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Cover: A grizzly, plump with fat reserves, endures an ice storm shortly before entering a den for a long winter’s hibernation. Photograph by Johnny Johnson. Story on page 50.
**A Lost Atlantis**

Seeing pictures of the research vessel *Atlantis I* in your fine article, “Mappers of the Deep,” by Marie Tharp and Henry Frankel (October 1986) brought to mind the first *Atlantis*. She was a two-masted schooner on the lines of a Gloucester fisherman or *Bluenose*, sailed by my good friend Columbus Iselin, a staff member of the Woods Hole Oceanographic Institution. She was so named because Columbus had an idea that there might be a lost continent of Atlantis deep in the mid-Atlantic somewhere. She had no radio or engine save for a Ford tractor engine on deck to reel up a mile or two of piano wire attached to a deep net for sampling fauna. I was a member of her crew on a passage from Plymouth, England, to Boston in 1928—a tough, windward voyage lasting about a month.

J. Lawrence Pool, M.D.
West Cornwall, Connecticut

**Roots of the Sweet Potato**

When we eat an ordinary potato, we are eating a tuber that actually is an underground stem of the potato plant and that produces “eyes,” or buds. But the edible portion of the sweet potato plant is an enlarged root, not a tuber as stated by Raymond Sokolov in a recent column (“The Sweet Potato Perplex,” March 1986). The growers also save the roots to use as propagating material for the following year. They cure the roots, not to dehydrate them, but to encourage the wounds to heal rapidly so that they are not invaded by decay organisms (bacteria or fungi). In the late winter, the growers place the roots in plastic- or glass-covered “sprout beds.” Each entire root is placed horizontally about four to six inches under the surface, and many adventitious buds form on a root, especially on the end that was the top in the previous year. The sprouts grow up to the surface, and soon the bed appears as a green mass of leaves. At planting time they “pull” the sprouts that break off from the parent root. These sprouts have produced many roots on the underground part of the stem. These rooted sprouts are the planting material for the crop, not the roots that produced them.

Unfortunately, this practice leads to a number of disease problems, which is why I have gotten involved with this crop at the College of Agriculture at the University of California at Davis. In particular, I, along with others, have been working with the extension agents and growers to provide virus-free planting stocks through a “clean stock” program.

Robert N. Campbell
Davis, California

**Errata:** The pink sandstone in the picture on pages 56-57 of the November 1986 issue gets its color from ferric oxide, not ferrous oxide; and on pages 62–63, the dark rocks behind the sand dunes were once 3 miles under the sea, not 3,000.
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Telltale Teeth

From the mouths of prehistoric Indians comes evidence tracing their northeast Asian ancestry

by Christy G. Turner II

When I recently turned to the notes of my 1977 studies at the American Museum of Natural History, I was reminded that on July 1 it was warm, muggy, and overcast outdoors; debilitatingly humid in the anthropology storerooms. That discomfort has been overshadowed in my memory by the thrill of the discovery I made that day when I examined small pieces of burned human bone and teeth excavated by the late Junius Bird many years earlier in two caves in southern Chile. These delicate fragments were all that remained of twelve Indians cremated by their friends or relatives 11,000 years ago. My excitement grew as I identified, with the aid of a hand lens, a number of tiny dental anatomical features that I had previously recorded hundreds of times not only in prehistoric and living Indians, Aleuts, and Eskimos but also in northern Chinese, Japanese, Mongolians, and Siberians. For me, a relationship between northeast Asians and these remote Chilians was clinched when the last bit of bone proved to be a heat-cracked lower jaw fragment with a three-hole socket for the first molar. Three-rooted lower first molars are common in Asians but rare in European or African populations, whose lower first molars normally have two roots. That Chilian mandible still is the oldest known example of a three-rooted lower first molar in the New World.

There are more than two dozen largely independent traits of tooth crowns and roots that serve admirably to characterize living and ancient populations, as well as aid in reconstructing past and present biological affinities. Teeth are ideally suited for this research because they preserve well, their structure is genetically determined, and their form is not as much influenced by a person’s diet, health, exercise, age, or sex as is that of bones. Dental anatomy is also evolutionarily quite conservative: very little change takes place over several thousand years. This quality is helpful for assessing the origin of Native Americans, who have been in the New World for at least 12,000 years.

Scientists have recognized for some time that populations differ in the percentage of their members who exhibit certain traits. About 1 percent of Europeans have three-rooted lower first molars, for example, compared with 30 percent of Chinese. Other alternative root forms are the single-rooted versus multirotted upper first premolar and the single- versus double-rooted lower canine. With respect to tooth crowns, lower first molars can possess four, five, or six primary cusps, or elevations, on the chewing surface, and upper molars may have an additional lingual (tongue-side) feature called Carabelli’s cusp. Another important distinguishing trait is the degree to which the lingual surface of incisors is ridged or curled at the sides. Incisor shoveling (as this feature is called, because the shape is similar to that of a shovel) is most marked and frequent in Asians and American Indians. It is much less common, as well as less pronounced, in Europeans and Africans. By comparing the frequencies of these and other traits one can decide which past and present human groups are most similar and therefore most closely related.

The story of the peopling of the Americas begins in the Old World, where early ape and hominid evolution took place. Because Asia was connected with North America by the Bering land bridge as recently as 12,000 years ago, anthropologists and archeologists look to Asia as the ancestral homeland of the Indians. Kazuro Hanihara, one of the many scientists who have researched this possibility, demonstrated a general resemblance between Japanese teeth and those of certain American Indians. In fact, Hanihara has proposed that Japanese and American Indian teeth are both members of what he terms the Mongoloid dental complex.

In examining other East Asian populations, I have concluded that the Mongoloid dental complex has two major components. In northern Asia, tooth structure is generally more complicated than in the southeast. Incisor shoveling, for example, is more frequent. Northern Asian teeth thus contrast more strongly with European and African teeth than do those of Southeast Asians. I term the pattern of Southeast Asian trait frequencies sundadonty because it is characteristic of all the populations of mainland and island Southeast Asia surrounding the now submerged Sunda Shelf. The northern pattern I call sinodonty because I first identified it in a large set of Chinese skulls excavated from the 3,000-year-old site of An-yang.

Sindonty appears in the three skulls from the 18,000-year-old upper cave site of Choukoutien in northern China, so it must have evolved sometime earlier, perhaps 30,000 years ago. Being more complicated, it must have derived from the related but simpler sundadont pattern of Southeast Asia. Sindonty could not have evolved from the European dental pattern, which is even simpler than sundadonty. Thanks to help from USSR Academy of Science anthropologists, I have established that there are known skeletal remains west of Lake Baikal and the Lena River that could serve as ancestral stock for any group of sinodonts.

Over the past twenty-five years, I have studied more than 200,000 prehistoric teeth from the New World, representing the remains of some 9,000 individuals (prehistoric teeth are the preferred source of information, since more recent teeth may reflect European admixture). From this research I have concluded that two dental facts stand out as most significant in the Americas. First, all Native American groups possess the sinodont pattern. Despite claims made on the basis of
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odd bits of cultural information for Near Eastern, African, Polynesian, or European origins or pre-Columbian contact, the dental evidence from the prehistoric North and South American Indian, Aleut, and Eskimo skeletons I have studied indicates that the ancestors of all Native Americans originated in northeast Asia. Because dental microevolution appears to be rather uniform throughout the world, the dental differences between northeast Asians and American Indians can be used to calculate when these two populations separated. My estimate is that sinodonts first crossed over to Alaska not much before 15,000 years ago. If pre-Columbian non-Asian contact subsequently occurred (for example, the few Viking visitors to Newfoundland), with respect to teeth, it left no recognizable genetic effect.

Second, the large sample I have analyzed falls statistically into three New World dental groups, although there are no divisions comparable in magnitude to the Asian division between sundadonts and sinodonts. Most northern is the Aleut-Eskimo cluster, which is characterized by very high frequencies of three-rooted lower first molars and single-rooted upper first premolars, and relatively low frequencies of incisor shoveling, Carabelli's cusp, and other traits. To the south, almost all North and South American Indians form a second cluster. In this big but homogeneous division, trait frequencies tend to be the opposite of what is found in the Aleut-Eskimos. The third dental cluster contains Northwest Coast and Alaskan interior Indians. The characteristics here tend to be intermediate between those of Aleut-Eskimos and the large North and South American Indian group. For example, three-rooted lower first molars occur in 27 to 41 percent of Aleut-Eskimo samples, 6 to 11 percent of North and South American Indians, and 10 to 22 percent of the Northwest Coast—Alaskan interior division.

There are three possible explanations for the New World subdivisions. One is that the clusters evolved in the New World from a single founding population. To have diverged in this way, human groups would have had to have been subjected to some environmentally related selective pressure, but the dental clusters do not correlate spatially with specific New World environments. Second, there might have been two migrations from Siberia, with the intermediate Northwest Coast—Alaskan interior Indians formed as a New World hybrid population. This possibility can be rejected on the basis of other genetic information. Aleut-Eskimos possess some genes, such as the B variant in the common ABO blood system, not found in Northwest Coast and Alaskan interior Indians and lack others known for these Indians. Moreover, the two groups exhibit the greatest genetic differences where they border on each other.

The third possibility is that the three dental clusters represent three separate migrations from Asia. While this cannot be determined by the dental evidence alone, independent New World linguistic, archeological, and genetic studies support this conclusion. Under this scenario, the ancestors of the New World peoples emerged about 20,000 years ago, when the north China sinodont population began to expand northward, entering uninhabited regions. During the several millennia required to settle eastern Siberia, small bands of closely related individuals were confined to major river systems by bordering mountain ranges capped with glaciers. As a result of random change, dental characteristics began to vary among these relatively isolated groups.

Perhaps the first to move toward the Bering land bridge were bands that hunted and fished their way northeastward in the Amur basin, eventually reaching the frozen Sea of Okhotsk. There, faced with millions of sea mammals, they created a maritime hunting culture. Beginning 16,000 years ago, after the height of the last Ice Age glaciation, both Asian sea mammals and humans expanded toward Alaska along the southern coast of the Bering land bridge. Once in the Amer-

Who Is Related to Whom:
Population Frequencies of Shovel-shaped Incisors

Maps by Geographics

Teeth reveal a lot about the biological relationships among world populations. For example, the high frequency of incisor shoveling among all northeast Asians and New World peoples distinguishes them from Southeast Asians and from Europeans and Africans. This and other tooth traits support the view that migrants from northeast Asia settled the New World. A tripartite subdivision in the New World suggests that there may have been three principal migrations.
Lenox.
icas the maritime people spread along the Aleutian chain and the arctic coasts of Alaska, Canada, and Greenland, founding the Aleut-Eskimo population.

A second wave of migrants may have consisted of wandering bands of hunters and fisherfolk who discovered the northward flowing Lena River, reached Beringia, and moved into Alaska without encountering as major an environmental change as did the Amur folk. These interior Beringian people developed the social hunting skills and technology needed to dispatch large animals, such as mammoths, and about 12,000 years ago, they left Alaska to settle all of eastern Canada and most of North and South America.

Archaeological finds suggest a third migration originated between the Lena and Amur basins, giving rise to the Indians who settled the Alaskan interior. These people remained there and along the Northwest coast, but shortly before Europeans entered the New World, some bands pushed south along the Pacific coast to northern California, and others we know as Apache and Navajo reached the Southwest by A.D. 1500.

Additional research on prehistoric teeth may someday provide independent confirmation of these three migration routes. Meanwhile, the story of the peopling of the Americas has an interesting dental footnote. A few years ago, my Arizona State University colleague Donald H. Morris identified a rare form of upper premolar crown; he named it the Uto-Aztecan premolar because of its presence in Southwest Indians belonging to this language family. In studying Native Americans from Alaska to Chile, I have found this premolar only in the major grouping of North and South American Indians. It is absent in Aleuts and Eskimos, and only one North Pacific skull from Kodiak Island might have possessed it. By itself this rare dental variant suggests the likelihood of at least two migrations.

The genetic mutation responsible for the Uto-Aztecan premolar must have occurred about the time ancestral Indians reached the headwaters of the Missouri River, because I have found the trait in southeastern U.S. Indians, in some South American craniums, and of course in prehistoric Aztecs and several Southwest and California Indians. I have never found it in any of thousands of Asian, Pacific, Siberian, African, and European craniums.

Could there have been a migration into the New World before the sinodons? Thanks to biologists all over the world, we know a lot about fossil, recent, and living human teeth. Not only do living Native Americans follow the sinodont pattern, but nowhere in the New World has a prehistoric skeleton been found with other dental characteristics. If any humans predated the emergence of the sinodonts reached the Americas, their skeletal remains have yet to be unearthed.

