempt to pin him to the ground. Wrestling males thrash about for a few seconds, until the loser somehow communicates his desire to depart, which he does hastily as his victorious rival delivers a few parting bites.

In effect, males compete to possess small territories on choice fly-attracting baits. The winner gets the perch from which to feed on flies and mate with incoming females. As a rule, big males win and small males lose. Males of this rove beetle species happen to be highly variable in body size and only the larger males come equipped with truly spectacular, wraparound jaws, so small males are also outmatched by large ones in biting ability. Given the small size of their weaponry, their retreat is hardly surprising.

But small males do have a special weapon in their arsenal: deceit. In our study, we captured a number of beetles in order to label them by sex. Although males were larger on average than females, exceptions were common, so we had no way to tell by sight whether a small or intermediate-sized individual was a male or a female. If we happened to pair off a male with a female, however, the male quickly identified himself by courting and copulating with the female. In this way, we gradually built up a number of identified males and females, each uniquely marked with colored dots on its back.

When we freed the marked individuals near a dung pile, what we saw astonished and then delighted us. A large male ap-

proached a marked beetle, one that we knew to be a smallish male. But instead of biting and clashing with his rival, the small male turned around, just like a female, to present the tip of his abdomen to the larger male, which responded by tapping his head against the abdomen of the smaller beetle just as if he had encountered a female.

The smaller, deceptive male permitted his competitor to tap away to his heart's content but whenever the courting male attempted to copulate, the smaller male moved a short distance forward—in the manner of an unreceptive female. The larger male followed and resumed tapping the abdomen with his head; the female mimic paused and then walked slowly forward a short way with his suitor in pursuit. Several minutes passed in this fashion before the courting male seemed to realize that something was amiss, at which point he began to bite at the other male, sending him scurrying off. But the homosexual encounter lasted far longer than the typical aggressive bout between males, which usually ends in a few seconds with the speedy departure of the defeated beetle.

Once we were alert to the possibility of sexual mimicry by males, we began to look for it carefully, no longer assuming that cases of prolonged, unsuccessful courtship involved a male and an unreceptive female. Female mimicry proved to be fairly common, particularly when a small male encountered a large opponent. The advantage gained by this curious behavior also became clear: instead of wasting energy in futile fights with superior rivals, female mimics can wander about with a duped male in tow, dispatching flies that they would never have gotten had they been promptly driven off by an aggressive competitor.

Even more exciting was our discovery that a female mimic could actually court and mate with a female while at the same time occupying a territorial male with deceptive courtship. This happened when a female-mimicking male came across a female while leading his pursuer forward. The female mimic immediately began tapping the female's abdomen while simultaneously permitting the rival male to continue tapping at his abdomen. If the female was receptive, she lowered her abdomen, at which point the deceptive male withdrew his abdomen abruptly from his rival's head and twisted it under his body to reach the female to copulate. During the half-minute mating, the duped male stood motionless behind the copulating male that had so successfully deceived him. After mating, the female mimic raced off, chasing the female away as he went.

Female mimics are not locked into this role for life, however; they can switch it on or off depending on the circumstances. Marked individuals known to practice mimicry in the presence of a larger rival were perfectly capable of fighting with smaller beetles. In one striking case, a small beetle, which was engaged in homosexual courtship with a larger rival, encountered a still smaller male. The deceptive male then attacked the newcomer and, with much snapping of jaws, drove him back from the dung on which he and the large territorial male were perched. After this success, the small male resumed his homosexual interaction with the large male, which he could not have defeated in a fight.

The Costa Rican rove beetles may be masters of deception but they are not alone. Examples among insects abound. Immature males of the European rove beetle *Aleochara curtula,* for example, produce scents identical to those generated by mature females. As a result, these males smell like potential mates to mature rival males and are tolerated at carcasses where they can find their favored food—blowfly larvae. Or consider a much more famous example of deception in the insect world, the predatory firefly *femmes fatales* in the genus *Photuris,* which lure males of other firefly species to their doom by flashing the appropriate "come hither" signal of a sexually receptive female.

Deception by any creature poses an intriguing evolutionary puzzle. It is not in the best interests of a male rove beetle to be fooled into treating a fellow male as a potential mate, and it is positively deadly to be tricked by a firefly *femme fatale*. One wonders how a responsiveness to deceptive signals can long persist in populations if individuals that are deceived either die or lose mating opportunities and food to competitors. Surely individuals that ignore deceitful signals would be more likely to leave descendants, so that eventually members of the species would be immune to false signals. The same logic could be applied to the flies that are lured to predatory beetles perched on leaves.

Perhaps the reason that some kinds of trickery persist is that successful deception is usually based on the exploitation of a generally advantageous response to a signal. The male firefly that flies quickly to a particular kind of flashing signal often encounters a female of his own species and thereby gains a chance to reproduce. Only rarely is the signaler a killer female of another species. The male that utterly ignores the coded flashes of killer females might live a long life, but such a "cautious" male would have few or no descendants to carry on his resistance to deceit.

By the same token, the Costa Rican rove beetle probably lures little flies within attack range by capitalizing on its prey's reaction to key chemical cues. Female-mimicking beetles clearly exploit the eagerness of their fellow males to copulate, which is an adaptive attribute on average because it encourages males not to miss any chance to mate.

People often imagine insects to be automatons with simple and rigid behavior patterns, but the Costa Rican rove beetles give the lie to that stereotype. We suspect that as people observe insects more closely, they will find many more cases in which these diminutive creatures respond to life's complex demands with behavioral flexibility that includes the capacity for creative deception.

John Alcock is a professor of zoology at Arizona State University, and Adrian Forsyth is the senior director of conservation biology for Conservation International in Washington, D.C.

In the Eyes of the Beheld

by Michael Dorris

Bodies before a camera may be formally posed, may be clothed or unclothed, may be arranged in clusters or viewed individually, depending on the photographer's whim or artistic purpose, but in a human face the eyes belong to the subject alone, and their expression transcends era and culture, ultimately overpowering manipulation and objectification. The eyes are key to understanding many of the 303 black-and-white photographs and 8 color images and portraits culled from a major 1985 exhibition at Princeton University and now collected in *The Photograph and the American Indian*. Compiled and introduced by Alfred L. Bush, curator of the Princeton Collections of Western Americana, and Lee Clark Mitchell, chair of the Princeton Department of English, this handsome book is divided into six sections having vaguely to do with periods of photographic technology, along with biographical sketches of the artists whose work is included and a sixteen-page bibliography.

From the earliest photograph of a Native American Christian preacher visiting England, made in 1835, to the most recent, of a couple of mid-1980s Native American Princeton undergraduates, the eyes tell most of the story. Regardless of the context—props and paraphernalia, phony settings, and staged, agenda-laden accouterments—the eyes don't lie; they look out from the vintage pictures in this book with expressions mostly cold, imposed upon, resentful, trapped by a lens in a flash of powder. For a century of snapshots eclectically shuffled together from many disparate tribes and regions, the eyes are wide open, reflecting sights we cannot now imagine but for the knife-throw angle of their silent gaze.

THE PHOTOGRAPH AND THE AMERICAN INDIAN, by Alfred L. Bush and Lee Clark Mitchell. *Princeton University Press, $79; 334 pp., illus.*

A major reason for this inscrutability is the odd and counterproductive disorganization of the volume itself. Despite Lee Clark Mitchell's rather defensive and

Pawnees outside earth lodges near Loup Fork, Nebraska, 1871
William Henry Jackson; The Princeton Collections of Western Americana. Gift of Sheldon Jackson

Arizona Navajo Tom Torlino in 1885, before and after his arrival at the Indian Training School in Carlisle, Pennsylvania
John N. Choate; The Princeton Collections of Western Americana

overgeneralized explanatory sixteen-page introduction, the photographs are presented without a coherent internal narrative that deals with chronology, subject, tribal group, geographical region, or artistic composition. Presumably, we are expected to view each image discretely, devoid of historical or sociological context. The book subtly implies, disclaimer notwithstanding, that Indians are just...Indians, internal distinctions between them too irrelevant to note, except perhaps for the apparent conclusion that they generally look happier and more relaxed when photographed by other Indians instead of by European Americans.

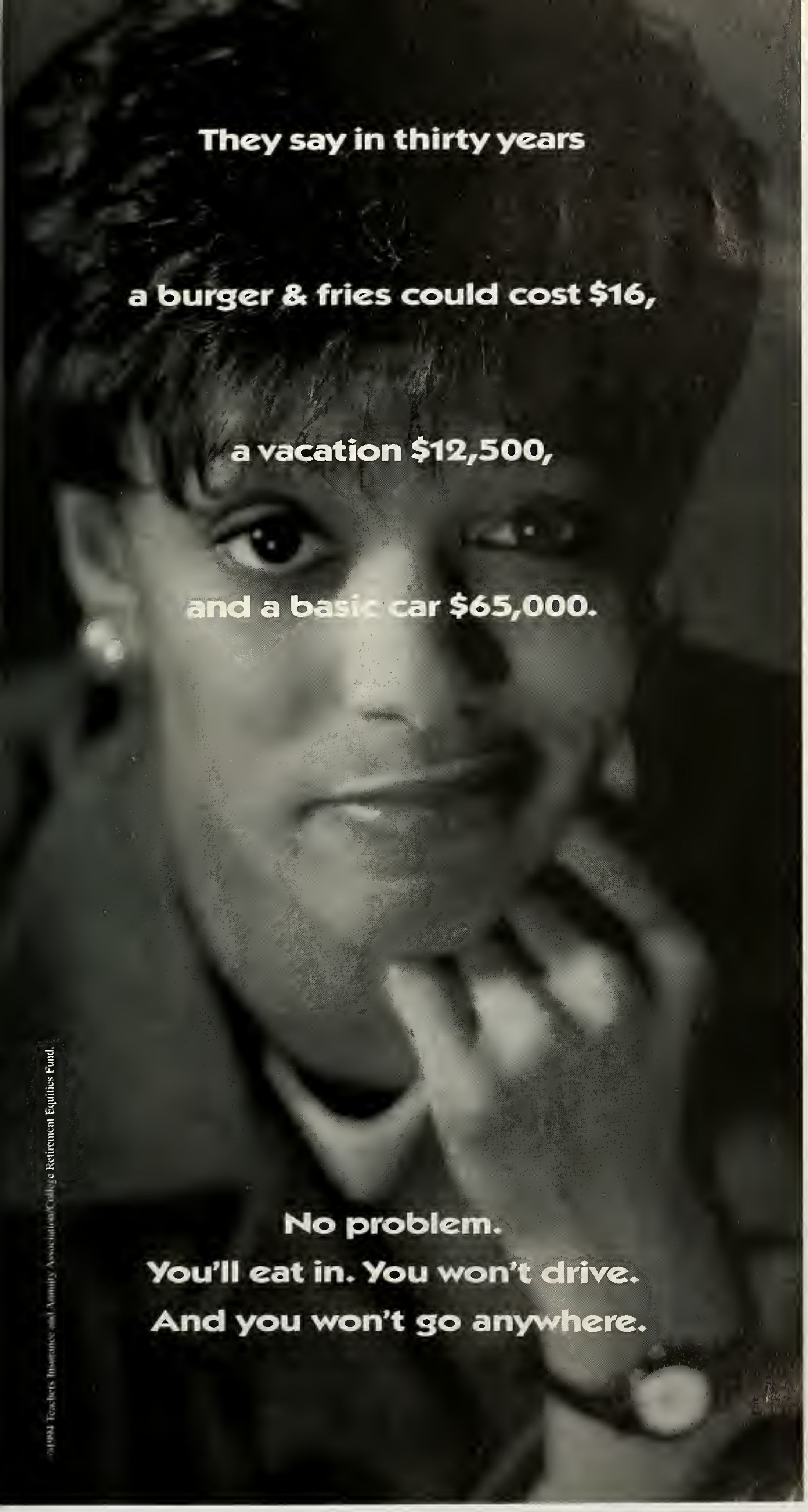
This naïve and retrograde approach (the authors fail to provide so much as a map to identify the locations of the tribes involved, as if such data didn't matter) invites us to project our own uninformed imagination in the interpretation of each shot, encouraging the perpetuation of clichéd ironies and discontinuities: Hey! there's an Indian dressed up like a European! or Wow! Isn't that Western sky *big*! An annoying and unnecessary strain of fallback romanticism is present here because we are allowed—even forced—to look without knowing what or whom we're seeing.

Not that the photographs themselves aren't powerful and full of their own information. As the authors correctly point out, many portraits contain a wealth of ethnographic information about material culture—clothing, ornamentation, style, the manufacture of the occasional basket or pot. A descendant of one of the subjects or a scholar acquainted with a particular societal tradition could gain much from a close examination of both the intentional and the unintentional inclusions a given photographer elected to document, especially in those photographs made outside a studio with its ersatz painted backdrop.

Look, for instance, at John K. Hillers' (1843–1925) "Zunis on the roofs and in the plazas of their Pueblo, September, 1879" (plate 69) or at "Pawnees gather outside their earth lodges near Loup Fork, Nebraska, for what is most probably a ceremonial occasion, 1871" (plate 1). In the latter image, photographer William Henry Jackson (1843–1942) records a scene bursting with data—earthen dwellings in a circular pattern, formal constellations of blanketed men and women observing something at the center. The area is cleared of vegetation, bleakly situated; yet it is obviously a village upon which much labor has been expended. More than simply a picture, this is an artifact of Pawnee ethnohistory, a unique one-way mirror that pierces time, that makes the past and present momentarily coterminous.

Fascinating as it is to study this photograph—for its technique and framing, if nothing else—imagine if it were accompanied by a text in which a modern Pawnee elder speculated on its action and meaning, on who was present and why, on whether or not this "probably...ceremonial occasion" has an enduring tribal-specific significance. To deprive the image of its deeper intellectual illumination is the equivalent of hanging it in a dim and obscure gallery.

The same could be said of the many "before and after" shots of students forced to attend boarding schools, primarily the one at Carlisle, Pennsylvania. The facing 1885 portraits (plates 102 and 103) by John N. Choate (1848–1902) of "Tom Torlino, Navajo" give new meaning to the word *scalped.* The poignancy of loss is almost palpable as the dazzling outward


They say in thirty years
a burger & fries could cost $16,
a vacation $12,500,
and a basic car $65,000.
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Verna Catholique and her son, Snowdrift, Northwest Territories, 1984
Dorothy Chocolate; The Princeton Collections of Western Americana

trappings of long hair, traditional jewelry, and woven blanket are replaced by a pinched uniform suit and blunt coiffure. In a reverse of the recently criticized *Time* cover photo of an artificially darkened O. J. Simpson, a trick of overexposure makes the acculturated version of Tom Torlino's skin seem whiter. But the real transformation is told in his eyes, which go from strong and concerned to a fixed grimness that no inflicted costume, no coerced external assimilation can disguise.

Yes, the pictures do speak for themselves—but not as loudly as they might have. At the expense of their freedom, young people were squeezed into uncomfortable roles, the unwilling impersonations of who an arrogant, paternalistic government thought they should be. A viewer unfamiliar with U. S.-Indian history needs information on the nineteenth-century imperialistic policy that made the kidnapping and virtual imprisonment of American Indian children not only legal but also righteous in the minds of those carrying it out. And an observer of these sad and shameful recordings needs to know something of what happened after the photographs were taken—when these boys and girls, for the most part unemployable in a racist society, were sent home with a gaping hole in their lives, strangers to their parents and themselves, untutored by examples of traditional nurturing, unable or unwilling to speak their languages, legally prohibited from the practice of their religion. What became of Tom Torlino, Navajo?

Simply asking the question matters,

even if the answer is unrecoverable, even in an exquisitely produced, well-intentioned book of interesting photographs, for there is no divorcing the people in these pictures from the fate that, through no fault of their own, overtook them. There can be no neutral pictures of slaves or Holocaust victims, no politically uncharged images of attempted cultural genocide.

The mood changes toward the end of the book, although the implication that this is so because Native Americans have become more skilled in the use of a camera is perhaps overstated. Of equal importance is that the society as a whole now finds the myth of noble savages (unless one thinks of certain sports mascots) harder to swallow, and as a result, the motif of "The Indian" can be replaced by actual human beings.

A good example of this welcome trend is Dorothy Chocolate's charming 1984 "Verna Catholique, with her son, Snowdrift, Northwest Territories" (plate 296). Framed by the rough-hewn walls of their house, their windowpane reflecting a sweep of cluttered subarctic landscape, a mother and her child float in hyperspace, mutually delighted in their embrace, telling their secrets not to any camera but to each other.

Despite all the might-have-beens and should-have-beens, the hundreds of pictures included in *The Photograph and the American Indian* are finally, as a group, as ambiguous in their assemblage as they were in their original taking. The goals of the 110 photographers whose work is represented range from entertainment to documentation, from sociology to art, from contempt to enshrinement. In a reverse way, the artists themselves are revealed by the Indian people whom they sought out for their images: illusive Native Americans, as portentous and fascinating subjects, are the constant, while attitudes toward them leap and fall like a cultural seismograph. *The Photograph and the American Indian* is a cache of rich raw material, and though it inexplicably lacks the tools necessary for extracting some useful wisdom, the eyes that glare and stare—and sometimes smile—from its pages remain unforgettable.

Michael Dorris is an adjunct professor of anthropology and Native American studies at Dartmouth College and the author of several books, including Native Americans: 500 Years After, The Broken Cord, *and, most recently,* Paper Trail.

Starry Wilderness

by Gail S. Cleere

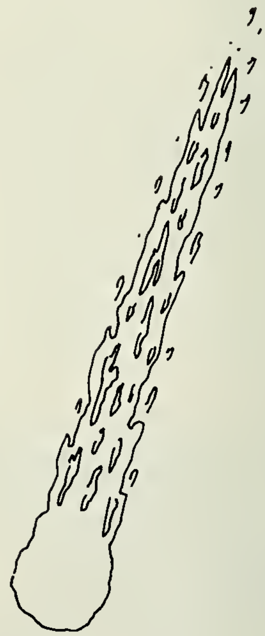
As the curtain of night descends slowly during November, the summertime Milky Way sinks over the western horizon, and the familiar stars of winter push their way up in the east. Among the most familiar of these wintertime stars are those of the great mythological hunter Orion, a constellation that straddles the celestial equator and is therefore visible from all inhabited places on the earth at some time during the year. In the Northern Hemisphere, Orion rises in early evening in November and is high in the southeastern sky by midnight.

According to Richard Hinckley Allen's classic *Star Names: Their Lore and Meaning,* the name Orion may be from the Sumerian *Uru-Anna,* meaning "light of heaven." Allen's and other texts also suggest that the name is Greek for "warrior." Whatever the origin of its name, however, Orion is magnificent—it contains fifteen stars above magnitude 4 (magnitude 6 is traditionally given as the limit of naked-eye visibility) and another five stars above magnitude 5. It is also the only constellation in our sky that features two first-magnitude stars, Betelgeuse and Rigel.

As we watch Orion throughout the winter months, we face away from the center of the Milky Way and gaze toward the stars that make up its Cygnus "arm." We are residents in a spiral galaxy with great wispy arms of stars slowly rotating around a central disk once every 230 million years.

The sun, with its paltry gaggle of attendant celestial bodies, is located about two-thirds of the way from the center of the Milky Way to the edge of the galactic disk; it currently resides just outside the Orion "spur" off the galaxy's Cygnus-Carina arm, from which we emerged just 60 million years ago. For 50 to 100 million years before that, we were traversing the arm. (That is the sky the dinosaurs would have seen.)

Most recently, we seem to be escaping from the Gould belt of stars, a region of bright objects on the edge of the Orion spur, which includes the bright naked-eye stars that give Orion its outline: Betelgeuse, Rigel, Orion's three "belt" stars, and the stars and nebula in Orion's "sword." Betelgeuse is a very old red giant that has become unstable, puffed up, and swollen—ready to become a supernova at any time. On the other hand, Rigel, opposite Betelgeuse in Orion's knee, is a blue-white, still relatively young supergiant.



When looking at Orion, the eye is quickly drawn to the three stars that

form the giant's belt, Mintaka, Alniham, and Alnitak, but the most interesting area, the Orion nebula, is found immediately below these stars. Visible in dark skies with the naked eye, the nebula appears as a fuzzy patch of light. We are looking inside swirling clouds of gas and dust embedded with hundreds of new stars. With a small telescope, the four bright stars that make up the Trapezium can be seen. The light they throw off as they emerge from this region of intense star formation enables us to see the nebula, a tremendously active region some thirty light-years in diameter, where stars coalesce from the surrounding gas. (To give an idea of its size, if our solar system measured one inch in diameter, the Orion nebula would stretch across five and a half football fields.)

Beyond the young stars of Orion's nebula, we are looking away from the center of the Milky Way—out toward the vast, starry wilderness of other galaxies and universes far beyond our own.

The Planets in November

Mercury, skimming over the bright star Spica, has its best morning apparition of the year this month, low in the east–southeast sky about forty-five minutes before sunrise. On the 12th, it will appear above brilliant Venus.

Venus passes between the earth and the sun on the 2d, but by midmonth the planet has moved far enough west of the sun to be easily visible in the predawn sky. Venus slowly inches its way toward the first-magnitude star Spica in Virgo. From the 12th to the 15th, Venus plays tag with Mercury. On the 30th, the waning moon pays a call, passing below and to the right of Venus.

Mars, which rises just before midnight, starts out the month in the constellation Cancer; by December, it moves into Leo. Early on the morning of the 25th, look for Mars approaching bright Regulus in the heart of Leo and the waning gibbous moon passing well to the south. Mars brightens slowly throughout the month.

Jupiter will be invisible during the first half of the month. On the 17th, Jupiter is in conjunction with the sun (passing behind the sun as seen from the earth). By month's end, Jupiter has moved far enough away from the solar glare to be visible very low in the predawn east–southeast sky, passing very close to Mercury on the 28th. In the brightening morning twilight, scan the horizon with binoculars about forty minutes before sunrise to spot the two planets. Binoculars will help distinguish Jupiter (the bright object on the left) from Mercury.

Saturn is in the faint constellation Aquarius. At sundown, the ringed beauty is nearly due south and will not set in the west until midnight. On the 11th, look for Saturn below the first-quarter moon.

Uranus and **Neptune**, just west of Sagittarius, slowly sink below the horizon after sundown.

Pluto passes behind the sun on the 20th and moves into the morning sky.

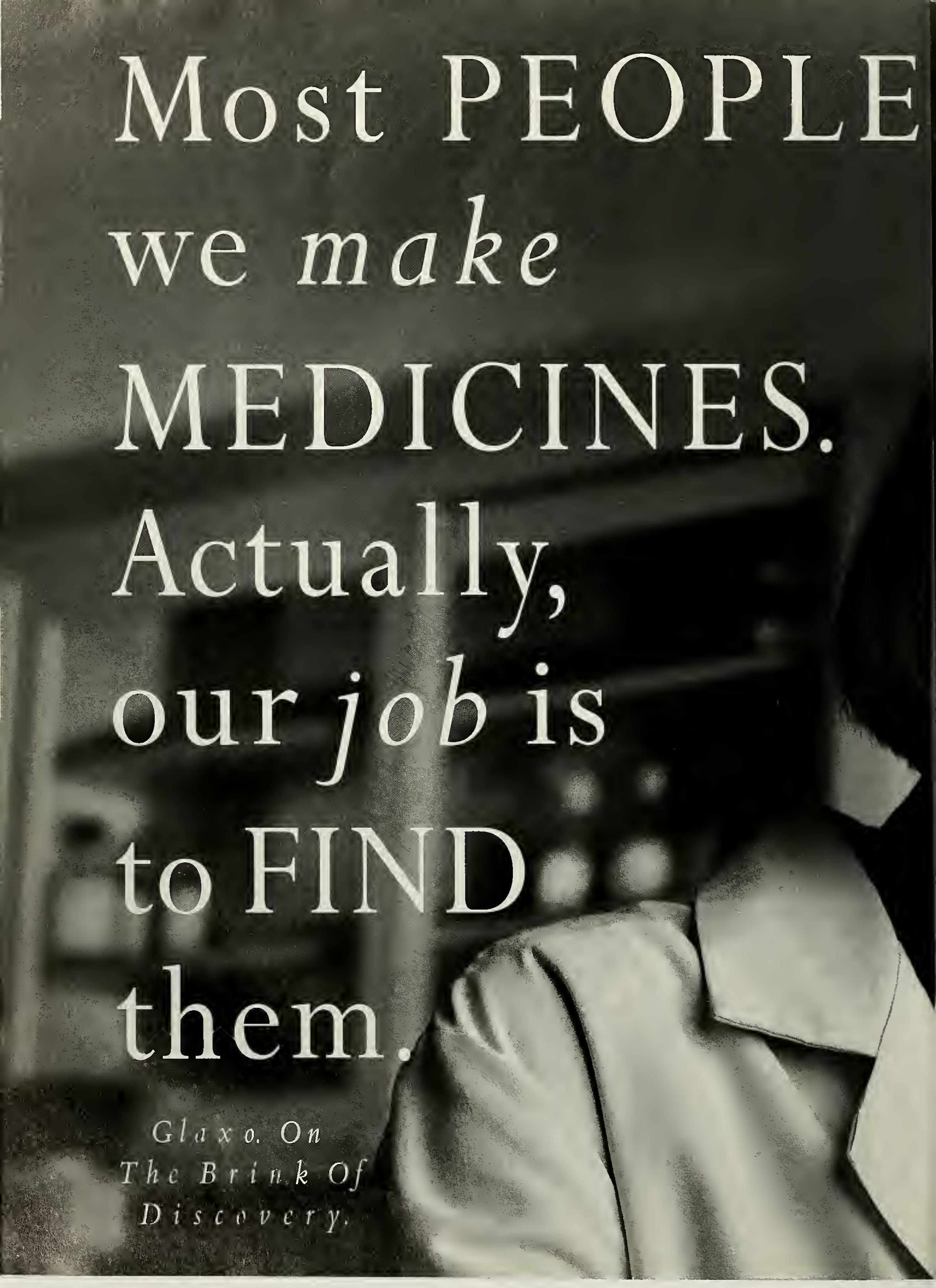
The **Moon** is new on the 3d at 8:35 A.M., EST; the first-quarter moon occurs at 1:14 A.M., EST, on the 10th. The moon is full on the 18th at 1:57 A.M., EST, and reaches last quarter at 2:04 A.M., EST, on the 26th.

On November 3d, a total eclipse of the sun takes place when the new moon passes directly in front of the sun just ten hours before it reaches perigee, or closest distance to us. This eclipse will encompass nearly half the earth's surface, sweeping along a path almost 9,000 miles long. Totality will be visible along a narrow strip running westward across northern Chile to southern Brazil. A partial eclipse will be widely visible, however, throughout South America and southern Africa. The moment of greatest eclipse occurs over open ocean at 8:39 A.M., EST, off the coast of southern Brazil, where totality will last four minutes and twenty-two seconds. About an hour and a half later, Cape Town, South Africa, will witness a partial eclipse that blocks nearly 90 percent of the sun's disk. The eclipse ends shortly afterward south of Madagascar in the Indian Ocean.

On November 18, the moon will pass through the faint outer shadow of the earth, and a penumbral eclipse of the moon will occur. This eclipse actually begins half an hour before midnight, EST, on the 17th, and mideclipse takes place at 1:44 A.M., EST, on the 18th, when the northern side of the moon should be noticeably darker than the southern side.

The Leonid meteor shower unfortunately will probably reach its peak on the 18th, the same morning as the full moon, which will overwhelm the show with its brilliant light. Nonetheless, check out the sky between approximately 2:00 and 5:00 A.M. for unusually brilliant meteors streaking from the direction of Leo, the lion. This is the famous meteor display that can produce "storms" of tens of thousands of meteors per hour during the return of its parent comet (Tempel-Tuttle) to the inner part of the solar system. The comet is due to return in February 1998, so this year the Leonids may provide a few bright forerunners of its main stream of debris.

Gail S. Cleere lives in Washington, D.C., and writes on popular astronomy.


Most PEOPLE
we make
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Actually,
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MILLIONS OF PEOPLE LIVE IN THE SHADOW OF AN ILLNESS FOR WHICH THERE IS YET NO CURE. BUT THEY LIVE IN HOPE. THE HOPE THAT SOMEWHERE, SOMEHOW, THERE WILL BE AN ANSWER.
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Research & Medicines
AT GLAXO, WE MAKE MEDICINES. BUT OUR REAL JOB IS TO FIND THEM. AND OUR SEARCH CONTINUES. RELENTLESSLY. UNCEASINGLY. THROUGHOUT THE GLAXO NETWORK OF SCIENTISTS COMMITTED TO FINDING ANSWERS. AND MEDICINES. HOPE IS REAL, THE SEARCH GOES ON.

Stand-up Chemist

Do the beaker folk have a sense of humor?

by Roger L. Welsch

I recently met with a panel of local scientists up at Slick's Big Table Tavern and the conversation turned, as it so often does, to this column and issues of modern science. "I'll bet your column on astrophysics a few months ago got plenty of astrophysicians boiled," offered my plumber friend Woodrow.

"Well, yes, it did," I admitted. "But truth to tell, it's pretty hard to write anything without upsetting someone, especially when you're trying to be funny. And let's face it, science has taken a bum rap from popular culture for a long time. Scientists are more often than not portrayed as crazy, not funny. Think of Dr. Frankenstein, for example. Or Dr. Jekyll."

"Or Dr. Scholl," suggested Lunchbox, our local auto body repairman.

"Or Dr. J," said Luella, the dishwasher from over at Harriett's Chew 'n' Chat Cafe.

"Imagine going to a party and running into a scientist," said Slick, with obvious compassion. " 'Hi,' I say. 'I'm a barkeep. And this is my wife, LaVerne, hairdresser and flower arranger—imagine trying to keep those two things separate and straight. She leads an interesting life, I can tell you for certain. And this is Luella, who set the county record for dishwashing at last year's Mother's Day buffet. And these are Woodrow and Lunchbox, plumber and sheet metal master, except on some Saturdays when they dance at bachelorette parties under the nom de plume Quarter Ton o' Fun.'

"Here I've made it clear that me and my friends lead remarkable, dramatic lives. But then the guy I'm talking to says, 'I'm an astrophysler.' Man, where can a conversation go from there? There's nothing from science that goes well with onion dip and wine coolers, I'm willing to bet."

"I can't buy that theory, Slick," I said. "I received two letters about that column from physicists who refuted point by point in earnest what I had written in jest. But I also got many more letters from physicists who said that the piece had given them a good laugh and they would like to reprint it in their department newsletter or maybe a class casebook or even a Christmas letter. To tell you the truth, I think science—both the study and the materials studied—are inherently funny."

"Not chemistry," moaned Luella. "I took chemistry four times in high school twenty-two years ago and I distinctly remember that we never laughed once. Astrophysics may sometimes be funny, but not chemistry."

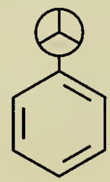
The Big Table Forum argued the issue a while but we finally realized we were at a considerable disadvantage in that the closest thing we had in attendance to a chemist was Slick himself, and he made it clear he wouldn't mix free drinks for anyone. ("Science be damned," as he put it.)

Most scientists don't give us folklorists credit for knowing much, but believe me, this is one thing we do know: The places where orally, informally transmitted materials thrive is precisely within small, esoteric, isolated groups of people. Stockbrokers have traditional customs, farmers have traditional beliefs, hookers have traditional language, even folklorists do. Chemists have traditional humor—I'd bet money on it.

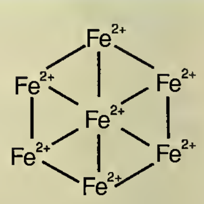
So, I wrote to Dr. Pill-Soon Song, Dow Chemical Professor and chairman of the chemistry department of the University of Nebraska, one of the many educational institutions where for decades I successfully avoided contact with anything even remotely like a hard science. (There is a reason, after all, that they are called "hard.") I asked Dr. Song, "Is there a humor of the

HIOAg

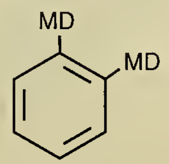
Hi O Silver
Ag is the symbol for silver.



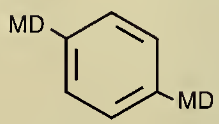
Mercedes Benzene
A hexagon with the dashes as shown represents a benzene (C_6H_6) molecule.



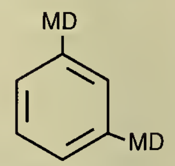
Ferris Wheel
Ferrous is the name of iron in many of its compounds, and Fe^{2+} is the symbol for ferrous iron.



Orthodox
Adjacent positions on a benzene ring are said to be "ortho" to each other, and MD is a doctor.



Paradox
Opposite positions on a benzene ring are said to be "para" to each other.



Metaphysicians
Positions that are neither opposite nor adjacent are said to be "meta" to each other.

science of chemistry…a science-specific, in-group tradition of laughter?"

He responded that there indeed is, and provided examples: "Old chemists never die, they just fail to react," and "How do you know if a person is a chemist? He's the one who washes his hands *before* he goes to the bathroom." Just as I had hoped, there was also one joke that means absolutely nothing to anyone who is not a part of the in-group: "The Chemist's Rule: Never take more than three data points. There will always be some kind of graph paper on which they fall in a straight line. Chemist's Rule First Corollary: If you only have one kind of graph paper, never take more than two data points."

"I'll pass your letter around the department and see what else we can scratch up," wrote Dr. Song.

A couple of weeks later I got a follow-up letter from an old friend, Jim Carr, of the university's chemistry department. "A lot of chemical humor involves fictitious names for chemical substances," he wrote, providing a few examples along with detailed explanations for the uninitiated. ("There are dozens more," he offered.) Aha! Just as I suspected: there is not only humor about science but also a humor of science. Even chemistry, Luella.

Dr. Song, like any good scholar, even dug up a reference for me, R. L. Weber's *Science with a Smile* (Philadelphia: Institute of Physics Publishing, 1992). I got a copy of that seminal study, and if any doubts remain in your mind that science is funny, *Science with a Smile* should put them forever to rest—unless you satisfied your science requirement, as I did, with a few extra semesters of R.O.T.C. In that case, you won't understand a thing.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

A female otter and her three pups survey the river from a log.
Michael S. Quinton

Otter Limits

On Nevada's desert rivers, otters are restricted to oases created by beavers, willows, and some thoughtful ranchers

by Peter V. Bradley

A chisel-toothed kangaroo rat bounces away across the parched sand at my feet. A member of a family of rodents that has long been deprived of free water, the kangaroo rat has evolved the ability to metabolize the stuff from rock-hard Indian rice grass seeds. All around me, the scene repeats itself—a desert teeming with examples of organisms that collectively have spent a large part of their evolutionary capital on physical and behavioral adaptations that daily mean the difference between life and certain death by desiccation. Yet only a half mile away, a four-foot-long river otter broods her young in the security of an abandoned beaver lodge. Sage thrashers and Brewer's sparrows flush as I wind through brittle stands of upland greasewood and saltbush on my way from road's end down to the banks of the Humboldt River in Nevada.

The northern river otter has adapted to a wide variety of aquatic habitats, from coastal marine environments to high mountain lakes. Northern Nevada, however, is one of the few areas where the animals survive in a desert habitat, confined to narrow river corridors. This is where I've been for three years now, defining the otters' role in this fragile ecosystem by detecting what they have left behind. Piles of otter excrement, reeking four-by-one-inch constructions of fish bones and crayfish exoskeletons, webbed five-toed tracks in the river mud, and tunnels in hay meadows where the elusive otters have beat down a shortcut connecting two river meanders—these were my prizes, my ultimate goals. Even a glimpse of the animals seemed too much to ask.

I was therefore surprised when a mother otter and her three pups—hesitant but curious—greeted me from the opposite bank. At first, the mother's reaction to my presence reminded me of a pronghorn antelope's curiosity just prior to flight. A pronghorn sometimes walks right toward you, seemingly mesmerized by the obvious danger. Then suddenly, it takes to rapid flight, white rump patches flashing in the morning light. The difference here was that no rapid flight followed the period of curiosity. The mother otter slipped into the stream and glided through the water twenty feet away, scribing an arc in the glassy pool between me and her chocolate brown pups huddled on the opposite shore.

I couldn't help but sit and stare for some time. The animal's body seemed perfectly matched to a carnivorous life on the river. The missilelike head, neck, and trunk tapered into a long, powerful, muscular tail. Her coat, dark brown above and almost white underneath, mimicked color patterns in many predatory fishes (presumably a parallel evolutionary adaptation that may allow the otter to avoid detection just long enough to make a kill). Her stout whiskers can supposedly detect movement in turbid waters. All this, combined with powerful jaws equipped with bone-

Beaver dams create ideal conditions for river otters in many areas, but in the desert they are essential. Even a low dam, below, can pool enough water from melting snows to see otters through the sweltering summers.
Peter V. Bradley

shearing carnassial teeth and the weasel family's almost legendary boldness-to-bodyweight ratio, makes river otters the uncontested top carnivores of America's rivers.

She stared at me as she effortlessly swam by and on the fifth arc, shot a glance at her three pups and coasted downriver, submerging in a deep pool a hundred yards away. Within a minute, she was back at her pups' side, with a large, agitated crayfish protruding from her mouth. Her three dependents quickly devoured the live prey and their mother soon brought them a second crayfish. Each time, the prey was alive, presumably to arouse the carnivore in her little ones.

This process of gathering breakfast went on for a good thirty minutes, interrupted only once by a transient beaver. The two large, semiaquatic furbearers gave each other a wide berth, the otter lazily swimming, head out of the water near her pups; the beaver hugging the opposite shore and in the process, gliding directly under my feet, unaware of my presence. Perhaps because a beaver had come too close on a previous visit, on this occasion the adult female otter offered a low, ominous growl that kept him moving on his way. At least that is the standard anthropocentric interpretation. It could just as easily have been a "top of the morning" greeting or some ancient carnivorous insult reserved for Rodentia. The important thing was that something was said.

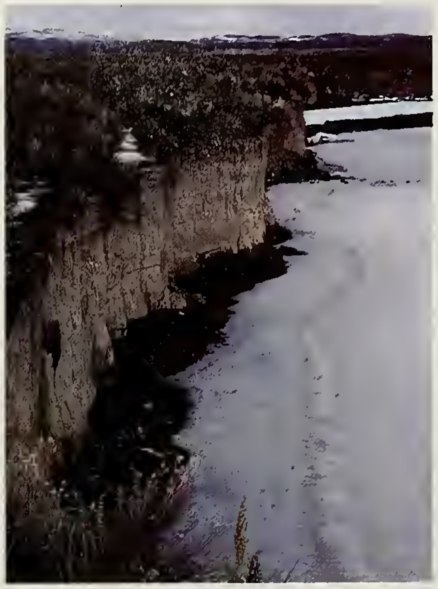
I was so excited by the mother otter's seeming indifference to my presence, and by this unprecedented opportunity to observe her, that I nearly forgot about my scheduled rendezvous with my wife, Susan, downstream at the end of the day. I canceled my survey of the river, made a quiet exit, and ran the two miles to the truck in hopes that Susan, too, would have an opportunity to observe the family group. On our return, the pups had retired to the safety of their willow lodge den and their mother was keeping watch at the entrance, her sleek head just above the water level at the edge of the large pile of willow branches on the opposite shore.

As Susan and I hiked the two miles back to the pickup in the approaching twilight, our three years of study began to jell. How appropriate it seemed—to take leave of a family of Great Basin river otters snug inside the confines of their abandoned beaver lodge. The evidence for a powerful commensalism between the carnivore and the oversized rodent engineer had become overwhelming—so much so that it is difficult to imagine a healthy river otter population in the central Great Basin without the influence of an equally healthy beaver population.

Nevada otter populations appear to be determined in part by the number of preexisting den sites, of which beavers seem to be the sole providers. Along the desert rivers, female otters almost always raise their litter of one to five pups in abandoned beaver constructions. The two most common dens are the typical beaver lodges—

Len Rue, Jr.

A beaver races up the side of its dam, left, chasing off a trespassing otter. Humboldt tributaries that have been stripped of willows, below, run wild during the spring floods, cutting deep, otterless channels into the sagebrush desert.
Peter V. Bradley

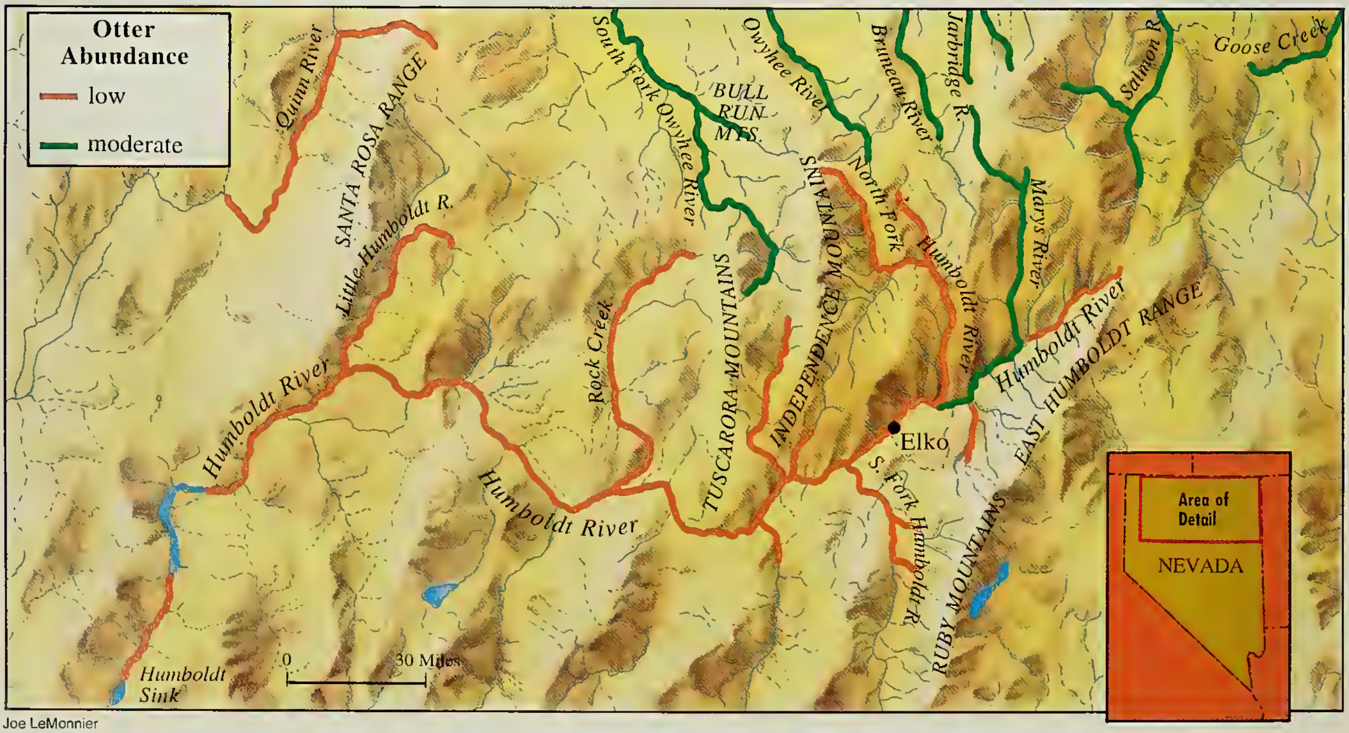


made of willow and rock, bound together with river mud—and tunnellike burrows in mud banks, with at least one entrance below the surface of the water. Studies in other parts of the west have shown that river otters use a number of sites for their dens, including hollow logs and talus slopes. For the most part, however, these do not exist in Nevada. There is simply no alternative for the big river weasel that either never figured out how to build its own home or simply preferred not to do so.