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Origins of the Three New World Dental Groups

By William C. Cherry

In the Arctic, Aleuts and Eskimos are the dominant group. In the South, the most North and South American Indians are dominant, and in the West, the Northwest Coast and Beringian Interior Indians are dominant. The migration of the Aleutians into the Arctic, followed by the migration of the Beringians into Alaska, eventually led to the peopling of the Americas.
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The Panda’s Thumb of Technology

We have an example of the principle of imperfection at our fingertips

by Stephen Jay Gould

The brief story of Jephthah and his daughter (Judg. 11:30–40) is, to my mind and heart, the saddest of all biblical tragedies. Jephthah makes an inimmediate vow, yet all must abide by its consequences. He promises that if God grant him victory in a forthcoming battle, he will sacrifice by fire the first living thing that passes through his gate to greet him upon his return. Expecting (I suppose) a dog or a goat, he returns victorious to find his daughter, and only child, waiting to greet him “with timbrels and with dances.”

Handel’s last oratorio, Jephtha, treats this tale with great power (although his librettist couldn’t bear the weight of the original and gave the story a happy ending, with angelic intervention to spare Jephthah’s daughter at the price of her lifelong chastity). At the end of part 2, while all still think that the terrible vow must be fulfilled, the chorus sings one of Handel’s wonderful “philosophical” choruses. It begins with a frank account of the tragic circumstance:

How dark, O Lord, are thy decrees!... 
No certain bliss, no solid peace, 
We mortals know on earth below. 

Yet the last two lines, in a curious about-face, proclaim (with magnificent musical solidarity as well):

Yet on this maxim still obey: 
WHATEVER IS, IS RIGHT

This odd reversal, from frank acknowledgment to unreasonable acceptance, reflects one of the greatest biases (“hopes” I like to call them) that human thought imposes upon a world indifferent to our suffering. Humans are pattern-seeking animals. We must find cause and meaning in all events (quite apart from the probable reality that the universe both doesn’t care much about us and often operates in a random manner). I call this bias “adaptationism”—the notion that everything must fit, must have a purpose, and in the strongest version, must be for the best.

The final line of Handel’s chorus is, of course, a quote from Alexander Pope, the last statement of the first epistle of his Essay on Man, published just thirteen years before Handel’s oratorio. Pope’s text contains (in heroic couplets to boot) the most striking paean I know to the bias of adaptationism. In my favorite lines, Pope chastises those people who may be unsatisfied with the senses that nature bestowed upon us. We may wish for more acute vision, hearing, or smell, but consider the consequences.

If nature thunder’d in his op’ning ears 
And stunn’d him with the music of the spheres 
How would he wish that Heav’n had left him still 
The whisp’ring zephyr, and the purling rill!

And my favorite couplet, on olfaction:

Or, quick effluvia darting thro’ the brain, 
Die of a rose in aromatic pain.

What we have is best for us—whatever is, is right.

By 1859, most educated people were prepared to accept evolution as the reason behind similarities and differences among organisms—thus accounting for Darwin’s rapid conquest of the intellectual world. But they were decidedly not ready to acknowledge the radical implications of Darwin’s proposed mechanism of change, natural selection, thus explaining the brouhaha that the Origin of Species provoked—and still elicits (at least before our courts and school boards).

Darwin’s world is full of “terrible truths,” two in particular. First, when things do fit and make sense (good design of organisms, harmony of ecosystems), they did not arise because the laws of nature entail such order as a primary effect. They are, rather, only epiphenomena, side consequences of the basic causal process at work in natural populations—the purely “selfish” struggle among organisms for personal reproductive success. Second, the complex and curious pathways of history guarantee that most organisms and ecosystems cannot be designed optimally. Indeed, to make the statement even stronger, imperfections are the primary proofs that evolution has occurred, since optimal designs erase all signposts of history.

This principle of imperfection has been the main theme of these essays for several years. I call it the panda principle to honor my favorite example, the panda’s false thumb, subject of an old essay (Natural History, November 1978) that reemerged as the title to one of my books. Pandas are the herbivorous descendants of carnivorous bears. Their true anatomical thumbs were, long ago during ancestral days of meat eating, irrevocably committed to the limited motion appropriate for this mode of life and universally evolved by mammalian Carnivora. When adaptation to a diet of bamboo required more flexibility in manipulation, pandas could not redesign their thumbs but had to make do with a makeshift substitute—an enlarged radial sesamoid bone of the wrist, the panda’s false thumb. The sesamoid thumb is a clumsy, suboptimal structure, but it works. Pathways of history (commitment of the true thumb to other roles during an irreversible past) impose such jury-rigged solutions upon all creatures. History inheres in the imperfections of living organisms—thus we know that they had a different past, converted by evolution to their current state.

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isms (we know, after all, about our own appendixes and aching backs). But is the panda principle more pervasive? Is it a general statement about all historical systems? Will it apply, for example, to the products of technology? We might deem it irrelevant to the manufactured objects of human ingenuity—and for good reason. After all, constraints of genealogy do not apply to steel, glass, and plastic. The panda cannot shuck its digits (and can only build its future upon this inherited ground plan), but we can abandon gas lamps for electricity and horse carriages for motor cars. Consider, for example, the difference between organic architecture and human buildings. Complex organic structures cannot be reenvolved following their loss; no snake will redevelop front legs. But the apostles of so-called postmodern architecture, in reaction to the sterility of so many glass-box buildings of the international style, have juggled together all the classical forms of history in a cascading effort to rediscover the virtues of ornamentation. Thus, Philip Johnson could place a broken pediment atop a New York skyscraper and raise a medieval castle of plate glass in downtown Pittsburgh. Organisms cannot recruit the virtues of their lost pasts.

Yet I am not so sure that technology is exempt from the panda principle of history, for I am now sitting face to face with the best example of its application. Indeed, I am in most intimate (and striking) contact with this object—the typewriter keyboard.

I could type before I could write. My father was a court stenographer, and my mother is a typist. I learned proper eight-finger touch-typing when I was about nine years old and still endowed with small hands and weak, tiny pinky fingers. I was thus, from the first, in a particularly good position to appreciate the irrationality of the distribution of letters on the standard keyboard, called QWERTY by all aficionados in honor of the first six letters on the top letter row.

Clearly, QWERTY makes no sense (beyond the whiz and joy of typing QWERTY itself). More than 70 percent of English words can be typed with the letters DHIATENSOR, and these should be on the most accessible second, or home, row—as they were in a failed competitor to QWERTY introduced as early as 1893. But in QWERTY, the most common English letter, E, requires a reach to the top row, as do the vowels U, I, and O (with O struck by the weak fourth finger), while A remains in the home row but must be typed with the weakest finger of all (at least for the dexterous majority of right handers)—the left pinky. (How I struggled with this as a boy. I just couldn’t depress that key. I once tried to type the Declaration of Independence and ended up with: th1 ll men re cre ted equl.)

As a dramatic illustration of this irrationality, consider the accompanying photograph, the keyboard of an ancient Smith-Corona upright, identical with the one (my Dad’s original) that I use to type these essays (a magnificent machine—no breakdown in twenty years and a fluidity of motion unmatched by any manual typewriter since). After more than half a century of use, some of the most commonly struck keys have been worn right through the surface into the soft pad below (they weren’t solid plastic in those days). Note that E, A, and S are worn in this way—and note also that all three are either not in the home row or are struck with the weak fourth and pinky fingers in QWERTY.

This claim is not just a conjecture based on idiosyncratic personal experience. Evidence clearly shows that QWERTY is drastically suboptimal. Competitors have abounded since the early days of typewriting, but none have supplanted or even dented the universal dominance of QWERTY for English typewriters. The best-known alternative, DSK, for Dvorak Simplified Keyboard, was introduced in 1932. Since then, virtually all records for speed typing have been held by DSK, not QWERTY, typists. During the 1940s, the U.S. Navy, ever mindful of efficiency, found that the increased speed of DSK would amortize the cost of retraining typists within ten days of full employment. (Mr. Dvorak was not Anton of the New World Symphony, but August, a professor of education at the University of Washington, who died disappointed in 1975. Dvorak was a disciple of Frank B. Gilbreth, pioneer of time and motion studies in industrial management.)

Since I have a special interest in typewriters (my affection for them dates to those childhood days of splendor in the grass and glory in the flower), I have wanted to write such an essay for years. But I never had the data I needed until Paul A. David, Coe Professor of American Economic History at Stanford University, kindly sent me his fascinating article, "Understanding the Economics of
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The puzzle of QWERTY's dominance resides in two separate questions: Why did QWERTY ever arise in the first place? And why has QWERTY survived in the face of superior competitors?

My answers to these questions will invoke analogies to principles of evolutionary theory. Let me, then, state some ground rules for such a questionable enterprise. I am convinced that comparisons between biological evolution and human cultural or technological change have done vastly more harm than good—and examples abound of this most common of all intellectual traps. Biological evolution is a bad analogue for cultural change because the two systems are so very different for three major reasons that could hardly be more fundamental.

First, cultural evolution can be faster by orders of magnitude than biological change at its maximal Darwinian rate—and questions of timing are of the essence in evolutionary arguments. Second, cultural evolution is direct and Lamarckian in form: the achievements of one generation are passed by education and publication directly to descendants, thus producing the great potential speed of cultural change. Biological evolution is indirect and Darwinian, as favorable traits do not descend to the next generation unless, by good fortune, they arise as products of genetic change. Third, the basic topologies of biological and cultural change are completely different. Biological evolution is a system of constant divergence without any subsequent joining of branches. Lineages once distinct, are separate forever. In human history, transmission across lineages is, perhaps, the major source of cultural change. Europeans learned about corn and potatoes from Native Americans and gave them smallpox in return.

So, when I compare the panda's thumb with a typewriter keyboard, I am not attempting to derive or explain technological change by biological principles. Rather, I ask if both systems might not record common, deeper principles of organization. Biological evolution is powered by natural selection, cultural evolution by a different set of principles that I understand but dimly. But both are systems of historical change. There must be (perhaps I now only show my own bias for intelligibility in our complex world) more general principles of structure underlying all systems that proceed through history—and I rather suspect that the panda principle of imperfection might reside among them.

My main point, in other words, is not that typewriters are like biological evolution (for such an argument would fall right into the nonsense of false analogy), but that both keyboards and the panda's thumb, as products of history, must be subject to some regularities governing the nature of temporal connections. As scientists, we must believe that general principles underlie structurally related systems that proceed by different overt rules. The proper unity lies, not in false applications of these overt rules (like natural selection) to alien domains (like technological change), but in seeking the more general rules of structure and change themselves.

The Origin of QWERTY: True randomness has limited power to intrude itself into the forms of organisms. Small and unimportant changes, unrelated to the working integrity of a complex creature, may drift in and out of populations...
by a process akin to throwing dice. But intricate structures, involving the coordination of many separate parts, must arise for an active reason—since the bounds of mathematical probability for fortuitous association are soon exceeded as the number of working parts grows.

But if complex structures must arise for a reason, history may soon overtake the original purpose—and what was once a sensible solution becomes an oddity or imperfection in the altered context of a new future. Thus, the panda’s true thumb permanently lost its ability to manipulate objects when carnivorous ancestors found a better use for this digit in the limited motions appropriate for creatures that run and claw. This altered thumb then becomes a constraint imposed by past history upon the panda’s ability to adapt in an optimal way to its new context of herbivory. The panda’s thumb, in short, becomes an emblem of its different past, a sign of history.

Similarly, QWERTY had an eminently sensible rationale in the early technology of typewriting but soon became a constraint upon faster typing as advances in construction erased the reason for QWERTY’s origin. The key (pardon the pun) to QWERTY’s origin lies in another historical vestige easily visible on the second row of letters. Note the sequence: DFGHJKL—a good stretch of the alphabet in order, with the vowels E and I removed. The original concept must have simply arrayed the letters in alphabetical order. Why were the two most common letters of this sequence removed from the most accessible home row? And why were other letters dispersed to odd positions?

Those who remember the foibles of manual typewriters (or, if as hidebound as yours truly, still use them) know that excessive speed or unevenness of stroke may cause two or more keys to jam near the striking point. You also know that if you don’t reach in and pull the keys apart, any subsequent stroke will produce a repetition of the key leading the jam—as any key subsequently struck will hit the back of the jammed keys and drive them closer to the striking point.

These problems were magnified in the crude technology of early machines—and too much speed became a hazard rather than a blessing, as key jams canceled the benefits of celerity. Thus, in the great human traditions of tinkering and pragmatism, keys were moved around to find a proper balance between speed and jamming. In other words—and here comes the epitome of the tale in a phrase—QWERTY arose in order to slow down the maximal speed of typing and prevent jamming of keys. Common letters were either allotted to weak fingers or dispersed to positions requiring a long stretch from the home row.

This basic story has gotten around, thanks to short takes in Time and other popular magazines, but the details are enlightening, and few people have the story straight. I have asked nine typists who knew this outline of QWERTY’s origin and all (plus me for an even ten) had the same misconception. The old machines that imposed QWERTY were, we thought, of modern design—with keys in front typing a visible line on paper rolled around a platen. This leads to a minor puzzle: key jams may be a pain in the butt, but you see them right away and can easily reach in and pull them apart. So why QWERTY?

As David points out, the prototype of QWERTY, a machine invented by C.L. Sholes in the 1860s, was quite different in form from modern typewriters. It had a flat paper carriage and did not roll paper right around the platen. Keys struck the paper invisibly from beneath, not patently from the front as in all modern typewrit-
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ers. You could not view what you were typing unless you stopped to raise the carriage and inspect your product. Keys jammed frequently, but you could not see (and often did not feel) the aggregation. Thus, you might type a whole page of deathless prose and emerge only with a long string of E's.