If that were not enough to verify this curious association, I found evidence that suggests beavers are also responsible for maintaining healthy populations of prey for the otters in Nevada's rivers. Pools created upstream from beaver dams teem with crayfish, freshwater mussels, mountain suckers, sculpin, red-sided shiner, speckled dace, Lahontan cutthroat trout, and the introduced Asiatic carp. As is common during the "dry season" in this driest of states, the fury of the spring floods gives way to a gentle flow. The rivers then trickle, dribble, and dry up in the furnace of August. This is when beaver-made pools and ponds take on the critical role of providing sanctuary for aquatics that have no other place to go. These can also be times of great abundance for far-ranging otters. Male otters, which are unwelcome near the dens and play no part in raising their young, wander three to four times farther than females. Moving from pool to pool in ninety-mile circuits—not unlike one of his distant relatives in a Friday seafood buffet line—a male otter finds easy pickings where prey are concentrated by annual drought cycles. During the height of the dry season, the density of life in these pools is, in part, what determines how many otters can live on any given reach of river.

By far of greatest import to the otter, and probably the linchpin of the beaver–otter relationship, is the beaver's penchant for irrigation. Underground water tables delineate the boundaries of riparian wetland vegetation in the Great Basin desert; only where water lies close to the surface is the land green. Upstream from each beaver dam, the water table rises to a new level, expanding the corridor of lush river vegetation snaking through the desert valleys. Healthy Great Basin river ecosystems rely heavily on this stream bank vegetation. Overhanging willows and hay meadow vegetation block much of the direct sunlight, making for cooler water temperatures. Cool waters sustain higher levels of dissolved oxygen. These same overhanging branches provide a constant rain of organic litter, which forms the basis of the aquatic food web. Invertebrates turn this rain into protein that eventually finds its way into the muscle fiber of the river's top carnivore.

An even more critical function of willows and hay meadows is that their root systems stabilize stream banks during yearly spring floods. In May and June, Nevada's 12,000-foot mountain ranges release their torrents of snowmelt. The life



Joe LeMonnier

The old bed of the meandering Humboldt River—once an ideal habitat for otters—is still evident on the river plain, left. Before reaching the sink where it evaporates in the desert heat, the new channel (near the top) cuts a relatively straight path. Map, below left: A few tributaries of the Humboldt River, where willows and beavers are found, still support a moderate number of river otters.
San Juan Stiver

and health of valley river ecosystems hinge on whether stream banks are sufficiently armored to prevent soil erosion—stream banks like the ones provided by rancher Bill Wright and his sons on the Marys River.

The Wright family's Mala Vista Ranch spreads along 7,100 acres of the Marys River floodplain at the base of the Jarbidge Mountain wilderness in northern Nevada. Native hay meadows, old willow forests, and cattail-bulrush wetlands dominate the river valley. When the great floods of 1983 and 1984 hit northern Nevada, Bill's river was ready for them. Stream banks armored by old-growth willows and hay meadow vegetation held the precious floodplain soils in place. Meandering channels riddled with beaver dams slowed floodwaters, dissipated flood energies, and absorbed much of the sediment loads from upstream properties not so well tended. The exception, rather than the rule, the Mala Vista was one of the few ranches on the Humboldt River system to avoid ecological disaster at the hands of the big floods.

Number two son, Preston Wright, and I were standing chest deep in a patch of Great Basin wild rye one crisp July morning, looking out over a fresh-cut hay meadow bordered by fog and river willows when I asked him what was unique about his family's stewardship of the river. Armed with a stem of timothy between his teeth and a degree in English from Stanford University, he stared off into the distance and carefully formulated his answer: "Well, it's simple really. We're old-fashioned. We never have disturbed our willows along the river. The operators who kill their willows in hopes of raising more grass hay are shooting themselves in the foot. In most cases, willows are the only thing holding these riverbanks together." In the early 1970s, Preston's father was the first to refuse federal dollars thrust at private landowners by the U. S. Department of Agriculture to entice them to cut down the willows. The trees were thought to suck up too much water, when, in truth, they actually help to conserve it on the river floodplains. For saving the trees, Preston's father is now nicknamed "Willow Bill."

Preston continued, "Also, we raise hay in this valley for winter feed and we don't turn the cows into these fields until the end of the growing season. We like to leave something for the wildlife." A greater sandhill crane interrupts our train of thought with its distress call, a loud, metallic rasp that echoes across the floodplain.

We climbed into an old dusty pickup and drove downriver to a spot Preston seemed particularly fond of. At road's end, we walked half a mile through and around sedge, rush, and cattail marshes to a yard, where hay had once been stacked. White-faced ibises, willets, yellow-headed blackbirds, gadwalls, and green-winged teals rose in clouds around us. A semi-intact fence still enclosed an old, brown, twenty-foot-high haystack. Water and marshland surrounded the yard. Preston pointed toward the river 150 yards away. "We've hayed this field since I was a boy. Three years ago, beaver built so many dams through there that the river silted up, spilled its banks, and flooded these fields."

"Did that cut into your winter feed supply?"

"No, not really. We generally have more than enough hay to take the herd through the winter."

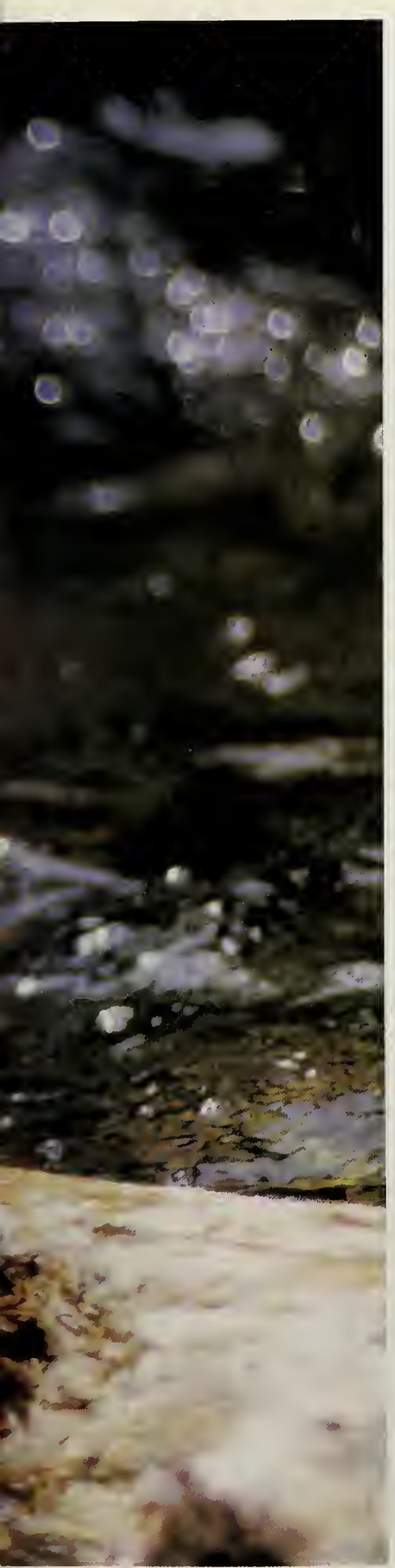
"So you're going to let the beaver do their thing?"

"Sure. They keep the water table up, and the birds seem to like it."

I thought about the beavers, the willows, the new marsh, and the redirected river as Preston's comment—"they keep the water table up"— kept coming back to me. Could it be that over the centuries this humble rodent was somehow responsible for thousands of redirections of this river across its mile-wide floodplain and the concurrent deposition of leagues of rich floodplain topsoils—the foundation and keystone of the desert riparian ecosystem? I climbed the old stackyard to improve my view of the floodplain. Once on top, it became evident that another local mammal or mammals had recently enjoyed the same vista. A large river otter latrine was perched atop the last four bales of the abandoned stack. Crayfish exoskeletons, fish bones—the works.

In the coming months, Sue and I had no trouble finding abundant signs of river otters along the seventeen miles of Marys River that wound through the floodplain stretching across the Mala Vista Ranch, nor did we have trouble finding traces of them on similarly healthy reaches of the Humboldt River system. We found the greatest abundance of otter signs on stream reaches that either had dense mature willows or dense hay meadows lining both banks of the stream. Reaches most frequented by otters also had an abundance of beavers and meandered through valleys, dropping at a gentle rate of only a few inches per mile.

Painfully obvious, however, was how rare these healthy riparian ecosystems had become. Hundreds of miles of Great Basin



Erwin and Peggy Bauer

After foraging in the river for hours, an otter, left, emerges from the water to rest on a log. In an otherwise arid landscape, willows and a beaver dam, below, retain the waters of Marys River on the Wright's ranch.

Peter V. Bradley

rivers had lost their ability to withstand normal spring floods. Their channels incised, their water tables lowered, their meanders abandoned, river valleys began to take on the appearance of the surrounding Great Basin desert—green rabbitbrush and sagebrush blanketing their floodplains. Otters did not do well along these degraded streams, perhaps because there was little to eat and nowhere to sleep.

Those streams with little or no sign of otters were those where the native riparian vegetation had been replaced by upland species—sagebrush, rabbitbrush, greasewood, exotic brome grasses, and forbs such as cocklebur, Canadian thistle, and curly dock. Beavers were rare to absent, and streams had lost their meandering character and had instead become essentially straight. Vertical mud banks rose as high as twenty feet above entrenched, braided, sickly streams where no trout swam and no willows grew. Mud banks were often streaked with reddish brown horizontal stains marking historic water tables—a sort of pictographic history of a river floodplain's slow death.

Water-loving plants and animals declined as water tables dropped, and whole populations of wood warblers, willows, Preble's shrews, and American tree sparrows eventually disappeared from the once verdant plains. Today, otters use these barren streams only as travel corridors in their search for better hunting grounds or unclaimed territories. One finds a random track in the river mud, a single scat atop a sage-covered riverbank, but no evidence of permanent occupation.

Only from the air could I appreciate the full extent of the damage to these riparian systems. Meandering channels that once watered the land are now choked with six-foot-high sagebrush thriving in the rich river silt. By last count, the Humboldt River system had recently lost thirty-seven miles of stream channel, primarily as a result of human activity that caused the rivers to abandon their meanders and cut more direct routes across the terrain.

Atop one of these abandoned meanders on the North Fork of the Humboldt River was where I found the forked trunk of an old coyote willow still firmly rooted in the dry desert like the last free-standing, slightly tilted tombstone in a forgotten cemetery—the only reminder of a once thriving wetland-riparian corridor. The seed that produced this forgotten tree had once germinated beside a healthy beaver dam. Strangely, a snowy egret rose from the cavernous stream course a hundred

An otter pursues a fish across the ice. Along rivers, such large meals, combined with an abundance of crayfish and other small prey, make up the animal's diet.
Daniel J. Cox; Allstock

yards away where it had been dining on three-inch-long, red-sided shiners and speckled dace—the only fish that can survive the tepid, oxygen-poor waters of the lower North Fork today. After nearly being hunted to extinction for its elegant white plumage in the early part of this century, this fish-eating bird seemed to be benefiting from the destruction of a river ecosystem. The snowy egret may have had trouble handling the six-pound Lahontan cutthroat trout and the deep, narrow, willow-lined channels that were once part of the North Fork Humboldt River ecosystem.

Almost like going back in time now, I'm once again standing at the river's edge in an old whiplash willow forest not a quarter mile from the abandoned haystack on the Wright ranch. It's subzero, bone-chilling cold, and my snowshoes squeak as my weight shifts in the two feet of fresh powder. Perfect stillness slowly replaces my labored breathing as I stand motionless beside a steaming pile of river otter excrement. It slowly melts a depression in the river ice as I ponder the cost–benefit ratio of taking my mittens off and bare-handing the mixture into a sandwich bag for future food habits studies. I decline for awhile and listen to the stillness.

The first time the sound came I barely acknowledged it. To my right, a very faint tinkle sounded, like that of a very small icicle falling through the willow canopy. Two minutes later it happened again, and I realized it was far too cold for icicles to be falling. I slowly turned my head, and there he was—a large male otter—only his head and neck protruding from the small hole in the river ice. A piece of the paper-thin ice that had formed over the hole since his last visit was lodged between his rounded brown ears. Our muzzles began to form icicles as we stared at each other, belching hot steam into the January morning air. I wondered if he knew he was living on one of the last great reaches of the 600-mile-long Humboldt River system, a section that had not yet been grazed, channelized, or deforested into oblivion. Looking into his eyes, I felt he knew. □

"I could really use a vacation tha

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The Soil's Breath

As some scientists probe the skies and oceans for answers to questions about climate change, others are digging deeper into the mysteries of life below the surface

by Tyler Volk

Soil seems like passive stuff when I ramble over it during woodland searches for birds. But when I sit at my computer, assembling data at the planetary scale, the soil reveals itself as one of the most active organs in the earth's "body."

Organisms living on and within the soil—beetles, worms, and other invertebrate creatures, along with fungi, roots, bacteria and other microbes—produce a ceaseless flow of carbon dioxide as they respire. This flood of colorless and odorless gas, the soil's breath, enters the atmosphere and annually exceeds, by more than ten times, the amount of carbon dioxide emitted by all human activities, including the burning of fossil fuels.

For thousands of years, before there were factories, before vast tracts of forest were cleared or burned to grow crops and graze herds of cattle, the various flows of the global carbon cycle were closely balanced. The amount of carbon dioxide that passed from ocean to atmosphere matched that from atmosphere to ocean; the carbon from atmospheric carbon dioxide incorporated into plant tissue during photosynthesis was matched by a return flow during respiration by bacteria, animals, and fungi.

But now—thanks to the industries, homes, and cars that spew out carbon dioxide as a combustion byproduct of their appetites for fossil fuels—the scales have been tipped, and the atmosphere's store of this potent greenhouse gas has been growing. Some (but, crucially, not all) of this new carbon dioxide then continues its journey, spreading through the byways of the global carbon cycle, the constant circulation of the carbon atoms that are essential to life on earth. No one knows for certain just how much new carbon the cycle can absorb without being thrown out of whack or just where the new carbon will wind up.

The great exhalation from earth to air is key to comprehending the role of soil in the global cycle of carbon. Unlike the simple forms of carbon in the atmosphere (the three-atom carbon dioxide, for instance) and in the ocean (primarily the five-atom

Trees take the carbon dioxide they need for photosynthesis from the air around them. Respiring leaves return some of the gas to the atmosphere, while still more passes into the soil as roots respire.
Michael Busselle; Tony Stone Worldwide

Jim Brandenburg; Minden Pictures

Fungi decompose leaves, below, and other plant debris on the soil's surface, while untold numbers of tiny organisms, including more fungi, bottom, feed on underground stores of organic carbon. When these microorganisms respire, they release carbon dioxide. Right: As tilled fields lie exposed to the sun's warming rays, microbes in the soil go into high gear. A result of the increased microbial respiration is the especially large amounts of CO_2 these fields exhale.

Gregory G. Dimijian; Photo Researchers

David Scharf; Peter Arnold, Inc.

(False-color image; x 4,800)

bicarbonate ion), most carbon in the soil, derived from living matter, is complex, bound into large molecules (long chains of cellulose, massive blobs of protein). Taken together, these partly decomposed, jettisoned tissues of life, called humus, are interwoven into the variegated quilt of soil, along with bits of minerals, tiny organisms, gases, and water. The carbon in humus is what makes soil dark, crumbly, and spongy. Humus, too, gives soil its luscious "earth" aroma.

Soil has so far largely resisted scientific efforts to decipher much of its inner dynamics, but we do know that almost all the earth's store of soil carbon is found within the top three feet (exceptions are the deep carbon stores of tundra and peat bogs). Furthermore, about a third of the gaseous carbon emitted from soil comes from its uppermost layer of decomposing litter. This litter—fallen leaves and twigs, older, overgrown stems of moss, and rotting seed casings—is mined by fungi, worms, bacteria, and other denizens of the surface soil. These organisms and their predators metabolically burn the carbon in the high-energy molecules of litter and release it, linked with oxygen, as carbon dioxide.

The remaining two-thirds of the soil's flux of gaseous carbon is exhaled at deeper levels and must make its way up through the tiny spaces between mineral grains and humus particles. About half comes from the respiration of roots (and from mycorrhizae, the ubiquitous, minuscule fungi intimately associated with roots). Unlike cells in leaves, root cells do not use up carbon dioxide in photosynthesis; instead, like breathing animals, they are overall emitters of the gas. This root respiration is one reason that gases within the soil of a midwestern wheat field in summer contain a concentration of carbon dioxide more than a hundred times that of the atmosphere.

Respiration by soil microbes generates the other major portion of the soil's "deep" breath. These tiny organisms feed on the carbon in organic matter, some of which reaches them when decaying surface litter is worked downward by worms, beetles, and other soil dwellers. But the largest source of this high-energy organic carbon is already deep within the soil in the form of roots and their associated fungi. Small

roots and fine root hairs in particular are continually withering away as local pockets of soil become depleted of moisture or nutrients. As roots decompose, carbon directly enters into the soil at many depths. We expect to find deep roots in forests, but even grasslands support a pool of soil carbon that may exceed in depth the upward reach of the stems and seed heads.

Whatever the source of the soil carbon, microbes spend their short lifetimes transforming it into carbon dioxide. Most of these humus-digesting microbes have not been named or, indeed, even isolated by scientists because they cannot be kept alive outside the complex matrix of associations in their soil habitats.

Taken together, the exhalations of microbes, roots, fungi, earthworms, and other organisms generate one side of the "budget" for the soil's carbon pool. What about the other side? In general, for a pool to maintain itself, outbound flows must be balanced by those inbound. Root respiration, for example, depends upon the products of photosynthesis sent downward through stems and trunks. Similarly, the microbes and other organisms at the surface and deeper in the soil are supplied by photosynthesis with the litter that falls and the roots that die. Altogether, the 60 billion tons of carbon in the carbon dioxide vented from the soil each year are nearly equal to the annual amount of carbon bound into the tissues of land plants globally. (Estimates place the products of photosynthesis consumed by aboveground herbivores at less than 10 percent of the total.)

How do the incoming flux from photosynthesis and the outgoing soil's breath affect the amount of carbon stored in the soil? Earthwide, the amount of carbon in humus is two to three times the amount of carbon in atmospheric carbon dioxide. However, the pool's mass varies from place to place by more than tenfold. Why?

Generally, the more you eat, the wider your girth. And all else being equal, a soil fed more organic matter by its plants will contain more soil carbon. But all else is rarely equal. Some people remain rails no matter how many milk shakes they slurp, while others remain obese even on highly reduced diets. The difference is in the rate of metabolism, a difference that can determine the bulk of carbon in soils, too.

The rate at which soils consume the carbon received from plant tissue is linked to environmental conditions, such as temper-

For all their lush vegetation, tropical rain forests store little carbon in the soil. Warm temperatures and abundant moisture mean that organisms in the surface litter and in the soil remain active year-round, providing few opportunities for carbon to build up.
Will and Deni McIntyre; Photo Researchers, Inc.

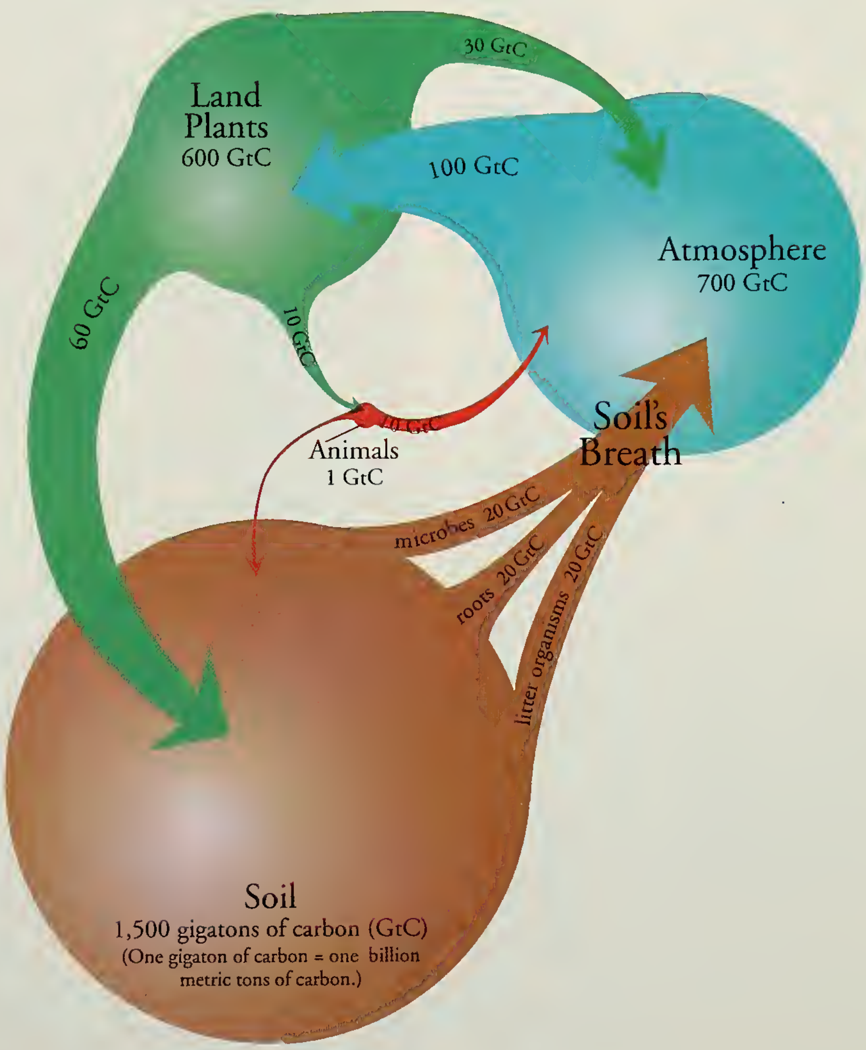
ature, rainfall, and soil structure, that influence the activity of the soil microbes, the organisms that contribute most to the soil's breath. Chief among these conditions is temperature. When warm, the microbes become even more active and frenetically transform soil carbon into carbon dioxide, which then flushes into the air.

A vivid example of the effect of temperature on this flushing is the difference in the soil carbon of tropical grasslands, or savannas, and that of temperate grasslands. On average, helped by a more intense sun, the savannas grow about 50 percent more material than do grasslands in the higher latitudes (45 grams of carbon per square foot per year compared with 30 grams). But savannas have roughly only a fifth the soil carbon of temperate grasslands (400 grams per square foot versus 2,000 grams). The reason for this striking difference is that at high latitudes, microbial activity slows to a near standstill during the cold winter, reducing the exhalation of soil carbon. The resultant bigger pool of carbon remaining in the ground contributes to the richness and fertility we admire in prairie soils.

Human activities, especially since the invention of the plow, also affect the balance between the inflow of fresh organic materials to the soil and the outflow of carbon dioxide, and thus the mass of organic soil matter. As a farmer tills the fields, the soil tends to become warmer and more aerated, which increases the rate of decomposition. On average, soils brought under cultivation lose about a fourth of their carbon pool before settling into a new steady state. Careful management, on the other hand, can increase carbon retention. Gardeners, for instance, often more than compensate for tilling by adding compost and manure.

Large-scale shifts in the soil's breath are under scrutiny as indicators—and perhaps amplifiers—of global change. The anticipated trend of rising temperatures as a result of the increasing carbon dioxide will certainly invigorate the exhalation from earth to air. Already we have indications of a dramatic change in the tundra soil of

Carbon Flux and the Soil



About 60 billion metric tons of carbon enter the soil every year, mostly in the form of fallen plant matter and photosynthesized "food" sent from the leaves of plants down into the roots. (The relatively small flux of carbon from animals to the soil is not quantified in the diagram.) An approximately equal amount exits annually in the form of carbon dioxide as soil organisms respire. However, human activities, such as the burning of fossil fuels, are adding dramatically to the amount of CO_2 in the atmosphere. How soil and other components of the carbon cycle will be affected by the increase is still unknown.
Source: Tyler Volk. Estimates represent an idealized, balanced condition. Diagram excludes oceans.

Leaves cover the ground in a French forest. Rising levels of atmospheric CO_2 may affect how long the carbon in this decaying foliage will be stored in the soil.
Michael Busselle; Tony Stone Worldwide

Alaska. Based on corings and gas measurements, this polar soil, which had been storing carbon since the glaciers melted ten thousand years ago, has switched to being a net source to the atmosphere. Based on knowledge of microbial activity as a function of temperature, some researchers estimate that the observed warming of about one degree Fahrenheit during the twentieth century could already have increased the amount of carbon dioxide coming from the soil by about a billion tons per year, or about a sixth of our own production of the gas from fossil fuels.

In addition to changes in the outgoing flux from the soil's carbon pool, might there be changes in the incoming flux—for example, from the direct effect of carbon dioxide on photosynthesis? For most plants, more carbon dioxide in the air stimulates photosynthesis by boosting the pressure that drives the gas into the leaves, where it is used to produce organic matter such as starch, cellulose, and protein. Every species will respond differently, some adjusting better than others to changing circumstances. Depending on their responses to increased CO_2, some species may drop out completely and others may expand their range to become new members of plant communities.

Scientists studying the carbon cycle have been calculating just how much carbon to subtract from their budget sheets for the atmosphere, specifically from the carbon dioxide fertilization. The best estimates thus far tally about one billion tons of additional carbon entering storage in such forms as tree trunks, ground litter, and soil humus. Thus, as a bottom line, the increased soil's breath attributable today to rising global temperatures might just be balanced by an increased flux to storage—if we are lucky. Of course, for a complete prediction of atmospheric carbon dioxide, we still have to examine deforestation, reforestation, entry and exit zones of carbon dioxide to and from the ocean, the dissolution of minerals, energy technologies, and the politics of international responsibility. But these are still other stories in the ongoing saga of the carbon cycle. □

A male superb fairy-wren in full breeding plumage perches atop hydrangea blooms in Queensland, Australia.
Roger Brown; Oxford Scientific Films

Faithful Philanderers

Superb fairy-wrens pair for life but play a mating game in which infidelity is the rule, rather than the exception

by Raoul A. Mulder

Masses of bright yellow acacia blossoms—the heralds of spring in southeastern Australia—provide a backdrop for a male superb fairy-wren perched among them. He is basking in a small patch of sunlight, his iridescent blue cap and ear tufts glitter against the velvet blue of his throat and back. As I watch, the bird reaches out to pluck one of the flowers and flies with it to a nearby bush. I can only dimly make out his silhouette as he skulks in the dense vegetation, but he appears to be watching a female fairy-wren foraging nearby. The gray brown female hops on the ground and pounces on insects with brisk efficiency. Suddenly, the male appears beside her and starts to perform a curious display, holding the yellow flower in his outstretched beak.

The transformation in his appearance is remarkable. Normally a plump little bird with a long, jauntily carried, upright tail, he now creeps along the ground with his body held at an angle and twists from side to side, tail drooping and cheek feathers splayed out. Intent on her foraging, the female glances only occasionally in the direction of the posturing male. When a second male enters the scene, the first breaks off his performance as abruptly as it began. Pursued by the new male, the petal bearer departs, but with a curious undulating flight in which he holds his body almost vertically, his tail pointed downward and his blue and black feathers displayed to maximum effect.

In my notebook, I jot down the details of this now-familiar sequence of events. This is one of many hundreds of displays I have observed since 1987, when I started my investigation of the mating system of superb fairy-wrens, but each is as absorbing as the first. The displaying male is a bird from my study population known as BRY, an acronym derived from the small blue, red, and yellow rings I have placed on his legs to allow me to distinguish him from the many other males at the site. The rings betray BRY as an intruder into a territory neighboring his own, chased out by the resident male. My notes list this as his fifth visit to the territory this season, and

Jen and Des Bartlett; Bruce Coleman, Inc.

A female attends her low, dome-shaped nest, below. Constructed of dry grasses and lined with parrot feathers, the nest will house a clutch of three to four eggs. Left: A female emits a distress call, a typical reaction when harassment by displaying males becomes intense.

Graeme Chapman

they show that at various times he has briefly abandoned his own mate to visit, and to attempt to seduce, every one of the four females that live in territories around his own. In the course of my study, I have learned that, far from being unusual or aberrant behavior, these displays play a key role in the bizarre mating system of this species.

Fairy-wrens are small songbirds belonging to the genus *Malurus*, distributed throughout Australia and Papua New Guinea. The brilliant breeding plumage of the males has earned many of the thirteen species in the genus effusive common names, such as the "superb," the "splendid," and the "lovely" fairy-wren. Anyone observing a male superb fairy-wren for the first time during winter might be puzzled by these superlatives. This is because the colorful feathers are shed after each breeding season, and males molt into a plain gray winter, or eclipse, plumage in which they closely resemble females. Males spend variable lengths of time in this plumage; some retain it for as long as eight months, whereas others molt back into nuptial plumage after only a few weeks. A very small fraction of birds skip the eclipse phase altogether in some years, molting directly from one set of blue feathers to another.

Anecdotal reports of petal carrying are scattered through the ornithological literature for almost every fairy-wren species that has been observed in any detail. The color of the flower most commonly carried varies from species to species, but either augments or starkly contrasts with the males' plumage. For example, red-backed wrens of northern Australia carry red berries, and the turquoise-plumaged splendid fairy-wrens of western Australia bear purple flower petals, but bright yellow is the color of choice in the superb fairy-wren.

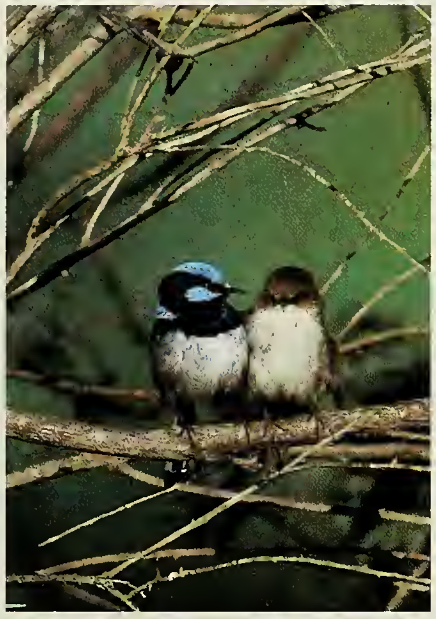
My study site is a botanical garden on the slopes of Black Mountain, in Canberra. These gardens provide fairy-wrens with ideal habitat: a mixture of dense undergrowth and open tracts set in eucalyptus woodland. Although the climate is seasonal in this part of their southeastern Australian range, superb fairy-wrens do not migrate and maintain the same territories year-round. They also maintain the same social mates, usually until one member of the pair dies. Roughly forty territories cover the study site, with each family of fairy-wrens defending its patch against its many neighbors.

Fairy-wrens are highly social birds known for their cooperative behavior. Depending on breeding success in previous seasons, the permanent occupants of a territory may range from just a pair to a family group with as many as three "helper" sons. Whereas in most bird species the young leave home before they reach adulthood, superb fairy-wren sons often remain on the territory of their parents for several years before dispersing, even though their sisters are forced to leave before the year is out. Shortages of females and vacant territories provide an incentive for sons to stay at home rather than strike out on their own. In exchange for being allowed to stay, these young males assist with the care of newly hatched siblings. They help to feed them, and they protect them during their vulnerable first few weeks of life by acting as sentries to warn of approaching predators. In case of danger near the nest, the birds adopt a curious distraction behavior that has been dubbed the "rodent run." They scurry along the ground in a weaving trail with their tails touching the ground and their wings fluffed up, looking much like mice.

Like many other perching birds in the Southern Hemisphere, superb fairy-wrens have a long breeding season that extends for six months or more through the austral spring and summer (September of one calendar year to March of the next). The female builds the nest without any assistance from her mate. It is a dome-shaped structure made from dry grasses, usually concealed in dense vegetation and lined with a soft bed of parrot feathers (crimson rosellas are common around Canberra). The clutch of three or four eggs, which the female alone incubates, will hatch after about two weeks. Barring mishaps, the young will fledge another two weeks later. Within days, the female will be hard at work building another nest, entrusting the care of the fledglings to her mate and the helpers. Frequently, however, the nest is detected by a predator—between 40 and

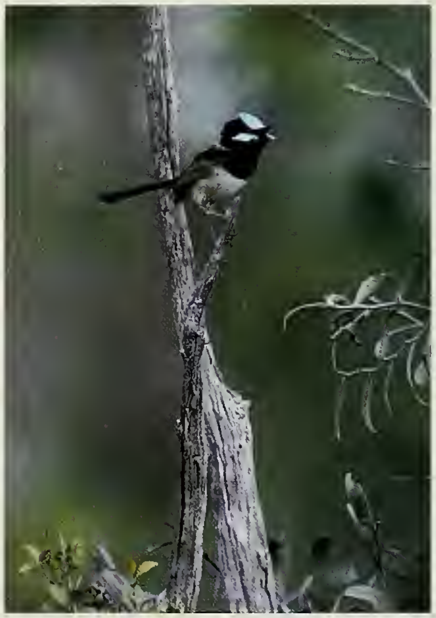
Superb fairy-wrens share a preening session. Only members of the same social group (mated pairs or a female and one of her nest helpers) indulge in this behavior.

C. Allan Morgan



Brilliant cheek feathers still splayed out, a male concludes a display. Males roam into neighboring territories and adopt such flamboyant poses to attract females.

Graeme Chapman



Graeme Chapman

60 percent of all nests are preyed upon before the young can fledge. Some females will build up to seven nests and lay more than twenty eggs without fledging any young. The list of probable nest predators includes rats, feral cats, foxes, and snakes, but the worst predator appears to be another bird, the pied currawong. Regurgitated pellets found underneath currawong nests contained fairy-wren leg rings, evidence that currawongs feed their chicks fairy-wren nestlings.

While females are building nests, their mates are typically engaged in an intensive campaign of visits to females in neighboring territories. Displays with petals are reserved for such excursions, and flowers are rarely, if ever, offered to their own mates during normal pair courtship, which is brief and basic. However, the petal is not an indispensable ingredient for display; males often perform their routine as enthusiastically without one.

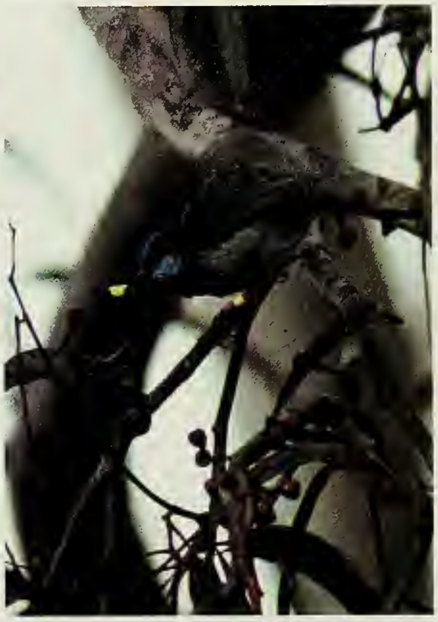
Only males that have attained their blue nuptial plumage perform displays, which they begin just as soon as their molt permits. They "make the rounds," using the same petal while visiting several territories in succession, and they appear to be finely attuned to the reproductive condition of females. During the female's fertile period—usually the week before she lays her clutch—she is subjected to a constant stream of visits. During one twenty-minute observation of a female, I counted seven intruders. As her mate attempted to drive out one male, another would come courting. If the interloper succeeds in copulating with a fertile female, he may produce young at no expense to himself. The enormous burden of feeding and the risks of protecting the young wren he has fathered are borne by the female's mate. Such deception is difficult or impossible for the cuckolded male to detect.

Females, however, are selective about the males they mate with, and copulation, as in many bird species, is very much under the control of the female. Without her cooperation, any attempt to inseminate is likely to prove futile. Female superb fairy-wrens are easily able to avoid intruding males, and copulations occur only when a female solicits them. For this reason, males probably pay their frequent visits to females merely to advertise themselves as candidates for "extra-pair copulation." I suspect that after evaluating numerous suitors, females make furtive excursions to copulate with the male or males of their choice.

This idea is difficult to verify, since human observers rarely witness copulations—even those between paired males and females—in any species of fairy-wren. But an examination of male reproductive anatomy reveals that they have large reserves of sperm. At the start of each breeding season, all males, including helpers, develop a swelling around the base of their cloaca, known as the cloacal protuberance. This protuberance results from a seasonal 300- to 400-fold increase in the size of the internal testes, making these sex organs almost twice as large as those of other birds with a similar body mass of one-third of an ounce. Males of other species of birds with large reproductive organs are known to mate very frequently, and it is likely that the exaggerated size of these structures in fairy-wrens is an adaptation permitting frequent, if secretive, copulation, or the transfer of large volumes of sperm.

To obtain evidence of just how often extra-pair copulations were taking place, I

Intent on catching a neighboring female's attention, a male brandishes a yellow flower petal as an element of his display, below. After the feverish activity of the breeding season, males molt into subdued winter plumage, left.
Raoul Mulder



turned to DNA fingerprinting, a laboratory technique that allows a bird's parentage to be determined through genetic patterns. I found that an extraordinary 95 percent of broods in my study population contained at least one nestling that was not the offspring of the resident male. In total, 76 percent of almost two hundred nestlings tested were fathered by an outsider.

While superb fairy-wrens may be an extreme example of infidelity, evidence exists that such "adulterous" avian behavior, although on a more modest scale, is commonplace among species previously thought to be monogamous. For example, in North American red-winged blackbirds, about 25 percent of nestlings are the result of extra-pair fertilization, and in tree swallows, more than 50 percent.

Why should so many females consort with males other than their mates? One hypothesis holds that a female gains "good genes" for her offspring by mating with intruder males of high quality—that is, males that are long-lived, healthy, or that otherwise have a competitive edge. Since the number of high-quality males is limited, few females will be able to pair with the most desirable male. Mating with outsiders may then provide a female with an avenue by which to improve her offspring's quality—their ultimate success at reproducing and surviving. She does this by acquiring the sperm of a neighboring male that may be superior to her mate. DNA fingerprinting data lend support to this idea. First, they show that in the arena of opportunistic fatherhood, there are only a few winners and many losers. Of sixty-eight adult males living in and around a core set of territories in which all the fathers could be identified, only a handful—nine—fathered all of the extra-pair young. Females apparently have some way of discriminating among males and are in remarkable agreement when deciding with which to mate.

The DNA fingerprinting results also showed that a remarkable number of the most successful males were closely related. Male BRY, two of his sons (one with his mate and one extra-pair) and an extra-pair grandson were responsible for almost half of all the extra-pair fertilizations. The success of this single patriline provides evidence for the good genes hypothesis; it suggests that the extra-pair sons of successful philanderers themselves grow up to be successful philanderers—in other words, sons may inherit their father's genes for features that females perceive as indications of high quality. Some of these successful males were helpers in their own groups, providing further evidence that success has more to do with a male's genes than with his social status.

One way in which a female might evaluate the quality of a male is in the timing of his molt. Older males and those that are in better body condition molt early and thus have a head start in clocking up visits to females. By choosing an early molter, females can be confident that they are choosing one of a select number of males that are in superior condition and have proved their ability to survive. Because superb fairy-wrens are nonmigratory and stay in the same territory throughout the year, displays can start several months be-

Graeme Chapman

Nestlings about seven days old await an insect meal, below. Given the rampant infidelity among superb fairy-wrens, chances are that at least one of the young is probably not the offspring of the resident male. Opposite page: A male pauses to scan for predators before transporting an insect to the concealed nest.

NHPA; A.N.T.

fore the breeding season. Females therefore have ample time to learn to recognize their neighbors, and through the timing and frequency of their visits have a basis for comparing them with other males and their social mate.

Why do males contribute to the feeding of young that they have almost certainly not fathered? In pairs, males generally gain some paternity (fathering on average one of the three nestlings in a typical brood). In such cases, the female is dependent on the contributions of the sole mate. In an artful manipulation, she mates predominantly with an extra-pair male of her choice, but also allows her mate limited copulation access, placing him in a bind. His dilemma is that he has no way of telling which of the nestlings is his own. To abandon feeding them is to put at risk the survival of his own, hard-won genetic progeny; but by provisioning, he provides a free lunch for the young resulting from his mate's adulterous encounters.