Sholes filed for a patent in 1867 and spent the next six years in trial-and-error efforts to improve his machine. QWERTY emerged from this period of tinkering and compromise. As another added wrinkle (and fine illustration of history's odd quirks), R joined the top row as a last-minute entry, and for a somewhat capricious motive according to one common tale—for salesmen could then impress potential buyers by smooth and rapid production of the brand name TYPE WRITER, all on one row. (Although I wonder how many sales were lost when TYPE EEEEE appeared after a jam!)

The Survival of QWERTY: We can all accept this story of QWERTY's origin, but why did it persist after the introduction of the modern platen roller and front-stroke key? (The first typewriter with a fully visible printing point was introduced in 1890.) In fact, the situation is even more puzzling. I thought that alternatives to keystone typing only became available with the IBM electric ball, but none other than Thomas Edison filed a patent for an electric print-wheel machine as early as 1872, and L.S. Crandall marketed a writing machine without typebars in 1879. (Crandall arranged his type on a cylindrical sleeve and made the sleeve revolve to the required letter before striking the printing point.)

The 1880s were boom years for the fledgling typewriter industry, a period when a hundred flowers bloomed and a hundred schools of thought contended. Alternatives to QWERTY were touted by several companies, and both the variety of printing designs (several without typebars) and the improvement of key-stroke typewriters completely removed the original rationale for QWERTY. Yet during the 1890s, more and more companies made the switch to QWERTY, which became an industry standard by the early years of our century. And QWERTY has held on stubbornly, through the introduction of the IBM Selectric and the Hollerith punch card machine to that ultimate example of its nonnecessity, the microcomputer terminal (Apple does offer a Dvorak option with the touch of a button but emblazons QWERTY on its keyboard and reports little use of this high-speed alternative).
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To understand the survival (and domination to this day) of drastically suboptimal QWERTY, we must recognize two other commonplaces of history, as applicable to life in geological time as to technology over decades—contingency and incumbency. We call a historical event—the rise of mammals or the dominance of QWERTY—contingent when it occurs as the chance result of a long string of unpredictable antecedents, rather than as a necessary outcome of nature’s laws. Such contingent events often depend crucially upon choices from a distant past that seemed tiny and trivial at the time. Minor perturbations early in the game can nudge a process into a new pathway, with cascading consequences that produce an outcome vastly different from any alternative.

Incumbency also reinforces the stability of a pathway once the little quirks of early flexibility push a sequence into a firm channel. Suboptimal politicians often prevail nearly forever once they gain office and grab the reins of privilege, patronage, and visibility. Mammals waited 100 million years to become the dominant animals on land and only got a chance because dinosaurs succumbed during a mass extinction. If every typist in the world stopped using QWERTY tomorrow and began to learn Dvorak, we would all be winners, but who will bell the cat or start the ball rolling? (Choose your cliché, for they all record this evident truth.) Stasis is the norm for complex systems; change, when it happens at all, is usually rapid and episodic.

QWERTY’s fortunate and improbable ascent to incumbency occurred by a concatenation of circumstances, each indecisive in itself, but all probably necessary for the eventual outcome. Remington had marketed the Sholes machine with its QWERTY keyboard, but this early tie with a major firm did not secure QWERTY’s victory. Competition was tough, and no lead meant much with such small numbers in an expanding market. David estimates that only 5,000 or so QWERTY machines existed at the beginning of the 1880s.

The push to incumbency was complex and multifaceted, dependent more upon the software of teachers and promoters than upon the hardware of improving machines. Most early typists used idiosyncratic hunt-and-peck, few-fingered methods. In 1882, Ms. Longley, founder of the Shorthand and Typewriter Institute in Cincinnati, developed and began to teach the eight-finger typing that professionals use today. She happened to teach with a QWERTY keyboard, although many competing arrangements would have served her purposes as well. She also published a do-it-yourself pamphlet that was widely used. At the same time, Remington began to set up schools for typewriting using (of course) its QWERTY standard. The QWERTY ball was rolling but this head start did not guarantee a place at the summit.

Many other schools taught rival methods on different machines and might have gained an edge.

Then a crucial event in 1888 probably added the decisive increment to QWERTY’s small advantage. Longley was challenged to prove the superiority of her eight-finger method by Louis Taub, another Cincinnati typing teacher, who worked with four fingers on a rival non-QWERTY keyboard with six rows, no shift action, and (therefore) separate keys for upper and lower case letters. As her champion, Longley engaged Frank E. McGurrin, an experienced QWERTY typer who had given himself a decisive advantage that, apparently, no one had thought of before. He had memorized the QWERTY keyboard and could therefore operate his machine as all competent typists do today—by what we now call touch-typing. McGurrin trounced Taub in a
well-advertised and well-reported public competition.

In public perception, and (more importantly) in the eyes of those who ran typing schools and published typing manuals, QWERTY proved its superiority. But no such victory had really occurred. The tie of McGurrin to QWERTY was fortuitous and a good break for Longley and for Remington. We shall never know why McGurrin won, but reasons quite independent of QWERTY cry out for recognition: touch-typing over hunt-and-peck, eight fingers over four fingers, the three-row letter board with a shift key versus the six-row board with two separate keys for each letter. An array of competitions that would have tested QWERTY were never held—QWERTY versus other arrangements of letters with both contestants using eight-finger touch-typing on a three-row keyboard or McGurrin’s method of eight-finger touch-typing on a non-QWERTY three-row keyboard versus Taub’s procedure to see whether the QWERTY arrangement (as I doubt) or McGurrin’s method (as I suspect) had secured his success.

In any case, the QWERTY steamroller now gained crucial momentum and prevailed early in our century. As touch-typing by QWERTY became the norm in America’s typing schools, rival manufacturers (especially in a rapidly expanding market) could adapt their machines more easily than people could change their habits—and the industry settled upon the wrong standard.

If Sholes had not gained his tie to Remington, if the first man who decided to memorize a keyboard had used a non-QWERTY design, if McGurrin had a bellwacket or drank too much the night before, or Longley had not been so zealous, if a hundred other perfectly possible things had happened, then I might be typing this essay with more speed and much greater economy of finger motion.

But why fret over lost optimality. History always works this way. If Montcalm had won a battle on the Plains of Abraham, perhaps I would typing en français. If a portion of the African jungles had not dried to savannas, I might still be an ape up a tree. If some comets had not struck the earth (if they did) some 60 million years ago, dinosaurs might still rule the land, and all mammals would be rat-sized creatures scurrying about in the dark corners of their world. If Pikaia, the only chordate of the Burgess Shale, had not survived the great sorting out of body plans after the Cambrian explosion, mammals might not exist at all. If multicellular creatures had never evolved after five-sixths of life’s history had yielded nothing more complicated than an algal mat, the sun might explode a few billion years hence with no multicellular witness to the earth’s destruction.

Compared with these weighty possibilities, my indenture to QWERTY seems a small price indeed for the rewards of history. For if history were not so maddeningly quirky, we would not be here to enjoy it. Streamlined optimality contains no seeds for change. We need our odd little world, where QWERTY rules and the quick brown fox jumps over the lazy dog.*

*I must close with a pedantic footnote, lest nonaficionados be utterly perplexed by this ending. This quirky juxtaposition of uncongenial carnivores is said to be the shortest English sentence that contains all twenty-six letters. It is, as such, de rigueur in all manuals that teach typing.

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

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Computer Dating

How can we be so sure that Saladin crossed the Orontes River just after 7:00 A.M. on April 11, 1176?

by F. Richard Stephenson

Xerxes, emperor of Persia, was murdered on or about August 6, 465 B.C. On October 1, 331 B.C., Alexander the Great and his Macedonians crushed the Persian armies under Darius III in the battle of Gaugamela, in today's Iraq. Saladin, leader of the Moslem armies, took the city of Ascalon (Ashqelon, in what is now Israel) from the Crusaders after a fierce battle on September 4, 1187. And on October 2, he took Jerusalem.

How do historians know these dates, sometimes to the hour? Or are such statements about major events merely inspired guesses about the remote past?

From the earliest times, saga singers and, later, the first historians were interested in fixing the dates of events; the problem was how to do it. The ancient Greeks often marked dates by stating who the archon, or chief magistrate, was in a given year. Thus the record shows that the Peloponnesian War between Athens and Sparta began in 431 B.C. when Pythodorus was archon of Athens and that a Carthaginian attack on Sicily was mounted "in the year when Hierommon was archon of Athens."

Since archons were elected annually and since the Greeks knew each archon from the seventh century B.C. on, they were quickly able to calculate the year a historical event occurred. We can do so as well—not from the seventh century, but from about 500 B.C. on. Thanks to a list covering two hundred years, from 500 to 300 B.C., compiled by the Greek historian Diodorus of Sicily, a first-century B.C. historian. Also preserved into modern times were similar lists, such as one of Roman consuls, that date events after 300 B.C.

However, the dates of archons before 500 B.C. are uncertain, and even the post-500 dates may yield the year when an event occurred but may not allow us to fix the exact day of its occurrence. Eventually, various peoples—Egyptians, Babylonians, Chinese, Greeks, Hebrews, Hindus, Romans—developed calendars to suit their particular needs. Their aims were both religious and practical: to keep track of various ceremonies and as an aid to agriculture. To be useful, a calendar had to keep pace with the seasons and match the solar year of about 365 1/4 days.

Most civilizations divided the year into twelve months, but there are actually about twelve and a third lunar months in a solar year. Therefore, the calendar makers either divided the year into twelve artificial months, which did not keep track of the moon (as is the case with our modern calendar), or they used twelve lunar months and three or so added an extra month so the year always began during the same season.

Civilizations with a strong astronomical tradition—for instance, the Babylonians and the Chinese—preferred to keep track of the moon, whereas more practical peoples—such as the Egyptians and Romans-employed artificial months, that is, months that had nothing to do with the moon. In more recent times there has been a whole string of calendars—the Julian, the Moslem, the Mayan, and the Gregorian, to mention a few. None of these follows the solar year exactly, although the Gregorian calendar closely approximates it. The Moslem calendar is unique in world history for it is exclusively lunar. A year consists of twelve months of twenty-nine or thirty days, so that the beginning of the year continually moves through the months, coming back to its starting point about every thirty-three years.

The problem faced by modern historians is how to deal with the inaccuracies of those ancient calendars. Apart from the major difficulty of trying to fix the year when an event occurred, it is often hard to determine the time of year. This is especially true for the old Roman calendar, which before the time of Julius Caesar arbitrarily changed the length of the month. In 190 B.C., the start of the year was 117 days in error, but by 168 the discrepancy had fallen to 72 days, rising again to 90 days in 46 B.C. Hence it is not surprising that a modern historian often finds it impossible to determine exactly what day in our modern calendar an ancient event took place. And this is only the beginning, because often no year is given for an event.

Until recently, in such cases the historian was at a loss. But the ability of today's historian to fix with exactitude the occurrence of such major celestial events as eclipses and to tie these to ancient accounts has opened up enormous possibilities in historical dating. For example, several ancient Greek poets, such as Archilochus (in the seventh century B.C.) and Pindar (fifth century B.C.), mention eclipses in their writings, frequently using vivid imagery. When they tie these accounts to major events, the references provide us with a means of accurate dating.

Astronomical dating is by no means a new idea, however, and it was particularly in vogue during the nineteenth century. But historians then were only able to make rough calculations as to when eclipses and the like occurred. Today, computer programs make the remarkably complex calculations needed to compute the rapid and irregular motion of the moon in its monthly orbit around the earth, and historians can produce reasonably accurate pictures of what ancient skies were like. This process requires approximately a thousand numerical terms for each eclipse. Moreover, even the earth's daily rotation cannot be relied on as a time keeper. Studies of some accurately dated ancient and medieval eclipse records, principally those in which the observers made careful estimates of the time of day or night, reveal that the length of the day is gradually increasing. Although the rate of increase—about one-fiftieth of a second every thousand years—may seem trifling, in the million or so days that have elapsed since the earliest reliable astronomical records (700 B.C.), the earth has lost several hours compared with an ideal clock that would keep perfect time, neither gaining nor losing. (Of course, such a clock doesn't exist, but the movements of the moon and the planets provide an approximation of this ideal.) The above-mentioned loss is produced largely by the tides and must be carefully allowed.
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for if there is more than one eclipse, to insure the correct one is identified.

Eclipses of the sun and moon have the greatest value in ancient chronology since by medieval times, dating was often fairly securely established. Nevertheless, there are several notable exceptions. A total eclipse was seen in the twelfth century by Saladin on one of his many campaigns against the Crusaders. In his chronicle of events, Imad-ed-din, Saladin’s chief secretary, reports that the eclipse took place when Saladin’s army was crossing the Orontes River (in Syria). He wrote, “The Earth was in darkness and the stars shone clear in the midday sky.” Imad-ed-din gives the correct lunar month (Ramadan), but the year of the Hegira (the flight of Mohammed from Mecca to Medina in 622) is in error. This corresponds to a.d. 1175, but we can readily show that the eclipse actually took place on April 11 in the following year. The local time may be deduced as just after 7:00 a.m.