In families with helpers, the female is assured of the contributions of the helper sons and is no longer solely dependent on the aid of her mate. She need make few copulatory concessions to him, and his paternity then dwindles to one nestling in every ten. Not surprisingly, in these cases the male barely visits the nest, but the helpers compensate for the reduction in his efforts. Their contribution appears to be a form of rent paying that allows them continued residence in the group. If they do not contribute, they may be expelled from the group by the paired male and lose the many benefits of continued home residence—including the opportunity to eventually gain paternity in another group. When helpers leave the group for even a short while during the breeding season, neglecting their responsibilities, they are punished severely by the paired male, through attacks and long chases that may last for up to a day. By manipulating helpers in this way, the paired males may be able to insure themselves to some degree against the costs of wasted effort in feeding young that might not be their own and simultaneously gain more free time to seek their own extra-pair copulations.

As I follow BRY on his way back to his own territory, he drops the bright yellow petal. Moments later, I notice he has substituted a dragonfly, which he carries to a small prickly shrub in the heart of his territory. After several quick scans of his surroundings, he moves into the bush; I hear nestlings begging. Within the space of a few minutes he has changed from philanderer to model parent. □

Last of the Caribbean Whalemen

In the Windward Islands, a few fishing crews still survive by pursuing the leviathan

by John E. Adams

To most people, whaling calls to mind large, steel-hulled vessels that cruise the deep seas for months at a time in search of sperm whales, humpbacks, and other giant cetaceans. Less well known are shore-based whaling operations, involving boats that are launched from beaches and crews that chase their quarry within sight of land. These shore fisheries account for only a minuscule catch, but for a small number of coastal communities scattered throughout the world, they provide an important source of income and food.

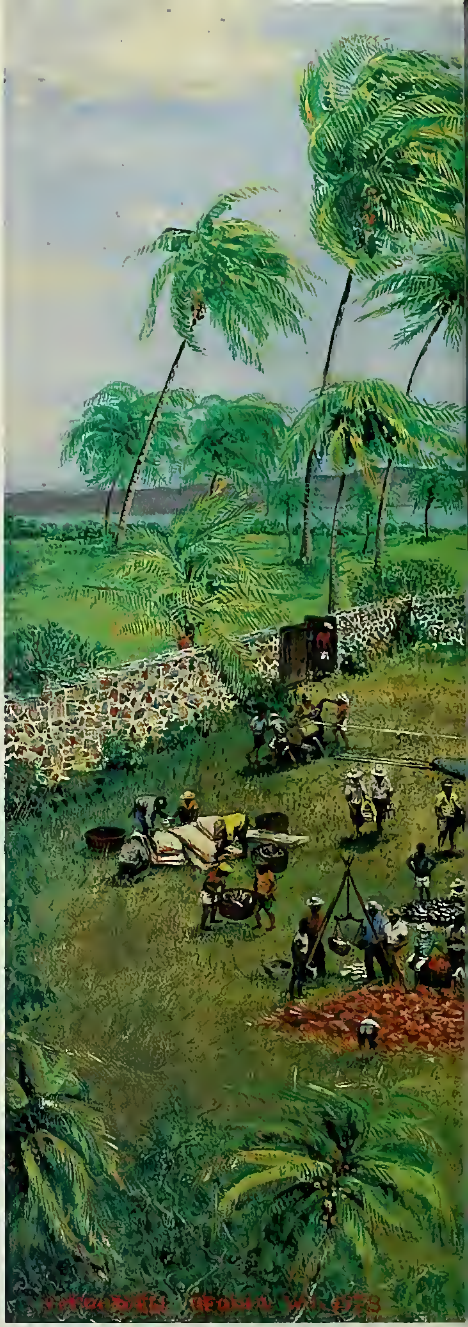
Four such whaling operations still exist in the Windward Islands, the southern group of the Lesser Antilles. The few remaining crews—mainly elderly men—operate out of Barrouallie in Saint Vincent, Friendship Bay in Bequia, and Castries and Vieux Fort in Saint Lucia.

Although International Whaling Commission (IWC) bans have sought to put an end to whaling, the commission's rules do not as yet protect small cetaceans, such as the porpoises, dolphins, and pilot whales still hunted in the Windwards. In addition, Bequia's operation is authorized as an aboriginal fishery by the IWC and therefore allowed the take of two humpback whales each year for subsistence (*see* "A Blessing to the Island" page 72).

But how did whaling get to the Caribbean in the first place? Colonial trade reports and logbooks from New England whaling ships reveal that throughout the nineteenth and early twentieth centuries, Yankee whalers made regular cruises to the warm waters of the southern Caribbean Sea in search of sperm, humpback, and pilot whales. New England whalers left Provincetown and New Bedford about the middle or end of January and sailed directly to the Windward Islands, where they hunted cetaceans from Martinique to Trinidad until late April or May, when the larger, migratory whales such as humpbacks had calved and moved northward with their young to colder Atlantic waters.

Toward the end of the nineteenth century, the main interest of the fleet was

After a day's labor, whalemen head home across the strait between Bequia and Mustique. Migrating humpback whales often pass through this channel in February and March, as they move from the North Atlantic to their Caribbean wintering grounds.
John Olsson



A 1978 painting by Bequian artist Sam McDowell shows a large humpback being butchered for food at the whaling station at Petit Nevis, off the coast of Bequia. Harpooner Athneal Ollivierre is pictured at the head of the whale.
Sam McDowell

melon oil (extracted from the foreheads of pilot whales), a product not only shipped to New England but also bartered for provisions in Dominica and the other Windward Islands. In the process, scores of men from the southeastern Caribbean were recruited by the Yankee vessels for six-month voyages to the lower New England ports. It was through these contacts that several West Indians learned whaling and boat building. Many returned to their home islands to start fisheries of their own.

The earliest of these shore-based whaling operations was established in Bequia about 1875, by William T. Wallace, a former estate owner. Fashioned after New England technology, it served as a model for the development of nearly a score of other whaling concerns in the southern Windwards. Large whales were spotted from hilltops and given chase in small, open boats that were beached at protected coves on the coasts of islands. After each capture, the whale's carcass was towed to a trying-out works where its blubber was stripped and rendered into oil, and the meat salted and dried for local consumption. While New Englanders sought whales for their oil, West Indians valued the meat more highly.

At its peak (1880–1920), whaling in the southeastern Caribbean supported upward of twenty whaling establishments; each usually consisted of a minimum of two open sailing boats with six-man crews, and crude, onshore processing facilities to render oil from the blubber. The Grenadines—an archipelago of small, rugged islands lying between Saint Vincent and Grenada—boasted six fisheries: two in Bequia, two in Canouan, one on Union Island, and one on Isle Caille, near Carriacou. The fisheries had a combined fleet of nearly thirty boats and employed two hundred people, not counting the vendors who marketed whale products throughout the islands.

I first learned of the existence of Caribbean whaling in 1964, when, as a graduate student in geography, I was making a general study of the maritime industry in the Grenadines. I wanted to study the local whaling industry, not as a marine biologist but as a way to experience and better understand a life different from my own. My tools were the time-honored ones of geographers in the field: notebook, camera, and map. My methods were to observe, question, and, I hoped, to participate in whaling activities.

When I embarked on my project in Saint Vincent the next year, it was still a British colony inhabited by nearly 80,000 English-speaking subjects. (Saint Vincent achieved independence in 1979 and is now a self-governing nation of about 115,000 citizens, with administrative jurisdiction over several of the Grenadines, including Bequia, Union Island, and Canouan.) Then, as now, the majority of the island's inhabitants were of unmixed African ancestry. Among the island's minorities were people of mixed African and white parentage, East Indians, and whites.

Like most other islands in the West Indies, Saint Vincent based its economy on agriculture, producing bananas and other tropical crops for export and food crops for local consumption. Great numbers of people worked as manual laborers on private or government-managed estates and on their own small plots of land.

The more accessible Caribbean islands had already been developed by resort interests for the tourist trade, but Saint Vincent and the Grenadines were still off the beaten track and likely to be recommended for the more adventuresome traveler. The sleepy tranquillity of the south Windwards didn't last long, however. By the mid-1960s, they were the scenes of feverish land speculation and building.

Fortunately, I was able to carry out most of my observations before the south Windwards were completely changed by outside influences. I focused my attention on Barrouallie, a small farming and fishing community on Saint Vincent's west coast. At the time, the town's whaling industry consisted of twelve open sailing boats and

their crews, numbering seventy-two men. This figure did not include the boat owners, who normally did not go whaling themselves, but lent their boats and gear to others in exchange for a share of the proceeds from the sale of oil and meat. About a score of women vendors prepared and hawked whale products in the island's markets, mainly in Kingstown, Saint Vincent's capital city.

I sought out the founder and sage of the Barrouallie whaling industry, Griffith Arrindell. By then retired from whaling, he was nonetheless a man of considerable stature in the community. Griffith invited me to stay at his home, a small, two-story dwelling located between the waterfront and the town square.

For several days Griffith and I discussed the Barrouallie fishery: its beginnings, its technology, the social and economic background of its boat owners and crew members, and its markets, problems, and prospects.

Griffith had decided to start a whaling enterprise in the early 1930s. The major impetus for developing the business was the market for melon oil, which was used in the United States to lubricate watches, chronometers, and other fine instruments. It had seemed like a good plan. The coastal waters of Saint Vincent were well stocked with short-finned pilot whales (locally known as blackfish for the jet black skin covering their bodies), the necessary technology was available in Bequia, men were eager to work, and there was a local demand for blackfish meat. Early in 1932, Griffith purchased two boats and whaling gear from the Bequia fishery; he learned the technique of whale hunting from some old-timers at Barrouallie and Saint Lucia who had periodically hunted dolphins.

Griffith recalled striking his first blackfish on May 26, 1932, which, in essence, marked the beginning of the Barrouallie fishery. The most important cetacean hunted by Barrouallians, the short-finned pilot whale measures roughly ten to sixteen feet in length, with large males weighing upward of two tons. A gregarious animal, it travels in groups numbering from a few individuals to more than a hundred. Blackfish are seen and hunted throughout the year, weather permitting, with significantly greater concentrations from February through June.

At the time, sperm whales, locally called sea gaups, were also pursued, but fewer than a half dozen were landed annu-

ally. Unlike blackfish, sperm whales were usually not encountered near the coast. They moved in deeper waters and generally out of range of the whaleboats, which seldom extended their range more than nine or ten miles offshore. Sperm whale oil was used for lighting and cooking, but its flesh was not esteemed. A few killer whales, known as white fish, for their white underbelly, were also taken.

Barrouallians chased the big game first, but when this failed, they hunted various species of dolphins. Owing to the abundance of dolphins and their tendency to swim close to a boat, whale hunters were usually successful in striking them, and many were landed each year and sold in Kingstown for their meat and, in the early years, for their oil.

The Barrouallie enterprise survived the Depression years by blackfishing for the local market, and slowly the fleet expanded. The peak effort spanned three decades, from the mid-1940s to the early 1960s, when the fleet grew from a half dozen boats to nearly twenty. A small amount of melon oil was exported from Barrouallie to a New England firm during this period.

Griffith kept a diary of his blackfish operations from September 1946 through 1951, detailing the day-by-day catches, weather conditions, and problems encountered in the fishery. From October 1 through October 31, 1946, for example, his three boats made the following catch: eight blackfish, five porpoises, nine sharks, and one sperm whale that measured thirty feet in length. A December 5 entry read: "Joy to the boys, all three boats caught one day." But happy notations were rare. The log told more often of heavy winds and rains, squalls, torn sails blown away, harpoons lost, whales lost, and disputes with the crews.

Between 1960 and 1970, the yearly blackfish catch in Barrouallie ranged from about 200 to more than 400, the average being about 250. Daily and weekly landings varied considerably. On May 6, 1966, for example, whalemen made a near record catch of twenty-one blackfish, one boat taking six.

I asked whether I could accompany Griffith on a whaling trip, and he assented. The whaleboat we sailed on, like all of those in Barrouallie, had been purchased from Bequia boat builders, who are highly skilled at their trade. Like the old Nantucket craft used in Bequia, the Barrouallie whaler was (and is) double-ended, earning the local name "two bows." It is, however, wider of beam proportionate to

Joshua Basseches

Left: Bequia whalers prepare to tow in a humpback cow. Killed in the winter of 1986, it was the first such catch for local fishermen in a few years. Below: Women vendors retail dried pilot whale meat in Kingstown, Saint Vincent, 1981. Known locally as island bacon, the product is one of the least expensive flesh foods on the island and in demand among the island's agricultural laborers.

John E. Adams

its length, deeper of hull, and somewhat shorter and heavier than its prototype. It is also equipped with a centerboard that, lowered through a slot in the hull, helps to protect against lateral drift.

The gear included forty fathoms of shooting line, 120 fathoms of heavy manila rope, standing line, four harpoons, three lances, and a box of 12 gauge shotgun shells, from which the pellets had been removed. The shells were fired from the barrel of a modified shotgun mounted on a swivel and carriage seated on the bow deck. Griffith said that the gun harpoon had been introduced from Saint Lucia in 1958, displacing the traditional hand harpoon in striking whales. It hadn't been a very difficult decision to make. The handheld harpoon, made of a soft iron blade and shank attached to a five-foot hardwood shaft, was heavy and couldn't be thrown more than a few yards. The gun-fired harpoon, on the other hand, had a range of about forty yards, with a normal charge consisting of the amount of powder contained in one 12 gauge shell, plus a quarter measure of powder extracted from a second shell.

The bamboo mast was raised, sails set, and we got under way, accompanied by two boats, with four more to follow, bringing our fleet to eight boats, including the whaler that had set out earlier. Our small fleet fanned out in a broad semicircle, sailing northwest, west, and southwest of Barrouallie. Each boat hunted independently and kept at some distance from the others.

The wind velocity dropped and the four crewmen, sitting in staggered positions in front of me, had to resort to rowing, while the mate at the stern directed the boat with a twenty-three-foot-long, oarlike rudder. The captain stood ready behind the bow gun. Eventually the captain climbed the mast to get a better look at a herd moving ahead of us. I heard him say disappointedly: "They's wild fish, no use going for them." The wild fish had been hunted before and were spooked, so they simply kept a safe distance from our boat. No amount of manpower or wind power could catch up with these fast-moving cetaceans. "Tame fish" had not been hunted before, perhaps being newcomers to Saint Vincent, and allowed boats to approach within striking distance.

When the gun-fired harpoon was introduced, whale landings increased significantly, but within a few years, the number of strikes dropped dramatically as the whales, apparently reacting to the danger of being close to the whaleboats, began to keep a safe distance. Now, other innovations were on the way. One boat owner planned to replace the heavy manila rope with lighter nylon line in hopes of increasing the range of his harpoon seven or more yards for a maximum range of about sixty to seventy yards. More dramatic and costly plans were being made to install inboard and outboard engines to "run down the fish" for an easy strike.

The captain decided to return to shore, but on our way to Barrouallie, we struck a porpoise, a member of a large herd that was being pursued by a dozen killer whales. At 3:00 P.M. we reached our destination. Bilge rock was emptied on the beach, gear stored away, and the porpoise

Nathalie Ward

A bottlenose dolphin, right, lies on the beach after being taken by the Barrouallie fishery. Local whalers rarely hunted dolphins until the last two decades. But as the pilot whale stock was depleted and the islands' human population soared, these small cetaceans—scorned by the upper classes as a food source—became an important part of the local diet. Below: Villagers butcher a humpback whale on Petit Nevis.

Tim Wright

was strung up on a coconut tree to protect it from a pack of emaciated dogs. The next morning, the hundred-pound carcass was delivered to Kingstown, where it was butchered for fresh meat in the primary meat market.

That evening the captain, mate, and I discussed the economic problems in Barrouallie and Saint Vincent. The mate explained that he was "doing blackfishing 'cause there's nothing else to do." He spoke of his frustrations in trying to hunt blackfish and "the little money that the poor whalemen get for the fish." He added that "blackfish is serious business for the men in this place. There's no payday in Barrouallie. We must go make our own keep. That's the way it is for us here." With whaling and two acres of land rented from a nearby estate for provision crops, the mate struggled to support five children and a woman with whom he shared a communal living arrangement.

At that time, the main ambition of Barrouallians was to emigrate to the United States, Canada, or England, but given the numerous restrictions and the expense, emigration was virtually impossible. Many were desperately looking for work in a skilled trade in Kingstown, but job opportunities were very limited. The majority of whalemen were plying their trade as a stopgap measure, while looking for some other form of employment.

A blow to Barrouallie's oil business came with the passage of the U.S. Marine Mammal Protection Act in 1972, prohibiting imports of whale products to the United States. In response to the closure of this vital market, local entrepreneurs made attempts to retail whale oil (both melon and body oil) locally for cooking, lighting, and as a medication to cure respiratory infections. But revenues were disappointing and scarcely covered the cost of boat and gear maintenance.

When I briefly visited the island in 1970 and 1974, I learned that agricultural jobs hadn't kept pace with the rapidly growing population, and an increasing number of men either went to Kingstown looking for work or were turning to the sea for their livelihood, on a part-time or full-time basis. Locally, the major marine industries were trolling for pelagic fish and seine fishing for the fork-tailed jackfish, or bigeye scad, and other schooling species near the shore.

Barrouallie's whaling fleet, however, had been reduced to only two active crews. According to the Barrouallie Fishermen's Cooperative Society, the Barrouallie fishery landed 383 blackfish in

1968. Thereafter, landings plummeted to 117 in 1976 and only 25 in 1979. Whalemen reported sighting far fewer cetaceans than before. Whether this phenomenon was due to the depletion of blackfish on a worldwide basis or to a change in the migratory habits of the cetaceans is unknown. Whatever the cause, the Barrouallie blackfish enterprise virtually collapsed in the 1980s.

In the early 1990s, it persists as a relict industry, with only two boats. Both have 35-horsepower outboard engines, which are less expensive to maintain and operate than the inboard engines that propelled the crafts in the late 1960s and 1970s.

Increasingly, dolphin landings have supported the fishery. This meat, much cheaper than any other source of animal protein on the island, is sold fresh in Kingstown. The oil is marketed primarily in Saint Vincent and Trinidad. The fishermen's cooperative society reported that from January to October 1992, several thousand pounds of porpoise meat were delivered to Kingstown. An undetermined amount of blackfish flesh, which is relished on that island, was sold locally, along with melon oil. More than 200 gallons of the oil were delivered by inter-island trading schooner to Trinidad.

Whaling still is deeply ingrained in the culture of Vincentians and Bequians. While select crews of skilled whalemen do the hunting, the butchering of whales is a community affair in which adults participate in exchange for several pounds of the highly relished meat. Whaling is also a dramatic testimony to the skills, ingenuity, and courage of men who, facing desperate economic conditions, turned to the sea as a means of supporting themselves and their families. In fact, Bequia's history traces the evolution of a people who made an important social and economic transition, from being landsmen, struggling to making a living in agriculture, to being almost wholly dependent on fishing and the maritime trade. Whaling was a key element in this change. Barrouallie and other seaside communities in the Caribbean have experienced a similar transition. □

A Blessing to the Island

by Nathalie Ward

Whaling is a set of brave-thinking and poor men—it's not an easy life. It's a living. It's food, but it's more. It helps furnish the house. Whaling is the most helpful thing in Bequia—a tradition that come down from generations.

—*Athneal Ollivierre, harpooner, age 73*

Each year, Bequia's hundred-day whaling season is ushered in by the blessing of the whaleboats in late January. The season corresponds with the humpbacks' return from northern seas to the shallow, protected islets and cays of the Grenadines—where the whales loaf, mate, and have their calves from January through May.

The hunt is focused on the seven-mile channel running between Bequia and Mustique. Traditionally, lookouts stationed on hilltops and outlying cays signal the "whalermen" of sightings by "flashing glass" (mirrors) and radio. The crew consists of the harpooner, the boatsteerer, and four ordinary seamen.

Only one whaleboat, *Why Ask*, remains. Modeled after the Yankee "beetle boat," it is a twenty-seven-foot, double-ended wooden craft outfitted with a high-peaked spritsail main and jib and equipped with a centerboard, removable rudder, and 400 pounds of heavy "rockstone," which acts as ballast. Lying on whalebone skids, the whaleboat is launched from the beach at Friendship Bay on Bequia's southeast coast.

The methods and tools of Bequia's whalers are virtually unchanged from those of the original nineteenth-century fisheries. The hand-thrown harpoon, or iron, weighs about twenty-five pounds and can be pitched accurately a distance of only about fifteen feet. Once the iron holds fast and the whale is brought alongside the boat, an eleven-foot lance dispatches the animal by puncturing its heart or lungs. As a last resort, a bomb gun (a forty-pound shoulder gun) equipped with an exploding cartridge is used to secure the whale.

A landed whale on Bequia represents a blessing to islanders. The animal is towed to Petit Nevis, a small cay one-quarter mile offshore, where the carcass is flensed (stripped of blubber) and processed for its meat and oil. The processing facilities include a concrete ramp, a winch with a block and tackle for hauling the carcass and facilitating the butchering; the tryworks, consisting of two large coppers, or cast iron boilers, for rendering blubber to oil; and a palm frond canopy that shelters those who distribute the meat and blubber.

Hundreds of the island's residents gather on Petit Nevis to buy whale meat, which is relished throughout the Grenadines. Humpback "beef" is sold locally and is prepared by women who either corn (salt and dry) it or dove it (cook it with herbs and preserve it in whale oil).

Harpooner Athneal Ollivierre and the whalemen are revered locally. Yet today, few men are interested in "taking it [whaling] on"—as the life style offers little remuneration, and the risk and effort of whaling make it difficult to recruit new members.

But when a whale is spotted and the shouts of "Blows, blows" are relayed onshore, work stops. The schoolchildren are given an extended recess, and hundreds of people gathered along the bay scream instructions and shouts of encouragement to the whalers at sea. Ollivierre says,

If you hear those people ashore, how they going on—singing' and rejoicin' when we catch whale. When I come back to bayside, people coming to lifting me up [out of the boat] and sharing me out. Water come from my eye.

Nathalie Ward is a marine mammal biologist and anthropologist who teaches at the Boston University Marine Program in Woods Hole, Massachusetts. She is also a research associate at the Center for Coastal Studies in Provincetown, Massachusetts.

Blessing the Bequia fleet, 1987
Dana Jinkins

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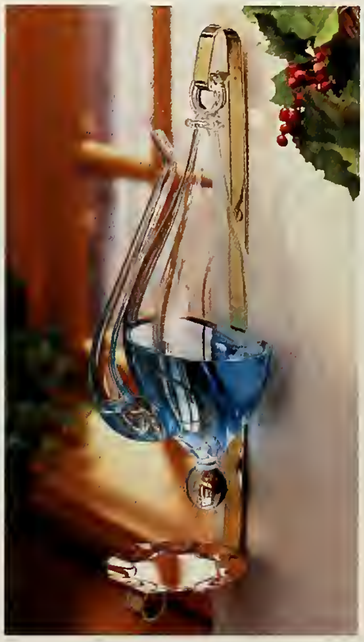

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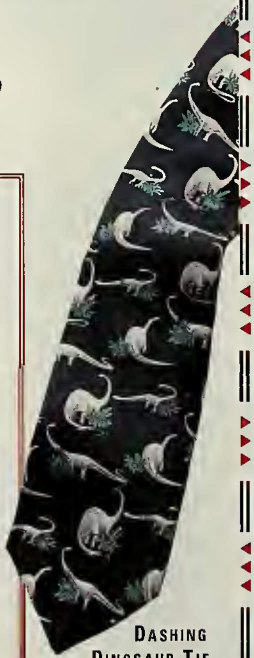

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The Museum's twenty-fourth annual Origami Holiday Tree will be displayed in the Roosevelt Memorial Hall from Tuesday, November 22, to early January. The fifteen-foot tree will be decorated with 1,500 folded-paper animals, including insects and dinosaurs, created by origami enthusiasts from around the world. Silver- and gold-foil paper stars will provide the tree with a glittering garland, and a menagerie of large origami dinosaurs will surround the tree's base. For more information about origami at the Museum, call (212) 769-5635.

AT THE PLANETARIUM

The latest findings from the Hubble Space Telescope will be the subject of a slide-illustrated talk by astrophysicist Robert Brown, of Johns Hopkins University's Space Telescope Science Institute. The lecture, part of the series "Frontiers in Astronomy and Astrophysics," will be given on Tuesday, November 15, at 7:30 P.M. Tickets are $8 ($6 for members).

Planetarium visitors will travel back nearly 2,000 years to explore the skies of the first Christmas, when the Wise Men of the East followed the special star that led them to Bethlehem. The holiday Sky Show, "Star of Christmas," begins Wednesday, November 23, and runs through Sunday, January 1. For prices and show schedules, including the Sky Show "Update: The Universe," call (212) 769-5900.

THE SAMARITANS

A documentary about the customs and ceremonies of the Samaritans, a little-known people who separated from the Jewish mainstream more than 2,500 years ago, and who now live in two small enclaves in Israel and Jordan, will be shown on Thursday, November 17 at 7:00 P.M. in the Main Auditorium. The film's creator, Johanna Spector, will introduce *The Samaritans: People of the Sacred Mountain* and provide background on these people, who once numbered in the hundreds of thousands and lived throughout the Levant. Call (212) 769-5606 for ticket information.

EYES OF THE WORLD

The gemstone alexandrite, a variety of chrysoberyl, was first discovered in the Ural Mountains and named after Czar Alexander II of Russia. Henry F. Kennedy, an American miner in Brazil, traced chrysoberyl to its pegmatite-granite source. He will talk about alexandrite's special features, including its dramatic color change from emerald green in sunlight to ruby red in candlelight. Kennedy will also describe how gem cutters create the cat's-eye effect in precious stones. The slide-illustrated talk will be held on Wednesday, November 9, in the Kaufmann Theater. It will be accompanied by an exhibit of cat's-eye gems, including an alexandrite, an emerald, an aquamarine, a tourmaline, and a ruby. For information, call (212) 769-5606.

FEMALE GENITAL MUTILATION

Each year, 85 to 114 million girls and women are genitally mutilated in circumcision ceremonies. On Wednesday, November 30, at 7:00 P.M. in the Kaufmann Theater, Nahid Toubia, a physician from the Sudan and an associate professor at Columbia University's School of Public Health, will talk about this worldwide, coming-of-age ritual, as well as some of its health complications and psychological effects. For information, call (212) 769-5606.

A HISTORY OF GOSPEL MUSIC: I'VE GOT A FEELIN'

Singer, pianist, composer, and lecturer L. D. Frazier will discuss spirituals, jubilee songs, and gospel music on consecutive Thursdays, November 3 and 10, at 7:00 P.M. in the Kaufmann Theater. His talks will be accompanied by audiotapes of singers such as Clara Ward, Mahalia Jackson, Alex Bradford (known as the Little Richard of Gospel), J. Earle Hines, and J. Robert Bradley. Call (212) 769-5310 for more information.

THEODORE ROOSEVELT IN AFRICA

Upon leaving the presidency in 1909 at the age of fifty, Theodore Roosevelt organized the largest African safari ever mounted. It started at Mombasa, in what is now Kenya, and ended on the Nile in Egypt. On Thursday, November 3, his great-grandson Tweed Roosevelt will talk about the ten-month hunting and collecting expedition. Some of the more than 13,000 specimens collected by President Roosevelt can be seen at the Museum. The slide-illustrated talk will begin at 7:00 P.M. in the Kaufmann Theater, and tickets are $15. For information, call (212) 769-5310.

THE LAST PANDAS

Lu Zhi, a leading authority on panda research in China, will provide first-hand details about fieldwork in the Wolong Forest Preserve of western China, where the last

ISTORY

wild pandas live. Her slide-illustrated talk on conservation efforts to protect the panda will be presented on Saturday, November 12, at 2:00 and 3:30 P.M. in the Kaufmann Theater. Tickets are $7 ($2.50 for children). For more information, call (212) 769-5310.

THE PEOPLE AND CULTURE OF MONGOLIA

Peter M. Foggin, chairman of the geography department at the University of Montreal, will talk about the history and contemporary life of the people in Mongolia, with a special emphasis on the correlation between animal disease and human health. His lecture will take place on Thursday, November 10, at 7:00 P.M. in the Kaufmann Theater. Tickets are $12. Call (212) 769-5310 for more details.

THE EVOLUTION OF THE IMAGINATION

The Touchstone Center, a New York based arts organization that works with children, is sponsoring a series of four Tuesday-evening lectures on the evolution of the imagination and its role in human thought. Speakers will represent such fields as anthropology, archeology, art history, literary criticism, education, and semantics. On November 15, Ian Tattersall, curator and chairman of the Museum's Department of Anthropology, and Alexander Marshack, research fellow at the Peabody Museum of Archeology and Ethnology, will begin the series with a discussion on "The Meaning of Objects." On November 22, Elizabeth Sewell, a poet, and Paul Shepard, Avery Professor of Human Ecology at Pitzer College and the Claremont Graduate School, will talk about "The Origin of Metaphor." On November 29, author Roger Lipsey and Hasel Dean-John, a Seneca storyteller and linguist, will focus on "The Awareness of the Spiritual." On December 6, Touchstone Center's founder and director, Richard Lewis, will conclude the series with "An Evening of Thoughts," and audience members will be invited to participate. The talks begin at 7:00 P.M. in the Kaufmann Theater, and tickets are $35 for the series. Call (212) 769-5310 for information.

These events take place at the American Museum of Natural History, Central Park West at 79th Street in New York City. The Kaufmann Theater is located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

Fort Gadsden Dome, Florida

Robert H. Mohlenbrock

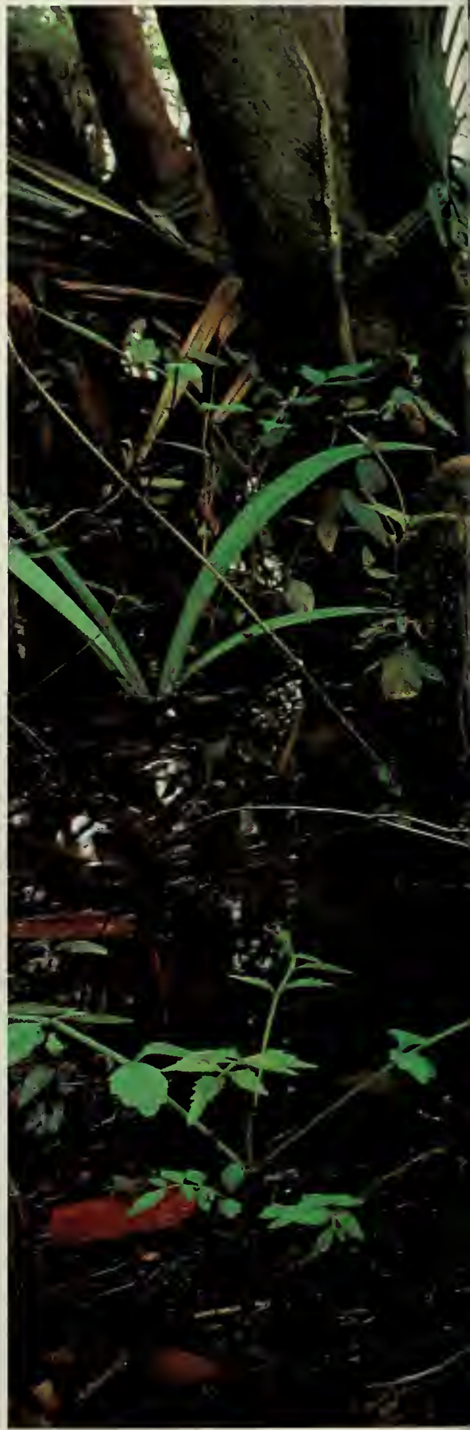
Built by the British to recruit blacks and Indians to fight against the United States in the War of 1812, Fort Gadsden was abandoned after sustaining just one devastating blast. Today a replica of the wooden fort stands at the historic site, which falls within Apalachicola National Forest in Florida's panhandle. The surrounding terrain consists primarily of sandy flatwoods, with stands of sixty-foot-high longleaf pines seeming to stretch endlessly toward the Gulf of Mexico, some twenty miles south. Here and there, however, shallow depressions filled with standing water support shorter, dome-shaped patches of pond cypress trees and other vegetation. This type of wetland, known as a cypress dome, is found only in the Coastal Plain of the southeastern United States. One easily accessible dome is three miles southeast of Fort Gadsden, off Forest Highway 143.

Cypress domes have a rounded profile, with trees rising thirty feet or so at the center, surrounded by lower trees and shrubs at the periphery. Covering a few acres, they arise where the terrain is perhaps five feet lower than the surroundings. Water seeps through the sandy soil from the higher ground but can drain only slowly through the nearly impervious, mucky floor of the dome. As a result, water usually stands in the dome for most or all of the year. At the center of the dome, where the ground is lowest, the water may be three to four feet deep.

Pond cypresses are gray-barked, gnarled trees that often have an irregular, flattened top. Although some botanists consider them the same species as the more common bald cypress, close observation of the two reveals their distinctness. According to Robert K. Godfrey, the authority on the flora of the Florida panhandle, the most obvious difference is in the orientation of the leaves. Most of the pond cypress leaves are twisted so that they stand erect along the upper side of the twigs, creating a featherlike effect. By contrast, the leaves of bald cypress are arranged in a spiral all around the twigs.

In addition, pond cypress leaves are gradually tapered and rigid, while bald cypress leaves are soft and flat and abruptly tapered at the tip. The bark on older pond cypress trees breaks up into vertical, rectangular plates about one inch thick, while the bark of the bald cypress shreds into thin strips. Both kinds of trees produce woody "knees" when subjected to standing water over time, but those of the pond cypress are shorter and nearly columnar, with thick bark over their tips, while those of the bald cypress are longer and more conical, with thin bark at the tip.

The pond cypress trees are what make it easy to spot a dome while traveling through Apalachicola National Forest, but many other plants are adapted to living in and around these habitats. A few other trees that are at home in standing water are red maple, pop ash, and swamp black gum (another controversial species, since a



Pond cypresses, below, grow in a water-filled depression near Fort Gadsden. Opposite page: The flower of a yellow pitcher plant.
Both photographs by Helen Longest-Slaughter; Nature Images

White bachelor's button blooms in the summer at the edge of the cypress dome.
Alfred Scholz

number of botanists do not regard it as distinct from the upland black gum).

The climbing pieris, a woody vine in the heath family, germinates in the mucky soil of some of the domes. The stem grows upward beneath the outer bark of a tree, often a pond cypress; then, two or more feet above the water, it bursts through the bark and arches out, bearing green, leathery leaves. Eventually it produces white, bell-shaped flowers and spherical, dry seed capsules.

Two species of Saint Johnsworts—shrubs with narrow, needlelike leaves and reddish, fibrous bark—are found in cypress domes. Both may grow six feet tall. The clustered Saint Johnswort prefers the shallower water at the periphery of the dome; if the water level fluctuates a lot, the shrub may put out slender, woody prop roots, which provide additional anchorage, from the lower part of its stem. Chapman's Saint Johnswort grows near the center of the dome if the water is deep enough. Its bark consists of soft, spongy cork one to two inches thick, which protects it well from fire.

Myrtle-leaved holly, a shrub with short, narrow, leathery leaves and tiny red berries, may attain the stature of a small tree while growing in the standing water of a cypress dome. Four other shrubs, all with clusters of white flowers, are found at the periphery. These are sweet pepperbush (with leaves that resemble those of an alder), titi, black titi, and storax. Small, shrubby, blue-berried hollies, known as gall berries or ink berries, grow just outside the borders of the dome. Diverse wildflowers and sedges are also distributed throughout the dome, their location dependent on water depth or the degree of saturation of the soil.

Carnivorous plants are often present. The tall, yellow pitcher plant grows in shallow water, while the parrot pitcher plant, whose insect-trapping leaves lie flat on their back, lives in heavily saturated soil along the edge. Commonly growing along with the parrot pitcher plant are two sundews, whose leaves have sticky hairs that glisten in the sunlight and trap tiny insects. One of the sundews has a cluster of leaves, usually red, that consist of an elongated leaf stalk and a small round blade. The other, known locally as sunthreads, has slender, gray, erect leaves up to eight inches long and one-eighth inch wide.

Several kinds of butterworts grow in the saturated soil outside the cypress domes. These insect-trapping plants with solitary flowers have a small cluster of leathery leaves whose edges are rolled upward. Some of the leaf cells secrete an oily substance that apparently gives off a fungus-like odor attractive to gnats. The insects that investigate the smell become mired in the plant's secretion and drown. The leaves then roll further upward and inward to form a shallow cup into which digestive enzymes are secreted. Any object containing nitrogen appears to trigger the leaf to secrete the digestive enzymes. As a result, the butterwort will digest not only gnats but also pieces of leaves and small seeds.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U.S. national forests.

Fort Gadsden Dome
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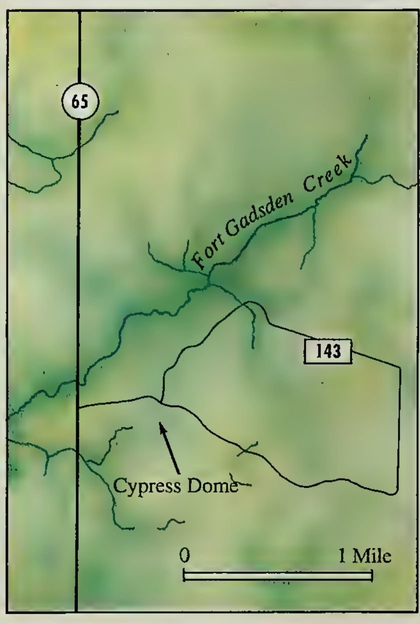

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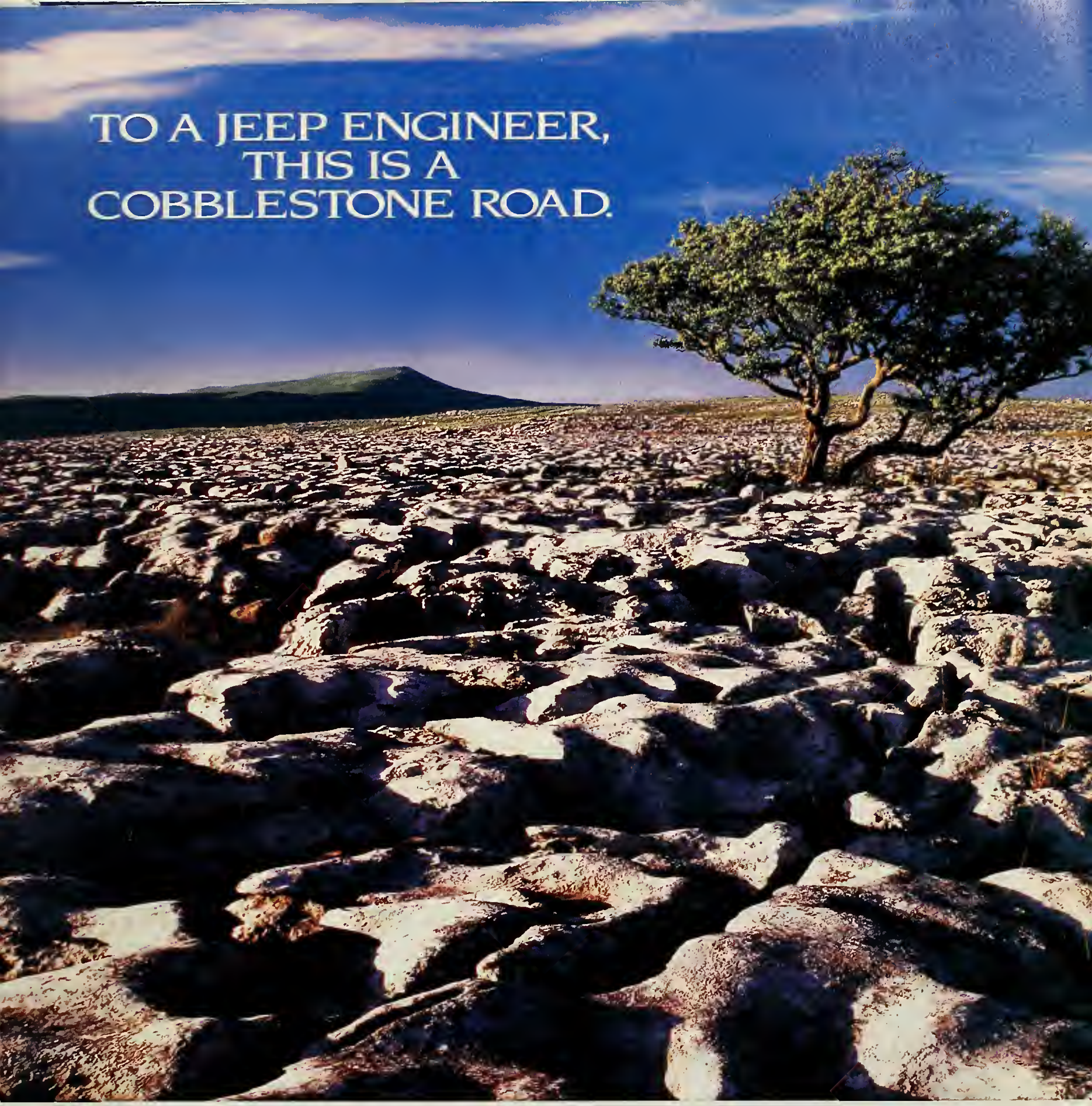

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Gerry Ellis

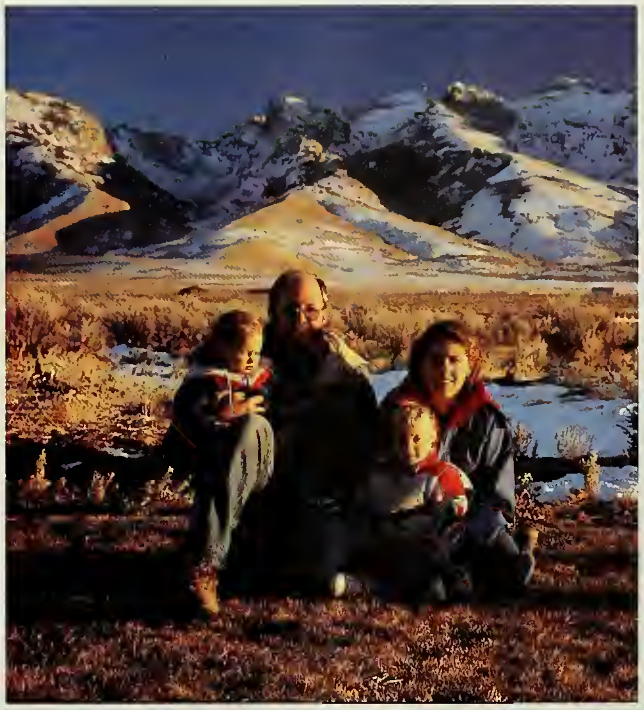
A Passionate Protector

Silhouetted against a patch of light in Costa Rica's Corcovado National Park, a plant ant on the stem of a crimson passionflower guards a leafy cup of nectar against all comers. (The plant's name comes from the Passion of Christ because its frilly corona reminded Spanish priests of a crown of thorns.) Native to the rain forests of Central and South America, most of the five hundred species of the passionflower family depend on insects or birds to carry their pollen. Vines with bright red blossoms are usually pollinated by hummingbirds, but their extralarge stores of nectar also draw some insects that harm the plant and are useless to its reproductive cycle.