Like many other eclipses in medieval times, this one was noted elsewhere. The Christian chronicler Michael the Syrian independently observed the same event in Antioch, giving the exact date. He writes: “The Sun was totally obscured: night fell and the stars appeared... This was a sad and terrifying sight which caused many people to lament with weeping; the sheep, oxen and horses crowded together in terror. The darkness lasted for two hours; afterwards the light returned.” Two hours may be an overestimate for the duration of a total eclipse, but not infrequently, observers were so shocked by the sudden darkness that they lost all sense of time.

Eleven years later, on the day that the Crusaders surrendered the city of Ascalon to Saladin, there was another large eclipse that fixes the date of this event precisely. Saladin had already captured in rapid succession several other important Christian strongholds. The computed date of the eclipse is Friday, September 4, 1187. Although the obscuration of the sun was only partial, 91 percent of the sun would have been covered at 2:20 P.M. The eclipse would have been significant enough to be regarded as an omen of disaster. Worse was to follow, for within less than a month, on October 2, Jerusalem itself was also taken by the Moslems.

On his fourth voyage to the Americas, Columbus was stranded on Jamaica. His ships were damaged, provisions were running out, and the native Indians were threatening to stop trading food for baulks. From navigational records, Columbus knew a lunar eclipse was about to occur. The night of the eclipse he told the Indians the moon would be permanently removed from the sky if they stopped supplying food. As the moon disappeared, the terrified Indians promised to give Columbus food if he would return it. Just before the end of the eclipse, he agreed. The moon reappeared and the food supply went on. Using today’s computer technology, astronomers date that eclipse as occurring shortly after 6:00 P.M. on February 29, 1504 (a leap year on our calendar).

This material was adapted from Eclipse, by Bryan Brewer (Seattle: Earth View, Inc., 1978).
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Even if an eclipse was not associated with an important ancient event, it could still provide a useful check on the chronology of the period. Such is the case for the Peloponnesian War, which lasted twenty-seven years. The contemporary historian Thucydides, in his detailed history of the war, noted three eclipses: two of the sun and one of the moon. In each case he gave only the year of the war and the season. The dates are: first year, summer (a very large partial solar obscuration in which stars became visible); eighth year, early summer (a partial eclipse of the sun); and nineteenth year, summer (a lunar eclipse). The calculated dates of these eclipses are August 3, 431 B.C., March 21, 424, and August 27, 413. These dates confirm that the general chronology of this early period is very reliable. In particular, the eclipse of 431 B.C. reached a magnitude of 87 percent at Athens, which would have made Venus visible by day.

The Persian emperor Xerxes, who reigned between 486 and 465 B.C., is perhaps best known for his unsuccessful invasion of Greece in 480. His campaign there was marked by the battles of Thermopylae and Salamis—familiar names to students of ancient history. When his mile-long boat of bridges across the Hellespont (Dardanelles) was twice washed away by a storm, he is said to have had the sea scoured with 300 lashes by his soldiers. Fifteen years later, Xerxes was murdered—one by his son or by members of his court in the Persian capital of Persepolis. How do we know these dates are accurate when we’re not even sure of the year of Xerxes’ birth (about 519 B.C.)? His death is accurately fixed by one of the Babylonian astronomical texts in the British Museum. A year or so ago these clay tablets attracted much attention when they were found to contain early references to Halley’s comet (see “The Babylonians Saw that Comet, Too,” Natural History, December 1985).

One of these broken tablets, measuring only about four square inches, gives a list of lunar eclipses at eighteen-year intervals—a lunar period well known to the Babylonians. This was compiled by Babylonian astronomers from observations made between 609 and 465 B.C. Near the end of this list, between two eclipse reports in the same year, we find the following statement: “[Lunar] month V, day 14 [?], Xerxes was murdered by his son.” The sign for the day of the month is unfortunately damaged and could be anything from 14 to 18; the year is not given at all. Nevertheless, using the lunar eclipse observations, we can establish a narrow range of dates with considerable confidence. Although the year is not provided, it can be readily deduced from the eighteen-year Babylonian sequence of lunar eclipses as 465 B.C. However, even if the year had only been known approximately, it could still have been dated by the two eclipses that were reported at about the same time. The first of these occurred when the moon was in the constellation of Sagittarius and the second on the fourteenth day of the eighth lunar month. For many years both before and after 465 B.C., we find no such combination of eclipses; it can be found only in 465 itself. The calculated dates of the two eclipses are thus June 5 and November 30 in that year. These dates enable us to determine that the fifth lunar month began on July 22 in 465. Hence we can conclude that Xerxes was murdered some time between August 4 and 8 in 465 B.C.

The Persian dynasty came to an end with the death of Darius III, following his defeat by Alexander the Great at Gaugamela in 331. It is recorded that Darius fled from the field of the battle—his second ignominious escape from a conflict with Alexander. Greek historians such as Arrian and Plutarch record an eclipse of the moon occurring eleven nights before the battle. This was described as total or very nearly so. The year is definitely known (by the archonship of Aristophanes in Athens) and corresponds to 331 B.C. In any case, the only large eclipse of the moon visible in western Asia at about that time took place on September 20, 331. This fixes the date of the battle, an important event in the history of Alexander’s conquests, as October 1.

One of the most intriguing of ancient eclipse observations was made at sea in the fourth century B.C. by Agathocles, who had set himself up as tyrant of Syracuse some years before. The most detailed record is provided by Diodorus, who gives the year as the archonship of Hieromemon in Athens (310 B.C.). Just before the time of the eclipse, Agathocles and his fleet of sixty ships were blockaded in Syracuse harbor by the Carthaginians. They managed to escape in the confusion when some grain ships arrived. Diodorus continues: “They gained unlooked for safety as night closed in. On the next day there was such an eclipse of the Sun that utter darkness set in and the stars were seen everywhere. Thus Agathocles’ men, believing that the prodigy portended misfortune for them, fell into even greater anxiety about the future.”

Five days later, Agathocles landed near Carthage, where he proceeded to attack his enemies’ homeland with considerable success. The date of the eclipse—August
The Gregorian calendar, introduced by Pope Gregory XIII in the late sixteenth century, has become almost worldwide. This is the Gregorian calendar, introduced by Pope Gregory XIII in the late sixteenth century. Under the guidance of the Jesuit astronomer Christopher Clavius, the new scheme was designed to replace the less accurate Julian calendar and was first adopted in October 1582.

The Gregorian calendar is a very good approximation of the solar year of 365.2422 days. Every year that is divisible by four is a leap year—apart from those century years that are not divisible by 400. Thus, A.D. 1700, 1800, and 1900 were not leap years but 2000 will be. It is easy to see that in a 400-year period there are 146,097 days (400 x 365 + 97), making the average length of the year 365.2425 days. Hence, compared with a truly solar calendar, over about 3,000 years the Gregorian calendar is only in error by about one day. Very small further refinements to our modern calendar have been proposed but are not likely to be put into effect during our lifetime.

F. Richard Stephenson is an astronomer and senior research fellow in the Department of Physics at the University of Durham in England.
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Turkana nomads and their herds of zebu cows, goats, and sheep gather at a watering hole early in the dry season. Such holes are dug by hand in dry riverbeds. Now shallow, the holes may be up to forty feet deep later in the dry season. The dry branches around the holes keep the animals from falling in. In the background, acacia trees grow out of lava outcroppings.

(Photograph by Victor Englebert, Black Star)
Beating the Odds in Arid Africa

When drought brought thousands of East Africans to famine camps, the Ngisonyoka held their ground, their herds, their traditions—and survived

by J. Terrence McCabe and James E. Ellis

Around the brackish waters of Kenya's Lake Turkana, in the Great Rift Valley of East Africa, fossil beds holding evidence of the earliest humans emerge from a desert of sandy wastelands and volcanic rubble. This one-time cradle of humanity is now a harsh and inhospitable environment where drought and famine are all too common. But the pastoralists who live there, raising livestock and tending herds, still successfully lead the nomadic life that has been followed there for thousands of years. And they continue to survive despite concerns that the days of the nomad are numbered.

In the late 1960s, scientists concluded that the large wandering herds of cattle grazing precious grasslands were inherently destructive of the arid environment. So, during the 1970s, administrators from local governments and international relief organizations promoted irrigation agriculture and fish culture as alternatives to pastoralism. But the alternatives failed. After the severe drought of 1979–1981, and another in 1984, many development efforts were scrapped in favor of famine relief. In the early 1980s, almost 80,000 Turkana pastoralists, nearly one-third of the population, occupied famine camps from the shores of Lake Turkana to the border of Uganda supported by the Kenyan government and foreign donors.

With massive relief efforts under way in the northern and central Turkana districts, we, along with a group of colleagues, began investigating the Turkana pastoralists to the south. There, the Ngisonyoka Turkana seemed to be going about their business as usual and surviving despite the devastating drought. While they suffered temporary hunger and losses among their livestock, for the Ngisonyoka there was no famine, no environmental degradation, and no need for outside relief. We set out to find out why.

We began our journey by donkey into the vast region west of Lake Turkana. It was the territory of a people who studiously avoided contact with outsiders, and it took us several months to gain the trust of the few families with whom we eventually traveled.

The Turkana migrated from the south-
ern Sudan into northern Kenya in the mid-eighteenth century. Today, some 200,000 Turkana live in this region. Occasionally warlike and without any clear system of chiefs or officials, the Turkana are divided into nineteen tribal sections, each with its own grazing area.

The Ngisonyoka tribal section, consisting of some 9,600 people, 85,000 sheep and goats, 9,800 cattle, and 5,300 donkeys, occupies 5,500 square miles of land. Within this area families move frequently, seven to fifteen times a year depending on the availability of forage, water, the size of their individual herds, and the degree of hostility among the various tribes. And although each move may cover only five to eight miles, knowing when to move is the key to the self-reliance and survival of the Ngisonyoka.

Through the annual cycle of brief rains followed by a long dry season, the Ngisonyoka and their livestock travel from the low-lying plains of the Rift Valley into the bare lava hills and grass-covered mountains. Along the way, their herds graze on both perennial and annual grasslands, dwarf shrub lands, dense bushlands, savannalike grasslands, and true woodlands near the beds of the many
ephemeral streams. While near Lake Turkana there is only moonlike volcanic rubble and dunes covered with desert shrubs, doum palms, and acacia trees, the Ngisonyoka's plains are grasslands, with often dense bush and wooded stream beds.

Far to the west the rift escarpment rises steeply and spectacularly, up to 10,000 feet above the valley floor. Between these mountains and the plains are 6,000-foot hills that are crucial to the Ngisonyoka pastoralists. There is more rain and more vegetation. Runoff from seasonal mountain storms feeds the intermittent sand rivers that stripe the sandy plains of the valley floor. Acacia woodlands line these rivers and spread into dry, dwarf shrub grasslands. By knowing when and where to satisfy the forage needs of their herds, then utilizing the livestock to provide milk, meat, and blood for their own needs, the Ngisonyoka continually manage a complex food web. By making the most of the vegetation of one region but moving on before it's overgrazed, the Ngisonyoka also manage a fragile environment.

Wet seasons are the good times for the Turkana. Soon after the vegetation responds to the rains, Ngisonyoka herd owners, together with their wives, children, dependent relatives, and livestock, converge on their home area in an encampment known as an awi. The herders return from distant grazing lands with their camels, goats, sheep, and short-horned zebu cows. Soon the plains are dotted with homesteads, hundreds of huts made of skins lashed to acacia branches. Food is abundant and enemies are far away.

Most nights the silence is broken by the calls of young men summoning their neighbors to communal dances that often last until daybreak. Songs are sung without accompaniment and recount the
From the major wet season encampment (largest hut in map below), Ngisonyoka nomads disperse ever more widely as rains cease and grasses wither. First, zebu cattle that no longer provide milk are herded north to higher plains for grazing. This preserves forage for milking herds, but as the dry season intensifies, families are forced to travel south in ever smaller groups. Animals giving milk remain with the family, those no longer with milk are taken to the hills where occasional rains still provide water and vegetation. Here, however, herders risk raids from rival tribes. The dry season wells, right, are deep and mostly worked by women.

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<th>Family settlements including milking livestock</th>
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strength and beauty of a favorite ox, the defeat of enemies, the ability of nature to provide the necessities of life—in short, the joys of a pastoral existence. Young men and women share in the excitement of being reunited with friends and lovers. Luckily, labor requirements for both sexes are minimal during this time, and tired dancers return to their own awi before dawn to sleep for a few hours before the next work day begins.

Women visit relatives, make clothes, relax, and in general, revel in the few months of relative ease and safety. Children exhibit a level of energy not seen at other times of the year and often play "hyena and cow" until late into the night.

Most social functions, such as weddings, also occur in the wet season. When herds are healthy, Turkana ceremonies are accompanied by the slaughter of animals and the eating of meat. All Turkana love to eat meat and will gorge themselves when the opportunity arises. During a large wedding that we recently attended, three camels, three oxen, and ten or more goats and sheep were slaughtered. Hundreds of animals were transferred from the groom's family to the bride's, and more than a hundred and fifty people joined in the singing, dancing, and feasting.