In its evolutionary war against such unwelcome guests, passion vines have become hosts to an external immune system—resident colonies of wasps or ants that patrol the plants' stems, leaves, and flowers to repel all intruders. These guardians, which destroy the eggs or larvae of any invading insects, are rewarded with special nectar produced by the leaves. Among the vine's traditional enemies is a stingless bee that flowers will not admit because of its size and shape. Adopting a bold strategy, the bee alights behind the flower and chews its way into the rear wall of the main nectaries—the plant's Fort Knox. Vigilant ants, however, can usually intercept and expel such nectar thieves. About three-quarters of an inch long, the ants attack fiercely with stingers and powerful jaws and can deter an intruder of any size—as more than one botanist has painfully discovered.—*R.M.*

Photograph by
Michael and Patricia Fogden

Authors



With Nevada's Ruby Mountains as a backdrop, **Peter V. Bradley** (page 36), his wife, Susan, and his two sons, Bo and Jed, pose in their backyard. Although born in Frankfurt, Germany, Bradley proudly points out that he was conceived in Nevada, where, except for short stays in Idaho, California, Oregon, and Washington, he has lived all his life. Bradley received his M.S. in wildlife ecology from the University of Nevada at Reno in 1986, after completing his three-year survey of Nevada's river otters. The Nevada Division of Wildlife sponsored the study and then hired Bradley as a wildlife biologist following its completion. His current duties there include monitoring and rehabilitating populations of nongame species (vertebrates not hunted or trapped) in the northeast third of the state—an area the size of Maine. When Bradley is not traveling about Nevada checking on its wild inhabitants, he enjoys tramping in the hills, reading, canoeing, playing the guitar, and drinking dark beer. For further reading on river otters, the author suggests "Ecology of River Otters in West Central Idaho," by W. E. Melquist and M. G. Hornocker (Wildlife monograph No. 83, *Journal of Wildlife Management,* 1983).

Michael Fogden (page 86) and his wife, **Patricia**, are freelance photographer-writers, with long experience as field biologists. For twenty-five years they have photographed such diverse subjects as warbler migration in Uganda, ecosystem disruption in Mexico's Sonoran Desert, and frill-necked lizards in Australia. During fifteen years of work in Costa Rica, they have trained their lenses on the flowers, snakes, insects, and frogs of the tropical rain forest. Michael earned a doctorate in ornithology from Oxford University's Edward Grey Institute and has worked as an ornithologist for the Sarawak Museum in Malaysia. Patricia studied zoology and botany at Manchester University and later completed her doctoral thesis on the dentition of bats at London University. Of the ant on the passionflower pictured in the "Natural Moment," the Fogdens write: "Because the subject was at the edge of a sunlit clearing, we had a rare opportunity to take an ambient light picture of a forest insect. There was just enough reflected light to softly backlight the petals. We metered the background and then opened up our 105 mm Micro-Nikkor lens to f/4, a stop or two above the meter reading to insure that the flower was not a total silhouette."

An associate professor of biology and earth system science at New York University, **Tyler Volk** (page 48) has found his research on the global carbon cycle to be a great way to work in numerous disciplines, including atmospheric science, earth history, and oceanography. He is particularly interested in the role living things play in the grand chemical cycles of our planet. Volk's first book, *Megapatterns Across Space, Time, and Mind,* will be published this spring by Columbia University Press. The book explores universal patterns of form and function in such diverse fields as biology and linguistics, and incorporates his interests in mythology, art, and architecture. In summer, Volk "heads for the hills" in a cross-country drive to a trailer near the Gila National Forest of New Mexico. He takes along a computer and fax machine, but no radio or television. Town is an hour and a half away by car, but that's okay; Volk says watching the animals that come to feed around the trailer is entertainment enough. For an introduction to the global carbon cycle and climate change, he recommends Jonathan Weiner's *The Next Hundred Years* (New York: Bantam Books, 1991).

Raoul Mulder (page 56) first noticed male superb fairy-wrens performing frequent petal displays—carrying bright yellow petals in an attempt to grab the attention of females—in 1987, while he was working on his undergraduate honors thesis. He continued to study the ecology and surprising breeding system of this species over the next six years, earning his doctorate in 1993 from the Australian

National University. Currently a postdoctoral research associate in the Department of Zoology at the University of Cambridge in England, Mulder does much of his fieldwork in Madagascar, studying paradise flycatchers at the Berenty Reserve in the southern part of the huge island. He also serves as a technical consultant for an ecological monitoring program administered by the World Wide Fund for Nature in the Andohahela Reserve, a large area containing a unique transition zone between rain forest and spiny desert. For readers wishing to learn more about recent findings on the varied mating systems of birds, Mulder recommends *Sperm Competition in Birds: Evolutionary Causes and Consequences*, T. R. Birkhead and A. P. Møller, eds. (London: Academic Press, 1992). *Birds of Australia*, by Ian Rowley (Sydney: Collins, 1982), includes a chapter on the superb fairy-wren.

John E. Adams (page 64) pictured here with his wife, Margaret, has been interested in nature and geography ever since childhood, when his father's job as a federal game warden brought the family to a series of homes in several different states. (A favorite was a houseboat in Louisiana's coastal marshlands.) As an undergraduate at the University of Minnesota, Adams started out as a geology major, but finding that the subject lacked "the human element," he turned more and more to cultural geography, the field in which he eventually earned his doctorate. After twenty-two years as a professor of geography at the University of Minnesota at Duluth, Adams retired but continues to write on the historical geography of fishing in the Windwards. For more on the origins of Caribbean whaling, he recommends Alexander Starbuck's *History of the American Whaling Industry* (New York: Argosy, 1964), the "classic publication on New England voyages to the West Indies," and Frederic A. Fenger's *Alone in the Caribbean* (Belmont: Wellington Books, 1958).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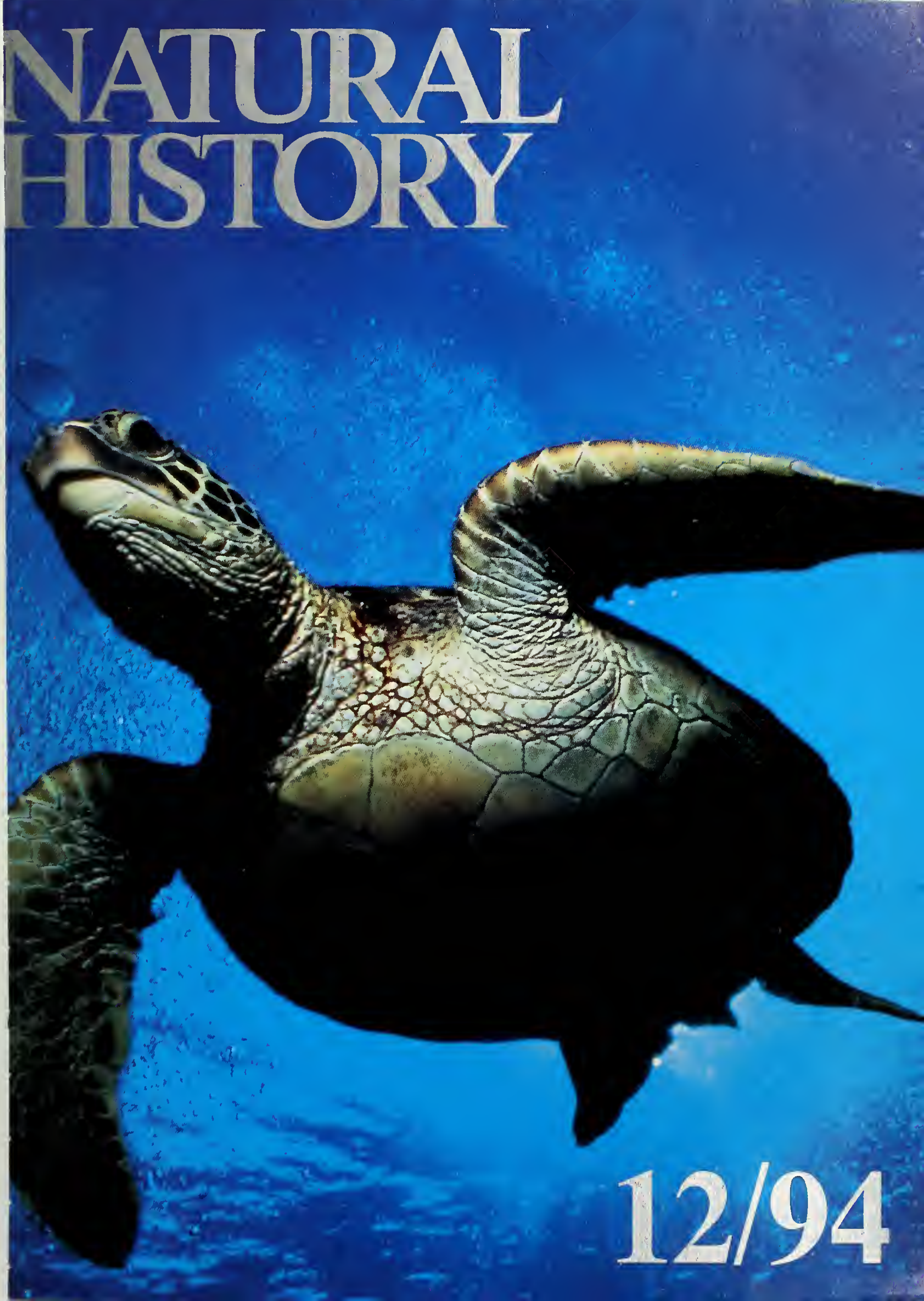

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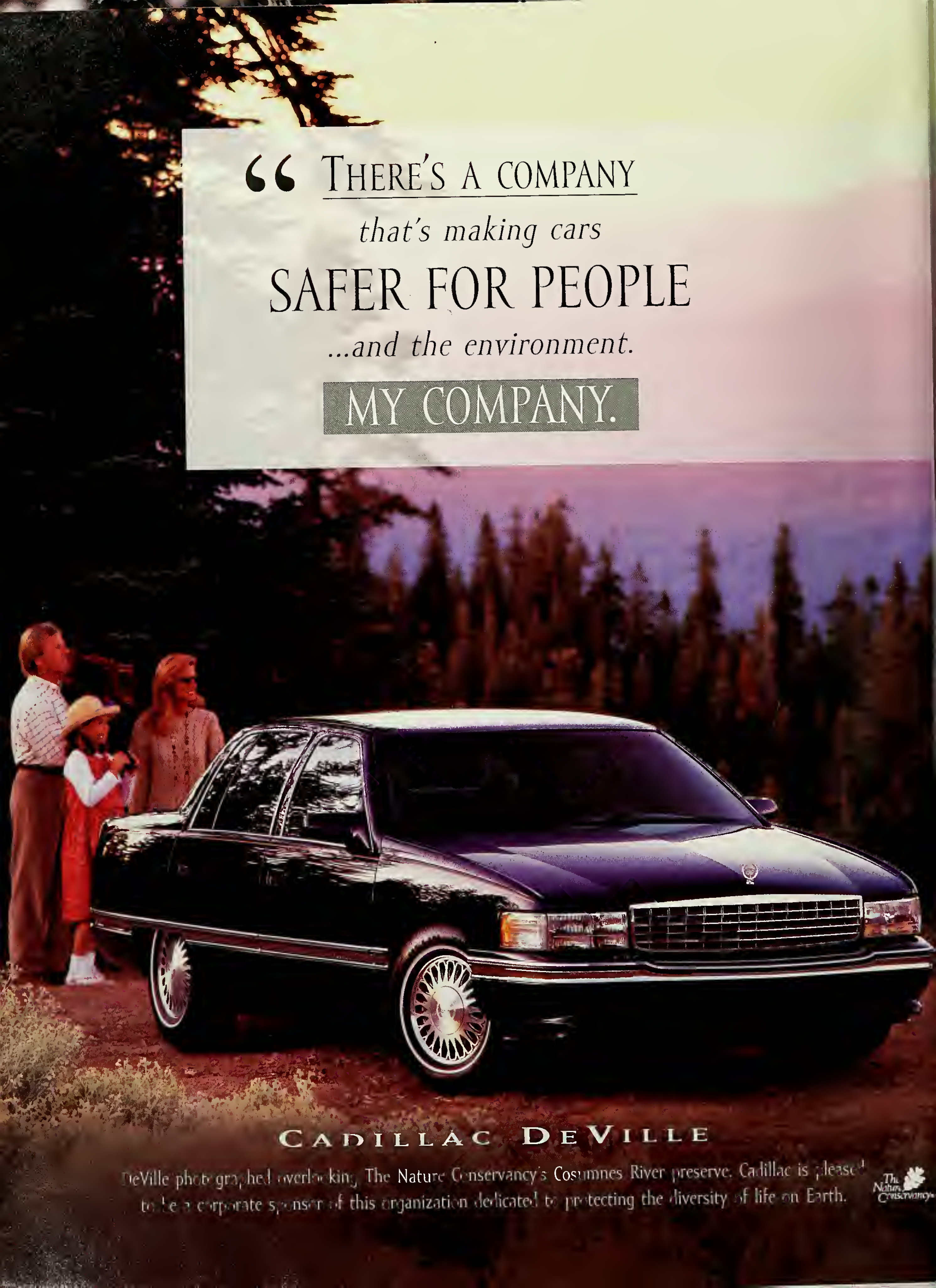

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Con

COVER: A green turtle swims in the Pacific near the island of Hawaii. DNA research is shedding light on the species' enigmatic migrations. Story on page 36. *Photograph by Doug Perrine; Innerspace Visions.*

If, as scientists say, genetic differences between human populations are negligible, why do we classify ourselves by race? The reason, writes this researcher, is that we tend to confuse biological with cultural heredity.

tents

Vol. 103. No. 12, December 1994

AH, MEENIE IT IS.

THE TRUTH ABOUT TEFLON

I enjoyed the recent article on Hawaii's geckos by Ken Petren and Ted J. Case ("Gecko Power Play in the Pacific," September 1994). Having lived in the tropics, I can attest to the value of geckos as insect destroyers. However, an aside on pages 57–58, implying that Teflon was a NASA product, needs rectifying.

For years I believed that NASA had invented Teflon. I would like to see us in space and give NASA credit for many things, but not Teflon, or polytetrafluoroethylene, which was actually "discovered" by Roy J. Plunkett as he was working on refrigerants for DuPont in 1938. The major reason the product did not become well known to the public was that it became part of the Manhattan Project, which developed the atomic bomb. One early Teflon product was gaskets, or seals. Teflon seals, it turned out, were resistant to certain corrosive gases utilized during the nuclear enrichment process, and thus Teflon was declared a military secret. The product did not lose this classification until after World War II. Several more years were to pass before successful commercial applications were developed.

WILLIAM M. KENDALL
Centreville, Virginia

The late Roy J. Plunkett, of DuPont's Kinetic Chemicals Division, made the serendipitous discovery of Teflon in 1938, finding the polymer by cutting open a small gas cylinder that had contained the monomer tetrafluoroethylene. In 1941, in DuPont's Chemical Department, I made the first sample of polytetrafluoroethylene that had been created on purpose. Subsequent development in DuPont's Plastics Department in Arlington, New Jersey, led to a process for producing the polymer on a small, commercial scale. The first Teflon product—made in 1944—was a nose cone for proximity fuses in bombs and artillery shells. Here it replaced cellulose acetate, which was unreliable because its transparency to the radiation on which the fuse depended changed as the polymer absorbed moisture. Teflon did not absorb moisture.

ROBERT M. JOYCE
Sun City Center, Florida

VERVETS, LEOPARDS, AND RESEARCHERS

I read with interest Lynne A. Isbell's article "The Vervet's Year of Doom" (August 1994). Isbell proposes that the die-off of fever trees (the monkey's preferred sleeping places) may explain why the monkeys suffered an increase in predation by leopards during the time she was studying them.

But Isbell also points out that the leop-

A leopard with its vervet victim
Stan Osolinski; Oxford Scientific Films

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ards' fear of her and her crew gradually dissipated over eight months and that vervet mortality from predation rose steadily whether she was doing fieldwork in the study area or was away in Nairobi. Did she consider the possibility that the leopards might have learned to use the presence of human researchers to locate populations of vervets? (The sight and scent of a large, ground-based human are stronger stimuli and are more easily followed than the sight and scent of a small, tree-perched vervet clan.)

I also wonder whether the leopards might have learned to use humans as hunting decoys. Even though Isbell claims that the vervets treated her as a "neutral" species, she was an additional large animal for the monkeys to keep track of. For every bit of vervet attention taken up by humans, there must have been that much less available to the monkeys for concentrating on the rest of their surroundings.

EDWARD C. DEMMOND
Ojai, California

LYNNE A. ISBELL REPLIES:

Mr. Demmond raises some interesting points. However, I would like to make clear that the predation rate did not rise steadily but leveled off after the burst of predation described in the article. In response to the first point, while it is possible that individual leopards could have learned to locate vervets by my presence, it is not a likely scenario.

First, hunters as skilled as leopards probably would not need my presence to locate vervets. (The monkeys are very easy to find, even for unskilled humans.) Second, after the first burst of predation, the vervets were as likely to disappear whether I was in the field or not, suggesting that these predators did quite well without me.

As for the decoy strategy, we know that humans can indeed affect the behavior of predators. Cheetahs, for example, sometimes use a tourist vehicle as a blind from which to ambush prey. Although we found that unhabituated vervets spent more time scanning for predators than habituated vervets did, we don't know what the scanning rate is for habituated vervets when humans aren't present. Both theory and empirical evidence suggest, however, that animals learn not to react to innocuous stimuli. The vervets in our study, for instance, differentiated among humans, tolerating the researchers but running away at the sight of Maasai herdsmen. We assume therefore that the monkeys didn't monitor the researchers at the expense of ignoring true threats. In addition, if I had served as a distraction for the vervets, then one would expect that they would have been preyed upon while I was with them. Actually, all the evidence we have on vervet disappearances suggests that I served as an inhibitor of leopard activity, at least at the beginning of the study.

Nonetheless, Mr. Demmond rightly draws attention to researchers' potential for affecting their subjects' survival. This is especially important for those who follow their subjects on foot, as primatologists commonly do, to consider.

UNIFORMITARIAN VERSUS CATASTROPHIST

Stephen Jay Gould, in "Jove's Thunderbolts" ("This View of Life," September 1994), has broadened the terms *uniformitarian* and *catastrophist* to include the biologists. Accepting this, how do the biological uniformitarians explain the gradual changes they believe occur? I am sure they do not rule out mutations in living cells caused by the passage of a cosmic ray through a gene.

Well, a cosmic ray is just as much a "bolt from the blue" as the bolide that struck the earth 65 million years ago or the Tunguska object or the Shoemaker-Levy comet. In fact, the mass equivalent of cosmic rays striking the earth may, over time, outweigh bolides.

Very likely, most changes occur because of some catastrophe, large or small, domestic or from the blue; but changes from small catastrophes only become evident over time.

LOUIS L. FERSTANDIG
Ridgewood, New Jersey

Common Pathways of Illumination

Humans and squid may literally look at things the same way

by Stephen Jay Gould

Ashley Montagu, one of our century's greatest writers of popular science, once gave me a marvelous lesson in the distorting power of half statements. We were having breakfast together at his hotel when two particularly obnoxious men intruded on our conversation, insisting that Ashley identify himself, since they were sure they had seen him on TV. Ashley, cool as could be, replied that he was "just a traveling salesman"—and all their complaints of "aw, c'mon, I know I seen ya on TV" could not budge him. When they had retreated out of earshot, Ashley turned to me and whispered "traveling salesman of ideas."

But the art of semistatement finds more frequent use, alas, in less benevolent attempts to distort an author's meaning for nefarious purposes. No semiquotation from Darwin's *Origin of Species* has been so frequently cited as the following partial passage from his section on "organs of extreme perfection and complication" in the chapter that he so honestly titled "Difficulties on Theory."

> To suppose that the eye, with all its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, could have been formed by natural selection, seems, I freely confess, absurd in the highest possible degree.

Antievolutionists continually cite this passage as supposed evidence that Darwin himself threw in the towel when faced with truly difficult and inherently implausible cases. But if they would only read the very next sentence, they would grasp Darwin's real reason for speaking of absurdity "in the highest possible degree." (Either they have read these following lines and have consciously suppressed them, an indictment of dishonesty; or they have never read them and have merely copied the half quotation from another source, a proof of inexcusable sloppiness.) Darwin set up the overt "absurdity" to display the power of natural selection in resolving even the most difficult cases—the ones that initially strike us as intractable in principle. The very next lines give three reasons—all supported by copious evidence—for resolving the absurdity and accepting evolutionary development as the cause of optimally complex structures:

> Yet reason tells me, that if numerous gradations from a perfect and complex eye to one very imperfect and simple, each grade being useful to its possessor, can be shown to exist; if further, the eye does vary ever so slightly, and the variations be inherited, which is certainly the case; and if any variation or modification in the organ be ever useful to an animal under changing conditions of life, then the difficulty of believing that a perfect and complex eye could be formed by natural selection, though insuperable by our imagination, can hardly be considered real.

In other words, natural selection can evolve the most intricate organs of vision, given (1) the existence of a graded array in complexity of eyes (as clearly found in a sequence from pigment spots able to detect light and darkness but not to form images, to simple pinhole cameras, to the lens eye of several phyla, including vertebrates, insects, and squid); (2) variation in size and form of eyes among individuals within populations (providing the "raw material" for natural selection to work); and (3) the potential utility of some of these variations (another requirement for the operation of natural selection).

While I criticize creationists for their incomplete quotation, I must also state that evolutionists miss a crucial and fascinating aspect of Darwin's full argument by generally failing to cite the very next line after his three arguments to refute absurdity (although, in this case, my colleagues do not distort Darwin, either intentionally or unintentionally, but merely lose out on something interesting and important). Darwin continues:

> How a nerve comes to be sensitive to light, hardly concerns us more than how life itself first originated; but I suspect that any sensitive nerve may be rendered sensitive to light, and likewise to those coarser vibrations of the air which produce sound.

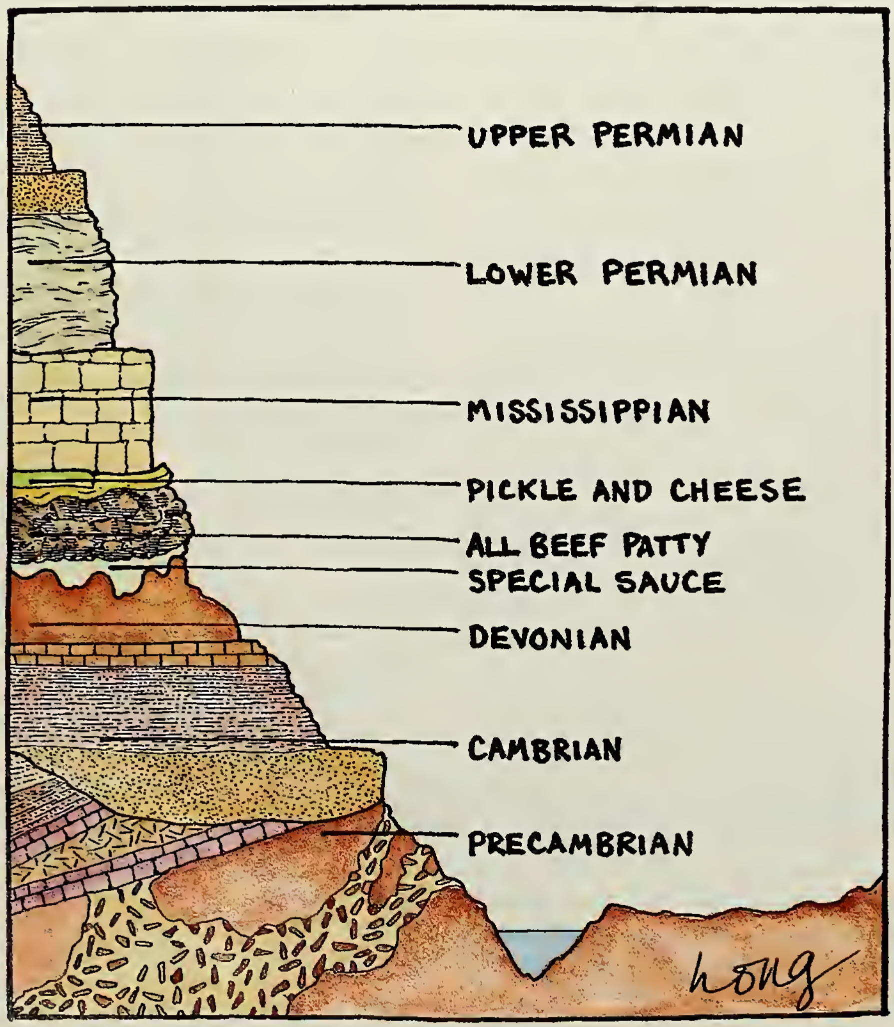
Darwin here discusses the vital historical principle of necessary structural prerequisites. Eyes don't emerge just because they confer such great utility, and therefore such advantages under natural selection. An organism must have the wherewithal for their potential construction beforehand—and since animals don't know their distant futures and cannot prepare the proper materials for later transformation in any conscious or preordained way, fortuity must always play a large role in any major evolutionary innovation. You have to catch a break from your own past.

Many features that would be eminently useful can't evolve because organisms don't maintain the structural prerequisites. A great evolutionist once remarked that even if humans had a capacity for moral perfection (which he greatly doubted), we could never evolve a pair a wings—for our

arms are already committed to other uses and our vertebrate body plan doesn't provide the variation that natural selection would need to fashion a third pair of appendages. In other words, in evolution as in motoring, you can't always get there from here.

This theme of necessary structural prerequisites gains importance because the naïve view of pop-adaptationism—perhaps the most conspicuous of all fallacies in the standard journalistic presentation of evolution—pays the principle no heed and therefore fails to grasp the fascination of evolution's fortuity and frequent failure to do the "sensible" thing. Under pop-adaptationism, useful features manage to emerge because, well, the organism evidently needs them and natural selection is such a powerful force for organic good. In this view, eyes evolve because sight is so advantageous. By extension, needs will be fulfilled and gains rewarded—as evolution follows a sensible pathway toward optimal fit between organism and environment.

But in the rarely quoted passage following his praise for natural selection in the evolution of eyes, Darwin reminds us that vision could never have evolved without a key prerequisite in the structure of neurons—namely, sensitivity to light. He does not know why neurons are so sensitive, and he also recognizes that evolutionists need not resolve this complex question from the cognate field of physiology (just as they don't have to solve the basically chemical problem of how life arose before studying its subsequent history of transformation). But a complete Darwinian argument requires identification and specification of such a structural prerequisite. In other words, we cannot simply say "eyes are so good; therefore natural selection can fashion them." We must also identify a preexisting biological substrate, in structure and variation, that natural selection can use to build this key innovation. Full evolutionary explanations must always combine a statement about structural constraint with an argument about functional advantages.

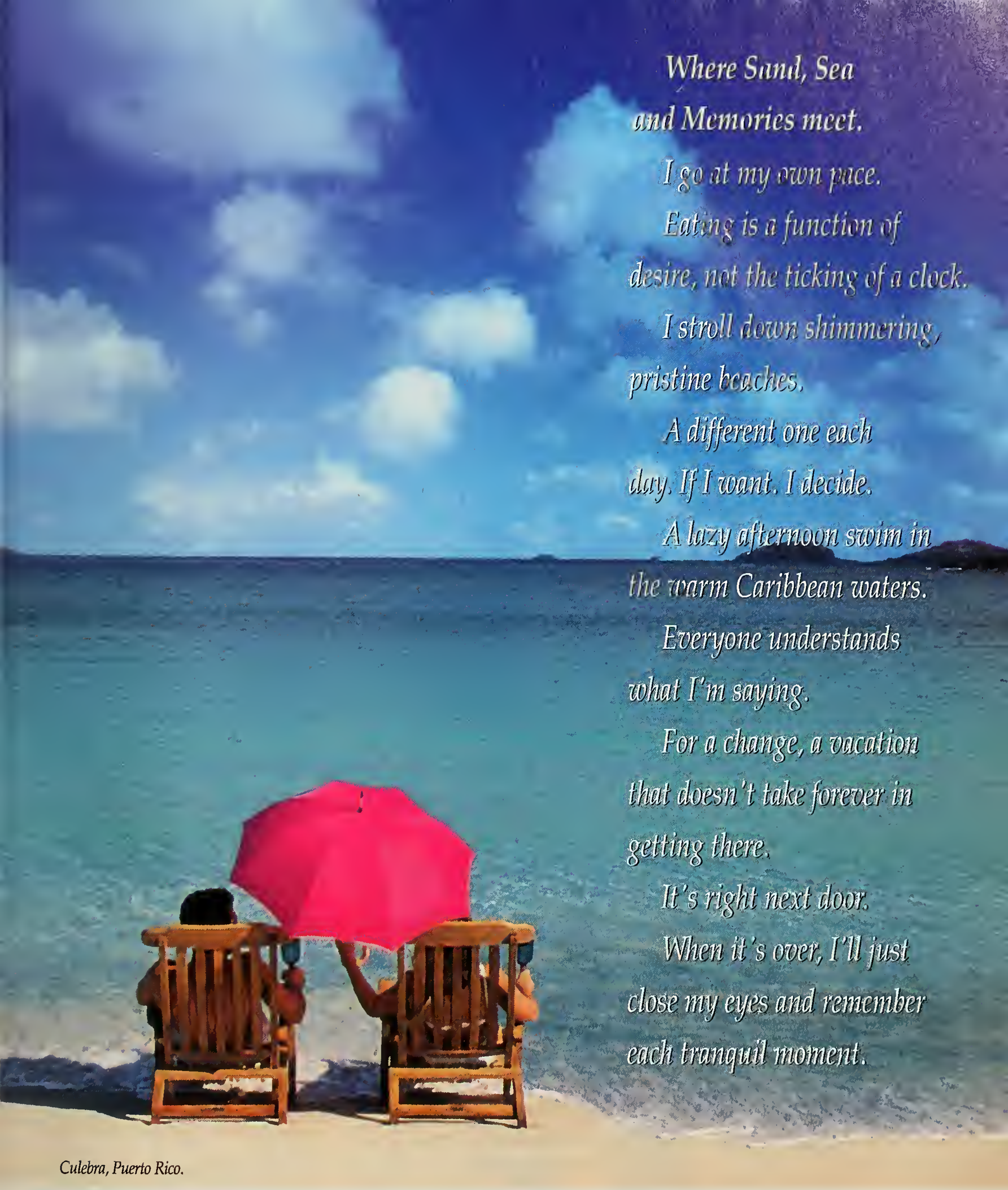


This theme has particular relevance to the evolution of eyes because, ironically (despite Darwin's own explicit reminder), the subject of structural constraint has been so generally ignored, and that of adaptation so emphasized and even celebrated. The three largest animal phyla have all evolved complex eyes with evident utility in the formation of images—the compound eye of insects and other arthropods and the single-lens eye of vertebrates and mollusks (squid and octopuses in particular). These eyes seem to follow markedly different evolutionary pathways in their origin. The compound eye is so distinct in design that no structural homology (descent from a common ancestor with eyes of similar form) can be claimed with vertebrates and mollusks. The single-lens eyes of squid and vertebrates, on the other hand, are strikingly similar in basic structure. Nonetheless, clear and fundamental differences in the architecture of embryological development also identify these eyes as separate evolutionary innovations.

Therefore, the independent evolution of complex, image-forming eyes in all these groups has become our classic textbook illustration of the enormous power of natural selection to produce similar (and eminently useful) results from disparate starting points, a phenomenon called "convergence" (and particularly emphasized for the structurally similar, but developmentally different, eyes of squid and vertebrates). Darwin himself discussed convergence at the end of his section on the evolution of eyes:

> I am inclined to believe that in nearly the same way as two men have sometimes independently hit on the very same invention, so natural selection, working for the good of each being and taking advantage of analogous variations, has sometimes modified in very nearly the same manner two parts in two organic beings, which owe but little of their structure in common to inheritance from the same ancestor.

Thus, eyes have become our standard illustration of natural selection's power and the organism's almost infinite malleability—like clay before a sculptor, to cite a metaphor often advanced at this point in the discussion. But are organisms so puttylike, and is natural selection so potent a builder? Of course no professional biologist would go so far in extolling selection and relegating preexisting structure to infinitely flexible raw material. Nonetheless, celebration of natural selection and de-emphasis of structural con-



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straint has been the characteristic bias of evolutionary theory since the 1930s, when modern Darwinism began its deserved triumph. And eyes provide the premier illustration of such an attitude, for flexibility must dominate over constraint if such complex and similar structures—paired organs up front, complete with lenses and retinas and, in the case of squid and vertebrates, of such comparable design—can evolve so often in total independence.

But is the independence so complete? Might a structural constraint of common inheritance be operating after all, despite the admitted differences in form (compound versus single-lens eyes) and developmental pathways (vertebrates and squid)? Might some inherited predisposition of anatomy or development, preserved in all eyed groups (despite half a billion years of evolutionary separation among vertebrates, mollusks, and arthropods), be providing a boost to the development of eyes from the past? Maybe natural selection doesn't have to start from formless raw material and then do all the work itself.

Such a contribution from common ancestry would have seemed almost risible as few as five or ten years ago—for strict Darwinians then argued that such a long evolutionary separation among phyla had permitted natural selection to tailor all initially common genetic sequences to the specific uses of each lineage—thus wiping out all important signs of shared genetic and developmental ancestry. In my view, the most exciting event in evolutionary theory during the past decade resides in the disproof of this assertion (one of the linchpins of education in my graduate student days during the 1960s, and thus requiring some major clearing of cobwebs from my own mental architecture).

Our modern ability to map detailed sequences of DNA, and to trace the operation of genes in early embryology, has finally permitted us to assess the role of genetic structure in the building of organisms. As the biggest surprise of this work, astonishing conservation of intricate genetic detail has been discovered across genealogically distant phyla, and for genes that are most crucial in building the basic body plan of organisms. Most strikingly, a set of genes in fruit flies and other arthropods, called the *HOM,* or homeotic, complex and crucial for proper differentiation of segments along the front–back axis (building antennae, mouthparts, and legs in the right places, for example), can also be found in vertebrates, where these genes maintain virtually the same DNA sequence and must therefore be products of shared ancestry. (In vertebrates, these genes, called the *Hox,* or homeobox, complex, have been duplicated and now exist as four copies on four different chromosomes.)

For nearly 150 years, since the death of the visionary French scientist Etienne Geoffroy Saint-Hilaire in 1844, no one had taken seriously the possibility of homology (similarity due to shared inheritance) between insects and vertebrates in the basic architecture of segmentation and differentiation of organs front to back. (Geoffroy had argued, wrongly in detail but correctly in spirit, as we must now recognize, that all complex animals are built on the same shared body plan, with the vertebra as an archetypal structure. He compared the jointed, external skeleton of insects with the backbone of vertebrates and actually argued that insects lived within their own vertebrae.) Ironically, Geoffroy was quite wrong in homologizing insect segments with the vertebrae of our spine—but he was right in arguing for homology of basic design. The comparable structure in vertebrates, however, turns out to be the transient segmentation of midbrain and hind brain during embryology—for the *Hox* genes of vertebrates influence the architecture of these structures in the same way as the nearly identical *HOM* genes of *Drosophila* regulate segments of developing fruit flies.

If the long hand of the past so constrains the fundamental building plan of two such distinct phyla, must we not rethink our previous assumption that convergence and independent evolution, not shared ancestry, lie behind such similar organs as the eyes of squid and vertebrates? In August 1994, in the most exciting advance in evolutionary studies of development since the finding of *HOM* and *Hox* homologies, Rebecca Quiring, Uwe Walldorf, Urs Kloter, and Walter J. Gehring announced the discovery of homology in an important gene crucial to the embryology of eyes in both fruit flies and vertebrates ("Homology of the *Eyeless* Gene of *Drosophila* to the *Small Eye* Gene in Mice and *Aniridia* in Humans," *Science,* vol. 265, pp. 785–89).

We have known for a few years about genetic homology of some common building blocks in visual systems. For example, all opsins, an important protein component of visual pigments in all phyla, show such similarity in their DNA sequences that they must be products of common ancestry, rather than separately evolved (for no convergence can be precise enough to produce near identity in thousands of DNA bases along a linear chain; only a common starting point can explain this de-

gree of similarity). In discussing this example in his 1990 article on "Optimization, Constraint, and History in the Evolution of Eyes" (*Quarterly Review of Biology,* vol. 65), Yale biologist Timothy H. Goldsmith wrote: "The eyes of cephalopods [squid and octopuses], arthropods, and vertebrates are not homologous, yet at the molecular level some of their constituent elements are."

These data are interesting, and they do contradict the previously favored notion that visual pigments must be convergent rather than homologous across phyla, but homology of something so far from the form of a building as bricks and mortar does not pack a powerful wallop for constraint. After all, we have known for some time that the basic molecules of life are widely shared—the nucleic acids themselves, ATP as the energy-storing compound of all organisms. Opsins are a bit more specific and impressive, but still ever so far from an eye.

The excitement of the latest discovery lies in its well-documented claim for homology in the actual, detailed pathway for building eyes as paired organs at the front end of an animal. I am not greatly moved to learn that my outhouse and the Great Wall of China both use bricks of similar composition and construction based on an inherited tradition of learning (not everyone agrees, but one common argument traces knowledge of both Western and Eastern brick making to a Babylonian source). But common blueprints for designs of integrated and complex structures indicate historical constraint of a far more comprehensive kind. (We do not doubt that the automobiles of China and the United States derive from a common tradition of invention and construction.) Homology in some singular molecular components of eyes seems interesting but unsurprising; homology in complex genetic and developmental pathways for building eyes (as has now been discovered) was both unexpected under usual views of evolution and downright revisionary in forcing a rethinking of many previous certainties.

To appreciate the impact of this latest discovery, we must review the history and comparative anatomy of eyes—especially in the light of Darwin's first argument about a series of transformations from rudimentary to most elaborate. The first stage is structurally and easily accomplished—a simple eyespot, on a surface or in a shallow pit, made by the aggregation of a small number of receptor cells (usually one to one hundred). These "eyes" cannot form images but can detect light and darkness, and therefore provide important information about environments. Ease of construction and evident utility led to the multiple evolution of such eyespots. In a famous article written in 1977, my colleagues L. von Salvini-Plawen and Ernst Mayr estimated that eyespots evolved independently among animals some forty to sixty-five times. Michael F. Land and Russell D. Fernald add, in their excellent article "The Evolution of Eyes" (*Annual Reviews of Neuroscience,* vol. 15, pp. 1–29, 1992), that only about five of some thirty-five recognized animal phyla failed to develop rudimentary eyes of this type.

From this nearly universal substrate, six animal phyla evolved eyes capable of forming images: the Cnidaria (where a few jellyfish have lens eyes); the Annelida, or segmented worms; the Onychophora (a fairly obscure group today, best represented by the velvet worm *Peripatus,* but much more common in the early fossil record of multicellular animals); and the three great phyla previously mentioned, Mollusca (where eyes grace members of all major subgroups, snails, clams, and cephalopods), Arthropoda, and our own Chordata. Both a structural series and a riotous display of diversity may be identified among image-forming eyes.

In a first step, a deepening of the pit for receptor cells into an optic cup and a narrowing of the aperture into this cup can produce a pinhole camera without any lens at all. A few mollusks have evolved pinhole camera eyes of this type—most notably the chambered *Nautilus* among cephalopods and the abalone *Haliotis* among clams. The next step, leading to such diversity in complex eyes, adds other layers and structures either to refract or reflect an image upon the retina. The simple lens eye works by refraction. Most aquatic animals use the lens as a primary device for forming an image, whereas many terrestrial groups, including mammals and spiders, develop more optical power in an outer cornea and use the underlying lens primarily for adjusting focus.

Most compound eyes also employ lenses, and each separate unit, called a facet or ommatidium (the fruit fly *Drosophila* has some 800 in each eye), forms a part, one pixel if you will, of a

"It's amazing how well they adapt to an urban environment."

total image, which the organism must then integrate as a single picture. Although compound eyes are best known in the great phylum of arthropods, they have also arisen independently in two other phyla, and in interestingly different anatomical places—on the tentacles of some tube-dwelling annelid worms and on the mantle edge (the "skin" visible at the gape between two valves) of some clams in the family Arcidae.

A far less common, but quite striking, anatomical variant relies upon reflection rather than refraction and places a concave layer of cells (called a tapetum) behind the retina (rather than using refraction through a lens in front of the retina). In some eyes, the tapetum only acts to increase light available to the receptors and does not focus an image, but if the concavity of the tapetum is great enough, and if the retinal surface moves far enough forward, then the tapetum can reflect an image upon the retina.