Herd owners, if they have sons or other young men to tend their herds, spend most days sitting under the "tree of the men" (usually the one that provides the most shade), recounting events of the past dry season and discussing the prospects for the upcoming year. Talk centers on pasture conditions, livestock health, herd growth, the timing and location of future moves, and enemy raids. Old relationships are reaffirmed and new ones struck up, each involving some exchange of livestock that may later prove critical to a family's survival. Through this network, a herd owner obtains animals in times of need. Turkana rarely talk about the impending dry season. The rains are too unpredictable. Instead, they talk strategy. For when the rains cease in June or July and the lush grasses the cattle have been feeding on wither and die, the Turkana must move.

Plants are the basis of the pastoral system. Altogether, more than sixty different plants make up significant portions of livestock diets. The energy from these plants translates into livestock milk, meat, and blood, which together make up more than three-quarters of the Ngisonyoka diet. Anthropologist Kathleen Galvin found that during good years and rainy seasons cattle milk may provide 15 to 20 percent of human food energy. But during the dry season, the grasses are among the first resources to disappear and the cattle can only produce enough milk for their calves.

Then the diversity of plants and livestock and the flexibility of the pastoral enterprise become important. Cattle and the young men who herd them leave the awi and retreat to mountain and hill pas-
tures. There, perennial grasses will sustain the cattle, though not in a productive state, throughout the long dry season. Herds of goats and camels remain with the family household longer. Goats will eat a variety of plants, and camels feed on the woody shrubs and trees that thrive into the dry season on water stored deep in the sandy soils of the plains. Camels continue to give milk. Galvin found that camels provide 56 percent of the total milk consumed by the Ngisonyoka, or about one-third of all their food energy, year-round.

Eventually, while there will be enough water for the people, there will not be enough for the livestock. The water stored during the wet season dries up. Wells dug by hand into the beds of sand rivers are often forty feet deep before they prove dry or unsafe and are abandoned. Then the people and animals leave the plains. Many nomads head for the dry-season springs of the lava hills, but forage is scarce on these burned and rocky moonscapes. Others migrate to the more mesic savannas and bushlands to the south but risk raids there by rival Pokot tribesmen.

Camel milk and livestock blood are the dry-season mainstays of the Ngisonyoka diet. A pint or more of blood may be drawn from a camel (less from a goat) and either drunk plain, mixed with milk, or cooked with grain or the grated husk of the palm fruit. Meals may be milk alone or, on occasion, supplemented by wild fruits, goat meat, and bartered or purchased grain. Although grain makes up 10 to 15 percent of food energy annually, it is particularly important during dry periods, when livestock production is lowest.

As food resources dwindle, poorer families travel with wealthier relatives. The size of herds is the measure of wealth among the Ngisonyoka, but since it is not socially acceptable for a wealthy man to deny food to poorer relatives, a man with 100 camels, 500 cattle, and 1,000 goats and sheep may not live much better than a poorer herder since he’ll be supporting many more dependents. The extra herds only put more distance between himself and poverty. Herd owners who are down on their luck, without herds or enough workers to attend to them, may strike up deals with relatives or friends. A loan of a milking animal or someone to help with the herds will be repaid to the lender when he himself is in need.

Movement becomes more frequent as the dry season intensifies. Now the goats and camels that are unable to produce milk must be separated from the milking herds and taken to grazing lands often three to six miles from where the rest of the family makes their camp. Water from springs or wells may be even farther away. With herders gone and the grazing land patchy, families become smaller and more isolated. If food is limited, female relatives and their children may be forced to seek food in towns in exchange for work brewing local beer or doing small tasks for the missions or Somali traders. Families try to stay together; herd owners are apprehensive about moving alone because isolated homesteads are far more vulnerable to attack. They move in groups of two to five households, sharing food and herding responsibilities; but the associations, of friends or relatives, are fragile.

People often complain of being lonely and solicit news of friends and relatives whenever they meet someone who is traveling. Under the tree of the men they still avoid speaking of the drought or when it will break. Although the advice of soothsayers may be sought, there is little reliance placed on the supernatural. Most of the talk is about the location of forage and the possibility of enemy raids.

Intertribal raiding has been a feature of pastoral life for thousands of years. The
principal enemy for the Ngisonyoka is the Pokot, a tribe of pastoral nomads who live to the south and west of the Ngisonyoka’s main dry-season pastures. Although there have been occasional periods of peace between the two tribes when livestock and other goods were exchanged, peace has always been short-lived.

Herd owners try to avoid those places where attacks are most likely to occur. During good dry seasons, Ngisonyoka herders disperse to the northeast lava hills where there is little threat of raiding. In drought years, however, the hills south and west of Ngisonyoka territory may be the only area where livestock forage can be found. In November 1980, two members of our research team witnessed a Pokot raid on an awi. Two children were killed and about 350 goats and sheep were stolen. The family was grief stricken, and the people got little sleep over the next nights, worrying about the possibility of another attack, while the lambs and kids bleated, calling for their lost mothers. Tensions remained high for weeks as rumors circulated wildly among those families pushing south toward the Pokot border. The Ngisonyoka were glad when at last scouts reported that rains had begun in the north and they could begin their return to the open plains.

The Ngisonyoka live a difficult and frequently dangerous existence, but their traditional pastoralism maintains a large population in a severe and unpredictable environment. By tapping a multiplicity of resources in a variety of ways and by sharing the effects of drought stress among families, they have managed to survive severe droughts without assistance. Damage to the environment from large numbers of livestock has not occurred. We estimate Ngisonyoka livestock consume only 7 to 9 percent of the region’s annual vegetation production. Their herds of livestock are no greater than the number of native animals grazing African regions with similar rainfall. Overgrazing has not occurred and drought has not brought mass livestock starvation.

The Ngisonyoka have worked out a strategy: they depend most on the most reliable resources in their environment—woody plants and camel milk; they exploit the most productive but ephemeral resources—grasses and cattle milk—when possible; when times are hard, they make use of their precious livestock—drinking its blood, slaughtering it for meat, or trading it for grain. These are never arbitrary decisions. For example, goats are most often slaughtered and traded because goat herds recover most rapidly.

The Ngisonyoka may also be successful because their system has not been disrupted by well-meaning but inappropriate development activities. In some parts of Africa, pastoralists were encouraged to settle and engage in agriculture or to produce beef for markets. These changes might be appropriate in regions of adequate rainfall where there is an established market system, but in places like the Turkana they enhance productivity and living standards in good years while increasing the possibility of famine and
Turkana women often wear fifteen pounds of glass beads. These do not stretch their necks but leave indentations in their shoulders. Once a woman has wed, she gives her beads to a younger sister, and her husband presents her with new ones. Men play-fight, right, using buffalo-hide shields and sticks cut from acacia trees. In battles with other tribes, nomads depend on rifles.

destitution during droughts. Irrigation often costs more than the value of what is produced. Raising cattle for market means reducing the size of the herd to increase the size of individual animals. When drought occurs the reduced herd size leaves herders with nothing to fall back on.

In the harsh environment of the Rift Valley, pastoralism has supported humanity for a long time. It would be a serious mistake to assume that such a time-tested strategy can easily be replaced by practices developed in another time and another place. Herds are more than a commodity to the Ngisonyoka. One down-on-his-luck herder told us he was distressed by the possibility that he might have to go to an agricultural settlement where the cost of a bride is paid in sweet potatoes and gourds instead of camels, goats, cattle, and sheep. For the Ngisonyoka, the good life—all life—begins with camels, goats, cattle, and sheep.
In The Lair of the Lusca

Fish swim upside down and divers risk rapture in the caverns of the Bahamian underworld

by Robert Palmer

The fishermen, farmers, and children of the Bahamas know it as the Lusca, a half octopus, half shark, which inhabits the deep island pools known as blue holes and draws fishermen and their boats down as it inhales, then exhales the indigestible flotsam. "De Lusca, mah, dat his hole. He drag our boat down theah. All th' conch, them crawfish, dey his'n now. We jus' lucky he doan' get us. Th' boat too, thas his now. That Lusca, he bad, mah!"

The appetite of the legendary creature is the result of tides pouring into a deep hole in the sea floor, creating whirlpools at the surface often strong enough to pull in floating debris or unwary swimmers. The pools of the Lusca lead down to complex, many-tiered cave systems whose innermost recesses form one of the oldest and most continuously stable environments in the world. They are relics of the ice ages, when the Bahamas were far larger than the scattered islands they are today.

The watery caves hold ancient secrets but do not yield them easily. Scuba diving scientists find that, mythical dangers aside, they are hazardous places to work. If things go wrong in an underwater cave 100 feet down, it is no easy rise to the surface—only a slow, tortuous return along dark winding passages, following a thin guideline through the underground maze. In open chambers where no light penetrates I have felt the exhilaration of spacewalking and also faced the fear of panic as I tried to pass, carrying two air tanks, through a body-sized crawl space.

The early days of blue hole exploration were the 1960s and early 1970s, when George Benjamin of Toronto and a team of skilled divers charted and explored many of the blue holes of South Andros Island. Later, British and American cave divers made spectacular discoveries beneath other islands, showing that blue holes were widespread throughout the Bahamas and held stores of often unknown animal life. Recent discoveries connect the animal life to the odd geology of the Bahamas themselves.

The limestone that makes up the Bahamas has never been folded, uplifted, or otherwise altered from the horizontal sheets of accumulated marine sediments.
A great marine blue hole, about a half mile in diameter, with its encircling ring of coral. Below the deeper blue of the pool lies a unique undersea realm.

Stephen Frink
There are caves beneath both marine and inland blue holes. In the diagram below the blue hole on the right is an inland blue hole. In the mixing zone (red line), fresh water in the hole meets the sea water that lies beneath the island surface, the island's limestone bedrock dissolves, and caves form. Soldierfish, right, are common inhabitants of the dark entrances of marine blue holes.

Joe LeRoiMonn

that form the base rock of the entire Bahama Banks. During the ice ages of the last million or so years, fluctuating sea levels alternately drowned the Bahama Banks completely or left them exposed above the sea by as much as 400 feet. During periods of exposure, winds swept sand into dunes that were then consolidated into rocky bluffs. These low dune ridges, eroded by rain and weather, form the only relief on the otherwise flat islands. The rest of the geology is found beneath the surface where the limestone is subject to the greatest erosion.

Underground, rainwater collects in lens-shaped reservoirs. This fresh water sits atop a layer of denser salt water that has saturated the rock beneath the island surface. Where these waters mix, the limestone is dissolved. Tidal flow carries the limestone-saturated water out to sea, more fresh water flows down, and more limestone is dissolved. A body-sized passage might take ten thousand years to form. Over many thousands of years, tiny pockets merged, forming isolated caverns, and these in turn linked, forming complex networks of caves. As ice ages came and went and sea levels changed, so did the position of the mixing zone, and caves formed at many different levels beneath the islands. Cave networks extend many hundreds of feet beneath the surface of the earth in a three-dimensional maze of interconnecting caves and fissures that makes the underside of the Bahamas resemble a gigantic Swiss cheese.

Through these caverns, tidal currents ebb and flow in the same way tidal creeks above ground carry water across the surface; whirlpools are formed on the incoming tide. When the tides change, the outflowing water surges in a clear upwelling at ground rock temperature: cool in summer, pleasantly warm in winter. The waters are particularly beneficial to sea creatures. They bear food into the caves—generous amounts of organic debris, plankton, and algal fragments. Cracks and crevices of the fissure network provide a route into the systems for a variety of marine and freshwater creatures. Stimulated by the increased food supply, some of the marine blue holes have an encircling ring of coral growth, a patch reef "doughnut" in the ocean having all of a reef's varied flora and fauna. Other blue holes lie in sea-grass beds and are marked by an overgrown halo of bare sand around their openings, where herbivorous fish can graze safely but still flee into the maw of the hole if predators arrive.

Down in the absolute darkness of the inner marine passages, away from the prying eyes of most divers and the hungry mouths of predators, organisms more common to the inner recesses of a surface reef line the walls, roof, and floor. Corals, sponges, ascidians, anemones, hydroids, and bryozoans—all sessile organisms—form a vast and colorful community, fiercely competing in a slow, imperceptible battle for space and for access to the twice-daily free lunch provided by the changing tidal current of the cave. Wall fauna grow wildly out into the water flow. Sponges and hydroids stretch up to three times their normal lengths, streaming two to three feet into the nourishing flow.

Hunters roam over these reeflike aggregations. Arrow crabs and scampering shrimps clean the cave walls of organic
matter that might otherwise choke the life beneath. Cowries graze, nibbling at choice polyps or other luckless creatures. Soldierfish and snappers lurk inside the cave entrances, occasionally venturing deeper. Tiny, many-colored cardinalfish and dull brotulids stray even farther inside. The fish orient to the nearest solid surface, so the local version of “up” may be different from that of the exploring diver, who finds it disconcerting, and not a little disorienting, to see fish swimming beside him, apparently upside down.

Deeper into the caves, the currents disperse into a million cracks and crevices, the force of the flow diminishes, and the last of the sediments fall from suspension into the water. This is the dune region, where long expanses of sand cover the floor of the cave. The colorful and varied community of the passages near the entrance cannot sustain its existence in these barren inner depths. The rock walls are bare, and the few remaining, tenacious organisms seem weak and flaccid. This is home to burrowers that seek out the last of the food the tides have provided. Small, white, globular sponges barely manage to sustain their existence on the fringes of life, and a few fragile fanworms meander along the walls, their calcite tubes growing to unusual lengths in their predator-free hunt for the merest morsel. While exploring these regions, I have come across less usual visitors, nurse sharks that seem to like the cool inner recesses, finding them a quiet retreat from the bustle of the sea.

When the seas fell from their last high stand—and for many blue holes this was almost 100,000 years ago—some holes were isolated from the rest of the ocean. These inland holes are vastly different from marine holes. They are lost worlds, relics of the Pleistocene Bahamas, and an important window on a past environment.

The halos of growth around their entrances in the pine forest are of copse, rings of dense broad-leaved foliage, bright orchids, and bromeliads. On the bare limestone flats west of Andros Island, the halos are of mangrove and salt-resistant scrub. Often, these blue holes provide the only direct access to the fresh water just below the surface, and both plant and ani-
mal life reflect this. On a recent expedition to South Andros, I was amazed by the profusion of birdlife around the inland holes: herons of every shape and size, wild pigeons, beautiful silent barn owls nestled in the steep cliffs, and the first recorded sighting of cave swallows in the Bahamas, seen nesting in the walls overhanging a blue hole entrance.

Unlike the ocean holes, the fauna of inland blue holes does not depend on the vagaries of current flow to bring nourishment into the caves. Rainwater percolating from the surface brings organic detritus from the forest floor above. Detritus sinks through the freshwater lens until it lands in the denser salt water of the mixing zone. Held in suspension and helped by bacterial action, it decays into an acidic organic broth that feeds a variety of microcrustaceans and further corrodes the limestone rock, assisting the process of cave formation itself.

The nutrient broth is the bottom of the cave food chain, feeding the microscopic swimmers that live in and below the mixing zone. Most of these cave crustaceans rear their young in a brood pouch beneath their carapace. The tiny offspring get a head start in a very competitive environment, not emerging into the fray until they are fully fledged miniature adults.

Less common, although one step higher up the food chain, larger crustaceans live happily on bacterial debris and microcrustaceans alike. These in turn fall prey to larger hunters, including an entirely new order of crustacean, Remipedia (from "many legged"), discovered in 1980 by biologist Jill Yager in Grand Bahama's Lucayan Caverns. These animals, the remipedes, look like small, swimming centipedes but are in fact more closely related to creatures seen in 150-million-year-old fossil remains. A lost world indeed! The several species of remipedes discovered in blue holes throughout the Bahamas since 1980 all stand at the top of the microcrustacean food chain and although tiny, appear to be quick and ferocious hunters. Microscopic hunters, however, make up the diet of cave fishes.

Most marine life perished as these lakes changed from salt to fresh water. The more tenacious adapted to a brackish-water existence. Of these, some survived in only one or two localities. One species of jellyfish is found only in two inland blue hole lakes on Grand Bahama. A crab found in an inland blue hole on Andros was previously known only from Brazil. Deeper beneath these freshwater lakes, fish are also adapting to a cavernous life. Spiny-cheek sleepers, a torpid variety of goby, lurk in the twilight zone of the cave mouths and occasionally stray several hundred feet into the caves. They hunt in darkness, as well as in daylight.

The only truly cave-adapted fish in the Bahamas is Lucifuga speleotes. Generally an inhabitant of the deeper saline region below the mixing zone, in certain sites it appears in the fresh or brackish water of the cave mouth. On Andros, these fish are prolific in the twilight zone of the shallower cave entrances and grow to more than a foot in length. All lack walking eyes, their vestigial sight organs appearing as dark spots beneath a layer of skin. Despite their tolerance of salinity change, they have recently been harmed by pollution and garbage dumping—modern threats to an ancient environment.

William Hart, of the Smithsonian Institution, and Tom Iliffe, of the Bermuda Biological Station, believe that blue holes are one link in a chain of crevicular habitats—caves, fissures, rocks of the sea floor—that stretches from one side of the ocean to the other, from the Americas, across the sea floor and the Mid-Atlantic Ridge, to Africa and the Mediterranean. Related amphipods are not only found in Bahamian caves but in marine caves in Bermuda, the Pacific, and the Yucatan Peninsula.

The origins of blue holes would then lie in distant Pangaea, the ancient supercontinent that split into fragments before dinosaurs walked the planet. When Pangaea spread apart and the Atlantic began to form, limestone sediments shaped the Bahama Banks. Into the early limestone, into the cracks and fissures of the new rocks, swam the direct ancestors of the species found there today. This happened more than a hundred million years ago, when the two sides of the Atlantic still remained in proximity. The creatures that chose this cavernous existence probably had a preference for darkness, and now close relatives have been found deep down in the blackness of the modern Atlantic sea floor.
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Last Stronghold of the Grizzly

Reduced to a pitiful few in the lower 48, grizzlies continue to thrive in Alaska. But what of their future?

by John W. Schoen, Sterling D. Miller, and Harry V. Reynolds III • photographs by Johnny Johnson

Shafts of bright sunlight pierce the thin overcast, and waves of cold mist swirl across the lush alpine ridge 3,200 feet above sea level. It is late June. Several hundred yards away, a dark form appears in the dull grayness, moving slowly and deliberately along the ridge. As the apparition comes closer, it penetrates the thick fog and reveals itself to be a large, dark brown female bear. Following closely behind her are two small cubs, born earlier that year in a rock cave 2,000 feet above sea level, on the steep west face of a mountain peak.

This family group is traveling a distinct trail of large, oval depressions, six to twelve inches deep and three feet apart, in the alpine tundra. These staggered depressions were first pressed into the tundra by bears following the retreat of the ice sheet 10,000 years ago. Since then, countless generations of their descendants have been stepping in the same tracks, and today, the depressions are near-permanent features of the landscape. Southeast Alaska has hundreds of such ridgeline trails, overlooking valleys of old-growth rain forest that stretch unbroken all the way to the coast.

The female guiding her cubs through the mist and down this ancient trail is a grizzly bear. She lives on Admiralty Island, the third largest island in southeast Alaska's Alexander Archipelago. The local Tlingit Indians call the island Kootzmahoo, which means fortress of the bears. Admiralty remains a stronghold; recent censuses, based on a mark-and-recapture technique with radio-collared bears, suggest that the 1,709-square-mile island is home to more than 1,500 bears.

With nearly one bear per square mile, Admiralty Island may have the densest concentration of bears in the world. Grizzly density is also high—one bear per every one to four square miles—elsewhere along the southern coast, particularly on the Alaska Peninsula, the Kodiak archipelago, and the southeastern islands of Baranof and Chichagof. Not all parts of Alaska can support so many bears, however. On the coastal plains of the North Slope, there is only about one bear per 300 square miles. This remote country provides only marginal habitat, in contrast to Alaska's southern coast, where winters are shorter and food is generally easier to find and more abundant; indeed, at certain times of the year, food—in the form of spawning salmon—is spectacularly abundant, sometimes seeming to nearly boil from the water as bears cruise the streams in search of an easy meal.

Alaska's grizzlies are currently the focus of intensive study. From the western Brooks Range in the harsh far north to Admiralty in the more accommodating south, a distance of more than 1,000 miles, researchers have been following radio-collared bears from den to death. Alaska's human population has gone from little more than 70,000 just prior to World War II to more than 500,000 today. This population explosion poses a potential threat to the grizzly, and the hope of researchers such as ourselves is that by increasing our understanding of this symbol of the North American wilderness, we may help to de-
When the streams are full of migrating salmon, confrontations between grizzlies fishing along the banks are not uncommon. This mother has her ears flattened back against her head, an aggressive sign indicating her readiness to defend her offspring against the bear in the water.

termine what it needs to survive in a changing world.

For all Alaskan grizzly bears, life begins in a protective winter den sometime in January or February. In her warm den, safe from howling storms and the murderous intentions of other bears, the female bear gives birth to between one and four naked cubs (two are most common), each weighing less than one pound. The cubs nurse enthusiastically and gain weight rapidly until, upon emergence from the den in the spring, they weigh about fifteen pounds.

Adult grizzly bears, in contrast, neither eat, drink, urinate, nor defecate while in the den, maintaining themselves through metabolism of their fat stores. Biologists now consider the winter dormancy of bears to be hibernation, but unlike other hibernators, the bears' core temperature does not drop significantly. Bears are also easily awakened from their winter sleep, a fact not soon forgotten by biologists working in and around winter bear dens. During the mild winter of 1985–86, for example, many bears (30 percent of all radio-collared bears on Admiralty and Chichagof islands) abandoned their dens in early winter. Presumably, the unusual melting conditions made the dens uncomfortably wet. Later, when the temperature fell below freezing, the bears denned up again.

Alaskan grizzlies begin to emerge from their dens in late March; bears may continue to appear well into June. Dates of den emergence vary annually and regionally depending on spring snow conditions. Males are the first to emerge, followed by single females, females with older cubs, and finally females with newborn cubs. After several months in the den, the bears are lethargic and have to change their metabolism completely. For the first week or so, they may not eat at all, partly because they are so sluggish and partly because the ground is often still covered with snow at this time. As the bears' metabolism gets back to normal, they begin to wander away. Females with newborn cubs, however, usually continue to hang around and sleep in the den for several more weeks.

Life is a risky proposition for newborn grizzly bear cubs. The young animals leave the security of their natal dens at three to four months of age; from 30 to 60 percent will die during their first year. How many and which cubs survive depends on a variety of factors, including population density (cub mortality is highest on Admiralty Island, where the dense population seems to encourage attacks on cubs by adult bears), experience of the mother (young mothers appear to lose more cubs), environmental conditions (failure of food crops and inclement weather may increase cub mortality), and chance (accidents and disease). The well-known fierce protective nessness of grizzly mothers doubtless saves many cubs, but even this is not always sufficient to meet the challenges the cubs must face.

For all bears, green cubs and seasoned adults alike, departure from the den site signals the start of the important business of eating. In the next four to eight months, they must build up enough fat reserves to carry them through the next winter in another den.

In early spring, bears throughout the state feed mostly on vegetation, particularly the young, succulent shoots of sedges and grasses, which usually appear first along snow-free river banks and lake edges. In south-coastal Alaska, grizzly bears commonly graze along tidal wetlands. Throughout forested areas, south-facing avalanche slopes are important foraging habitats for bears in early spring. There, they dig for roots and feed on emerging green plants. Omnivores, grizzlies welcome meat in their diet, too. In northern portions of their range, they search for winter-killed moose and caribou; in south-coastal areas, they may scavenge carcasses of deer and marine mammals and feed on eggs deposited by spawning herring on intertidal beds of seaweed.

Later in the spring, some grizzlies prey on newborn moose and caribou calves and, to some extent, deer fawns. In parts of interior Alaska, radiotelemetry studies have revealed that of all the moose calves that die in the first six weeks of life, more than half are killed by grizzlies. Some bears become very efficient predators indeed, capable of pulling down a full-grown moose.

Adult grizzlies, both males and females, will also attack and kill bear cubs. During the breeding season, we often see single bears following closely behind females with cubs along the narrow alpine ridges. On at least five occasions, grizzly mothers are known to have died defending their young. In one case, a radio-collared
female was killed and eaten by an adult male while her yearling offspring escaped. In another, a female was killed, and her offspring were never seen again.

Such encounters are not the norm, however. Individual bears will vigorously defend food caches and cubs against any threat, including other bears and, rarely, humans. But in general, adult grizzly bears go out of their way to avoid each other and are seldom seen in aggregations. Notable exceptions would be sites of concentrated food resources, such as caribou calving areas, garbage dumps, and salmon streams. At McNeil Falls on the Alaska Peninsula, as many as sixty bears have been observed at one time at a single location along the river. The most dominant and aggressive bears usually command the most productive fishing spots. Bears use body language and other signals, including grunts and roars, to discourage others from coming too close to a prized location. When, occasionally, these signals are ignored by an interloper, a skirmish ensues, which may consist merely of a quick nip or whack or possibly a savage charge resulting in serious injury.

Apart from such temporary gatherings, bears seen together are apt to be either a
mother and her cubs or subadult siblings. Young bears are generally weaned by their third spring, and by the time their fourth winter rolls around, most are on their own. Siblings may stay together for a year or two after weaning, sharing the same den. But as they approach breeding age, they adopt the more typical solitary grizzly life style.

There is one activity, of course, that requires contact: mating. Alaskan grizzlies breed between mid-May and July. In southern regions of the state, females may first breed as four- or five-year-olds, while farther north they may not breed until they are seven, eight, or even older. The female is receptive for ten to fourteen days and a male may stay with her throughout that entire period. (If a cub dies during the May to July breeding season, its mother will quickly come into estrus. This may explain some of the infanticidal behavior of adult males.)