Some organisms use both refraction and reflection. The mantle-edge eyes of swimming scallops (up to one hundred per animal), for example, have both a lens in front of the retina and a reflecting tapetum behind. In the most interesting use of a posterior tapetum as an imaging device, the deep-water ostracode *Gigantocypris* shapes a large tapetum into the form of a parabolic reflector, focusing light onto the bloblike retina in front (ostracodes are small and little known, but enormously abundant, bivalved marine arthropods). These reflectors may produce a poor image, but they are remarkable light-gathering machines in the low illumination of deeper marine waters.

Lens eyes are enormously variable among organisms, both in position and in form. A pair up front may be canonical in the groups we know best, but animals with different modes of life often evolve eyes in positions more suitable for their activities. Clams often develop a row of eyes along the mantle edge between the two valves or on the ends of their siphons, the tubes that project upward from the closed shell (and function for intake of nutrients and outflow of waste). Most intriguingly, or even amusingly, a group of polychaetes (segmented marine worms) typically move rear end first, rather than the usual vice versa. They have evolved a pair of eyes on their posteriors!

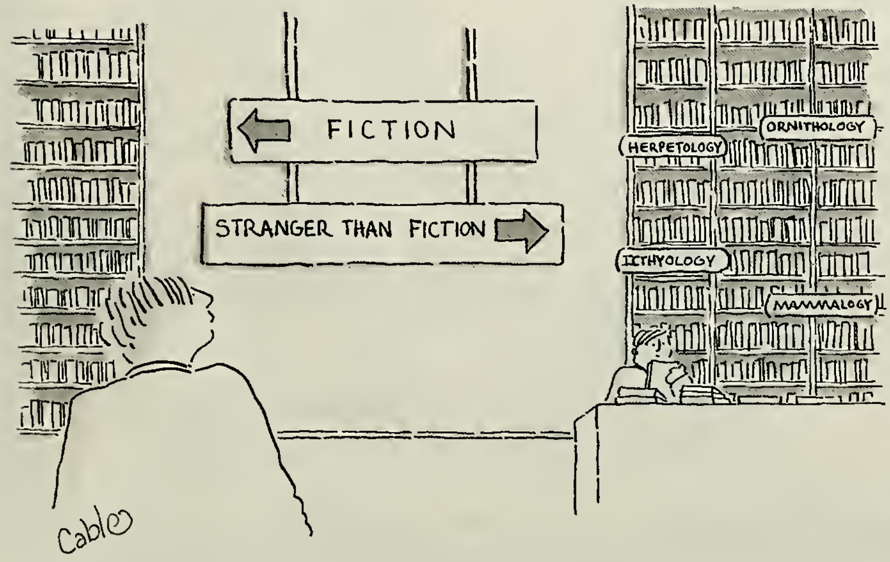
To cite just two anecdotes about variation in form: The copepod *Pontella* develops three lenses in males (two above and outside the eye proper) and two in females. (Copepods are another group of small and little known, but extraordinarily abundant, marine arthropods.) *Copelia,* another copepod, builds a narrow tubular eye with two distant lenses—and the entire structure both resembles and works like a telescope. But the retinal receptors are so few that only a dotlike image can be formed at any moment. Consequently, *Copelia* must constantly move its head and scan its surroundings in order to integrate a more complete image.

This riotous diversity seems to make historical constraint and preserved homology from common ancestry even more unlikely. After all, if eyes seem to form in almost any place and with such disparity of form in so many groups, then surely organic material is fully competent to answer any call from natural selection. Therefore, one would suppose the most common design of a single pair at the front end must represent an adaptive optimality for bilaterally symmetrical animals moving in the usual direction (and not ass forward like those rear-eyed polychaetes just described). This usual placement in all three of the most widely discussed lineages—squid, insects, and vertebrates—should represent pure convergence and absolutely independent evolution without any important constraint from retained homologies of common ancestry. And yet, however surprisingly, outstanding genetic homology has just been discovered.

Quiring, Walldorf, and their colleagues worked with a small family of homologous sequences known as *Pax* genes. These genes were first identified in the fruit fly *Drosophila* and owe their name (*Pax* stands for "paired box") to initial discovery of the key sequence within a *Drosophila* gene called *paired. Pax* genes were then identified in all vertebrates studied, from zebrafish to mice to humans. Nine *Pax* genes have been found so far in mammals. *Pax-6,* the best studied, must be a key factor in the development of eyes, for mutations at this locus cause severe ocular disruption. *Sey,* the *small eye* mutation of *Pax-6* in mice, for example, yields eyes of greatly diminished size in heterozygotes (normal copy of the gene from one parent and mutant copy from the other) and no eyes at all in homozygotes (mutant copies from both parents). A mutation of the same gene in humans produces *Aniridia,* a severe condition leading to limited development of the iris, absence of foveae, and malformation of the lens.

The so-called paired domain produced by these *Pax* genes, the major component of their homology, is a sequence of 130 amino acids coded by 390 nucleotides of DNA (remember that the genetic code is triplet, with three nucleotides designating one amino acid). The *Pax* genes of vertebrates retain remarkable similarity in their paired domains, despite a few hundred million years of evolutionary separation between fishes and mammals—a sure sign of homology, or inheritance of these genes from a common ancestor. For example, the paired domains in *Pax-6* of mice and zebrafish differ in only one amino acid out of 130.

Quiring, Walldorf, and colleagues have now identified and sequenced a *Dro-*



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sophila gene clearly homologous to *Pax-6* of vertebrates. The paired domain of this *Drosophila* version shares 94 percent identity with the amino acid sequences of mice and humans—a remarkable evolutionary conservatism across more than 500 million years of genealogical separation and between two phyla so apparently different that anyone, even ten years ago, would have scoffed at the idea of such stable homology.

But homology of structure does not establish any argument for genetic or developmental constraint in the evolution of eyes. We need to know what the *Pax-6* homolog in *Drosophila* does for developing fruit flies. Perhaps this gene plays no role in building the eye in insects. Quiring, Walldorf, and colleagues therefore went on to determine the chromosomal location of this *Pax-6* homolog and its function in the developing fruit fly. In their most exciting result, they mapped the *Pax-6* gene to the *ey* (or *eyeless*) locus on the fourth chromosome, a well-known position identified as the site of several mutations affecting the development of eyes. In other words, *Pax-6* is the *ey* gene (previously unsequenced for its DNA structure but known by its developmental effects). *Pax-6* is not only homologous in genetic structure between insects and vertebrates; it also acts as a major repository for the developmental blueprint of eyes in both distantly related phyla.

Moreover, modern genetic techniques permit the tracing of a gene's influence through development by probing for changing locations of transcripts (the working products of the gene's action) during embryology. Again, the pattern is strikingly similar in the two groups. In *Drosophila, Pax-6* is first expressed in the imaginal disk of the eye, but not in disks for legs or wings (imaginal disks grow within larval flies as precursor structures for adult organs)—and also in parts of the brain and ventral nerve cord. In mice, transcripts of the homologous gene appear first in the forebrain and hind brain and then along the whole length of the nerve cord. Quiring, Walldorf, and colleagues write: "This pattern of expression resembles the one found in *Drosophila*; the *ey* transcripts are detected first in the central nervous system, in the brain, and the ventral nerve cord." The authors then state their remarkable general conclusion:

> Because *Pax-6* is involved in the genetic control of eye morphogenesis in both mammals and insects, the traditional view that the vertebrate eye and the compound eye of insects evolved independently has to be reconsidered.

Some findings in science are particularly potent because they suggest such obvious, and eminently doable, extensions of great importance. Anyone discovering *Pax-6* homology of structure and developmental function between *Drosophila* and vertebrates would have to ask: How general is this phenomenon? Is *Pax-6* a master builder of eyes in all animals? The first signs of a positive answer are already in hand, based on some intriguing footnotes and side comments (for work in progress but not yet published) in the report of Quiring, Walldorf, and colleagues. They have already found homologs of *Pax-6* in two anatomically simple phyla that have evolved eyespots but not lens eyes—in the flatworm *Dugesia tigrina* and in the nemertean worm *Lineus sanguineus*. But we do not yet know whether these genes build visual structures in these two phyla.

With a good sense of style, Quiring, Walldorf, and colleagues saved the best hint for last. They have indeed looked for the *Pax-6* homolog in the most revisionary of all places—in squid, where convergence, rather than homology, with the vertebrate eyes has, for so long, been a textbook case. Again, tests for similar developmental function have not yet been made, but *Pax-6* homologs have been found in the squid *Loligo vulgaris*. Quiring, Walldorf, and colleagues end their paper by stating:

> Also, the hypothesis that the eye of cephalopods has evolved by convergence with the vertebrate eye is challenged by our recent findings...of *Pax-6* related sequences in the squid *Loligo vulgaris*. These findings may throw some new light on the fascinating problems of eye evolution.

In trying to summarize the importance of this work for evolutionary theory, let me provide an anecdote and a statement. So much of our conventional thinking must be tweaked, if not reversed. We must reassess our views on the weight of past influence and current adaptation. Naturalists tend to work by example as much as by principle, so I will share my first candidate for rethinking. I have always been amazed by the dorsal fin of ichthyosaurs. These seagoing reptiles, living at the same time as dinosaurs, evolved from fully terrestrial ancestors but look remarkably like marlin or swordfish. They grew a dorsal fin of the same form, and in the same position, as the dorsal fin of fishes. The function of this structure is well understood—a device, primarily, for the prevention of rolling side to side during swimming. Hydrodynamic engineers have found that the dorsal fin is optimal in form and position for this role.

Yet the dorsal fin of ichthyosaurs evolved from absolutely no precursor structure in 100 million years worth of ancestors (for these forebears were fully terrestrial, finless creatures, even though more distant fish ancestors had dorsal fins). Therefore, the ichthyosaur dorsal fin has always been regarded as another stunning example of convergence, or fully independent evolution of an organ by natural selection based on evident utility. But this view may not be right. If all or most animals hold *Pax-6* in their genetic repertoires, using the developmental consequences to build eyes of enormous variety, then perhaps the ancestors of ichthyosaurs retained unexpressed developmental information for building dorsal fins—a legacy from more distant fish ancestors—throughout the 100 million years of terrestrial evolution. Perhaps this reptilian dorsal fin (although not homologous in structure with that of fishes, for the ichthyosaur version contains no fin rays) could be built at all because distant ancestry provided a prerequisite—making the fin as much a consequence of constrained history as of immediate adaptation.

We have an unfortunate habit of regarding constraint as entirely negative, as limitation, in this case imposed by a restricted array of inheritances. But constraint, in both concept and language, also bears a positive meaning of providing a directed possibility, of channeling for potential benefit. Organisms need structural constraints of ancestry to build anything of interest. Constraints do restrict the range of outcomes, but their absence may preclude any outcome at all. Construct organisms with no neural sensitivity, as Darwin argued, and eyes might never evolve. Lose the genetic architecture encoded by *Pax-6* (and, no doubt, many other factors), and all reasonable possibility of generating an eye might evaporate. But lineages that retain these developmental pathways may then evolve and permute organs of vision into a wondrous variety of form and function. The past may only be prologue, as Shakespeare said, but the past is also promise. Let there be light, but also the wherewithal for perception.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

Phoenix Park, California

by Robert H. Mohlenbrock

Among California's diverse habitats are vernal pools, depressions that fill with water in winter, gradually dry up during spring, and then remain dry throughout the summer and autumn. They owe their existence to the Mediterranean type of climate, in which relatively mild, wet winters alternate with long, dry summers. The water that collects in the pools during the rainy season lasts well into spring because of a water-impervious layer of soil a few inches below the surface. In most cases, that layer is a hardpan of clay, but sometimes it is lava or other rock.

Torrents of rain and snowmelt from the Sierras filled California's flat valleys in prehistoric times, forming not only hundreds of vernal pools but even vernal lakes, which also disappeared during the dry summer. Before the first European settlers came to California, vernal pools apparently were very widespread in the young, fertile terrace soils of the great Central Valley between the coast ranges and the Sierra Madre. But with agricultural expansion, mineral extraction, and increased settlement, many of the vernal pools were destroyed. Today, most that remain are on high ground in the rolling grassland of the Central Valley. One protected field of pools lies in Phoenix Park in Fair Oaks, a suburb of Sacramento.

Phoenix Park stands on a grassy terrace above the American River, where bluffs of sand, silt, and gravel rise abruptly 160 feet above the north bank. Hardpan underlies much of the topsoil atop the bluffs, providing ideal conditions for the development of vernal pools. I visited the site in early May, leaving my car in the nearby parking lot. From there I walked through an intervening zone of blue oak savanna, where well-drained soil has encouraged the growth of well-spaced blue oak trees above an understory of scattered grasses and wildflowers.

Standing at the edge of the savanna and looking into the vernal pool field, I saw a series of shallow depressions separated by better-drained, low ridges known as hummocks. Several of the wildflowers and grasses growing on the hummocks, such as woolly brome grass, hair grass, storksbill, and cat's-ear, were weedy species about one and one-half feet tall. Others were colorful native wildflowers, including white and purple brodiaeas (members of the lily family), lupines, California poppies, and purple clarkia.

One of the significant aspects of vernal pools is that each is, to some degree, an isolated biological system. Even within Phoenix Park, no two pools have the same community of plants. In addition, many vernal pools host unique species. Most of these are annuals that have recently become distinct from their closest relatives. Perennials, which seem to diverge into new species more slowly, usually have a wider distribution.

At the time of my visit in early May,

about two inches of water still stood in the lowest part of the vernal pool depressions. There I saw strange-looking plants known as Vasey's coyote thistles, a species that because of its undivided leaves and tight flower heads, looks little like the carrot family to which it belongs. Each half-inch-diameter head of small, white flowers is surrounded by green, prickly, thistle-like bracts.

Elsewhere in the pool depressions, the soggy soil was carpeted with plants, many of them small with bright, colorful flowers. Among these were three species of downingias, a group of annual plants in the bellflower family that seem to thrive in vernal pools. Downingia species, with their blue, pink, or white flowers, are often distinguished only by one or two characteristics, such as the bristles that project from the pollen-producing anthers in the flowers. One species differs from the others only in its twisted bristles.

Other plants with small, colorful flowers included vernal pool mesa mint, with its dense head of purple flowers; pincushion navarretia, a miniature species of phlox; yellow cicendia, an annual gentian; woolly yellow-heads, with crowded yellow flower heads; and two kinds of annual goldfields, dwarf species with yellow, daisylike heads.

In Phoenix Park, pink checker mallow and yellow goldfields are conspicuous in a vernal pool depression.
Jo-Ann Ordano

I saw a few vernal pool wildflowers that were relatively large, with conspicuous flowers. Among these were vernal pool checker mallow with five white petals, each up to one inch long, and a brodiaea with three-quarter-inch-long purple petals.

Phoenix Park's pools also had some unusual plants. Tiny tillaea is a dwarf member of the sedum family, but unlike its relatives, tillaea does not have thick, suc-

Phoenix Park

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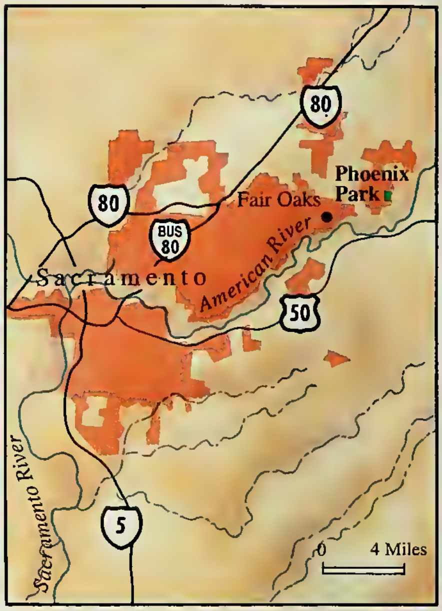


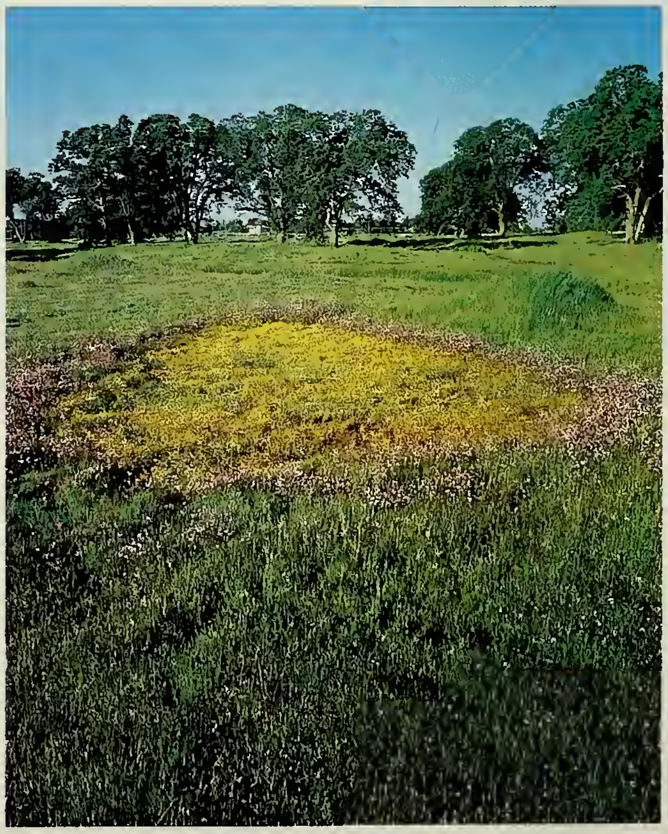
culent leaves. Flowering quillwort is a six-inch-high plant with slender, grasslike leaves and inconspicuous flowers. It is so different from other flowering plants that it is often classified all by itself in its own family.

Four kinds of plants in the Phoenix Park pools reproduce by spores rather than seeds. Although not true ferns, they are usually considered to be related to ferns and are sometimes referred to as fern allies. Three of these are quillworts, similar in appearance to the flowering quillwort except that their leaves arise from a bilobed corm, or swollen underground stem, that lies just below the surface of the soggy soil. Where the leaves attach to the corm, they dilate to form pouches in which the spores are formed.

The other fern ally, known as pillwort, consists of a few strands of grasslike leaves attached to a shallow, underground root system. Once a year, spherical spore cases one-eighth inch in diameter appear at the base of mature plants.

Many of the vernal pools that still exist in California's terraces, valleys, and foothills are on unprotected private lands that are subject to resource development and urban expansion. Unfortunately, these sites are easily accessible, and the pools are thus vulnerable to all-terrain vehicles and even to trampling and overcollecting by biologists.

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



Underlain by a hardpan of clay, a vernal pool collects water during California's mild, wet winters. The same basin, having dried out during the spring, supports a community of wildflowers.
Photographs by Thomas Hallstein; Outsight

Disney Dissonance

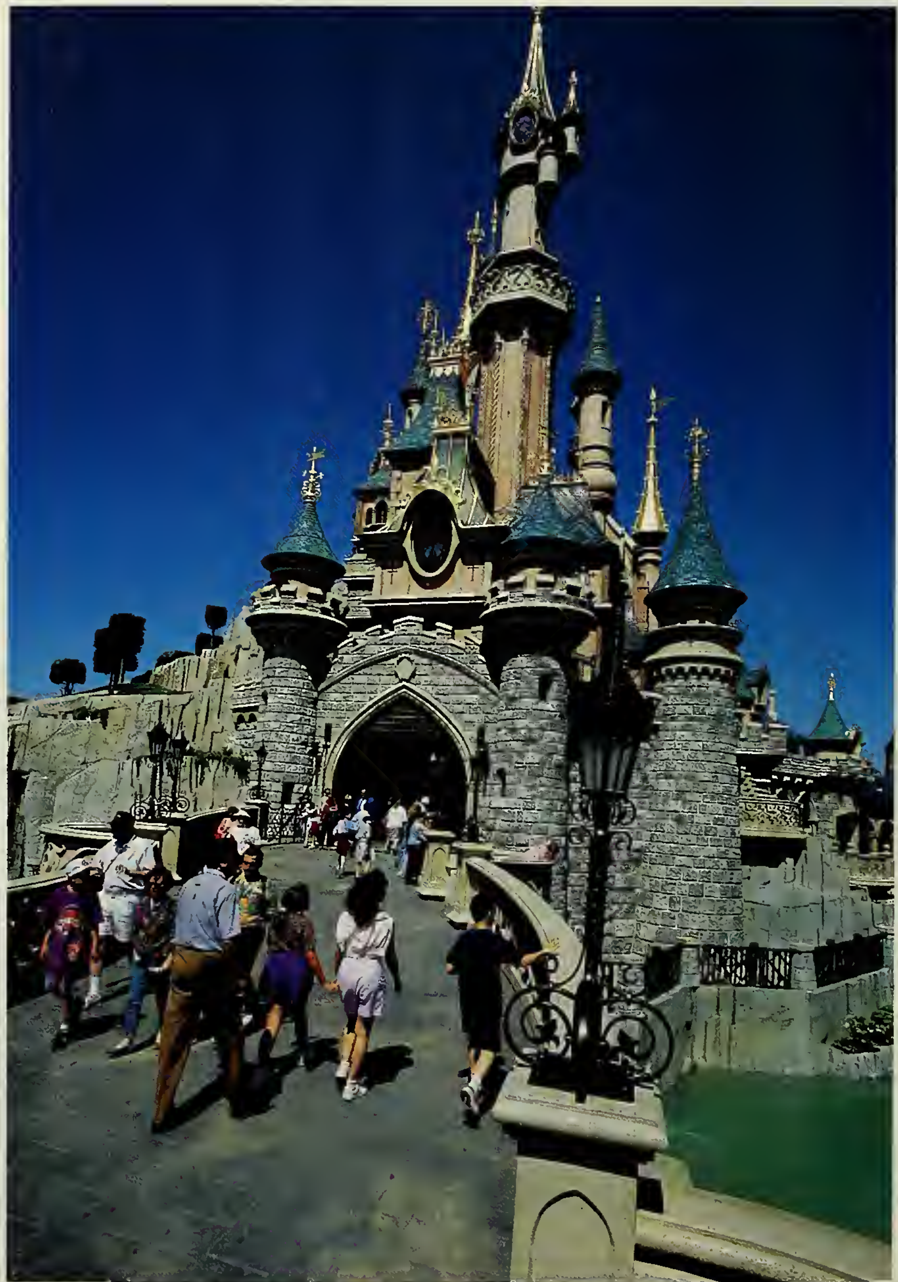
What happens when Americanized tales return to Europe?

by Samuel M. Wilson

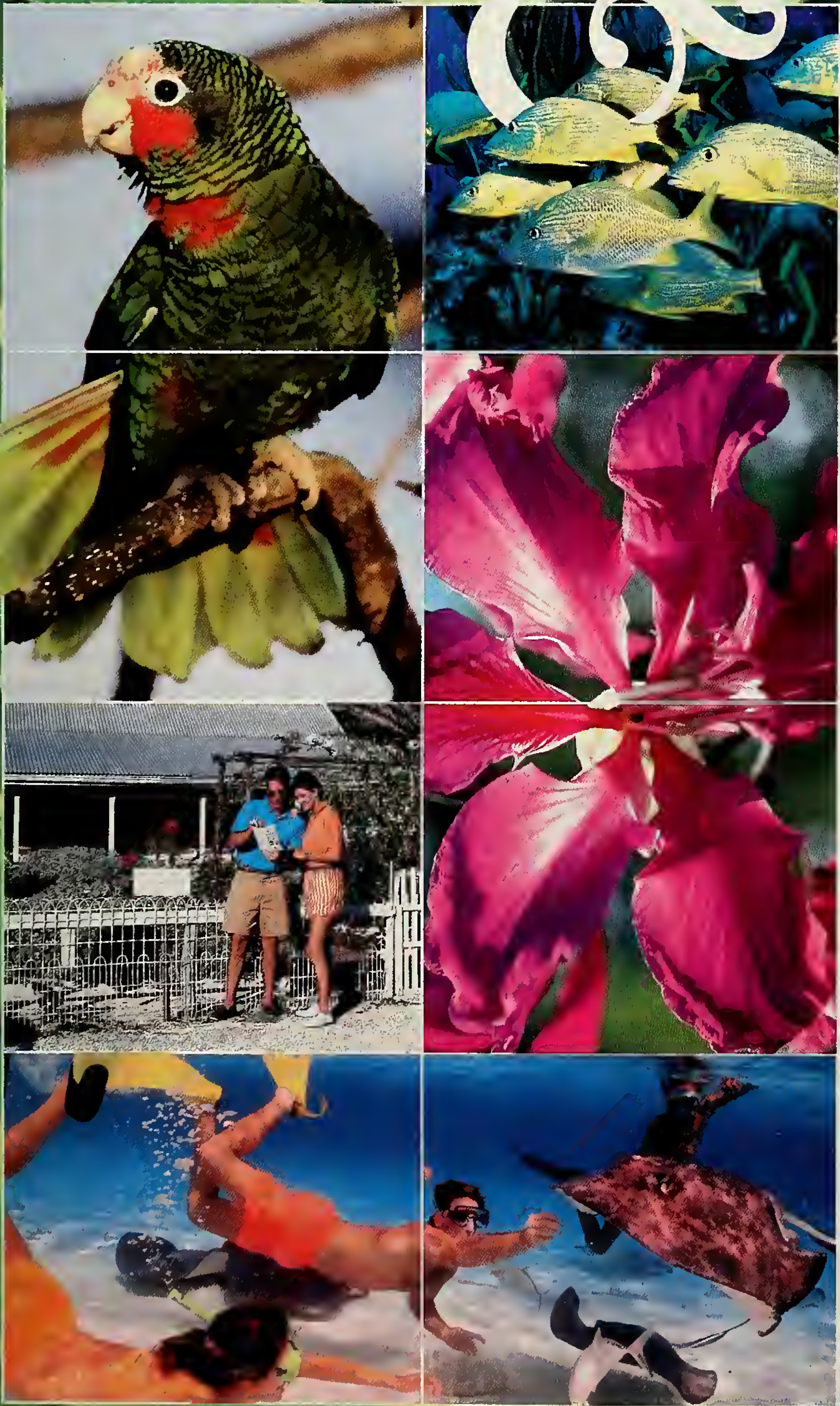
Last year I spent part of the summer with my wife and four-year-old daughter in the small town of Cholet, in the Loire Valley of western France. In the surrounding countryside, we visited some of the magnificent châteaux built between the twelfth and eighteenth centuries by some of Europe's most powerful families. Passing these off to a four-year-old as "castles," however, presented a problem, for none of the buildings measured up to what she thought of as *real* castles. They were nothing like Walt Disney's castles—places associated with stories of princesses and evil stepmothers and dragons—which have soaring spires, flying pennants, ramparts, moats, drawbridges, thrones, and dungeons.

What we saw were very nice houses with thick rock walls, some with moats and well-planted gardens. We explained that these were real castles, where the more down-to-earth versions of the stories happened. But to a four-year-old—who with great forbearance tolerated a land where all the other kids babbled incomprehensibly while her parents ate well and drank wonderful glasses of Vouvray, Sancerre, and Muscadet de Sèvre et Maine—this talk of castles was clearly a case of bait and switch.

All of which led us to visit Euro Disney, east of Paris. I was somewhat reluctant to go, if for no other reason than the considerable entrance fee ($120 for three). But then again, I was curious to see what was behind all the commotion in the French and American press. After opening with great fanfare in April 1992, Euro Disney was reportedly suffering from financial problems. In part, this was attributed to a strong negative reaction by many of the French toward what they perceived as



Tourists at Euro Disney, east of Paris, visit Sleeping Beauty's Castle.
Dave G. Houser



Cayman Airways

American cultural imperialism. (As it happens, we found that in August all the big hotels near the park were booked solid and the place was mobbed, suggesting that the rumors of Euro Disney's demise were exaggerated.)

Driving from Paris, we passed through a plain reminiscent of central Kansas—a basically flat landscape with rolling hills and agricultural fields. Then, with the spires of the Euro Disney castle looming in the distance like the Emerald City of Oz, we came to the fringes of the park, marked by the first of tens of thousands of newly planted trees. The road wound through a series of landforms that seemed characteristically Disneyesque—heavily planted earthen ridges rose just above eye level on both sides. These disorienting features control the way dramatic views unfold in the created landscape and hide the infrastructure of the huge theme park, with its delivery vans and garbage trucks. We parked half a mile away in the Goofy section of the sprawling parking lots and rode conveyer belts to the entrance, inundated with theme songs.

Euro Disney is in many ways spectacular and breathtaking, presenting perfected, idealized worlds with imaginative twists and turns. Every tile, stone, and trash can is custom-made. The "imagineers" are responsible for this; they are a large group of designers who craft wood, metal, plastic, plaster, and concrete to fit their extraordinary vision. In Discoveryland an ornate Victorian blimp docks in a ten-story-high ultramodern structure; nearby, a blasted spacescape of eroded metal and crystalline stone overflows with fountains of sparkling water. And in the center of the park is Sleeping Beauty's Castle—a *real* castle, with proper pennants and ramparts and a rather terrifying robotic dragon in its dungeon.

Even the rocks are manufactured. Someday I would like to research and write the comprehensive geology of Disney. Everywhere I looked, the walls and structures were covered in what one would certainly take for stone. It is all, however, something else—something that without my rock hammer I couldn't positively identify as plastic, fiberglass, or plaster. I counted twenty-four kinds of "rock," and within them all kinds of variations—granite slabs, slate tiles, blocks of dolomite, flaking shales, sparkling micaceous composites, lots of golden limestone, and others that resembled nothing I know of in the real world. There was, I might add, plenty of time to observe these materials as we inched our way along looping lines, waiting to get onto the rides.

We spent half a day in lines, on rides, and touring the attractions and at noon encountered one of Euro Disney's cultural and logistical problems. When midday arrives, the French expect to sit down to a proper meal, complete with table, waiter, wine and bread, and the other basic amenities one would find in any small French town. These things are difficult to find at Euro Disney, and expensive if you do find them. For Americans this is less of a problem; they eat on an irregular schedule and with different expectations.

Despite the pronounced American theme of Mainstreet U. S. A., the easiest fast food to find at Euro Disney is the French version—crusty baguettes split and filled with butter, cheese, and ham. After buying these, one must then find a seat where one can, which in our case was on the curb. On our second day we found a better way around the lunch problem by asking the French "cast members" where to eat. They directed us to Walt's, a quiet restaurant with good food, wonderful service, and in the background, classical string quartet arrangements of the theme songs we had been swimming through. And they served good French wine, something we had been told was forbidden in Euro Disney.

Most extraordinary at Walt's was the decor. The room we were in combined Victorian and Art Nouveau styles with an unusual futuristic twist. The dining room chairs were carved with the dials and trappings of time machines, and everywhere the mahogany woodwork was sculpted in flowing forms. The effect was reminiscent of the interior of Captain Nemo's submarine in the film *20,000 Leagues Under the Sea*. Original sketches and models for that film were all around, along with a remarkable collection of documents and illustrations from other projects. The restaurant and the surrounding art exemplified Walt Disney's utopia—nineteenth-century sensitivities and social order coupled with twenty-first-century technology.

The utopia reflected in the sketches on the walls of Walt's is perhaps Disney's best, unassailable because it is an idealized world that doesn't yet exist. The fantasies dealing with the past run into trouble, however, because no matter how mythical and ahistorical their presentation (as in the Peter Pan-inspired pirates section or Frontierland's Old West), there is a historical past haunting the background. I was especially aware of this at Buffalo Bill's Wild West Show, where you can "conquer the West from your dinner table." The conquering theme was never spelled out, but the way the show was staged made it clear that the only thing that needed conquering were the stereotypical Indians.

Nearly all the attractions in the park are linked to the stories told in Disney films. While many of these stories are based on European works or folk tales, they often

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Mail to: 1 Lands' End Lane, Dodgeville, WI 53595 differ from the more faithful versions that Europeans learn as children. In Sleeping Beauty's Castle, the centerpiece of Euro Disney, we climbed the stairs of the grand hall and walked through scenes from Disney's story of Sleeping Beauty. As we milled about in the crowd, we saw parents from all over Europe making quick interpretations—apparently trying to connect the Disney characters and events to those that their children knew.

Disney's Sleeping Beauty is but the prologue to a more sinister traditional tale, recounted in complete form by the French writer Charles Perrault (1628–1703). Perrault's version begins much the same as Disney's: a king and queen have a daughter after great difficulty conceiving. They invite the kingdom's seven fairies to the christening, so that each might bless the child with a gift. But they neglect to invite an old fairy who has been in seclusion for fifty years. The daughter is given gifts by six of the fairies—beauty, wit, grace, and so on—but the old fairy puts a spell on her that will cause her to die from pricking her finger on the spindle of a spinning wheel. The last good fairy, who has hidden in the draperies suspecting some meanness from the old one, comes out and commutes the spell to a sleep of one hundred years.

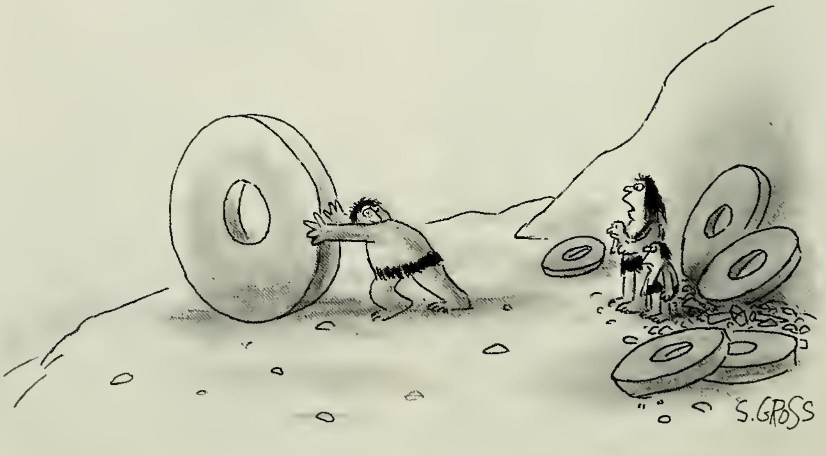
The princess grows up and, as foretold, pricks her finger and falls into her deep sleep. The seventh good fairy puts all the servants in the castle to sleep as well, so that the princess will not awaken alone, and causes thick vines to grow up around the castle. After a century, another family is on the throne (thus is incest averted), and the story of the princess and the spell has been nearly forgotten. The kingdom's prince is intrigued by the castle and enters, finding the princess. With his kiss, he breaks the spell. At this point, in Disney's version, the couple then live happily ever after.

Perrault's story continues, however. The prince and princess marry and have two children, but the prince keeps all this secret from his parents, the king and queen. Although the prince loves the queen, he does not trust her, for she is of the race of ogres. He fears she will succumb to her ogreish impulses, which include a taste for human flesh, especially that of tender young children.

The old king dies and the prince takes the throne, acknowledging his marriage to Sleeping Beauty and bringing her and their children into the capital. Soon he goes to war, however, and has to leave the kingdom and his family in the care of the old queen. The ogre in the queen soon expresses itself, and she orders the cook to serve up first the children and finally Sleeping Beauty herself for dinner. The clever cook fools her by substituting other meats and hiding the intended victims.

But the queen discovers the ruse and commands them all, including the cook and his family, to be bound and thrown into a tub crawling to the brim with toads and poisonous snakes. The prince, now king, returns in the nick of time to save them, and his enraged mother throws herself headfirst into the tub and is devoured. Only then, in Perrault's version, do they all live happily ever after.

The characters in Perrault's story are enmeshed in the politics of families and kingdoms and have difficult decisions to make. Good and evil are not spelled out so clearly as in Disney's tale; the villainous characters' evil is an inescapable part of their nature, which includes both good and evil, and is not the result of their jealousy or ambition. Perrault's Sleeping Beauty is a more complex fable, which may be read



"Why can't you hunt like the others instead of making us live off road kill?"

at several levels and with several morals.

Like the Disney version of Sleeping Beauty, the other Disney films adapted from European sources—*Cinderella, Snow White, The Little Mermaid, Pinocchio, Sword in the Stone, Robin Hood, Alice in Wonderland, Beauty and the Beast, Peter Pan*—are very much altered. Mickey Mouse, an original Disney creation, is popular in Europe, but the other characters do not seem to inspire as strong a reaction. The films have at their foundations a set of values that Disney believed in—for example, that through the unwavering conviction of moral individuals, good will prevail over evil, even against seemingly impossible odds. These values struck such a chord among Americans that the movies became very successful. But one cannot expect audiences from other cultures to react to Disney's message in the same way.

After our second long, hot day of lines and crowds and last dashes here and there, we left Disney's world and headed for western France, encountering Paris's all too real rush-hour traffic. The next day, still heading west, we stopped at another château (we had stopped calling them castles) and experienced firsthand what it is like to see a theme-park representation of a story different from the version we heard as children.

We took our daughter to the Château d'Ussé, said to have been the setting Charles Perrault had in mind while writing his version of Sleeping Beauty. In rooms high in the château, a series of scenes from the story were created with props and mannequins. Some of the scenes worked equally well for both the Perrault version and Disney's, but where they applied only to the older plot, we had a lot of explaining to do.

Child: Where's Maleficent?

Parent: (pointing to a mannequin that looked as if it were modeling royal bathrobes): That's Maleficent.

Child: No, where's the evil fairy, the mean one?

Parent: That's her.

(Child gives a sideways glance meaning, "Is this a joke?")

Thereafter we stayed away from European attractions that portrayed versions of stories that were different from those our daughter knew. I think that some Europeans have decided to steer clear of Euro Disney for similar reasons.

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☐ Black ☐ White ☑ Other

Racial categories are cultural constructs masquerading as biology

by Jonathan Marks

While reading the Sunday edition of the *New York Times* one morning last February, my attention was drawn by an editorial inconsistency. The article I was reading was written by attorney Lani Guinier. (Guinier, you may remember, had been President Clinton's nominee to head the civil rights division at the Department of Justice in 1993. Her name was hastily withdrawn amid a blast of criticism over her views on political representation of minorities.) What had distracted me from the main point of the story was a photo caption that described Guinier as being "half-black." In the text of the article, Guinier had described herself simply as "black."

David Burnett; CPI

How can a person be black and half black at the same time? In algebraic terms, this would seem to describe a situation where $x = \frac{1}{2}x$, to which the only solution is $x = 0$.

The inconsistency in the *Times* was trivial, but revealing. It encapsulated a longstanding problem in our use of racial categories—namely, a confusion between biological and cultural heredity. When Guinier is described as "half-black," that is a statement of biological ancestry, for one of her two parents is black. And when Guinier describes herself as black, she is using a cultural category, according to which one can either be black or white, but not both.

Race—as the term is commonly used—is inherited, although not in a strictly biological fashion. It is passed down according to a system of folk heredity, an all-or-nothing system that is different from the quantifiable heredity of biology. But the incompatibility of the two notions of race is sometimes starkly evident—as when the state decides that racial differences are so important that interracial marriages must be regulated or outlawed entirely. Miscegenation laws in this country (which stayed on the books in many states through the 1960s) obliged the legal system to define who belonged in what category. The resulting formula stated that anyone with one-eighth or more black ancestry was a "negro." (A similar formula, defining Jews, was promulgated by the Germans in the Nuremberg Laws of the 1930s.)

Applying such formulas led to the biological absurdity that having one black great-grandparent was sufficient to define a person as black, but having seven white great-grandparents was insufficient to define a person as white. Here, race and biology are demonstrably at odds. And the problem is not semantic but conceptual, for race is presented as a category of nature.

Human beings come in a wide variety of sizes, shapes, colors, and forms—or, because we are visually oriented primates, it certainly seems that way. We also come in larger packages called populations; and we are said to belong to even larger and more confusing units, which have long been known as races. The history of the study of human variation is to a large extent the pursuit of those human races—the attempt to identify the small number of fundamentally distinct kinds of people on earth.

This scientific goal stretches back two centuries, to Linnaeus, the father of biological systematics, who radically established *Homo sapiens* as one species within a group of animals he called Primates. Linnaeus's system of naming groups within groups logically implied further breakdown. He consequently sought to establish a number of subspecies within *Homo sapiens*. He identified five: four geographical species (from Europe, Asia, Africa, and America) and one grab-bag subspecies called *monstrosus*. This category was dropped by subsequent researchers (as was Linnaeus's use of criteria such as personality and dress to define his subspecies).

While Linnaeus was not the first to divide humans on the basis of the continents on which they lived, he had given the division a scientific stamp. But in attempting to determine the proper number of subspecies, the heirs of Linnaeus always seemed to find different answers, depending upon the criteria they applied. By the mid-twentieth century, scores of anthropologists—led by Harvard's Earnest Hooton—had expended enormous energy on the problem. But these scholars could not convince one another about the precise nature of the fundamental divisions of our species.

Part of the problem—as with the *Times*'s identification of Lani Guinier—was that we humans have two constantly intersecting ways of thinking about the divisions among us. On the one hand, we like to think of "race"—as Linnaeus did—as an objective, biological category. In this sense, being a member of a race is supposed to be the equivalent of being a member of a species or of a phylum—except that race, on the analogy of subspecies, is an even narrower (and presumably more exclusive and precise) biological category.


Alon Reininger; CPI

The other kind of category into which we humans allocate ourselves—when we say "Serb" or "Hutu" or "Jew" or "Chicano" or "Republican" or "Red Sox fan"—is cultural. The label refers to little or nothing in the natural attributes of its members. These members may not live in the same region and may not even know many others like themselves. What they share is neither strictly nature nor strictly community. The groupings are constructions of human social history.

Membership in these *un*biological groupings may mean the difference between life and death, for they are the categories that allow us to be identified (and accepted or vilified) socially. While membership in (or allegiance to) these categories may be assigned or adopted from birth, the differentia that mark members from nonmembers are symbolic and abstract; they serve to distinguish people who cannot be readily distinguished by nature. So important are these symbolic distinctions that some of the strongest animosities are often expressed between very similar-looking peoples. Obvious examples are Bosnian Serbs and Muslims, Irish and English, Huron and Iroquois.

Obvious natural variation is rarely so important as cultural difference. One simply does not hear of a slaughter of the short people at the hands of the tall, the glabrous at the hands of the hairy, the red-haired at the hands of the brown-haired. When we do encounter genocidal violence between different-looking peoples, the two groups are invariably socially or culturally distinct as well. Indeed, the tragic frequency of hatred and genocidal violence between biologically indistinguishable peoples implies that biological differences such as skin color are not motivations but, rather, excuses. They allow nature to be invoked to reinforce group identities and antagonisms that would exist without these physical distinctions. But are there any truly "racial" biological distinctions to be found in our species?

Obviously, if you compare two people from different parts of the world (or whose ancestors came from different parts of the world), they will differ physically, but one cannot therefore define three or four or five basically different kinds of people, as a biological notion of race would imply. The anatomical properties that distinguish people—such as pigmentation, eye form, body build—are not clumped in discrete groups, but distributed along geographical gradients, as are nearly all the genetically determined variants detectable in the human gene pool.

These gradients are produced by three forces. Natural selection adapts populations to local circumstances (like climate) and thereby differentiates them from other populations. Genetic drift (random fluctuations in a gene pool) also differentiates populations from one another, but in non-adaptive ways. And gene flow (via intermarriage and other child-producing unions) acts to homogenize neighboring populations.

In practice, the operations of these forces are difficult to dis-

☐ Black ☐ White ☐ Other

cern. A few features, such as body build and the graduated distribution of the sickle cell anemia gene in populations from western Africa, southern Asia, and the Mediterranean can be plausibly related to the effects of selection. Others, such as the graduated distribution of a small deletion in the mitochondrial DNA of some East Asian, Oceanic, and Native American peoples, or the degree of flatness of the face, seem unlikely to be the result of selection and are probably the results of random biohistorical factors. The cause of the distribution of most features, from nose breadth to blood group, is simply unclear.

Leong Ka Tai; Material World

The overall result of these forces is evident, however. As Johann Friedrich Blumenbach noted in 1775, "you see that all do so run into one another, and that one variety of mankind does so sensibly pass into the other, that you cannot mark out the limits between them." (Posturing as an heir to Linnaeus, he nonetheless attempted to do so.) But from humanity's gradations in appearance, no defined groupings resembling races readily emerge. The racial categories with which we have become so familiar are the result of our imposing arbitrary cultural boundaries in order to partition gradual biological variation.

Unlike graduated biological distinctions, culturally constructed categories are ultrasharp. One can be French or German, but not both; Tutsi or Hutu, but not both; Jew or Catholic, but not both; Bosnian Muslim or Serb, but not both; black or white, but not both. Traditionally, people of "mixed race" have been obliged to choose one and thereby identify themselves unambiguously to census takers and administrative bookkeepers—a practice that is now being widely called into question.

A scientific definition of race would require considerable homogeneity within each group, and reasonably discrete differences between groups, but three kinds of data militate against this view: First, the groups traditionally described as races are not at all homogeneous. Africans and Europeans, for instance, are each a collection of biologically diverse populations. Anthropologists of the 1920s widely recognized *three* European races: Nordic, Alpine, and Mediterranean. This implied that races could exist within races. American anthropologist Carleton Coon identified *ten* European races in 1939. With such protean use, the term race came to have little value in describing actual biological entities within *Homo sapiens*. The scholars were not only grappling with a broad north–south gradient in human appearance across Europe, they were trying to bring the data into line with their belief in profound and fundamental constitutional differences between groups of people.

But there simply isn't one European race to contrast with an African race, nor three, nor ten: the question (as scientists long posed it) fails to recognize the actual patterning of diversity in the human species. Fieldwork revealed, and genetics later quantified, the existence of far more biological diversity within any group than between groups. Fatter and thinner people exist everywhere, as do people with type O and type A blood. What generally varies from one population to the next is the *proportion* of people in these groups expressing the trait or gene. Hair color varies strikingly among Europeans and native Australians, but little among other peoples. To focus on discovering differences between presumptive races, when the vast majority of detectable variants do not help differentiate them, was thus to define a very narrow—if not largely illusory—problem in human biology. (The fact that Africans are biologically more diverse than Europeans, but have rarely been split into so many races, attests to the cultural basis of these categorizations.)

Second, differences between human groups are only evident when contrasting geographical extremes. Noting these extremes, biologists of an earlier era sought to identify representatives of "pure," primordial races—presumably located in Norway, Senegal, and Thailand. At no time, however, was our species composed of a few populations within which everyone looked pretty much the same. Ever since some of our ancestors left Africa to spread out through the Old World, we humans have always lived in the "in-between" places. And human populations have also always been in genetic contact with one another. Indeed, for tens of thousands of years, humans have had trade networks; and where goods flow, so do genes. Consequently, we have no basis for considering *extreme* human forms the most pure, or most representative, of some ancient primordial populations. Instead, they represent populations adapted to the most disparate environments.

And third, between each presumptive "major" race are unclassifiable populations and people. Some populations of India, for example, are darkly pigmented (or "black"), have Europeanlike ("Caucasoid") facial features, but inhabit the continent of Asia (which should make them "Asian"). Americans might tend to ignore these "exceptions" to the racial categories, since immigrants to the United States from West Africa, Southeast Asia, and northwest Europe far outnumber those from India. The very existence of unclassifiable peoples undermines the idea that there are just three human biological groups in the Old World. Yet acknowledging the biological distinctiveness of such groups leads to a rapid proliferation of categories. What about Australians? Polynesians? The Ainu of Japan?

Categorizing people is important to any society. It is, at some basic psychological level, probably necessary to have group identity about who and what you are, in contrast to who and what you are not. The concept of race, however, specifically involves the recruitment of biology to validate those categories of self-identity.

Dilip Mehta; CPI

Mice don't have to worry about that the way humans do. Consequently, classifying them into subspecies entails less of a responsibility for a scientist than classifying humans into subspecies does. And by the 1960s, most anthropologists realized they could not defend any classification of *Homo sapiens* into biological subspecies or races that could be considered reasonably objective. They therefore stopped doing it, and stopped identifying the endeavor as a central goal of the field. It was a biologically intractable problem—the old square-peg-in-a-round-hole enterprise; and people's lives, or welfares, could well depend on the ostensibly scientific pronouncement. Reflecting on the social history of the twentieth century, that was a burden anthropologists would no longer bear.

This conceptual divorce in anthropology—of cultural from biological phenomena—was one of the most fundamental scientific revolutions of our time. And since it affected assumptions so rooted in our everyday experience, and resulted in conclusions so counterintuitive—like the idea that the earth goes around the sun, and not vice-versa—it has been widely underappreciated.

Kurt Vonnegut, in *Slaughterhouse Five*, describes what he remembered being taught about human variation: "At that time, they were teaching that there was absolutely no difference between anybody. They may be teaching that still." Of course there are biological differences between people, and between populations. The question is: How are those differences patterned? And the answer seems to be: Not racially. Populations are the only readily identifiable units of humans, and even they are fairly fluid, biologically similar to populations nearby, and biologically different from populations far away.

In other words, the message of contemporary anthropology is: You may group humans into a small number of races if you want to, but you are denied biology as a support for it. □

Near Cocos Island, off the Pacific coast of Costa Rica, a green turtle and schooling creole-fish are silhouetted against the sun.
Marty Snyderman

Tracking Turtles Through Time

Genetic testing confirms that these ancient mariners return to nest at their natal beaches, no matter how distant

by Brian W. Bowen and John C. Avise

In the early hours of a tropical January morning in 1989, we were sprawled on the sandy beach of Ascension Island, peering toward the dark ocean, waiting for the next nesting green turtle to arrive. A volcanic rock five miles in diameter, Ascension rises from an undersea ridge in the middle of the Atlantic Ocean, about 1,400 miles from Brazil to the west and 1,900 miles from Angola to the east. The island may seem an unlikely breeding site for hundreds of creatures that spend most of their lives feeding on seaweed off the coast of South America. But at about 2:00 A.M., our first egg layer appeared, emerging slowly from the surf like some prehistoric monster. We remained still as she hauled her bulk ashore, passing within feet of us. Breathing heavily and showering us with sand from her thrusting flippers, the turtle set to the task of digging her nest.

Within an hour, the quarter-ton creature had excavated a pit about three and a half feet deep and six feet in diameter; at the bottom she carved out a rounded chamber with her hind feet. Next, she deposited more than 100 eggs, which resembled Ping–Pong balls. At first wary and skittish, she became oblivious to any disturbance once she began to lay. We took a single egg for genetic analysis and left her alone. Within two hours, the turtle had buried her eggs and returned to the sea, where she would remain for about two weeks until she was ready to lay another clutch.

From December to March each year, hundreds of female green turtles nest on Ascension, and their excavations crater the beaches. This tiny island is the only port of call in a remarkable journey. Some weeks earlier, the females left the rich seaweed feeding pastures along the coast of Brazil to embark on a 2,800-mile round trip to this solitary speck of land in the midst of open ocean. Once here, they deposit eggs on the beach every two weeks for a two-month period. Then, without benefit of their usual diet during the entire odyssey, they return to the Brazilian coast. Each female that nests on Ascension repeats this migratory circuit every few years during her reproductive life span of perhaps half a century or more.

We had made the long journey to Ascension Island, via a U. S. Air Force cargo jet, as part of our global study of green turtle behavior and evolution. Among other questions, we wanted to determine the evolutionary age of the Ascension Island rookery by comparing its breeding population's DNA with that of other nesting colonies. The late biologist Archie Carr, the father of marine turtle research, had stood on these same beaches some thirty years earlier and wondered why Ascension's green turtles had established such an improbable and arduous migratory circuit. Why not nest on convenient, sandy beaches along the South American coastline, where others of their species have found suitable nesting areas near feeding grounds?

Carr, like other naturalists of his day, was stymied in his study of green turtles. They range over vast areas of ocean, have generation lengths measured in decades, and seem to disappear entirely at certain times in their life cycle. New methods,

however, are beginning to reveal their natural history. Barnacles attached to turtle shells can be used to help map the reptile's migration routes. Age and growth rates can be read from annual layers of bone deposits, and telemetric pressure gauges can transmit individuals' diving depths back to researchers.

Our studies of the turtle's molecular genetics are providing another part of the story. To test various theories about turtle nesting behavior and population dynamics, we have been sampling mitochondrial DNA (mtDNA), a genetic marker transmitted only through the female line. We collect our mtDNA directly from freshly laid eggs in the wild.

Carr hypothesized that when Africa and South America were separated by a narrow channel some 60 to 80 million years ago, the ancestors of the present-day Ascension turtles may have colonized a proto-Ascension Island lying between the two continents. Over the ensuing tens of millions of years, the island, driven by continental drift, crept seaward by an inch or two each year, while the turtles responded by extending their migratory circuit just slightly each generation. Carr assumed that green turtles instinctively return to their natal beach, and that this population gradually followed the island's movement to its present position.

His bold hypothesis could not be tested at the time, but today we can bring molecular genetics to bear on the problem. If true, Carr's idea would imply, first, that female green turtles possess an instinctual drive (as well as the navigational capacity) to return to their natal site. Second, suitable nesting habitat would have to have been present continuously throughout the 65 million years of the Cenozoic era in an unbroken series of proto-Ascension Islands. Third, an Ascension population separated for 60 million years or more should exhibit large, measurable differences in its mtDNA from populations that nest elsewhere in the Atlantic. At our molecular genetics laboratory at the University of Georgia, and in collaboration with Anne Meylan of the Florida Marine Research Institute, we put the last proposition to a critical test.

MtDNA, a molecule that evolves rapidly, has been extremely useful as a genetic marker for defining female lineages within species (*see* "Nature's Family Archives," *Natural History,* March 1989). Our genetic assays of the green turtles'

Howard Hall

Green turtles near the Great Barrier Reef mate on the sea floor, left, about fifty feet underwater. Such pairs are often active near the surface as well. Map: Hundreds of female green turtles navigate 1,400 miles from Brazil to lay their eggs on Ascension Island, an isolated speck of land in the Atlantic Ocean. They stay near the island's beaches for weeks, deposit several clutches of eggs, then return to South America.

Joe LeMonnier

mtDNA produced clear results. Although there was a demonstrable genetic difference between the Ascension Island colony and most other Atlantic Ocean nesting populations, such as those in Suriname, Costa Rica, Venezuela, and Florida, the divergence was small. Based on the genetic differences between local populations, we found that Ascension must have been colonized within the last million years or, possibly, even much more recently. We believe, therefore, that continental drift was not a relevant factor. Nevertheless, Carr's imaginative scenario provided the stimulus for our genetic work and continuing investigations into green turtle behavior and evolution.

Green turtles are observed most easily when the females come ashore to nest and when the hatchlings first enter the sea. Young turtles emerge from the nest after an incubation period of eight weeks and—after running the gauntlet of gulls and other predators—immediately scramble into the ocean. No one knows precisely where they go for the next several years, but most scientists suspect that they drift in surface currents and ocean gyres. During this phase, their shells are bluish black on top and ivory white underneath—a coloration that makes them difficult to spot from both below and above the ocean's surface. Perhaps they traverse entire oceanic basins amid rafts of floating sargassum, feeding on the small animals and plants that live among these clumps of vegetation. Eventually, the juveniles begin to forage near the coast and switch to a primarily herbivorous adult diet. They do not become sexually mature until they are perhaps about thirty years old.

Since only females routinely ascend the nesting beaches, much of what is known about the green turtle's life cycle has come from tagged adult females. Based on recoveries of metal or plastic tags clamped on the turtles' flippers, the migration routes for several rookery populations have been traced. Typical females, like those in the Ascension population, migrate hundreds or even one or two thousand miles between nesting and feeding areas. Yet remarkably, each adult female returns faithfully to the same nesting beach season after season. Of the more than 28,000 nesting females tagged over the last thirty years at a large rookery in Tortuguero, Costa Rica, not one has ever been recovered nesting at another site. However, because no method was available to mark baby turtles with a physical tag that could survive the decades-long growth to maturity, researchers couldn't determine whether the adult females were returning to the site of their own hatching.

Many scientists suspect that female turtles become "imprinted" on their natal site and return to it as adults, as salmon and some other animals are known to do. But other explanations have also been proposed. Females may choose their first nesting site for some physical attribute it possesses and then, if egg laying is successful, fix upon that beach for all subsequent nesting. Another possibility is that inexperienced females may follow an experienced nester to a rookery and then return to that location throughout adult life. If either of these scenarios is true, there should be a good deal of genetic exchange (and therefore similarity) between populations of nesting females, particularly those

On a Galápagos island, a female green turtle digs her nest on a sandy beach, below, a feat usually accomplished in the middle of the night. A clutch of round and leathery turtle eggs, right, from Turtle Island, Borneo, are covered with sand and left to hatch in the sun's warmth with no further maternal attention. Baby turtles, far right, emerge from eggs after forty-five to sixty days. These hatchlings have been removed from the nest but not harmed; if undisturbed, they would have dug their way out of the sand.
Frans Lanting; Minden Pictures

that share feeding grounds or migration routes.

If turtles returned only to the beaches of their birth, however, the mtDNA differences between breeding populations should be well marked. Our mtDNA tests support this idea. Gene pools of many turtle rookeries around the world proved to be easily distinguishable from one another, which indicates considerable geographical isolation of female lineages. For example, when they are not nesting, turtles from the Ascension Island and Suriname rookeries mingle freely as they graze on algal seaweed "pastures" along the Brazilian coast. Yet eggs from fifty nests showed that no mtDNA genotypes were shared by these two colonies. Such findings lend support to the natal-homing hypothesis and are inconsistent with the idea that young females may learn the migration route by following older females.

While our genetic evidence supports the natal-homing hypothesis, the evolutionary divergence between nesting populations is quite small. If female lineages are exclusively attached to particular natal beaches over long periods of time, why aren't the genetic separations between populations much greater? One possibility is that some females occasionally switch

M. Harvey; Natural Science Photos

Yusuke Yoshino; Nature Production

nesting sites, thereby providing a trickle of genetic exchange between rookeries. Indeed the presence of rare, "vagabond" females that nest at more than one site has been documented in studies of marked individuals. One female tagged at a Venezuelan rookery (Aves Island), for instance, was later sighted nesting in Puerto Rico, some 400 miles distant, and another marked on Tromelin Island in the Indian Ocean was subsequently observed nesting on Europa Island, 1,300 miles away.

Another explanation for the shallow evolutionary separation between green turtle populations is the ephemeral nature of rookeries over geologic time. Even before they were decimated by humans, many rookeries may have been destroyed by natural processes, including intense predation of young or eggs, disease, climatic shifts, and destruction of beaches by hurricanes or changes in sea level. Much of present-day Ascension Island is now less than 300 feet above ocean level. Because the island slopes steeply and narrowly to a sharp central peak, a rise of a few hundred feet in sea level would submerge all the island's nesting beaches and result either in extinction of the colony or perhaps a mass exodus of turtles to other nesting sites. Since appropriate nesting areas emerge and disappear across geologic time, perfect natal homing by all turtles would lead to extinction, for the creatures would be putting all their eggs in too few geologic baskets. Through the long-term turnover of rookeries, however, all green turtles within an ocean basin might still exchange enough genetic material to evolve in concert, notwithstanding the accumulation of shallow genetic differences among nesting colonies.

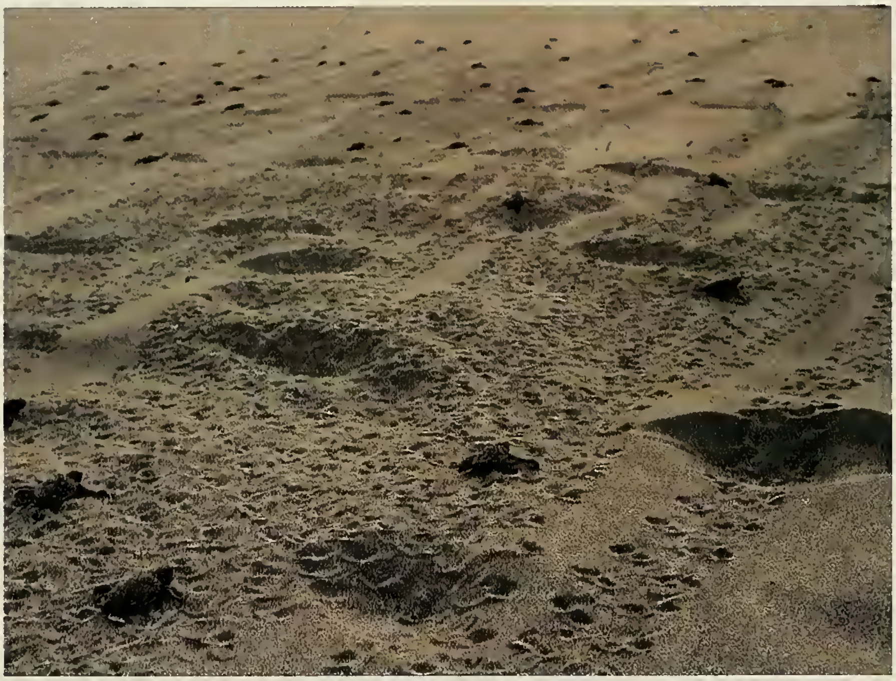
When Columbus navigated the Caribbean five centuries ago, green turtles were abundant, with perhaps millions of adults in that area alone, compared with a few hundred thousand today. By the end of the seventeenth century, the largest rookery (at Cayman Island) had been exterminated by overharvesting of eggs and adults, and turtles have never returned to nest there. Several other rookeries suffered a similar fate at human hands and have not been recolonized, presumably because of the strong propensity for natal homing. Thus, direct experience with extirpated colonies is consistent with the natal-homing scenario for green turtles. On the other hand, some of the islands where turtles nested in pre-Columbian times are suspected of being only a few thousand years old, so they must have been colonized by the turtles fairly recently. Most likely, green turtle nesting colonies become isolated in the short run—decades or centuries—because females return to their natal rookeries, yet remain connected over tens of thousands of years by periodic turnover and occasional genetic exchange between colonies.

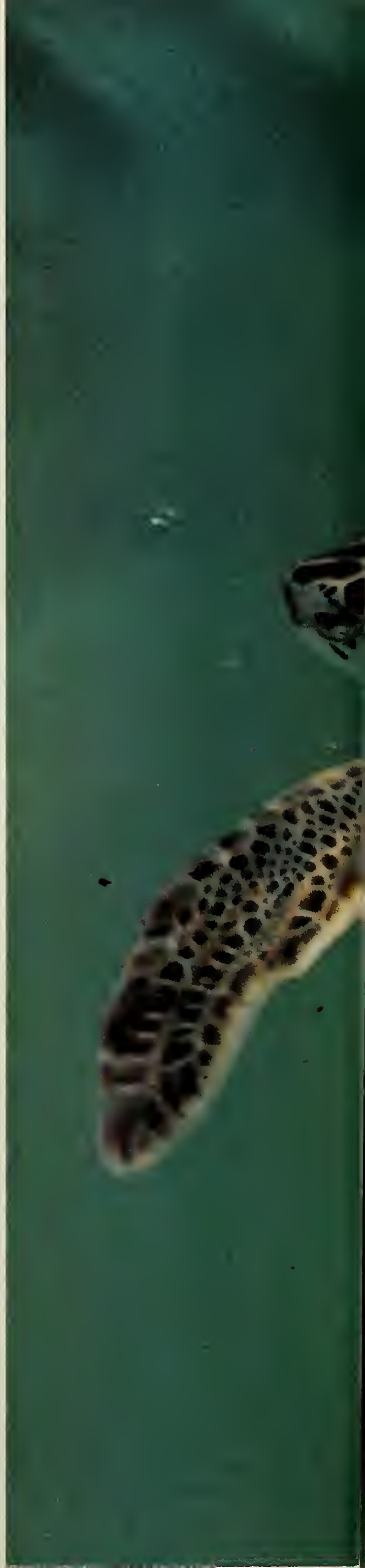
The navigational signals that guide the great migrations of green turtles remain a mystery. Their sense of smell may play a role, since marine turtles are known to possess fine discrimination for soluble chemicals. Ken and Catherine Lohmann, of the University of North Carolina, have recently demonstrated a geomagnetic sense, perhaps related to a magnetite pocket in the brain, that could provide turtles with an internal compass. Celestial cues, inertial guidance, and sensitivity to other environmental markers may also be involved. Whatever the mechanism, the small genetic separations between rookeries suggest that migratory routes to specific destinations such as Ascension Island may not be genetically fixed, or "instinctual." More likely, all green turtles share a capacity to rapidly learn cues to the location of their nesting beach during a critical period of early development. Thus imprinted, the individuals retain the information into adulthood, when they can use it

Douglas Perrine

Pocked with many nests, a beach on Chichi, one of Japan's Ogasawara Islands, serves as a rookery for green turtles, below. Hundreds of newly hatched babies scramble for the comparative safety of the ocean. Right: A young adult turtle, swimming in a tank at a Florida research station, shows its characteristic brown colors. Pigmented by a herbivorous diet, the turtle's internal fatty tissues are usually greenish yellow; it received the common name of green turtle from sailors who dined on its meat.

Yusuke Yoshino; Nature Production





to guide themselves home. Early learning, rather than "hard-wired" genetic behavior, would allow a more flexible response to altered nesting conditions, so that new migrational pathways could be established in even a single generation.

Since DNA from turtle cells' mitochondria is transmitted only in the maternal line, our mtDNA studies shed some light on the migrations of female turtles but have left unanswered similar questions about males. Although most spend their entire lives at sea, some males do accompany females to nesting areas, and a number of males tagged at breeding sites have returned to the same locations in subsequent years.

To learn more about the role of males in green turtle populations, our colleague Stephen Karl, now at the University of South Florida, studied genes transmitted through both parents. Using DNA from cell nuclei, which include the male's contribution, he found that samples from most nesting colonies share the same alleles (variants of genes), but in significantly different frequencies. (An analogy in humans would be to compare the appearance of blue eyes in England and Scandinavia. Both populations have the allele for blue eye color, but it appears much more often in the Scandinavian population.) In short, Karl's data show a moderate level of genetic exchange between rookeries. Since the rookeries appear to be isolated with respect to female (mtDNA) lineages, most genetic interchange must be mediated by males. Apparently, males occasionally mate with females from sites other than their own natal beach, allowing some exchange of genes between colonies that are relatively distinct on the maternal side.

What bearing do these genetic studies have on conservation plans for this endangered species? Despite our discovery of some intercolony gene flow through the males, green turtles should not be managed as if they were a single, homogeneous population. The independent female lineages at each nesting beach are a key feature of turtle demographics. Because females generally lay eggs in the vicinity of the beach where they were born, any extirpated rookery would not become naturally replenished over the short-term time scale of a few human generations. Each rookery, therefore, is a distinct natural treasure. □

The largest of the damselfishes, a garibaldi can deliver a painful bite in defense of its nest.
David Hall

Honey, I Ate the Kids

For garibaldi fish, devouring their offspring is not always a bad thing

by Paul C. Sikkel

After a ten-minute excursion, the female fish reversed course and headed back to her territory, navigating through a shallow forest of kelp anchored to the rocky reef below. The calm, clear water of Big Fisherman Cove, on the leeward side of California's Santa Catalina Island, enabled me to spy on her from fifty feet away. Her abdomen was swollen with eggs, and she swam in a rapid, rather uncoordinated manner. Upon arriving at her territory, she quickly expelled the surfperch and other fish intruders that had accumulated in her absence. She then retired to a crevice, emerging occasionally to pick small invertebrates from the boulders and clumps of iridescent bottom algae.

After a five-minute rest, she left her territory again. As she swam past a male, he performed three quick, vertical loops while making loud, thumping noises with his pharyngeal teeth. Each loop brought him closer to his nest, a mat of algae anchored to a boulder. Abruptly reversing her course, the female followed him to the nest, only to leave seconds later.

I had been tracking the female for more than two hours, and the air supply in my scuba tank had nearly expired. I wondered, "What's it going to take for her to spawn?" She had already traveled more than 100 yards along the perimeter of the cove and had visited a dozen males. Finally, she bellied up to the nest of Split-fin, a male marked by a narrow escape from a seal's jaws, and spawned. As she deposited thousands of tiny, bright yellow, elliptical eggs, the chosen male hovered excitedly in front of his nest, passing over it occasionally to shed his spermatozoa. The female completed her spawn in about fifteen minutes and left the male to resume his parental duties.

For a month, Split-fin had performed his courtship ritual every day without success, but recently he had become the most popular male in the cove. The color of the other eggs in his algal nest indicated that for the last four days, he had spawned each day. The newest eggs in his nest were bright yellow, but older ones were increasingly gray as dark pigments accumulated around the yolk sac. He worked as if he had just downed a double espresso, fanning the nest and chasing away small gobies and wrasses, which await any opportunity to pluck eggs from the nest. His parental devotion seemed complete. Then, he maneuvered toward the oldest clutch of eggs, which was four days old, and with several well-considered bites, each removing a circular patch of about 200 eggs, he devoured it!

The cannibal was a garibaldi fish (*Hypsypops rubicundus*), named after the Italian patriot who commanded a rebel army known as the Red Shirts. At about a foot long, the garibaldi is the largest of all the damselfishes and one of only two species of the predominantly tropical family that has invaded the temperate waters of coastal southern California.

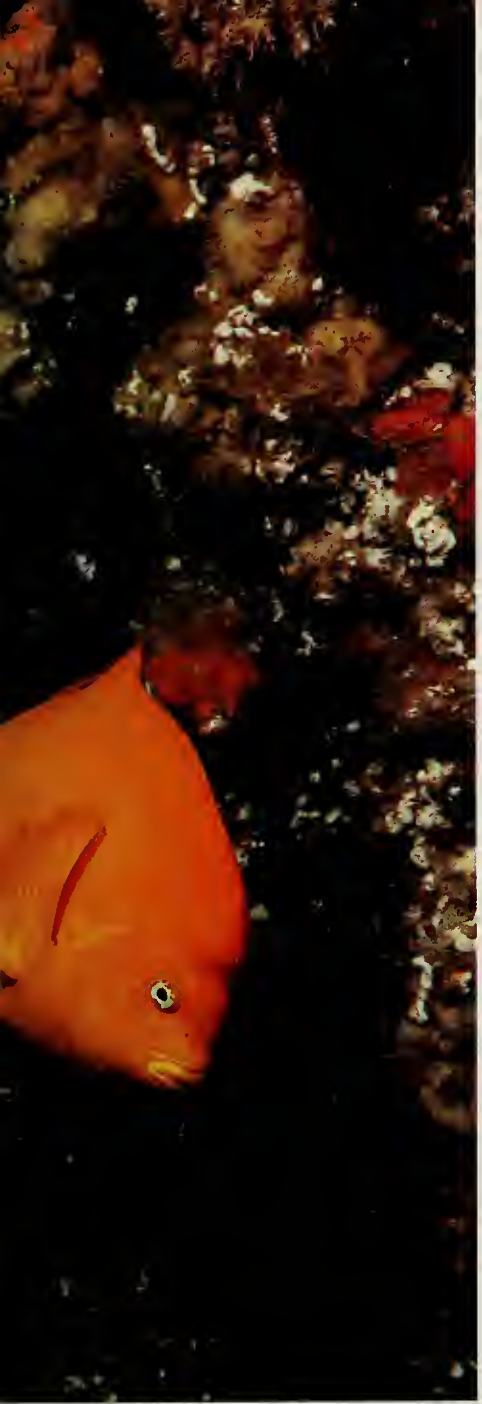
My interest in garibaldis began years before, on a warm July afternoon. As a junior high school student, I was snorkeling in the clear waters off Santa Catalina Island, a tranquil refuge just a two-hour boat ride from Los Angeles. From the surface, I noticed a bright yellow patch of eggs nested in a carpet of algae. As I approached for a closer look, a bright orange fish about a foot long intercepted me and clamped onto my cheek, leaving a circular wound. In a case of love at first bite, I was instantly intrigued by the fish that defended its territory with such ferocity.

Years later, as a graduate student at Oregon State University, I returned to Catalina, and for seven years, I investigated the reproductive behavior of this belligerent orange fish. I was particularly curious about how the females selected their mates (they choose several mates each spawning season) and how their behavior affected parental care in males. The clear water surrounding Catalina and the abundance of nesting garibaldis provided ideal conditions for my study.

Male and female garibaldis defend their exclusive feeding and shelter spaces year-round. In spring and summer, the male prepares a nest, usually on a vertical rock face, and begins courting spawning females. After females deposit eggs, he defends and cares for them until they hatch two to three weeks later. The tiny larvae then enter the sea of plankton and are swept away in the currents, probably never to be seen again by the parent.

For most damselfish males, creating a nest simply means cleaning off a piece of rock or coral, but male garibaldis spend about a month culturing a mat of filamentous red algae. By removing debris and unwanted algae species with their mouths or by vigorous fanning with their fins, the males insure that only red algae will grow on the rock. The mats can range in size from a square foot to almost a square yard. During their reproductive lives, the males tend to the nests in the same location, year after year for a decade or more. When a male dies or is displaced, the nest site will be used by a successor. Why garibaldis need the red algae to spawn remains a mystery, but one thing is certain: female garibaldis rarely spawn in nests sparsely covered with algae, and males with such deficient nests are often reluctant to court.

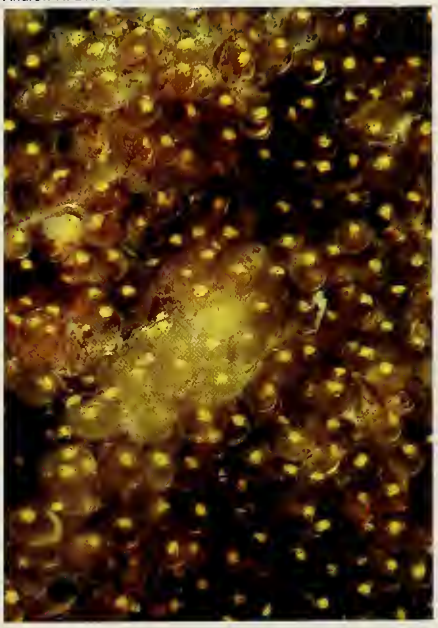
Although Split-fin had worked for weeks to get his eggs, his devouring some of them was, in itself, not surprising. Parents in many animal species, from amphibians to mammals, will kill, abandon, or even cannibalize their young. Behavioral ecologist Sievert Rohwer, at the University of Washington, has coined the term



Howard Hall

A male garibaldi, left, guards his red algae nest. The bright yellow color of the eggs indicates that they were laid recently. The yolks of the eggs, visible below, turn from yellow to gray after four or five days.

Andrew N. Drake



filial cannibalism to specifically describe the eating of viable offspring by parental fishes. Such behavior was once thought to be maladaptive; only "sick" animals killed or abandoned their offspring. But, as Rohwer and other contemporary ecologists have suggested, this behavior may, in the long run, enable parents to rear more offspring than they would otherwise.

What was so surprising was that Split-fin ate only the older eggs. Shouldn't parents guarding offspring of different ages be more likely to kill or abandon their youngest offspring and preserve the embryos that are closer to independence? Indeed, this is what many other fishes do.

I reviewed the field records I had accumulated over several years and found that filial cannibalism was fairly common in garibaldis, occurring in about 15 percent of the broods that had eggs of different ages. I also found that when the males ate their eggs, the older ones were much more likely to be sacrificed. How did this odd behavior benefit the males? I suspected that it was somehow linked to the female garibaldi's finicky behavior in choosing a male's nest.

Female garibaldis usually spend hours visiting different males that have seemingly suitable nests without spawning, but I found that they are about five times more likely to approach a nest if it has young, yellow eggs than if it has no eggs. A nest with mostly young eggs is about twice as likely to attract a female as a nest with mostly older, gray eggs. More importantly, once a female enters a nest, the chance she will spawn is about twenty times higher if it has mostly or only yellow eggs than if it has no eggs. Females virtually never spawn in nests with mostly or only older, gray eggs.

Such female choosiness means that a male may have to spend weeks courting before he receives a single clutch of eggs. Once he receives one clutch, however, he can expect to receive more eggs in rapid succession, as long as he retains some eggs that are young enough to attract females. To test the value of young eggs in improving male spawning success, I removed all young eggs from the nests of some male garbaldis and removed only some of them from the nests of others. Males that retained some young eggs had received more eggs by the following day. Of the males that had lost all their young eggs, however, more than a third failed to receive any more eggs during that spawning season, and those that did waited an average of five days to get additional eggs. So, for males seeking to fill their nests, the younger eggs are precious.

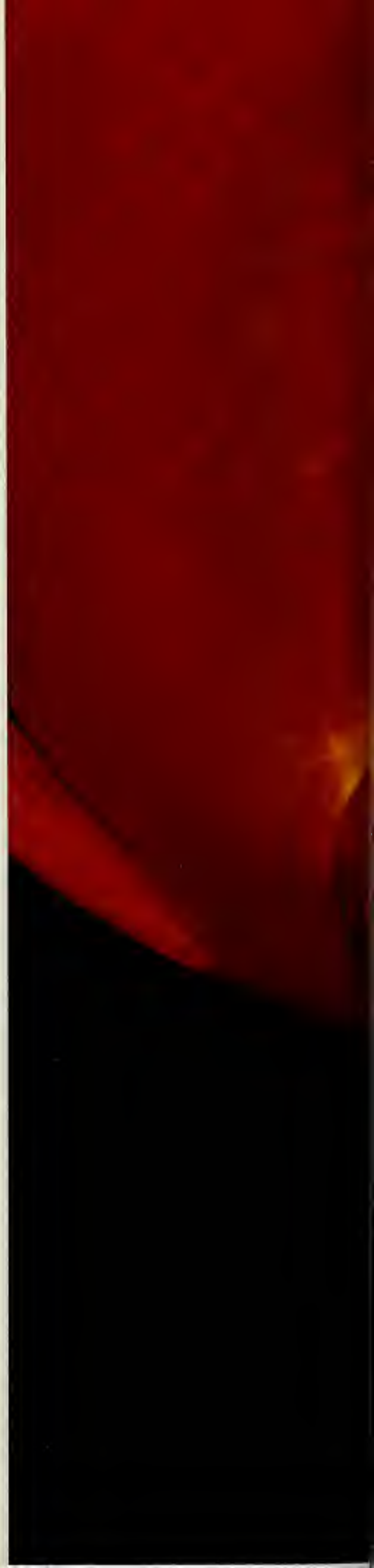
Although their attractiveness to females explains why males tended to avoid eating young eggs, I still wondered why males occasionally ate the older ones. One possible explanation is that these males needed additional energy to help them continue with the nesting cycle. But nesting males are surrounded by food in their territories. A closer look at female spawning patterns provided an alternative explanation. As it turns out, female garibaldis show the same bias toward young eggs *within* a nest as they do when choosing between nests. If a nest contains eggs in different stages of development, females will always deposit their eggs adjacent to the youngest eggs and will not lay next to eggs older than about two days. The amount of space available elsewhere in the nest seems to be irrelevant. Thus, the arrangement of eggs within the nest is crucial; if there is empty nest space around both older and younger eggs, additional eggs will accumulate only at the younger end—a waste of valuable nest space at the older end. A male, therefore, can maximize the number of eggs in his nest by cannibalizing older eggs that are in the "wrong" place, that is, those that are surrounded by empty nest space.

If males were eating older eggs for their nutritional value or for other reasons, position in the nest would make no difference. Split-fin, for instance, cannibalized an

Norbert Wu

A juvenile garibaldi, below, is decorated with iridescent blue spots that disappear after about five years, when the fish matures. An adult male, right, moves a sea urchin that was about to intrude on his algal nest.

Andrew N. Drake



older clutch bordered by empty nest space. But he did not eat eggs of any age if only younger eggs were next to vacant areas. My field records revealed that this was indeed a general pattern among garibaldis in the cove. And when I experimentally altered the position of the eggs in the nest, the same pattern asserted itself.

Males always cannibalized these older clutches when the eggs were three or four days old—about the age when eggs are no longer attractive to females. This made sense to me in terms of energy expenditure. If males waited longer to eat the clutch, they would waste precious time and energy caring for a clutch that would eventually be eaten. By cannibalizing exposed older eggs, they create a space in which younger eggs will be deposited. More eggs will continue to accumulate until the nest is filled to, or near, capacity. I calculated that, on average, males that cannibalized exposed older clutches gained six times that number of younger eggs in the available nest space. The few males that failed to cannibalize exposed older clutches filled a smaller proportion of their nest than males that did.

So, what appeared at first to be an enigmatic sacrifice of valuable older offspring is really an ingenious long-term management strategy for males. (Some males end up with as many as twenty clutches.) Why female garibaldis prefer nests with young eggs remains a mystery. Studies of other species have shown that males may invest more effort in the care of larger broods. In garibaldis, I have found evidence that males are indeed more attentive to larger broods and that eggs in larger broods may benefit from a safety-in-numbers effect. A female's clutch remains with other eggs for a longer period if it is placed among eggs of the same developmental stage.

Whatever the reason, females in some other fish species also have an affinity for nests that already contain eggs, and males of these species have become equally adept at taking advantage of this. Male sticklebacks, for example, have been reported to steal eggs from the nests of neighboring males, and males of other fish species will take over nests that contain eggs fertilized by another male, increasing their own chances of spawning. Males of some darter fishes have gone one step further by evolving structures on their dorsal fins that resemble eggs. In a scenario fit for the tabloids, paternal males and choosy females appear to be locked in a sexual merry-go-round that revolves around the vulnerability of their offspring. □

A game-farm cougar strides through a snowy meadow in Montana's northern Rocky Mountains.
Joe McDonald

Lions in Winter

Unlike most mammals in temperate climates, the elusive cougar breeds all year round

by Ian Ross

High on the north-facing slope of Mount Hoffman, overlooking the Sheep River in southwestern Alberta, is a steep-sided canyon cloaked in Engelmann spruce. When I explored it on January 9, 1990, the canyon was partly filled with snow. The day was still and cloudless, but a dense ice fog blocked my vision, even across this narrow valley. Direct sunlight hadn't reached the valley's far slope for four months, and wouldn't again until May. At noon the canyon's air temperature registered –36° F.

I was following the tracks of a cougar known to us as Luna, whose radio collar signals had led me to this frigid canyon. Her tracks in the fresh snow led out of the valley; by backtracking, I was guided directly to her nest, a shallow depression roughed out of tamped-down vegetation. Located beneath the low-hanging branches of a small spruce tree, where it was hidden from overhead view and protected from snowfall, the nest contained two kittens about nine days old. The tiny cougars, weighing about a pound each, could barely support themselves on their short legs and pushed themselves about on their bellies. Their eyes were open but probably had still been closed the day before. On my approach they mewed softly and squirmed about.

Camera-shy Cougars

Cougars are so adept at concealment that they are almost impossible to photograph in the wild; and sharp, well-composed pictures of the animals are extremely hard to come by. When stalking their prey, the big cats hide behind screens of vegetation and rarely venture into open spaces near humans. This article is accompanied by some rare, authentic images of wild mountain lions, along with others of game-farm animals. In each case, the provenance of the image is clearly labeled.—*The editors*

Luna had left her kittens at least four hours before, and the directional signal from her radio collar told me she was on a south-facing slope about three miles away, probably hunting mule deer and elk. In this weather, deer and elk feed in the open all day, and stalking one from cover would be difficult for the mother cougar. Before this morning, Luna had not left her kittens since they were born, so she was probably hungry and eager to make a kill.