During the breeding season, males travel widely looking for receptive females. Serious fighting between males often occurs at this time. These fights may produce numerous, deep, open wounds, and many mature males carry scars from battles of previous years.

When a male finds himself alone with a female, he may stay with her for a week or more—the bears need time to break down their antisocial tendencies and open the way for more amorous leanings. One June, we observed a radio-collared female keeping company with what we presumed to be the same male for several weeks. The pair remained within a relatively small patch of tidal wetland adjacent to a spruce forest. They frequently walked side by side, sometimes in a large circle, seemingly oblivious to everything around them.

Following copulation, the fertilized egg floats free in the uterus until the fall, when the mother retires to her den. Only then is the egg implanted into the uterus wall. A short two to three months later, the helpless young are born. Relative to the mother’s weight, bear cubs are proportionately smaller at birth than most mammals. The average interval between litters of cubs for female grizzlies in southern Alaska is three to five years and sometimes much
Already maimed by wolves, the bull caribou at left was resting on a gravel bar when it was spotted by a grizzly. The bear immediately took off after the caribou, which made a stiff-legged attempt to escape. Within thirty seconds, the bear caught up to the caribou (which turned to face its attacker) and threw itself on the bull’s neck. The caribou managed to remain upright for a full fifteen minutes, constantly trying to break away, before going down.

longer in the north. This long interval, combined with the small average litter size, means the reproductive potential of grizzly bears is low. How serious the practical consequences of this low reproductive potential can be is all too painfully clear in the Yellowstone ecosystem. There, where perhaps 200 grizzlies remain, scientists have calculated that the annual loss of only one or two reproductively mature females may mean the difference between maintaining a stable grizzly population and eventual extirpation.

By mid-July, the breeding season in Alaska is beginning to wind down. Depending on the timing of local fish runs, coastal grizzly bears start searching for fish streams. By late summer, most grizzlies along the southern coast are exploiting the rich bounty of salmon returning from the sea to spawn in Alaska’s rivers and streams. Bears are great individuals, and their different approaches to fishing exemplify this. Some bears are very patient, standing quietly in shallow eddies. (The best fishing holes are usually narrow, shallow tributaries, where fish are easily caught.) There, they efficiently trap fish against the stream bottom with their forepaws and then lift them out of the water with their massive jaws. Others are aggressive fishermen, running up and down the stream or even diving into the shallow water after the fish, sometimes with questionable results. A few bears will swim around in deep pools and dive for dead fish lying on the bottom. Some simply steal from other bears or scavenge partly eaten carcasses along the stream bank. Along with such temperamental differences, experience plays a big role in the development of a bear’s fishing skill; older bears are more efficient.

The salmon season is a time of plenty, and the largest grizzlies are those whose home ranges include this abundant, nutritious food resource. Females attain weights of 400 to 500 pounds, while adult males commonly weigh from 500 to 900 pounds. On the Alaska Peninsula and Kodiak Island, individuals occasionally top 1,200 pounds. In contrast, bears on the North Slope, where food is relatively scarce, weigh much less. Males there aver-

The Bear Facts

The brown bears of Kodiak Island, the grizzly bears of the Rocky Mountains and interior Alaska, the European brown bear, all are now considered to be the same species, Ursus arctos, despite tremendous variation in color, size, and habits. Among bear specialists, there used to be considerable discussion over the scientific classification for these big carnivores, but for most North Americans, “grizzly” says it all.

Historically, grizzly bears inhabited North America from the Mississippi River to the Pacific Coast and from northern Mexico through Canada and Alaska. Today, probably fewer than 900 are left in remote areas of Wyoming, Montana, Idaho, and Washington. In 1975, following extirpation over 99 percent of its former range, the species was declared threatened in the lower forty-eight states. Canada can boast considerably more bears—most of them in the Yukon and British Columbia, where perhaps twelve to thirteen thousand live. But in North America today, Alaska is truly the grizzly’s stronghold, with an estimated thirty to forty thousand bears.

Grizzly bears can be found throughout most of Alaska. In the southeast, they live on the mainland and on the northern islands of the Alexander Archipelago. They do not live on islands west of Unimak in the Aleutians or on islands of the Bering Sea.
age 380 to 450 pounds and females 200 to 240 pounds.

While northern bears are smaller than southern ones, their home ranges are much larger: females average 130 square miles on the North Slope versus 10 square miles on Admiralty Island. In all areas, males' home ranges are from two to four times larger than the females'. The largest home range ever recorded for an Alaskan grizzly was 2,287 square miles in south-central Alaska—almost twice the area of Rhode Island.

Once an adult bear establishes a home range (usually at about four to six years of age) it is generally faithful to that area in subsequent years. Young males are apt to wander in search of new horizons, while many subadult females stick close to home, on ranges within or adjacent to their mothers'. Interestingly, the females' limited wanderlust may significantly affect their diet. For example, for four years in a row, when most of the Admiralty Island bears moved down to coastal areas to feed on salmon, four of our radio-collared females remained on their inland, high-elevation home ranges, feeding on succulent vegetation, roots, berries, and small mammals. Presumably, these females, having established home ranges near their mothers', were simply unaware of the productive fish streams only a few miles away.

In northern Alaska, the low density and large home range size combine to keep bears apart. Farther south, however, the bears have to work a little harder to avoid each other. Intensive observations of twelve radio-collared bears on northern Admiralty Island have revealed that the animals space themselves out along the densely forested salmon streams. An extensive system of bear trails occurs along these streams, and here and there along the trails are distinctive "marking trees," which are scraped, bitten, and rubbed in the same spot by the bears year after year.
If a bear succeeds in claiming a productive fishing spot—often, as at left, a rock just downstream of rapids or falls—all it may have to do is stand still and snap up the fish as they swim by. Normally solitary animals, with jaws capable of inflicting severe, often fatal, wounds, grizzlies such as those below must be careful while warming up to a potential mate. Overleaf: As autumn comes to Alaska, grizzlies gorge themselves on berries, quickly converting the sugar to the fat they need to get them through the winter.

Perhaps these trees are signposts, enabling bears to tell when others are present and thus reducing the risk of conflicts.

Autumn comes early to Alaska and with it, the bears' last chance to fatten up for the winter. In northern portions of the state, bears feed extensively on ground squirrels, soapberries, blueberries, and occasionally carrion. Berries are especially rich in carbohydrates, which convert quickly and easily to fat. Grizzlies also kill moose and caribou injured during the rut. Farther south, they may fish late salmon runs—sometimes even into December, well after the first snowfall. Usually, however, most bears leave the fish streams in September, moving upward in search of late berry crops, particularly devil's club, currants, and blueberries.

Cold temperatures and snow begin to arrive in northern Alaska by mid-September. Following the first major storms in October, bears start to den. Unlike the black bear, which readily climbs trees and can enter hollow trees through holes high off the ground, the heavier grizzly, with its straighter claws, climbs with difficulty and so must den at ground level. In the north, most grizzlies dig their dens on steep, south-facing slopes after the topsoil has frozen hard enough to provide support. A typical den consists of an upward-sloping tunnel ending in a chamber about four feet in diameter. Bears commonly build a nest of vegetation on the floor of the chamber. The den, which is usually buried under deep snow as winter progresses, provides a warm microclimate in which the bear can hibernate comfortably, while outside, temperatures may fall below -50°F. These kinds of dens usually collapse in the spring thaw and are not used again.

In south-coastal regions, bears excavate their dens on steep, high-elevation slopes, often under a large spruce tree or right into the base of a large snag. On Admiralty, where natural rock caves are abundant, they are the preferred den sites. The ceilings of some rock dens have been rubbed smooth by centuries of bear use.

Pregnant females, followed by females with cubs, are the first to enter fall dens—usually during the first two weeks of October. Single females den next, followed by males. With the exception of females with cubs or subadult siblings, bears usually den alone. By late November to mid-December, most of Alaska's grizzly bears have retired to await the coming of a new year and a new generation.

The grizzly is a sensitive indicator of man's effect on his environment. Almost everywhere in the original range of this species, the increased presence of humans has directly correlated with the extirpation or significant reduction of local bear populations. The decline of the grizzly over most of North America can be traced to human ignorance or, where important grizzly habitats overlap valuable economic resources, unwillingness to accommodate the ecological and behavioral requirements of the bear. As the landscape is subdivided and resources allocated to a variety of uses, usually little consideration is given to assuring the long-term survival of the grizzly. Some scientists believe that in the isolated Yellowstone ecosystem, the grizzly may well not survive another cen-
The cubs below will soon accompany their mother into a winter den, where they will stay for up to six months. If they are lucky enough to survive to maturity, the cubs may one day achieve the awesome grandeur of the prime specimen at right, its thick coat glowing in the Alaska sunshine.

We still have the potential to provide the kind of enlightened management that the bears will need to survive. For example, we can encourage or require logging camps, mine developers, and small communities to install fuel-fired incinerators; this would significantly reduce the need to destroy "problem" (garbage-habituated) bears. Road development in important bear habitat could be minimized, and a few key watersheds could even be withheld from development entirely. But proper management of the human–bear relationship will not be established without farsighted planning, considerable effort, and, in some cases, relinquished opportunities for short-term economic gains. In all likelihood, the future of the grizzly bear in Alaska, and elsewhere, will depend more on creative people management than on wildlife management.
Comparatively tiny marauders, army ants risk dismemberment at the pincers of their prey, the brawny black species Camponotus vicinus. The army ants can occasionally overcome this rugged species by force of numbers. Even then, the casualty rate is high.
Ant Wars

The combatants employ chemical warfare, put up impenetrable defensive shields, and even display a kind of MX missile strategy

by Howard Topoff

1:15 a.m.: Dense cloud cover masks the moon. The cool wind is light but steady from the south, and I can barely hear the high-pitched squeals of grasshopper mice in the distance. From the corner of my eye, I glimpse a bannertail kangaroo rat chasing an intruder from the territory near its mound. And just thirty feet to my left is a Mojave rattlesnake, probably the same one I saw last night, hoping one of those rodents will pass its way. In the light cast by my miner's headlamp, I can see a column of ants rapidly crossing the desert floor. They are members of Neivamyrmex nigrescens, a species of army ant, and they are intent on raiding and robbing a nest of prey ants targeted by their scouts. News of the whereabouts of the prey's nest has spread rapidly throughout the army ants' ranks, and now, mobilized into a column 50,000 strong, they are ready for a fight. At the nest entrance of the prey ants, the desert-dwelling Novomessor cockerelli, an explosion—of sights, not sounds—ensues as thousands of Novomessor make a desperate effort to save their immobile, defenseless brood from the invaders by grabbing up individual larvae and pupae and making a run for safety. The night raiders pay little attention to the retreating ants. The Novomessor brood is what the army ants are after, and most of it is still sequestered deep inside the underground nest.

1:30 a.m.: A fifty-foot-long stream of booty-laden army ants has already formed, extending from the Novomessor nest back to the predator's bivouac. Even by army ant standards, their haul is a pretty good one.

Such scenarios are played out time and again in the American Southwest, as army ants, so notorious for their large-scale raids that they are known as the Huns and Tartars of the insect world, attack their prey. But as often as the army ants are victorious, they are stymied by the extraordinary array of defenses mounted by their target colonies.

This classic confrontation of predator and prey is only one of many in nature, but it is certainly one of the most intricate. While many social insects—bees, termites, wasps, and ants—work under the premise “united we eat, divided we’re beat,” few have mastered the technique of group predation. Harvester and carpenter ants, for example, will send out lone foragers that recruit their nestmates only after having found food. But army ants, as documented by fieldwork conducted in Arizona by me and my colleagues, have many strategies for extremely rapid foraging. Able to communicate messages chemically among thousands of ants, they can mobilize a sizable and replenishable strike force at a target within seconds.

But if the offensive capabilities of these predator ants are remarkable, the defenses of their prey are equally impressive. Our most recent studies reveal that target ant colonies resort to civil defense tactics, chemical warfare, counterattack, and even a version of the “MX missile ploy” (with ant colonies periodically moving to one of a series of new nesting quarters).

We began our study of offense and defense with the predators; in this case the ant genus Neivamyrmex, which consists of more than a dozen species and extends from coast to coast across the southern part of the United States. These ants share a major challenge with other colonial insects: they must forage for enormous amounts of food to feed their population. What target could be richer than the incredible store of protein, fat, vitamins, and minerals—all packaged into bite-sized eggs, larvae, and pupae—to be found in a nest of social insects?

A profile of the typical army ant colony is difficult to draw, because the more than three hundred species that exist worldwide have diverse ecological and behavioral characteristics. The geographical range of most species of army ants is restricted to the tropics, and these habitats contain the largest colonies. In Central and South America, for example, some species have colonies containing well over 250,000 individuals, and in Africa, colony size ranges up to 50 million. Despite the greater abundance and species diversity of tropical army ants, several groups have nevertheless adapted to more temperate climates in both hemispheres.