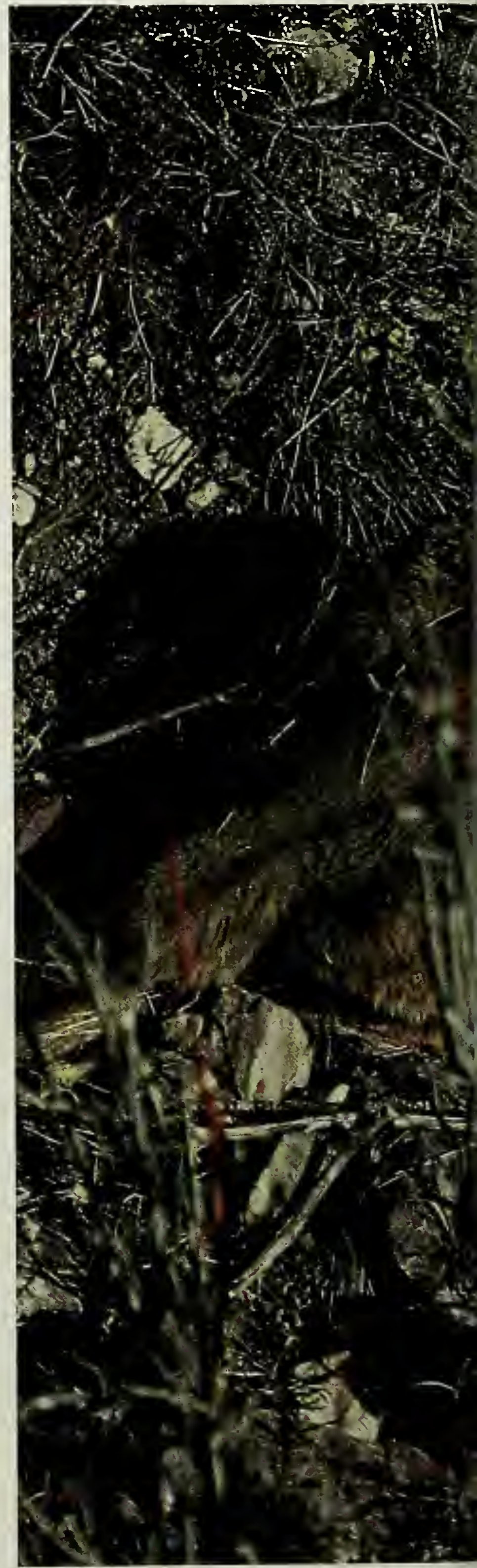
About a week earlier, when Luna's radio signal had indicated that she had not moved from one spot for some time, I became worried about her. However, when I investigated and found an aggressive and apparently healthy cat, I surmised that she had stayed in one place because she had just given birth. Now, having found her nest, I was happy to see the second litter Luna had produced during the three years she had been radio collared.

The key to our thirteen-year investigation of cougar ecology in Alberta has been the ability to find and follow the animals' tracks. No North American mammal is more seclusive than the cougar; the big cat's propensity to move only under dense cover makes it difficult to observe. In recent years, however, radio-telemetry has made locating collared individuals routine and has provided good data on their movements. But there has been very little direct observation of their day-to-day behavior. Once the radio beeps lead us to fresh tracks, however, we can follow the footprints forward or backward to discover what the cougars have been doing. This work is easier in winter, when snow covers most of the Rocky Mountain foothills.

Despite intense persecution over the past century, the cougar, also known as the puma, mountain lion, or panther, is the most widely distributed wild land mammal in the Western Hemisphere. Over its vast range, which extends from central Alberta and British Columbia to the southern tip of Patagonia, the cougar lives in many kinds of habitats, from sea-level swamps to high alpine slopes. In many cougar habitats, seasonal variations in climate are extreme, but the tawny cats can survive even where winter is severe. Their adaptability and resilience are especially evident in their reproductive ecology.

Most mammals that live in the temperate zone give birth to their young in spring. Zoologists believe this widespread pattern has evolved to enable newborns to benefit from the abundant food and warm temperatures of the season. Indeed, species that continue to give birth in summer and fall often lose offspring from the later litters. Cougars do not follow this general pattern. At Sheep River, where winter weather can be severe, we have documented cougar litters born in every month of the year. One-quarter of the litters we found were born in winter, between October and March.

Some newborn kittens, like Luna's, immediately face numbing cold, particularly when their mother has to leave them to hunt. For a solitary predator like the cougar, several days of intermittent hunting may be required to secure an elk or deer, and we have recorded absences from newborn kittens of up to thirty hours. The birth site chosen by Luna was typical. We found most litters in surface nests screened by vegetation; rarely were they in burrows or caves. Such open-air nests



offer little protection against the cold, and probably function mainly to hide the kittens from predators.

How do such small, helpless newborns survive the intense cold? Cougar kittens are covered with thick fur at birth, and their ears, tails, and legs are short relative to adult proportions. These features conserve heat and minimize surface area exposure. The two or three littermates huddle close together. Survival, however, still seems to be a matter of some luck. If their mother fails to bring back game during prolonged periods of extreme cold, the kittens will perish. Some endure close calls. Many cougars that we captured had bobbed tails or shortened ears, probably the result of early cases of frostbite. Overall, however, winter-born litters are as likely to survive as those that are born in other seasons.

There may be advantages to giving birth during winter. Some predators in southwestern Alberta, such as black bears and grizzlies, are still fast asleep in their winter dens when the cougar kittens are most vulnerable. Golden eagles, another threat in springtime, are usually absent during winter. Winter may also be a better time for the mother cougar to hunt. Many deer, elk, and moose are often half-starved by January and may be weaker and slower than at other times. Also, deep, crusted snow can cause them to flounder under the weight of an attacking cougar. Dense conifer stands that serve as warm cover for resting ungulates in winter may also work to the cats' advantage by providing them with hiding places from which to attack stationary prey.

Just how the female cougar's physiology or hormonal system functions to allow year-round breeding is unknown. Most big cats from tropical regions, in-

Cougars often stalk deer and elk from behind a cover of trees and shrubs but sometimes venture onto bare slopes when hunting mountain goats. In Glacier National Park, Montana, a wild cougar locks its jaws around a goat's throat (left, top and bottom), then looks up and snarls, guarding its kill (below). The cat had separated the goat from a herd of thirty, leaped on its back, and tumbled with it into a ravine.
Jim Mepham

A mother puma from a northwestern Montana game farm tends her kittens. In the wild, a mother may have to leave newborns alone for a day or two while she hunts for deer or elk.
Erwin and Peggy Bauer

cluding tigers, lions, and leopards, are capable of breeding throughout the year. Perhaps cougars evolved in warm climates and retained a tropical reproductive physiology as they expanded their ranges to the north and south.

Our field studies in Alberta, along with those of researchers in other areas, have contributed to a general picture of the cougar's behavioral ecology. Males and females lead very separate and different lives, both in their hunting patterns and in their use of territory. Females maintain a home range that is probably the smallest size possible to provide for her food requirements and those of her offspring. Cougars are intensely solitary and, although females' home ranges may overlap considerably, the animals usually avoid each other. When unrelated adult females do meet, they often fight or threaten each other, although serious injuries from such encounters appear to be rare.

Cougars hunt alone, even when they have to share the kill with their offspring. When a new mother brings down a deer or elk, she eats a portion of the meat, then covers the carcass to protect it from scavengers and returns to her kittens to nurse them. She will revisit the kill several times over a week or two. When the kittens become more mobile, she carries or escorts them to the kill site. Cougars appear to wean the kittens when they are two months old, although the youngsters will probably try their first meat at a few weeks of age. By four months their energy demands are considerable, and their mother increases her efforts to obtain meat for them. Sometimes the kittens accompany her as she searches her home range for prey, but their boisterous antics are likely to hinder her in the hunt, rather than help. Frequently, the mother will hide the kittens and proceed alone, returning to collect them after she has procured meat.

Regardless of her reproductive status, a female cougar's activities are focused around her supply of fresh meat. Except when nursing newborn kittens at a distant site, a female usually sleeps within a few yards of the latest kill. Her proximity provides additional security against most scavengers and conserves her own energy. An adult deer carcass can feed a lone female cougar for seven to ten days. But with two or three fast-growing kittens, that deer disappears quickly. When the juveniles are fifteen to eighteen months old and nearing the time that they will hunt on their own, they eat more than their mother does. Large families can eat a small deer in one sitting.

Male cougars defend their home ranges, or territories, against other males. These areas are several times larger than those of females, and the males travel greater daily distances in their wanderings. While territorial boundaries among neighboring males rarely overlap, each male's range may cross the undefended home ranges of up to eight adult females. Since male cougars are larger and more powerful than females, they would not seem to require a larger home range to insure adequate food resources. I think the males' large home ranges maximize their opportunities for contact with females. Males, too, are almost exclusively solitary. They often encounter females that are unreceptive to their advances and quickly move on. When they find a receptive breeding partner, however, the pair may consort closely for four or five days.

Male cougars also hunt large prey. At Sheep River, males feed primarily on young moose, which may provide more than 300 pounds of food—a larder than can last three weeks. Since a female cougar's estrus lasts about seven days, a male that stayed near a large carcass until he finished eating it would risk missing the reproductive peak of one of his neighborhood females. If she is not impregnated, the female will come into estrus again in about a month, but if she mates successfully, she will not be receptive again for up to two years. Young, sexually mature males that have not yet staked out their own territories by defending them against other males may also wander through the

area. If a mature male with an established territory does not seize a breeding opportunity, one of the younger, transient males may quickly take advantage of the situation. In such northern mammals as elk, deer, or bears, whose males mate with multiple partners, the females all come into estrus at about the same time. Males of these species must suspend their normal survival routine only briefly to insure their breeding opportunities. But because estrus in cougars can occur at any time of year, resident males must constantly be on the lookout for receptive females and ready to drive off trespassing upstart males.

I believe that their mating system causes male cougars to consume their prey in a different pattern than females. Rather than risk becoming tied down to a kill site, males frequently gorge themselves for a day or two, then diligently cover the carcass and leave it for up to two weeks. During that time they patrol their home ranges to hunt and possibly encounter receptive females. They may make another kill in a

Encounters with a Silent Predator

by Howard B. Quigley

The cougar is the most adaptable and widely distributed native mammal in the Western Hemisphere. Cougars thrive not only in the desert southwest of the United States and Mexico but also in the Rocky Mountains, the Amazon rain forest, and the Argentine pampas. But the tawny cat's greatest adaptive challenge has been in the United States, where it has lost nearly two-thirds of its previous range, most of it in the eastern forests.

Early American settlers systematically eliminated the cougar, a practice accepted as necessary not only by farmers and ranchers but also by zoologists and conservationists. In 1913, William T. Hornaday, the director of the New York Zoological Society, told forestry students at Yale that "the eradication of the puma from certain districts that it now infests to a deplorable extent is a task of immediate urgency.... At this moment pumas are a curse to the deer, elk, and other game." But despite this effort at eradication, the mountain lion persisted in the western United States and Canada because of its elusive nature and the vastness of western wildlands.

Scientific studies of cougars over the past thirty years, pioneered by Maurice Hornocker during the 1960s in central Idaho, have brought new understanding of this stalking, silent predator. In many ways, prior to these studies, our approach toward this animal was driven by a fear of the unknown and an unease about having a powerful but unseen hunter in the forest. Many thought cougar populations were denser than they were, and even zoologists had no understanding of the cat's territorial and hunting patterns.

Sound management is replacing fear and indiscriminate hunting, although in some places the shift in human attitude came too late. While only a handful of cougars survive in the eastern United States and Canada, the western populations have risen steadily over the past decade. There are now an estimated 5,000 in California; 2,000 in Idaho; 2,500 in British Columbia; and 700 in Alberta.

The recent increase in cougar numbers in the United States began with the elimination of their status as "vermin" with bounties on their heads. In California, cougars are a fully protected species, and in the Rockies, regulated hunting, together with an increase in the elk population, has helped promote their resurgence. With the cat population growing and with more and more people using wilderness areas for recreation, human–animal encounters are on the rise. Some people believe that the cats are becoming less shy.

Two runners were killed by mountain lions in the past five years, one in California and one in Colorado. In the state of Washington, a cyclist glanced over to see a cougar loping alongside him on a fire road. The cyclist stopped and held the bicycle out between him and the cat, but the lion was still reluctant to leave. Although cougars are normally known for their secretive, crepuscular activity, one strode through a California campground in full daylight with a coyote in its mouth. In Montana, a female puma tried to set up winter residence beneath the floorboards of a cabin in a compound that was occupied by humans.

A wild cougar treed by dogs
Ian Ross

Although sightings have increased dramatically, mountain lions are able to watch humans a great deal more easily than we can observe them. Are they changing their shy ways and becoming more aggressive toward people? Or are these young, inexperienced lions testing new marginal habitats? If so, how do we humanely deter the animals from their experimental forays? Field studies can answer some of these questions. But a renewed fear of cougars seems to me unwarranted. Even with increased contact, dangerous incidents involving lions and humans are still relatively rare. During the past century, there have been fewer than sixty documented attacks by cougars on people.

Howard B. Quigley is president of the Hornocker Wildlife Research Institute in Moscow, Idaho.

The extreme temperatures of the northern Rockies present no problem for this game-farm puma. The species can produce young in any season, even during severe winters.
Joe McDonald

different part of their large range and repeat the pattern. Eventually, they do return to the first kill and feed from it again if it has been relatively undisturbed.

Sometimes the male sacrifices his meat stores in order to protect his breeding opportunities. In warm weather, a cached carcass will spoil and be lost to the cougar. Coyotes, wolves, bears, and a host of other scavengers will make short work of any unguarded cougar kills they may discover. The relationship with other carnivores is one way; cougars rarely scavenge.

Cougars, nearly alone among solitary predators, consistently seek prey larger than themselves. African lions, wild dogs, and wolves all practice cooperative hunting of large prey. Most solitary hunters, such as weasels or foxes, generally prey on creatures smaller than themselves. Among the cats, leopards, cheetahs, jaguars, and lynxes usually follow this pattern. Attacking large prey can sometimes prove fatal for the hunter. Among Alberta cougars, we have documented some dramatic examples of what can go wrong in these violent struggles, which are the chief cause of death, aside from human hunters, in our study area. One young adult female suffered a broken back when the mule deer she was riding down a steep slope slammed into a pine tree. Another was speared by a sharp branch when the elk that she eventually killed tried to shake her loose from its throat. An adult male cougar that attacked a bighorn sheep lost his footing in the struggle, and both fell to their death over a ninety-foot cliff. When cougars lose carcasses to scavengers, they must hunt again, thus increasing their own risk. But male cougars are apparently willing to face additional dangers to further their chances of mating.

The low temperatures and short days of the long winters in the Alberta Rockies create a world of severe hardship. Some animals migrate, some hibernate, others barely pull through until spring arrives. We are just beginning to understand how the cougar manages to thrive in these subzero mountain winters. □

Thailand's Good Mound

Twenty generations of burials provide an intimate portrait of a Stone Age village

by Charles Higham and Rachanie Thosarat

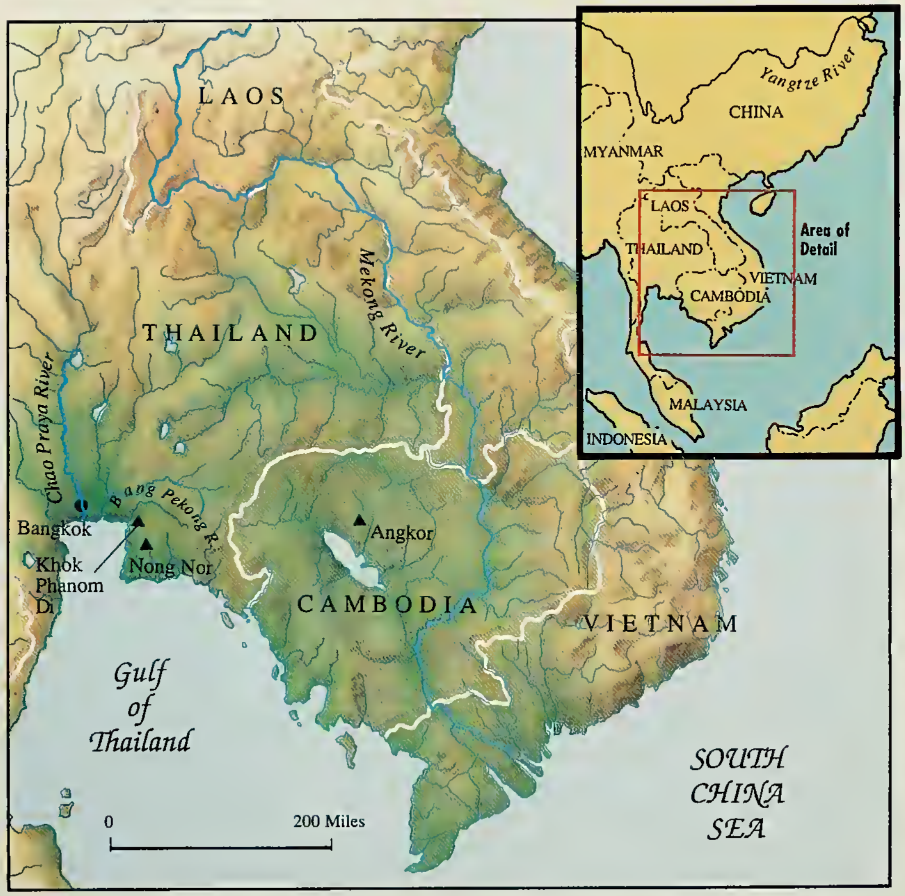
About 650 feet wide and 40 feet high, Khok Phanom Di, "the good mound," stands out on the flat flood plain of Thailand's Bang Pakong River. Unoccupied in living memory except for a Buddhist temple, the site passed as a natural hill until a

Illustrations by Salvatore Catalano

The prehistoric village of Khok Phanom Di is depicted as it may have looked about 3,800 years ago, before a changing coastline reduced access to the sea and a nearby river. In the village center, oval shelters contain the burials belonging to the various kin groups. Smoke rises near the edge of the mound where pottery is being fired.

The inhabitants of ancient Khok Phanom Di, map below, exploited many resources, including rice, which was originally cultivated in China's Yangtze Valley. Right: Women became the preeminent potters in the village, and their products, probably mainly ceremonial wares, were important items for trade.

Joe LeMonnier



bulldozer, cutting a new path to the top, revealed a deep sequence of archeological deposits. These contained abundant remains of shellfish adapted to coastal mud flats, although nowadays the sea lies fourteen miles to the west. Damrongkiadt Noksakul, a staff member of the local teachers' college, excavated a small test square, which we visited in 1981. Peering into the inky gloom, we saw layer upon layer of hearths, ash, and discarded shellfish remains stretching down twenty-eight feet. This preliminary excavation had yielded eleven human burials, numerous pottery shards, abundant remains of rice, and shells from species of mollusks and crustaceans adapted to life in an estuary and along the seashore.

The site intrigued us because little was known of prehistoric settlements in Thailand so close to the sea. Most archeological work on early groups had been done along small tributary streams in the interior. Yet the wealth of resources on the coast or along major rivers probably played an important role in the spread of rice cultivation and in making mainland Southeast Asia the home of some of the world's great early civilizations. The best known of these civilizations had as its court center Angkor (in present-day Cambodia), a site that represented heaven in stone and incorporated vast temple mausoleums for its deified lords.

Toward the end of 1984, we returned to Khok Phanom Di with an archeological team to excavate a square measuring one hundred square meters, or about 1,075 square feet. We had no illusions about the ease of our undertaking, which eventually involved the removal of 28,000 cubic feet of prehistoric material. We chose this single large square, however, in hopes of discovering the spatial arrangement of ancient life—perhaps house plans, the layout of a cemetery, or distinct areas for different activities. Our research was designed to find out about the way of life of the occupants and how their environment may have changed over the generations.

We erected a steel roof to shelter the square from rain and sun and arranged for electrical wiring. Water was piped in to allow us to clean the finds before sorting and packing them. Jill Thompson, a member of the team, set up a large metal tank to float plant remains out of the archeological deposits. Brian Vincent processed much of the pottery as it was recovered, and Bernard Maloney was on hand to analyze the remains of pollen, a key to understanding the changing environment in the vicinity of the site. After seven months of digging, we reached a compacted, sandy layer at a depth of about twenty-one feet. At last, we were able to stand on the river flood plain that was first occupied in antiquity. The Thai workers who were helping us—and who had shown as much interest in our discoveries as we did—were equally relieved to reach bottom.

In our square—still only a fraction of the total mound—we encountered part of a cemetery. We also observed that nearer the edge of the mound, the road-cut exposed layers of debris where prehistoric pots had been fired. The remains of houses probably lay elsewhere. In the earliest layers of the excavated material, we found extensive spreads of ash and much charcoal, along with pottery shards and blunted, well-used stone adz heads. Some of the pottery shards were encrusted with marine barnacles; judging from the species of ostracods and foraminifers, the earliest inhabitants established their settlement on a sheltered estuary of a major river near its entrance to the open sea. Dating of the charcoal showed that these early deposits were about 4,000 years old.

To determine the environment prior to the site's occupation, Bernard Maloney removed a series of cores from the natural sediments that surround the site (the base of the site itself was too hard for our equipment to penetrate). Beneath the present-day rice fields he found about eighteen feet of stiff, blue clay that had been laid

down under a shallow sea. The clay contained microscopic fragments of charcoal and the remains of pollen. By dating samples of the charcoal taken at different levels in the cores, he was able to estimate that the clay was deposited between 8,000 and 4,000 years ago. And by identifying and counting the pollen grains in samples taken at intervals throughout the deposit, Maloney was also able to get a picture of the vegetation.

Mangrove pollen dominated, reinforcing other evidence that the area was near the seashore. At times, however, the quantity of charcoal rose spectacularly and the pollen of grasses and some plants that flourish in rice fields today became more prominent. Such episodes occurred sporadically beginning 7,800 years ago. Several explanations are possible: natural forest fires, burn-offs by local hunters and gatherers, and the clearing of land by rice cultivators. Possibly, people frequented the area long before they settled at Khok Phanom Di itself, about 4,000 years ago. A modern fish pond dug into the marine clay near the site revealed a deep layer of ash and pottery that may belong to this earlier time (we didn't venture to date this material, since it was not covered by our research permit).

Toward the top of the sediment cores, Maloney found evidence for a major episode of burning and the proliferation of grass pollen. This stratum was dated to the early period when Khok Phanom Di was occupied and surely reflects the activities of its inhabitants. They probably were cutting the coastal forests for fuel, including that needed to fire clay vessels, which they shaped from the rich local source of clay. They may also have been burning off dry-season plant growth in order to make way for their rice.

Because their estuary provided a wide range of renewable food resources, the inhabitants of Khok Phanom Di were probably rarely, if ever, short of food. At low tide they collected the abundant shellfish that lived on the mud flats. The clay net weights we have found tell us that they set nets in the estuary for the many species of passing fish. They also took their boats out to coastal waters to fish by line, using barbed fishhooks made of bone, and cultivated rice in the freshwater swamps behind the coastal mangrove belt. These ideal conditions favored permanent settlement, and during the ensuing years, from 4,000 until 3,500 years ago, twenty-one feet of cultural debris built up.

The inhabitants of Khok Phanom Di were in a good position to trade upriver with people inhabiting the interior and along the coast with other maritime settlements. A sedentary way of life means that trading partners know where to find one another. It permits the accumulation of weighty personal possessions and makes

Archeological excavation of one opulent burial suggests it belonged to an outstanding potter who died in her midthirties. Over the generations, a family's fortunes rose or fell according to such individual achievement, rather than inherited status.

the construction of buildings worthwhile. And not least, it opens up the possibility of an expanding population. Where mobility is the rule, births need to be widely spaced, or there will be too many young children to carry. Permanence removes this constraint, and women can reduce the interval between pregnancies. The need to feed more mouths within such sedentary communities may help explain the rapid spread of agriculture that took place in many different parts of the world beginning 12,000 years ago.

Long-term occupation also allows for the maintenance of a cemetery as a resting place for dead ancestors. Such was the custom at Khok Phanom Di, where we found about twenty generations of burials (assuming an average interval of twenty-five years between generations). In preliterate times, the continuing presence of the ancestors may have helped signify the ownership of local land and resources.

Covered in red ocher and wrapped in shrouds fashioned from beaten bark cloth or sheets of asbestos fiber, the dead were interred face-up with their heads to the east. The oldest level of burials in the excavated part of the cemetery included only six interments, and they were very simple. Only one contained a durable grave offering—a necklace of twelve shell beads. Thereafter, burials accumulated steadily, and the accompanying grave goods became more elaborate, until the cemetery was abandoned.

The cemetery was arranged in a grid of at least six separate clusters. With time, new burials were placed over preceding ones, continuing the same pattern of clusters. We noted many post holes, the residue of building foundations. Their distribution is irregular, but some alignments hint that each of the grave clusters was housed within a wooden structure, forming, in effect, a collective tomb. Doubtless the wood decayed with time, and the structures had to be refurbished or replaced.

The space between the burials contained the remains of much activity. We found middens (refuse heaps), circular pits containing the remains of unopened—and therefore uneaten—shellfish, and thin layers of ash. Very likely burial was an occasion for funerary ritual, including graveside feasting and, perhaps, the placing of food in pits to provision the ancestors. At inland sites of comparable age, archeologists find bones from the legs of cattle or pigs, with no sign of cut marks from butchering. The animals were probably slaughtered for a mortuary feast and a limb placed with the dead. These practices seem to have disappeared with the introduction of Buddhism and cremation.

When one of our Thai colleagues, Praphid Choosiri, examined the human remains, she sometimes found rare or unusual bone structures thought to be genetically determined. Two examples of these, with the technical names *metopic suture* and *os inca,* concern the presence of extra sutures between bones in the skull. She noted that successive interments in the grave clusters sometimes exhibit the same rare characteristic, suggesting that each of the burial areas was devoted to a particular lineage. Based on this assumption, we set out to reconstruct prehistoric family trees and consider their ups and downs.

We found that two lineages were especially stable, in that they continued for the full complement of generations for the life of the cemetery. For one reason or another, however, some lineages failed to maintain themselves. In general, we observed that infant mortality was high for the first eight or so generations, so perhaps these families died out. An alternative explanation is that, as the number of inhabitants grew, the leaders of some lineages left with their relatives to found new settlements elsewhere.

In studying the two stable lineages, we found that the quantity of grave goods varied considerably between burials: some had nothing, while others were very rich. They included lustrously burnished and decorated pots, iridescent shell beads, translucent shell disks, and stone adz heads. Small clay anvils used in making pots were found only with the remains of women, children, and infants. (Such an anvil would have been held inside the vessel as it was shaped with a wooden paddle.) On the other hand, twelve-inch-wide plaques fashioned from sea turtle carapaces, apparently worn as chest ornaments, were found only with the skeletons of men. Both men and women were interred with the stones used to burnish pottery vessels until they shone.

Neither of the two stable lineages appeared consistently wealthier than the other. Fortunes rose or fell after a generation or two, or at most three. This suggests that esteem and status—assuming these translated into mortuary wealth—had to be attained through personal achievement. They were not inherited by right, except to the extent that when infants died, wealthy parents were able to endow them with rare and beautiful grave goods. (Interestingly, infants less than a month or two old were not accorded such attention; perhaps they were still too young to be regarded as official members of society.)

Evidence of important changes at Khok Phanom Di emerged after the actual excavation, as our team of specialists completed their analyses of various kinds of data. Up to the ninth or tenth generation, the inhabitants of the village continued to exploit both the river and seacoast. Men had strong muscular development in their upper bodies, and men and women apparently had somewhat different diets—women had more caries and tooth loss, while men kept their teeth longer and therefore showed more tooth wear. People were interred with beautifully decorated pots, and many wore shell jewelry. Infant mortality was high.

Then, about the tenth generation, something happened to the maritime connection. Marine and coastal shellfish gave way to species from freshwater or backwater mangrove stands. Mangrove wood became less common in the charcoal. From this time on, men appeared less muscular. Shell jewelry practically disappeared, and even pottery vessels became less common and lacked ornate decoration. Men and women shared a new diet pattern, probably including fewer shellfish. And infant mortality rates dropped.

We think these changes were a reaction to a swift alteration in the environment, probably a major flood followed by a shift in the river channel away from Khok Phanom Di. A gradual deposition of sediment also left the site farther from the sea. Men, whose previous strength probably reflected habitual paddling of boats, now embarked on fewer coastal voyages. The local source of high-quality shell for ornaments also suffered as the sediments killed off preferred species. And the change in habitat or diet may have reduced the danger of certain diseases, improving infant survival.

After three or four generations of relative poverty, yet another pattern emerged. We encountered a very large grave belonging to one of the two main clusters. It contained the remains of a woman in her midthirties. Her body was covered with a pile of clay cylinders, which may represent clay destined for conversion into pots, and the broken pieces of five ornately decorated vessels. Her personal jewelry included 120,000 shell beads, two shell disks, a headdress, and on her left wrist, a bangle made of an exotic shell. In life, this woman must have been dazzling in her finery. Beside her right ankle lay a shell containing two burnishing pebbles next to a clay anvil. We think that she must have been an outstanding potter. She had well-developed wrist muscles, consistent with preparing and molding clay.

Beside her was a matching grave containing the remains of a fifteen-month-old infant. Again, we encountered a pile of clay cylinders, the body festooned with 12,000 shell beads, a bangle placed over the left wrist, beautiful pots, and a miniature clay anvil beside the right ankle.

Despite the opulence of these two burials, the succeeding generation in what we believe was the same lineage displayed very little wealth. In contrast, the other main lineage now attained greater status within the community. We found the remains of two women and a nine-year-old child buried beneath the two-foot-high raised floor of a rectangular mortuary building. Both women were buried with clay anvils, and one was buried with 11,000 shell beads. The child was accompanied by a thick shell disk and at least 18,000 beads.

Our interpretation is that the community adapted to its now more inland habitat by expanding its ceramic industry, already established owing to the settlement's rich resources and favorable location. This craft, apparently the province of women, might have provided a valuable commodity for trade. Perhaps more than ever, a potter's skill became a source of individual prestige and a route to wealth. Jewelry came to include new styles of heavy bracelets and disks made of tridacna and trochus shell. These species of mollusks are adapted to a clean, coralline habitat and so must have been obtained by exchange from some distance away.

As before, while individuals might attain the prestige evident in a rich burial, they do not seem to have been able to convert this into inherited status and rank. Rather, one family might be successful in one generation, only to be followed by less able or less fortunate descendants in the next. This might have reflected success or failure in craftsmanship and in exchange dealings with other communities, depending on individual skill or charisma. Only when a mortuary tradition in a single community can be followed over so many generations can we gain such an intimate glimpse into its operating principles. No similar site exists elsewhere in Southeast Asia, and very few in the rest of the prehistoric world.

Any community that relies on female potters for making vessels for mortuary ritual and exchange would be reluctant to lose them to other communities through marriage. We believe that the custom at Khok Phanom Di, at least for this later period, was for women to remain at their place of birth. In such a "matrilocal" community, failure to produce a female heir would have spelled the end of the lineage. This may explain the attention given to the details of child or infant burials, some of whom, presumably the young girls, were interred with clay anvils.

We also noted that proportionately fewer men were buried in the cemetery during the later phase, although at least one was well provided with grave goods. A possibility is that men were now using sailing craft to engage in long-distance trade, taking pots and returning with shells. The present-day seafaring people of southern Thailand have a tradition of such voyaging, which is usually the work of men. When they die at sea, their bodies are interred in caves remote from their home base.

Despite its renewed prosperity, Khok Phanom Di was eventually abandoned, about 3,500 years ago. Perhaps the inhabitants chose to move closer to the coast. While we cannot say what happened to them, we have subsequently excavated another cemetery about eight miles to the south, at Nong Nor. This cemetery was in use from about 500 to 800 years after Khok Phanom Di was abandoned. In some ways it shows a similar mortuary ritual, with the bodies oriented with the head to the east and clusters containing men, women, and children (but there is no buildup of successive graves that would enable us to trace individual family groups through time). At Nong Nor, the men were buried with the potter's anvils and usually had the richest grave goods. The artifacts include ornaments cast in bronze and tin as well as jewelry of serpentine, talc, carnelian, and jade, indicating wider trade contacts.

Khok Phanom Di is one in a series of sites that mark the origins and expansion of rice-growing agriculturists in the hot, densely forested lands of Southeast Asia. The spread of agriculturists can be reconstructed by identifying similarities between many languages spoken in southern China and Southeast Asia today and by tracing them back to a common origin. According to this linguistic and associated radiocarbon evidence, there was a transition to rice farming in the Yangtze Valley of China about 8,500 years ago. The ancestors of the Vietnamese and Khmer, as well as the Munda speakers of eastern India, apparently moved down the major rivers, bringing their farming economy along with them.

Recent evidence suggests that the first farmers reached Thailand about 4,500 years ago. Occupied between 4,000 and 3,500 years ago, Khok Phanom Di has provided us with the clearest available evidence for their way of life. At the time the site was abandoned, Southeast Asia was entering the Bronze Age, as copper and tin began to be cast separately or alloyed to create ornaments, weapons, and tools. The later site of Nong Nor already includes some of these artifacts.

In terms of social organization, however, little changed in Southeast Asia until about 2,500 years ago, when the smelting of iron ores was discovered or introduced. Regional leaders began to control metal-working specialists, who cast a new range of luxury bronzes, including drinking vessels and drums. Over the next 500 years, Southeast Asia joined ever widening trade networks, and powerful regional chiefdoms arose as the rivalry and competition over luxury goods grew. The later chiefs forged the first states in Southeast Asia, a heritage that culminated 1,000 years ago in the founding of the great holy city of Angkor. □

TECHNOLOGY UPDATE

900 MHz breakthrough!

New technology launches wireless speaker revolution...

Recoton develops breakthrough technology which transmits stereo sound through walls, ceilings and floors up to 150 feet.

Breakthrough wireless speaker design blankets your home with music.

By Charles Anton

If you had to name just one new product "the most innovative of the year," what would you choose? Well, at the recent *International Consumer Electronics Show*, critics gave Recoton's new wireless stereo speaker system the *Design and Engineering Award* for being the "most innovative and outstanding new product."

Recoton was able to introduce this whole new generation of powerful wireless speakers due to the advent of 900 MHz technology. This newly approved breakthrough enables Recoton's wireless speakers to rival the sound of expensive wired speakers.

Recently approved technology. In June of 1989, the *Federal Communications Commission* allocated a band of radio frequencies stretching from 902 to 928 MHz for wireless, in-home product applications. Recoton, one of the world's leading wireless speaker manufacturers, took advantage of the FCC ruling by creating and introducing a new speaker system that utilizes the recently approved frequency band to transmit clearer, stronger stereo signals throughout your home.

150 foot range through walls!

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The headphones and speakers have their own built-in receiver, so no wires are needed between you and your stereo. One transmitter operates an unlimited number of speakers and headphones.

Recoton's transmitter sends music through walls to wireless speakers over a 75,000 square foot area.

Crisp sound throughout your home. Just imagine being able to listen to your stereo, TV, VCR or CD player in any room of your home without having to run miles of speaker wire. Plus, you'll never have to worry about range because the new 900 MHz technology allows stereo signals to travel over distances of 150 feet or more through walls, ceilings and floors without losing sound quality.

One transmitter, unlimited receivers. The powerful transmitter plugs into a headphone, audio-out or tape-out jack on your stereo or TV component, transmitting music wirelessly to your speakers or headphones. The speakers plug into an outlet. The one transmitter can broadcast to an unlimited number of stereo speakers and headphones. And since each speaker contains its own built in receiver/amplifier, there are no wires running from the stereo to the speakers.

Full dynamic range. The speaker, mounted in a bookshelf-sized acoustically constructed cabinet, provides a two-way bass reflex design for individual bass boost control. Full dynamic range is achieved by the use of a 2" tweeter and 4" woofer. Plus, automatic digital lock-in tuning guarantees optimum reception and eliminates drift. The new technology provides static-free, interference-free sound in virtually any environment. These speakers are also self-amplified; they can't be blown out no matter what your stereo's wattage.

Stereo or hi-fi, you decide. These speakers have the option of either stereo or hi-fi sound. You can use two speakers, one set on right channel and the other on left, for full stereo separation. Or, if you just want an extra speaker in another room, set it on mono and listen to both channels on one speaker. Mono combines both left and right channels for hi-fi sound. This option lets you put a pair of speakers in the den and get full stereo separation or put one speaker in the kitchen and get complete hi-fi sound.

These wireless stereo headphones have a built-in receiver.

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Dannebrogopolis

Fred and Myrtle need a lesson in geography

by Roger L. Welsch

A pair of East Coast geographers, professors Fred and Myrtle Dinkumpoofer (I am using fictitious names to protect the guilty—who, incidentally, are almost always in far more need of protection than the innocent), are suggesting in public forums across the nation that the entire middle of the continent should be evacuated and turned back to the wild beasts, prairie fires, and locust storms. The argument of these urban planners seems to be that since this vast inland has so few people—fewer than two per square mile for its immense area—it obviously must be less productive than, say, Boston or Philadelphia. And since it is unproductive, it should be left to buffaloes, rattlesnakes, and gophers. (But, curiously, not to the Lakotas, Omahas, and Pawnees, who, one would think, do have some genuine claim to the region.)

Anyway, Fred and Myrtle have garnered a full measure of attention on their speaking tours and media appearances plumping their scheme, and more than their share of confusion and indignation here on the Plains. Plains folks just don't find it seemly or logical for

1. professors
2. who are urban planners
3. from the East Coast

to make plans for the disposition of

1. farmers and ranchers
2. who work for a living
3. on the Plains.

The situation is, in fact, a little like me deciding that since I am

1. not a horse
2. not female
3. not pregnant

maybe I should just go ahead and have a foal tomorrow, right after breakfast, especially if we have oatmeal.

Problem is, it is hard for people who know and love the Plains to think of them as unproductive, lacking the thousand or so miles distance that gives the Dinkumpoofers such unclouded vision. Nebraskans think not simply of our agriculture but also of products like Visegrip pliers, the strobe light, Triple-Crown winner Omaha, Marlon Brando, Willa Cather, Loren Eiseley, Robert Henri, Darryl Zanuck, Sandy Dennis, Dick Cavett, Johnny Carson, Hoot Gibson, Buffalo Bill, Crazy Horse, Red Cloud, John Neihardt, and thousands of others. Not to mention me.

Every one of the rectangular states arrayed like concrete blocks in the center of the nation can come up with its own list of notables, who may, after all, have become notable because of their origins on the Plains, rather than in spite of them. The world would be quite different without those people and products molded by a landscape consisting almost exactly of half sky and half earth.

When I think of the East Coast, I think of...well, nothing comes to mind at the moment except Bill Geist, and he's from Illinois. But that's just a reflection of my ignorance of the East Coast. Unlike the Dinkumpoofers, however, I understand and acknowledge my ignorance and would never for a moment think of suggesting that the East Coast be paved over and turned into a parking lot for New York City.

The most troubling part of the Dinkumpoofer thesis is that it is dead wrong geographically. Their idea seems to be that small towns on the Plains are dying and big cities elsewhere are burgeoning, so we should abandon small, dying towns and follow the yellow brick road to the big, booming cities.

Well, wake up and smell the statistics, O Academic Ones! In the past six years my town of Dannebrog, Nebraska, population 350, has added (by my casual estimate) 28 citizens, a growth factor of 8 percent. If you project that rate of growth, apply standard actuarial tables, carry your six, and take a stab, you can see plain as day that Dannebrog may soon be hosting the Olympics and maybe even getting a traffic light and parking meter before long.

Presuming that what is always will be is dangerous business in the social sciences (maybe everywhere). Four hundred years ago Edo, Japan, was a quiet fishing village of little note. Now, it's Tokyo. Two hundred years ago there was no Chicago to speak of. One hundred years ago, who had heard of Taiwan? Or Bullhead City?

My family took a trip to Cancún last year, and I thought I would use the occasion to give a geography lesson to our ten-year-old daughter, Antonia. I dug out our world atlas—a very good edition only a few years old—and turned to the page showing the Yucatán Peninsula. I couldn't find Cancún. I thought maybe I had found a mistake in what was supposed to be a reliable reference work. But no, thing is, ten years ago Cancún was not sufficiently large to be included on even fairly detailed maps. What is now a bustling city was then...well, like Dannebrog.

Not even the factors that determine community growth or collapse remain stable, which is why social projection is right up there with phrenology and weather forecasting when it comes to reliability. New York became New York and Boston became Boston because of the preeminent importance of sea traffic. Sea traffic needs ports, and ports necessarily appear where land meets water.

In an electronic and air traffic complex like modern America, it is not the edges of political, social, and commercial entities that offer advantage but the middle ground. As a result, centrally located "hubs" have become the "ports" of commerce. Moreover, in a system of synchronous, rather than serial, communications—telephone calls rather than mail, that is—being on the fringes of a body of time is as disadvantageous as being on the edge of a geographical land mass.

Someone trying to make phone calls from New York to Seattle loses three hours in the morning, when the Seattle office has not yet opened, and then another three hours in the afternoon, when New York has closed down but Seattle is in midafternoon hustle. The reverse is also true: Seattle loses hours in the morning, when New York is bubbling but it is not, and then again in the afternoon, when Seattle is just calming down from its morning coffee and New Yorkers are already back home, kicking back, and mixing evening cocktails. Half the workday of national businesses are presumed lost to the inevitable cross-continental telephone tag.

The obvious, logical, scientific, geographical projection is not that the Great Plains should be abandoned but that my town of Dannebrog, population 350, has a far better chance of being a center of commerce and culture in 2094 than, say, Newark, New Jersey.

So, if the Dinkumpoofers care at all about their descendants, they should learn a lesson we all know out here on the Plains: "Buy low, sell high." They should sell their home on the East Coast, replace it with a few residential lots in Dannebrog, Nebraska, or Junction City, Kansas, or Clarinda, Iowa, or Wessington Springs, South Dakota, and brace themselves for the boom.

But they probably shouldn't identify themselves as geographers. Dakotans, Nebraskans, Iowans, and Kansans are on the lookout for geographers much as they used to send out posses for rustlers—with a looped length of rope.

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

FOLKLORE OF WORLD CELEBRATIONS

A Senegambian lantern ritual, a Caribbean carnival, and other festivals from around the world will be the subjects of illustrated talks, lecture-demonstrations, and films on the first three weekends in December at the People Center in the Charles A. Dana Education Wing. On Wednesday, December 28, the Museum will observe the African American holiday Kwanzaa (Swahili for "first fruits of the harvest"). Customarily marked by week-long feasting and exchange of gifts from December 26 through January 1, Kwanzaa festivities will include performances, demonstrations and sales of African crafts, and the re-creation of a traditional African village market in the Museum's Hall of Ocean Life and Hall of Invertebrates. The programs are free with admission to the Museum. For information and a brochure, call (212) 769-5315.

CHILEAN ARTS AND ISSUES

In conjunction with the Mission of Chile to the United Nations, the Museum's Department of Education will present a series of performances and film programs highlighting Chilean culture. The *Grupo Congresso* will open the festival on Tuesday, November 29, at 8:00 P.M. with a repertoire of Latin American folklore, jazz, and contemporary music. On Friday, December 9, at 8:00 P.M., *Los Tres* will present a musical program that fuses folk, jazz, and rock and incorporates Chilean social issues. Films will be shown on Friday, December 2, at 7:00 P.M. and on Saturday and Sunday, December 3 and 4, from 12:00 to 5:00 P.M. The films include *Amnesia, Julio Comienza en Julio, Archipiélago, La Luna en el Espejo,* and *La Frontera.* Tickets are $5 per program ($4 each for two or more programs). For information and a brochure, call (212) 769-5315.

AT THE PLANETARIUM

On Monday, December 5, at 7:30 P.M., Michio Kaku, professor of theoretical physics at the City University of New York, will present a slide-illustrated talk, "Parallel Universes, Time Warps, and the Tenth Dimension." The lecture is part of the "Frontiers in Astronomy and Astrophysics" series. Tickets are $8 ($6 for members).

The Ensemble for Early Music will give its eleventh annual concert of medieval music in the Sky Theater on Wednesday and Thursday, December 14 and 15, at 7:30 P.M. Tickets are $20 ($18 for members).

Photographs of recent discoveries made by the Hubble Space Telescope (HST) are on display at the Planetarium in the exhibition "The Universe Revealed: Recent Images from the Hubble Space Telescope." Additional items on display include a seven-foot-long model of the Space Shuttle *Orbiter* deploying the HST, a five-foot-long model of the Optical Telescope Assembly of the HST, and a forty-five-minute video of the Hubble repair mission of December 1993. The exhibition will continue through September 4, 1995.

The holiday Sky Show, "Star of Christmas," will be shown through Sunday, January 1, with the ongoing Sky Show, "Update: The Universe." Call (212) 769-5900 for information, ticket prices, and show schedules.

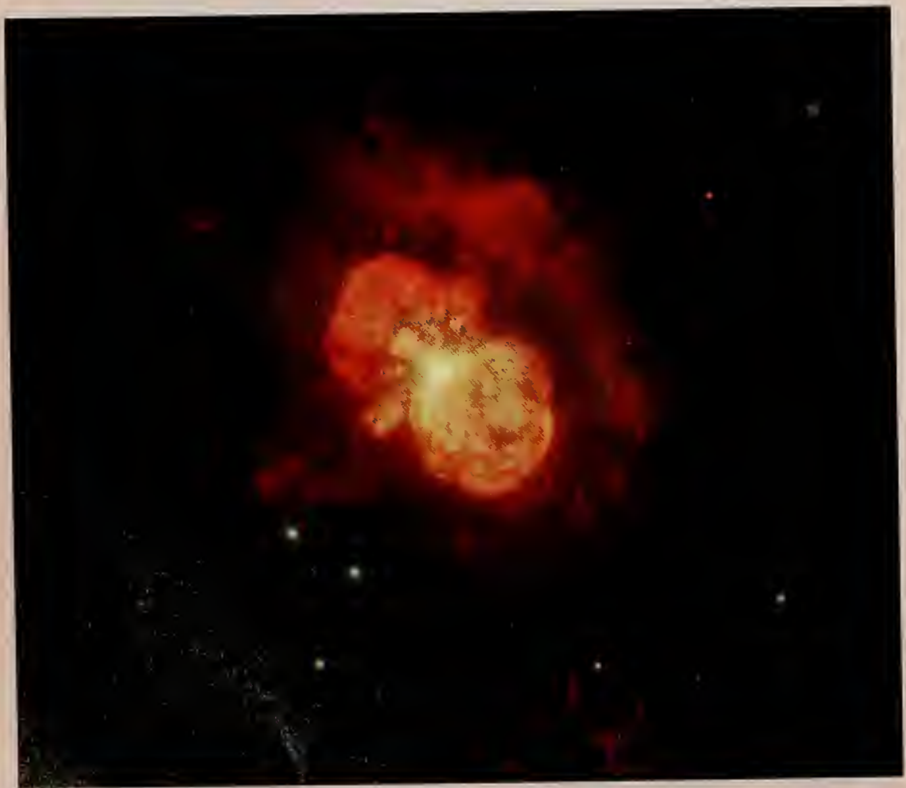
WORLD TOUR 2: GLOBAL EXPEDITIONS

On two Saturdays, December 17 and January 7, two special Museum tours will highlight the historic and scientific achievements of the Museum's research and collecting expeditions around the world. They begin at 6:30 P.M. at the second-floor Roosevelt Rotunda. The tours are free with admission to the Museum but limited to thirty-five people. Call (212) 769-5566 to register in advance.

GEOLOGY OF THE PLANETS

Much new information about the solar system has been collected since the first space probe, *Mariner II,* was launched to explore Venus on August 27, 1962. Geologist Sidney Horenstein, the Museum's coordinator of environmental public programs, will give slide-illustrated lectures on consecutive Thursdays, December 8 and 15, at 7:00 P.M. in the Kaufmann Theater. He will highlight discoveries made during the past three decades, with special focus on the geologic features of our solar system. Call (212) 769-5606 for tickets.

These events take place at the American Museum of Natural History, Central Park West at 79th Street in New York City. The Kaufmann Theater is located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.



A Hubble image records giant bubbles of gas blowing out of the star Eta Carinae at about two million miles per hour.
Space Telescope Science Institute

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This whimsical new collectible is inspired by the artistry of Japanese netsukes. Crafted of crushed marble and resin, these snuggling turtles have the appearance of real ivory. Remove top to reveal a small storage space. Imported from England. 2¼" high.

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The Solstice and a Star in the East

by Gail S. Cleere

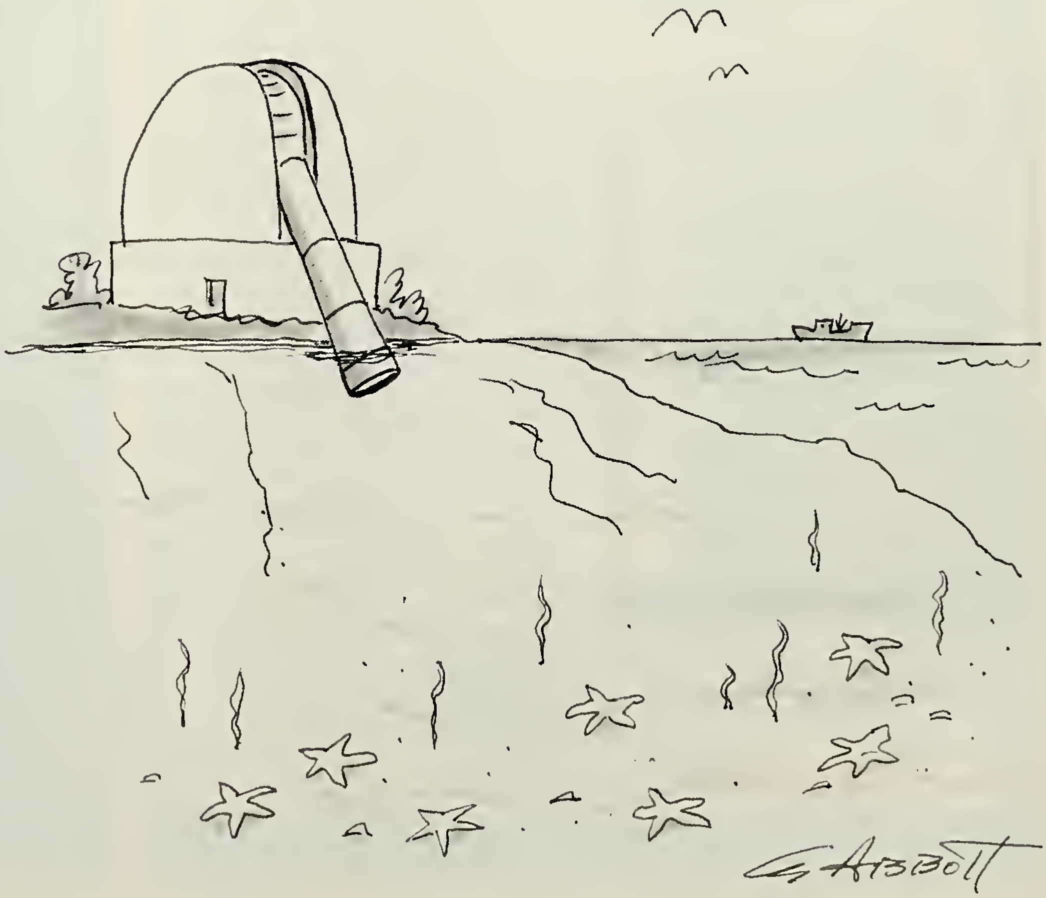
One of the most popular of the ancient Roman celebrations was the winter solstice, the birthday of the unconquered sun. This year the winter solstice occurs on December 21 at 9:23 P.M., EST, and from then on, until the summer solstice in June, the sun climbs higher in the sky each day, eventually bringing warmth and life back to the Northern Hemisphere. The Romans celebrated the solstice on December 25, following the week-long Saturnalia, a raucous festival of merry-making and social revelry. The early Christians adopted this date for the birth of Christ, possibly to turn an existing celebration to their own uses. It successfully amalgamated ancient tradition with new religious practices.

Yet there is more astronomy to the Christian Christmas story than simply the date of the winter solstice. For centuries, astronomers have pondered, puzzled, deliberated, and just plain mused over a few lines in Matthew's Gospel:

> There came wise men from the east to Jerusalem, Saying, Where is he that is born King of the Jews? For we have seen his star in the east, and are come to worship him.... Then Herod ...inquired of them diligently what time the star appeared.... lo, the star ...went before them, till it came and stood over where the young child was. (Matthew 2:1–9)

The exact nature of this "star" is still debated. What possible celestial object or phenomenon could have lured "wise" men to an obscure village in Israel, yet gone unnoticed by everyone else? The mysterious reference to a star seen in the east on or about the date of the birth of Jesus Christ is ambiguous, but be it myth, astrology, or the absolute truth, someone claimed to have seen something unusual in the sky, and that is what interests scientists.

Jesus Christ was probably born a few years (possibly as many as twelve) before the date set down by a Scythian abbot-turned-scholar, Dionysius Exiguus (Denis the Slight), in the sixth century. The Gospel of Luke tells us that Mary and Joseph went to Bethlehem, Joseph's home



town, in accordance with Augustus's decree for taxation, which was probably issued in 8 B.C. In 4 B.C., Herod died, although the Gospels of Matthew and Luke indicate that he was alive at the time of the Nativity.

The timing of the celestial apparition is further complicated by uncertainties over the time of year that it was seen. According to Luke, shepherds in the fields at the time of the Nativity listened as angels told them where and how to find the newborn babe. Spring is the season when shepherds stay in the fields to watch for newborn lambs, although they might also go out into the fields in late summer to allow the sheep to eat the crop stubble and fertilize the fields. Neither possibility matches a wintertime date for the birth of Jesus.

Over the years, explanations of what the Wise Men might have seen have included a variety of conjunctions, or planetary "close encounters"; comets (one may have been visible in 5 B.C. and another in 4 B.C.); a fireball; and a nova or supernova explosion of a dying star, which would have flared up where no significant star may have been seen before.

Many biblical scholars, including Jim Fleming, who lectures on historical geography and archeology at Hebrew University in Jerusalem, believe the "star" was none other than Halley's Comet. Calculations by NASA's Jet Propulsion Laboratory confirm that Halley's Comet could have been visible in the fall of 12 B.C., and the star's appearing twice to the Magi corresponds with the comet's appearance before and after perihelion. Fleming theorizes that the Wise Men's impression that the star helped "point" the way may have come from an appearance of the tail of the comet. The chief argument against Fleming's theory is that comets were usually considered to be omens of evil; they were thought to be the finger of a god pointing downward, warning of some famine, flood, or epidemic. The word *disaster* means "bad star."

Other explanations of Matthew's star include a possible and very significant sighting of Jupiter near the star Regulus in the constellation Leo in 3 B.C. Jupiter was known to the learned men and skilled astrologers of Persia and Babylonia as the "king" planet, and Regulus means "king." Regulus is in the constellation Leo, the astrological "sign" of the ancient tribe of Judah in Israel. To the Wise Men, this could have meant that a king would be born among the Jews, and they duly went to pay homage. Later, Jupiter would move into the constellation of Virgo, the Virgin.

According to the great early-seventeenth-century astronomer Johann Kepler, another significant conjunction might have occurred in 7 B.C., when Jupiter aligned with Saturn, the ruling planet of Judah, in the constellation Pisces (the "House of the Hebrews") three times. Mars overtook them both the next year, in 6 B.C. According to astronomer Guy Ottewell, although Jupiter and Saturn might come together three times in one year every 125 years or more, a grouping of Jupiter and Saturn with Mars occurs only once every 800 years. As it happens, such a rare conjunction of Mars, Jupiter, and Saturn will take place in April of the year 2000.

Most astronomers, meanwhile, agree on one thing: that a "Christmas star" can be delivered at almost any time, since there are always interesting things going on in the sky. This year, at the end of the month, watch for a beautiful scene just before dawn: Venus, Jupiter, and the crescent moon coming together in the east.

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The Planets in December

Mercury is not visible this month. It passes behind the sun in mid-December.

Venus blazes across the morning sky this month, reaching greatest brilliancy on December 9 (–4.7 magnitude). Watch the waning crescent moon pass Venus, then Jupiter, during the early morning hours of the 29th and 30th.

Mars rises in the east in the constellation Leo late in the evening. On the 8th, watch as the ruddy planet passes just above bright Regulus in the heart of Leo. On the 23d, the waning moon passes 9° (about the width of your hand held against the sky) below the planet.

Jupiter rises with Venus this month, having left the environs of the constellation Libra and moved into Scorpius. At the beginning of the month, Jupiter is low in the southeast as dawn's light overtakes it. As the month progresses, the planet gets higher and higher in the southeast before sunrise.

Saturn remains our only early evening planet and can be seen among the faint stars of the water constellation Aquarius. Look for Saturn just after sunset high in the southern sky surrounded by the faint stars of this region. On the 9th, the first-quarter moon sails high above the planet.

Uranus, Neptune, and **Pluto,** which are difficult to spot under the best of conditions, are all lost to solar glare in December.

The **Moon** is new on the 2d at 6:54 P.M., EST, and reaches first quarter on the 9th at 4:06 P.M., EST. Full moon occurs on the 17th at 9:17 P.M., EST, and is at last quarter on Christmas Day, the 25th, at 2:06 P.M., EST.

The Geminid meteors, the year's most spectacular shower of falling stars, peak on the night of December 13–14. The Geminids generally bring us forty to eighty meteors per hour. These meteors are believed to be the remnants of an extinct comet, whose core is now the asteroid Phaethon, orbiting between Mars and Jupiter. The Geminid shower appears to emanate from the constellation Gemini, seen just above Orion's right shoulder. This shower is best observed before sunrise, when the waxing moon is low in the west. Generally, meteor showers are best observed after midnight, when your location on the earth is turning most directly toward the shower.

Gail S. Cleere lives in Washington, D.C., and writes on popular astronomy.

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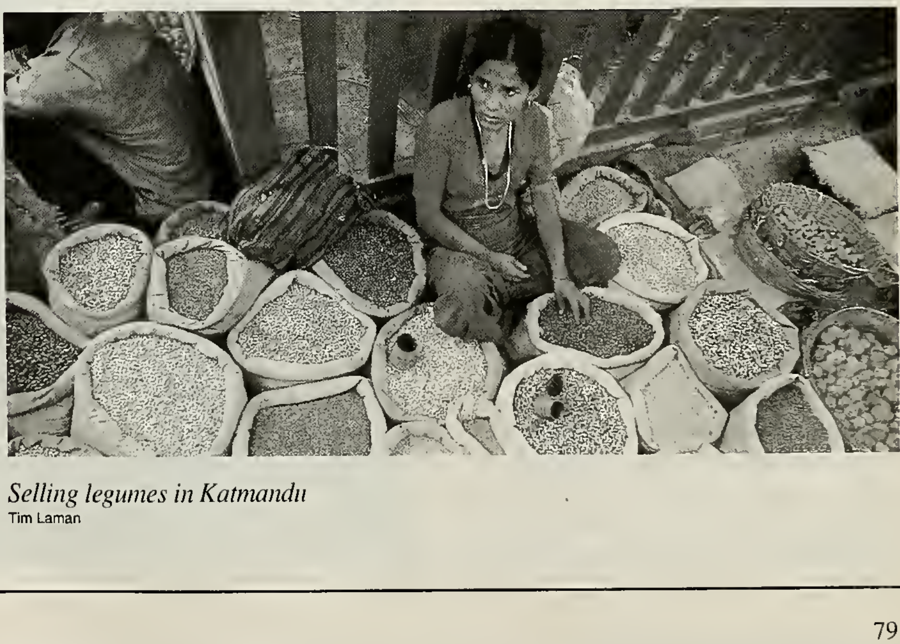


Selling legumes in Katmandu
Tim Laman

By Diversity Possessed

by David G. Campbell

"My truths," writes Edward O. Wilson in *Naturalist*, "...are the following: first, humanity is ultimately the product of biological evolution; second, the diversity of life is the cradle and greatest natural heritage of the human species; and third, philosophy and religion make little sense without taking into account the first two conceptions."

Wilson is, by any measure, one of the great biologists of this century: a synthesizer who brings disparate facts and divergent fields into unity, the cocreator of sociobiology, and a global voice in conservation. His autobiography is destined to be greeted with abounding interest. But *Naturalist* is more than the chronicling of a life. It is a frank appraisal of dogma and revelation, and the relationship between science and society. Moreover, it is a declaration of biophilia (a word Wilson coined), the epiphanic wonder of living on this life-mantled planet.

What are the wellsprings of scientific creativity? What nucleated this interesting mind? Wilson grew up in the 1930s and 1940s in the South, ostensibly a child of middle-class convention: the Baptist Church, the Boy Scouts, a year at the Gulf Coast Military Academy. The son of an itinerant government accountant, an alcoholic who meandered every year or so to a new town and eventually committed suicide, Wilson grew up in twelve cities, none farther north than the District of Columbia. By necessity, he adapted to a "perpetual role as new kid on the block," acquiring the outsider's perspective that decades later may have endowed his science with its startling originality. "I was a normal boy," he writes, "within reason." But curiosity and reason, of course, were his exceptional strengths. Small of stature and introverted, Wilson took solace in nature "as a sanctuary and a realm of boundless adventure," wandering in back lots, turning over stones, peering into rotten logs, noticing the panoply of species. "A lifetime," he writes, "can be spent in a Magellanic voyage around the trunk of a single tree."

Two accidents punctuated this lonely childhood, and these events, as much as the boy's innate characteristics, fated him to be a scientist. Both occurred in his seventh year, when he spent the summer with a foster family in Pensacola while his parents underwent a divorce. The boy made daily, solitary pilgrimages to the ragged shore of Perdido Bay, enchanted by the peculiar life forms tossed up by the waves. Now, in retrospect, he writes that "loneliness in a beautiful environment might be a good if risky way to create a scientist." But beachcombing, I submit, is also a way. Here, while wading in the warm, shallow Gulf of Mexico, Wilson had a vision that transformed him into a passionate biologist. A sea nettle, an opalescent pink jellyfish of complex gelatinous architecture, fretted with stringy red gonads and innumerable soft tentacles, drifted past in the still water. Wilson was mesmerized. "It came to my world abruptly, from I knew not where, radiated what I cannot put into words except—*alien purpose and dark happenings in the kingdom of deep water*." Fifty-nine years later, he writes, "the scyphozoan still embodies, when I summon its image, all the mystery and tensed malignity of the sea."

That same summer, while fishing in Perdido Bay, Wilson tugged a little too hard on the line and flicked a minnow-sized pinfish, dorsal spines erect, into his right eye. Within weeks, he was partly blind. However, the vision in his left eye was more acute than average at close range, and thus ideally suited for the examination of minute detail. "So inevitably, and given that I was looking at the world

The three-year-old Wilson, in 1932.

with only one visually acute eye, I became an entomologist." More specifically, Wilson became a myrmecologist, a specialist who studies the ubiquitous ants. "To put the matter as simply as possible: most children have a bug period, and I never grew out of mine."

The boy also had a gift of expression, certainly not an accident in his environment. His fifth-grade teacher wrote in a letter to Wilson's parents, "Ed has genuine writing ability, and when he combines this with his great knowledge of insects, he produces fine results." Such prescience! Fifty years later, Wilson won his second Pulitzer Prize (with coauthor Bert Hölldobler) for the monumental treatise *The Ants.*

As a teenager, Wilson showed inklings of the great synthesizer he would become. He "was exhilarated by the power and mystery of nuclear energy" and regarded physicist Robert Oppenheimer, whom he later met at Harvard, as a "master of arcane knowledge that had tamed for human use the most powerful force in nature." Wilson was also fascinated by the work of Erwin Schrödinger, who "argued not only that life was entirely a physical process, but that biology could be explained by the principles of physics and chemistry." He dreamed of "biology transformed by the same mental effort that split the atom" and, anticipating sociobiolgy, "of the grail, and the revelation of purest ray serene that gives wholeness and meaning to life. There must be a scientific explanation for religion, moral precepts, the rites of passage, and the craving for immortality.... Religion had to be explained as a material process, from the bottom up, atoms to genes to the human spirit."

For a time, he did not believe in his own genetic determinism. While a student at the University of Alabama, convinced that he could break the four-minute mile with sheer discipline and grit, Wilson bought a pair of clunky surplus Army boots and for an hour or two every evening trained in solitude, figuring that the added burden of the boots would bestow the winner's edge when he finally donned lightweight track shoes. "Do it alone, avoid the drag of teams, have no one witness your trials and failures, until you can accomplish some exceptional feat." But when he finally tried out, he ran the mile without distinction in just over five minutes. His career in track was over. "This result impressed me deeply. It seemed to show that heredity is destiny, at least in one important sense: taken to the limit of human capacity, performance follows a predetermined trajectory."

NATURALIST, by Edward O. Wilson. *Island Press, $24.95; 367 pp., illus.*

In 1952, leaving the South with a degree from the University of Alabama, the neophyte entered the yeasty intellectual environment of Harvard as a graduate student. He never left. Wilson was no longer satisfied with his comfy rambles in the boondocks and adopted the advice of his mentor and fellow graduate student William Brown: "to select large, important projects and to aim for publishable results.... Take a global view; don't sell yourself short with local studies and limited goals." Wilson's rise was inexorable.

In 1953, at age twenty-four, he was appointed to the Harvard Society of Fellows, "a happy indigent admitted to the company of lords," and like Darwin 122 years before, was given virtual *laissez-passer* to roam the world. Wilson collected ants—in Cuba, Mexico, New Caledonia, New Guinea, Australia, and Ceylon—taking samples of every kind. All of these destinations were islands, except Mexico, where Wilson climbed Pico de Orizaba, a virtual island of forest, tundra, and scree surrounded by denuded lowlands. He began to notice the disharmonies of island biotas: that certain species always seemed to displace others, that the number of species was a function of island size and distance from the mainland. These were the germinal concepts of the theory of island biogeography, which wouldn't be formalized for another decade. Also on this long voyage, the first inklings of Wilson the conservationist appeared. In New Caledonia he used "the universal formula for gaining access to tropical forest: crawl through a barbed wire fence, walk across a cow pasture, wade a shallow part of the river...and climb a hillside into the forest."

After graduation, Wilson was invited to join the faculty of the Department of Biology at Harvard, a place of "the amphetamine of ambition," of revelation...and infighting. Wilson's opponents were as obdurate and sparkling as diamonds. "Without a trace of irony," he writes, "I can say I have been blessed with brilliant enemies.... I owe them a great debt, because they redoubled my energies and drove me in new directions." The most formidable, perhaps, was James Watson, who, flush from characterizing the structure of DNA, was the ultimate reductionist. A newly minted assistant professor of biology at Harvard, Watson perceived molecular genetics as the grail of biology and regarded ecologists and taxonomists as old-fashioned "stamp collectors"; worse, they were impediments to the new and exciting domain that he invented. But Watson's campaign was hardly gentle. It was a revolution so acerbic that it eventually led to the fissioning of the Department of Biology. Watson, writes Wilson, was "the most unpleasant human being I had ever met...the Caligula of biology." For a decade, the term ecology became "a dirty word" at Harvard, according to Elso

Barghoorn, the esteemed paleobotanist at the Museum of Comparative Zoology.

In 1956, evolutionary biology and ecology were little more than descriptive natural history. They lacked the synthesis, the reductionism, of molecular genetics. These shortcomings troubled Wilson. "If heredity can be reduced to a chain of four molecular letters," he reasoned, "...would it not also be possible to reduce and accelerate the analysis of ecosystems and complex animal behavior?" Over the next three decades, determined to reform organismal biology, Wilson began a series of brilliant syntheses: the theory of island biogeography, the taxon cycle of island biotic evolution, the concept of character displacement, chemical signaling in ants, the comparative social behavior of ants, and eventually, sociobiology—the comparative behavior of animals.

"I began to worry...about the broader canvasses of ecology and evolution.... I felt certain that the future principles of evolutionary biology would be written in equations, with the deepest insights expressed by quantitative models." But he could not do it alone. "Mathematically semiliterate...unable to get digits in the right order while reading and copying numbers," Wilson entered a series of partnerships with gifted quantitative biologists: Robert MacArthur, William Bossert, Daniel Simberloff, George Oster, and Charles Lumsden. In these mutualisms Wilson provided the arcane bits of natural history and the synthesis; his colleagues provided the models. "They were my intellectual prosthesis," he recalls, "and I theirs."

At Harvard in 1953, after hearing lectures on the new science of ethology by Niko Tinbergen and Konrad Lorenz, Wilson began to craft the controversial field of sociobiology. The goal of sociobiology was as reductionist as that of molecular genetics: "A systematic study of the adaptive significance of animal—and human—behavior." Wilson's massive treatise, *Sociobiology*, published in 1975, had twenty-six chapters devoted to nonhuman animals and a twenty-seventh devoted to humans; the final chapter made all the difference. Wilson focused his gift for synthesis on the common behavioral characteristics shared by humans. "The Manhattanite and New Guinea highlander have been separated by 50,000 years of history, but still understand each other, for the elementary reason that their common humanity is preserved in the genes they share from their common ancestry."

Inevitably, sociobiology ran against the political and religious doctrine of free will. The Marxists, who believed that human behavior could be modified by its social context, were particularly threatened. "I conjectured," recalls Wilson, "that there might be single, still unidentified genes affecting aggression, altruism, and other behaviors," and that at least a component of these behaviors, therefore, were beyond the reach of nurture. Yet, Wilson argues, determinism is not necessarily ignoble. "I have a special regard for altruism and devotion to duty, believing them virtues that exist independent of approval and validation.... The sight of the Iwo Jima and Vietnam Memorials pierces for the witness they bear of men who gave so much...and the strength ordinary people possess that held civilization together in dangerous times."

Regardless, sociobiology evoked a furor, and Wilson felt that the criticism was often ad hominem and vicious. Shortly after the book's publication, a Boston-based group of academics formed the Sociobiology Study Group, dominated by Harvard's Marxist and New Left scholars Richard Lewontin and Stephen Jay Gould. The group published a critique of sociobiology in the letters section of the *New York Review of Books*, decrying sociobiology as politically dangerous and declaring that it tended to "provide a genetic justification of the *status quo* and of existing privileges for certain groups according to class, race, or sex." Lewontin was the eminent population geneticist of his time and, like Watson, was "the kind of adversary most to be cherished, in retrospect, after time has drained away the emotion to leave the hard inner matrix of intellect." He was also chair of the Department of Biology, and in Harvard Yard, few rose to Wilson's defense, although, as he learned later, many admired his stance. Wilson felt alienated, "like an atheist in a monastery," and even considered accepting jobs elsewhere.

The furor spread into other academic forums and metastasized into the popular culture. At a particularly McCarthyesque annual meeting in 1976, the American Anthropological Association formally debated whether to ban scholarly symposia devoted to the subject of sociobiology. Margaret Mead, who herself had once postulated a genetic ability that some people possess for particular skills, quelled the inquisition, condemning it as "book burning." Two years later, the screechy, politically correct members of the International Committee Against Racism assaulted a packed symposium on sociobiology organized by the American Association for the Advancement of Science, where Wilson was to speak. They hijacked the microphone and shouted slogans at the disquieted (in some cases, nearly panicked) audience. Wilson, in a cast with a fractured ankle, was drenched with a pitcher of ice water and verbally pilloried as being "all wet."

According to Wilson, "the greater problems of history are not solved, they are merely forgotten." So far, academia seems unlikely to forget sociobiology. Still controversial, it continues to influence the study of evolution, religion, art, and even legal theory. Today more than two hundred books and four scholarly journals—a small ivory tower—are devoted to sociobiology, and in 1989, Wilson's pioneering text was deemed by the fellows and officers of the Animal Behavior Society to be the most important book ever written on ethology.

"Science is modern civilization's highest achievement, but it has few heroes," he writes. Maybe so, but Wilson's journey is heroic, and it is beautifully depicted here. Wilson's autobiography, like his life, is a rich and nuanced odyssey, a reminiscence on discovery, society, science, intellectual fortitude, and on memory itself. I particularly commend it to young biologists, for it describes not only the passion and beauty of science, but an inspired scientist's survival strategies in academia, a society that is, alas, only human. "What happened, what we *think* happened in distant memory," he writes, "is built around a small collection of dominating images." Wilson's images happen to be some of the great events in a century of dramatic science, revolutions that transformed our relationship to the natural world.

However, to the end, Wilson is the humble naturalist, the beachcomber-child neotonous in wonder. "Like my fellow field biologists who waded with me into swamps and climbed forested hillocks, we were civilized hunters searching for something new that might be captured, something valuable enough to take back home and display at the tribal campfire."

David G. Campbell is Henry R. Luce Professor of Nations and Global Environment at Grinnell College in Iowa. His book, The Crystal Desert: Summers in Antarctica, *won the 1994 John Burroughs Medal. He is currently working on a book about Amazonian biodiversity.*

Hidden Assets

Photographs by Michael Quinton

Birds that tough out the winter in the mountains of Idaho need to be on the lookout for unlikely packages that may contain a meal. For year-round residents such as mountain chickadees, hairy woodpeckers, and Clark's nutcrackers, a wasp nest can prove to be a veritable piñata.

Like their cousins the jays and crows, nutcrackers are a boisterous and opportunistic lot. One hungry nutcracker, having discovered a yellow jacket nest in a dead aspen (inset), attacked it with such zeal that the nest plummeted to the snowy ground. Vigorously shaking its head and using its long, stout beak to hammer through the layered paper walls, the nutcracker expertly ripped apart the nest. According to photographer Michael Quinton, the bird acted as if it "knew exactly what it was doing." It then employed its beak as a probe, extracting inert adult yellow jackets and any dead larvae still ensconced in the small, hexagonal, silk-covered chambers. Thanks to a stretchy pouch under its tongue, the nutcracker was able to collect whole throatfuls of the insects.

Typically, nutcrackers use their beaks to pry open pine cones, particularly those of piñon pines, and to pluck out the seeds. Those not consumed on the spot can be carried away in the pouch, which holds some ninety piñon seeds at a time, and then buried, to be retrieved in leaner times. This nutcracker applied its caching skills to the bonanza at hand, removing larvae-laden sections of the nest and stashing them under the snow on tree boughs, perhaps for a late-winter snack.—*J. R.*

Authors

New York-born **Jonathan Marks** (page 32) has spent most of his adult life "vacillating between the natural and social sciences." After earning an undergraduate degree in natural science at Johns Hopkins, he went on to study in the genetics department at the University of Arizona but "failed to derive adequate inspiration from fruit flies and bacteria." While finishing his master's degree, he began to play softball with anthropologists, "and the rest is history." (Well, almost. After getting his Ph.D. in anthropology, Marks did a post-doc in genetics at the University of California at Davis.) Now an associate professor of anthropology at Yale University, Marks remains interested in "the place of humans in the natural order of things" and is studying the changes in chromosome structure that have accompanied our evolutionary divergence from the African apes. He is the coauthor, with Edward Staski, of the introductory textbook *Evolutionary Anthropology* (San Diego: Harcourt Brace Jovanovich, 1992). His new book, *Human Biodiversity: Genes, Race, and History,* is being published in January 1995 by Aldine de Gruyter.

Brian W. Bowen (page 36), shown here with a baby sea turtle in his pocket, is director of the Conservations Genetics Laboratory at the University of Florida, where his work has focused on the genetics of sea bass, sturgeon, Florida scrub lizards, manatees, and rattlesnakes. His special interest in marine creatures began at the age of seven, when his parents gave him a mask and snorkel to dive in Cape Cod Bay. He became interested in Ascension Island's turtle migration "because it is a classic enigma" and collaborated on the study with his former professor, **John C. Avise.** Avise, a geneticist, has applied molecular techniques to the study of kinship and evolution in a variety of animals. A professor of genetics at the University of Georgia at Athens, where he runs the molecular research laboratory, Avise has diverse interests reflected in his contributions to *Natural History,* ranging from coral clones (December 1984) to the uses of mitochondrial DNA in tracing evolutionary relationships (March 1989). For further reading about Chelonians, Bowen recommends Archie Carr's *The Sea Turtle: So Excellent a Fishe* (Austin: University of Texas Press, 1986) as a starting point. For an introduction to biochemical techniques for studying evolution, see John Avise's *Molecular Markers, Natural History and Evolution* (New York: Chapman and Hall, 1993).

Paul C. Sikkel (page 46) first studied fish behavior in the field at the Scripps Institution of Oceanography, where he worked for A. P. Klimley, who was studying the social dynamics of hammerhead sharks in the Gulf of California. "That hooked me for good, but I wanted to study something smaller that was easier to observe, so I began focusing on reef

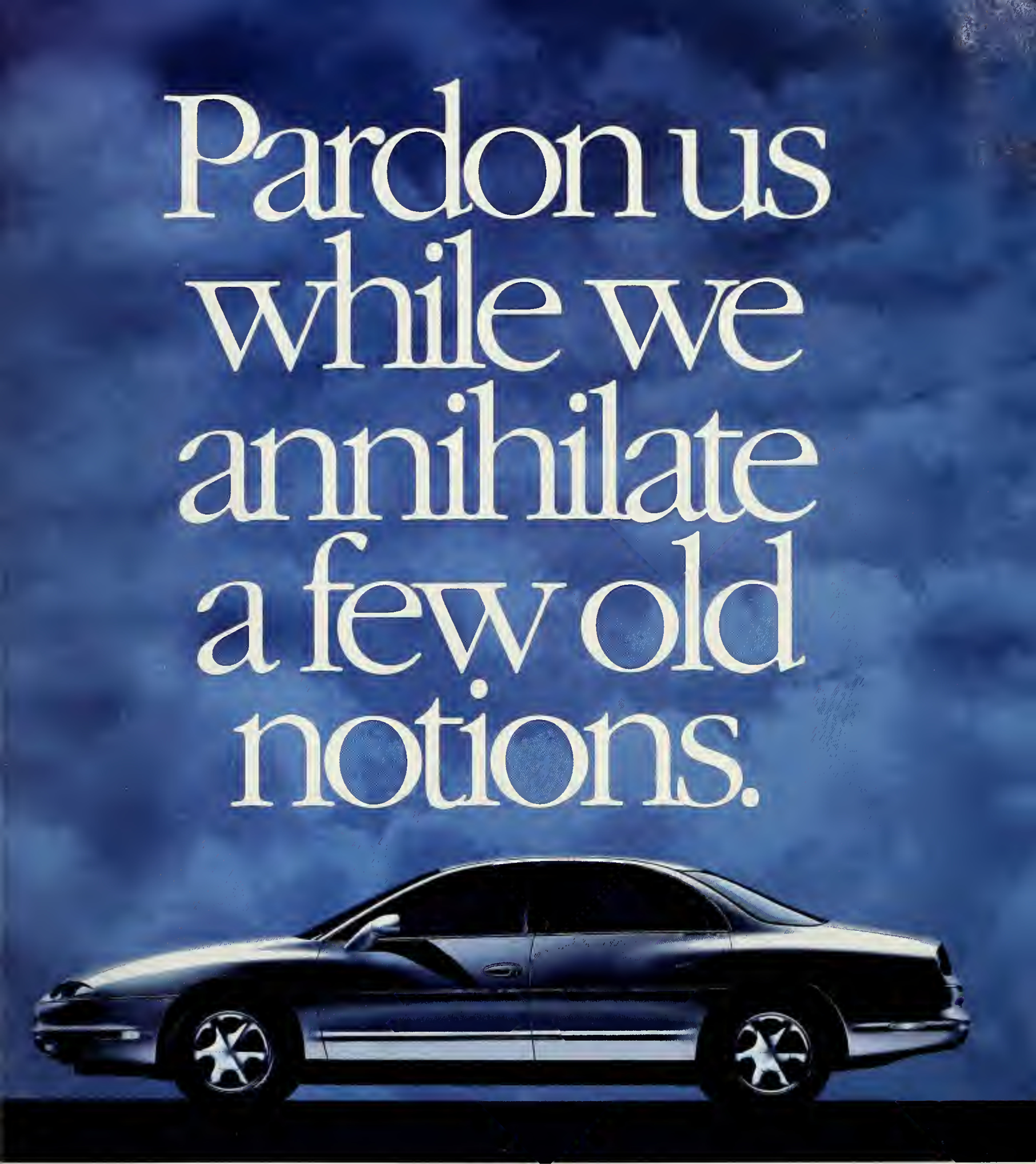
fishes." The garibaldis nesting on rocky reefs around Catalina filled the bill. His study of their reproductive behavior was the focus of his doctoral dissertation, as well as his article in this issue. Sikkel continues to study mate selection in reef fishes and is trying to solve the mystery of why garibaldis need elaborate red algae nests for their eggs. He is also involved with efforts to protect garibaldis from overexploitation by the aquarium industry. For reading on why animals occasionally devour their young, the author recommends *Cannibalism: Ecology and Evolution Among Diverse Taxa*, edited by M. Elgar and B. Crespi (New York: Oxford University Press, 1992).

Ian Ross (page 52) is a field biologist who studied grizzly bears, black bears, moose, bighorn sheep, and mountain goats in the wild before tracking North America's most elusive large mammal, the cougar. Born in Goderich, Ontario, in 1958, he has spent his life since the age of twenty in the Canadian wilderness. After earning a bachelor of science degree in wildlife biology from Guelph University in 1982, Ross says, he pursued "higher education in the foothills of the Rocky Mountains." As a senior wildlife biologist for Arc Wildlife Services, Ltd., in Calgary, he studies the population and habitat ecology of cougars and their responses to human disturbances. He hopes his basic research will ultimately contribute to the protection and conservation of large predators, both in North America and abroad. When not at work, what does Ross do for recreation? Why, he takes canoe trips through the Canadian wilderness, of course. For further reading on the ecology of large North American carnivores, he recommends Kevin Hansen's *Cougar: The American Lion* (Flagstaff: Northland, 1992) and Wayne Lynch's *Bears: Monarchs of the Northern Wilderness* (Vancouver: Douglas and McIntyre, 1993).

Michael Quinton (page 84) finds winter an especially rewarding time for wildlife photography. For more than fifteen years, he has been documenting the behavior of the animals that survive the long winters in the mountains of southeastern Idaho, near his home at the edge of Yellowstone National Park. He shot this month's "Natural Moment"—a Clark's nutcracker plundering a yellow jacket nest on a February day—using a Nikon F3 camera and a 400mm lens. His previous "Natural Moment," a winter scene of a pine marten and its prey, appeared in February of this year. At that time, Quinton and his wife and two young children were thinking of moving to Alaska to escape the growing human population of Idaho. Now they are about to do just that, having purchased a place in the Alaskan wilderness. There Quinton will have plenty of land, plenty of winter, and plenty of subjects. In particular, he looks forward to photographing tundra birds and, with the pristine fish runs in the state, to indulging a new interest, underwater fish photography. Quinton's photos have appeared in several books, including *The Ghost of the Forest: The Great Gray Owl* (Flagstaff: Northland Publishing, 1988). For more information on Clark's nutcrackers, readers can turn to "Remembrance of Seeds Stashed," by Stephen Vander Wall and Russell P. Balda, in the September 1983 issue of *Natural History*.

After earning his Ph.D. in archeology from Cambridge, **Charles Higham** (page 60) left England in 1968 to teach at the University of Otago in New Zealand and to make Southeast Asian prehistory his research specialty. He met **Rachanie Thosarat,** who was still an undergraduate at Bangkok's Silpakon University, at an excavation site in Thailand in 1975. She went on to the universities of Pennsylvania and Otago for advanced degrees

but has collaborated with Higham on field research ever since their first meeting. A huge, moated settlement and cemetery in northeast Thailand will probably be their next project, which they hope will yield information about the prehistoric cultures that led to the establishment of the state of Angkor. What do archeologists do in their spare time? Higham builds brick walls and runs a small commercial herb garden at his holiday cottage overlooking Lake Hawea in central Otago. Thosarat tends a garden full of roses, honeysuckle, and jasmine in the Thai countryside. For further reading, they suggest *Prehistory of the Indo-Malaysian Archipelago,* by P. Bellwood (New York: Academic Press, 1986) and *The Cambridge History of Southeast Asia,* edited by N. Tarling (Cambridge: Cambridge University Press, 1992).



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