Two major traits set army ants apart from the rest of the ant kingdom. One is
their periodic emigration to new nesting sites. These journeys are dramatic events in which the adult worker ants transport the entire brood population of eggs, larvae, and pupae up to several hundred yards to a new nest. Moreover in *Neivamyrmex*, these emigrations occur with remarkable regularity, as part of a behavioral cycle of alternating nomadic and stationary phases (see “Ants on the March,” Natural History, December 1975). The cycle is adaptive because nomadism provides army ants with new arenas in which to raid, thus increasing the probability of their finding enough food for newly developing larvae.

The other major distinguishing feature is the formation of efficient armies. Unlike stationary food sources, such as nectar or carcasses, that less aggressive ants depend on, army ant quarry are live and can fight back. The challenge of taking live prey has led the carnivorous army ants to conduct all aboveground activities in well-organized groups guided by complex patterns of chemical and tactile communication. Actual tactics vary among species. In deployment, for example, some species, including *Neivamyrmex nigrescens* from the United States, attack at night, sending out a single ant column from the nest at the very onset of raiding. The column then splits into a branching network of trails. Other species, such as the tropical *Eciton burchelli*, are day raiders and form a column that typically terminates in a fan-shaped swarm that may be several yards wide at its far end.

The key to efficient group predation by army ants is their use of a communication process known as chemical mass recruitment. When army ants advance across the terrain in search of food, each worker deposits a chemical trail from her hindgut. This exploratory trail is relatively stable and helps orient nestmates to follow. During this exploratory phase, traffic along the trail flows in two directions, with ap-
A larva grasped in its mandibles, a Camponotus festinatus worker escapes the army invading its nest by ascending nearby vegetation. Army ants will kill adult Camponotus, but their main goal is the protein-rich brood in the prey’s nest.

Raymond A. Mendez

Approximately equal numbers of workers moving to and from the nest.

When a suitable prey colony of termites, wasps, or ants is discovered, army ants on the raiding front become highly roused and begin to recruit nestmates and draw them to the target. The recruiters run back and forth along a small segment of the trail, contacting (that is, touching with their antennae) all other ants they encounter.

Field studies on Eciton by Ruth Chadab and Carl Rettenmeyer of the University of Connecticut showed that the recruiting ants deposit a pheromone that differs from that of the exploratory trail.

Our own studies were conducted with colonies of Neivamyrmex housed in laboratory nests at the Southwestern Research Station in Portal, Arizona. We were able to verify the existence of this recruitment pheromone and to show that it chemically evaporates considerably more quickly than the exploratory trail. In addition, the recruitment pheromone in Neivamyrmex is able to generate secondary recruiters: if an army ant worker comes upon a trail deposited by an excited recruiter, that worker behaves as if it too had found the food. Because many hundreds of army ants can become secondary recruiters, the wave of excitement that originates at the prey’s nest streams back toward the bivouac and outward along all peripheral columns. The net result of this dynamic communication process is the arrival of thousands of biting and stinging army ants at the target site within minutes after its discovery.

Chemical mass recruitment may seem a bit too efficient when more army ants assemble than can penetrate the target species’ nest. But this phenomenon, which we call recruitment overrun, turns out to be a surprisingly propitious aspect of army ant raids. For several minutes, the excess workers simply mill around outside the raided nest. The ants then quickly regroup into a new column that launches outward from the raiding site. Finally, additional recruited workers run right past the raided nest and become part of the new column that is now exploring the terrain for other colonies of prey.

Although mass recruitment enables army ants to mobilize legions of foragers, they occasionally come out empty-handed (actually, empty-mandibled). Such failures are invariably due to a variety of defenses that prey species mount when attacked by army ants.

Perhaps the least-specialized strategy is employed by a desert-dwelling harvester ant, Pogonomyrmex maricopa. Adopting what might be thought of as a civil defense ploy, it simply ceases activity and seals its nest entrance before army ants become active in the evening. A related species leaves its entrance open at night, even though all foraging has ended. When army ants attempt to enter the nest of this species, these harvesters completely plug the entrance with pebbles.

Pogonomyrmex rugosus, a burly species with a hard exoskeleton, powerful mandibles, and a whopping sting will aggressively counterattack any predator ants. At night, several dozen workers frequently cluster near their nest entrance. When any of these guards contacts an approaching army ant column, hundreds more are promptly recruited from the nest. The defensive phalanx virtually bubbles out of the hole, stinging and biting army ants in rapid succession. The result is a fight that may last through the night.
The "MX missile ploy" keeps the enemy guessing as ants periodically pack up and move the entire colony to one of several already excavated alternative nest sites.

and leave the battle site littered with the corpses of decapitated army ants and no small number of the tough counterpunchers as well. Similarly aggressive in its counterattack is Solenopsis xyloni, of the southwestern United States, a close relative of the fire ant. Several species of honeypot ants mount a chemical defense. They secrete a toxin called formic acid (for which the family Formicidae is named). After biting an intruder, the ant curls its abdomen forward and squirts formic acid into the fresh wound.

If aggression upon alarm represents one end of the antipredator spectrum, the opposite end is panic alarm leading to nest evacuation. Among the most favored prey items of Neivamyrmex are several kinds of myrmicine ants, Novomessor, Trachymyrmex, and Pheidole. When workers of these species encounter army ants several yards from their nest, they immediately return and elicit a mild form of alarm behavior. The adult workers remove their brood from the nest and mill around the surface of the nest entrance. If the army ant column closes in, the relatively calm milling behavior explodes into an evacuation, with brood-carrying workers and the queen scattering in all directions.

In laboratory tests with Novomessor, my graduate student Phil McDonald and I found an interesting developmental component to brood evacuation. When colonies of Novomessor are attacked by army ants, the youngest defending workers, or callows, remove very little of the colony's brood. As they mature, however, the callows become more efficient not only at brood removal but also in their ability to stockpile brood inside the nest prior to the evacuation process. Of course, if the raiding front of Neivamyrmex advances too quickly or from a direction in which no prey individuals are encountered, the army ant column can successfully penetrate the prey's nest before most of the brood is removed.

Although panic alarm and the ensuing nest evacuation are extremely effective behaviors in the short run, they pose a serious problem with respect to colony reorganization. During many nomadic raids, a colony of Neivamyrmex will bivouac overnight in the evacuated species' nest. Prey such as the fungus-growing ant Trachymyrmex, which lives in forested, rocky terrain at high elevations, solve this temporary housing shortage by remaining sequestered beneath rocks and leaf litter. When the army ants emigrate to another bivouac on the following night, the brood-carrying workers and queen trickle back to their old nest.

The problem is more severe, however, for the desert-dwelling species Pheidole desertorum. These vulnerable ants construct nests in a habitat with no leaf litter, few large rocks, and daytime temperatures that reach a lethal 120°F. My doctoral student Robert Droual recently uncovered the solution employed by these ants. Working in the high desert on the border between Arizona and New Mexico, Droual discovered that colonies of Pheidole excavate up to six alternative nests, all within a radius of several yards. The colony then moves from one nest to the other at unpredictable intervals, averaging about one move per week.

Although we thought that this was some kind of MX missile ploy, with Pheidole attempting to keep one step ahead of the army ants, we had no objective way to test the hypothesis, and Pentagon funding was not forthcoming. Nevertheless, at least one adaptive value of this nest complex became evident when Droual witnessed the results of an actual attack by Neivamyrmex. When a colony of Pheidole is scattered in all directions by army ants, returning workers temporarily

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<td>Neivamyrmex nigrescens</td>
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<td>Dorylus nigricans</td>
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The "TED" Spread

Well, how about, for example, a little-known technique that's been around for years...the way we call the "SuperInvestors"? You know, the guys who make their living at it. The fat cats. It's been one of their little secrets until now. It's called, simply, the TED Spread.

And here's what it offers:

- Anyone can do it—easily.
- You decide the amount to put at risk (as low as $100).
- You have the potential to double, or even triple your money—in months, not years.
- Takes 5 minutes of your time a day.
- Annualized returns of as much as 400%—and more—are possible.
- The opportunity usually occurs three, maybe four, times a year.
- I know, I know. It sounds too good to be true.

22 Great Little Investments

But I guarantee that if you read on, you'll surely change your mind when you find out more about the TED Spread.

So, what's a TED Spread? Well, let me break it up just a little. For over a year now we've been researching into what we've come to call The SuperInvestor Files. And so far we've come up with twenty-two great little investing numbers that your broker—if you have one—may not even know much about. And the first one we've put into plain English is The TED Spread.

Recipe for Success

The TED Spread is the first technique in the new series The SuperInvestor Files. How it works is explained in precise detail, in language anyone can understand. Nothing is left to your imagination...you'll be shown exactly:

- How and why the strategy works
- When and how to implement it
- Which brokers to contact (or use your own)
- Exactly how to place your order
- How to monitor your investment
- When and how to take profits
- Commission costs...tax treatment...

in other words—everything you need to know, even if you've never invested before in your life!

Don't Take Gambles

The special characteristics of The TED Spread make it an almost perfect investment for the small investor with limited funds or people who, though they may have more money, don't want to take unnecessary gambles. Yet, with only a few exceptions, the full workings of this technique have remained part of the private reserve of the big-money SuperInvestors—until now.

Why? Because very few small or conservative investors have ever had the privilege to be shown exactly how and why the strategy works—even though implementing it is easy.

The Upside, The Downside.

The strategy is based on interest rates—but here's the beauty of it: IT DOESN'T MATTER WHETHER RATES GO UP OR DOWN. You have the potential to make money either way. So as I've said already, with The TED Spread you have one of the few investments in the world featuring both limited and defined risk—and virtually unlimited profit potential.

Here's an example of what I mean. (Don't worry if you don't understand it fully; it's all carefully explained in The SuperInvestor Files.) After you've learned about The TED Spread, let's say you decide to put up $1000 to secure a position in a spread at 100 points—here's what would happen as it moved to various levels:

<table>
<thead>
<tr>
<th>Risers to:</th>
<th>Your profit is:</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 points</td>
<td>$10,000 (1,000% return!)</td>
</tr>
<tr>
<td>250 points</td>
<td>$3,750</td>
</tr>
<tr>
<td>150 points</td>
<td>$1,250</td>
</tr>
</tbody>
</table>

Bought at 100 points

<table>
<thead>
<tr>
<th>Dips to:</th>
<th>Your loss is:</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 points</td>
<td>$500</td>
</tr>
<tr>
<td>40 points</td>
<td>$1,500</td>
</tr>
</tbody>
</table>

An investment in a TED Spread can produce this kind of profit—sometimes in only a few months—with a level of risk you can hold to $1,000 or less. Of course you can double or triple these numbers by opening more spreads.

Now, get this—The TED Spread has never—repeat, never—dropped as low as 40 points. It has only rarely dropped below 80 points. It has, however, been as high as 500 points, and several times has reached 400 points!

Thus, The TED Spread risk is very limited...and the profit potential is virtually unlimited.

Now, if this short disclosure has intrigued you just a little, why not ask for a free look at the complete TED Spread File? After all, as one man told us, The SuperInvestor Files are "like getting ice cream in July!"

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Here's how you can get all the information you need—and more—on the TED Spread—Send your name and address to:

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Then we'll send you SuperInvestor File #1—The TED Spread. Read it, use it...pay for it only if you want to keep it. Otherwise send it back within two weeks of receipt and you won't owe a cent. Each file costs $25.00. So, if you decide to keep File #1 The TED Spread, we'll send a new file to you for a free two-week look about once a month. You send any one back, we'll gladly cancel you from the series.

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Address ________________________________
City ___________________________ State ___________ Zip ____________

Name and Address ____________________________

Date ____________________________

128074
Common bites nest natural nest relative harvester bites nest civil antipredator interaction require specific brood tories, banances, of spray secrete thus leased view, hazards. fore, wolf the the the nests. times they to toxin, Chemical single test, determine this workers, foraging to spiders, we raided. It shares freshly evacuation to. Alarm, therefore, should occur only when the benefits of nest evacuation outweigh the potential hazards. From an evolutionary point of view, we predicted that nest evacuation would not be elicited by general disturbances, such as encounters with nonpredatory foraging ants. Instead, dispersal with brood carrying should be a response specific to army ants and should therefore require some form of chemical or tactile interaction between predator and prey.

To determine the specificity of antipredator behavior, doctoral student Brent LaMon and I studied the response of an ant of the genus Camponotus. We selected this relative of the carpenter ant because it shares much of its range with Neivamyrmex, also forages at night, and exhibits panic alarm and nest evacuation when raided. Entire colonies of Camponotus were maintained in laboratory observation nests, with each nest connected to a large foraging arena. For the first test, a single worker of Neivamyrmex was released into the arena and removed as soon as it touched a Camponotus worker. In a second test, fifty army ants were let loose, thus creating a sharply higher level of alarm. For control tests, we sequentially introduced a variety of nonpredatory ants, including the fungus-growing ant Trachymyrmex, the harvester ant Pogonomyrmex desertorum, and two other species of Camponotus.

The results of these laboratory tests were entirely consistent with our predictions. Contact between army ants and Camponotus workers in the foraging arena caused an immediate evacuation of the entire colony. Frantic Camponotus adults hauled out their brood and climbed up the vegetation we had planted in the foraging arena. The Camponotus queen received no special protection during the melee, as she too scampered up the first available grass stem. The magnitude of the evacuation was the same whether we used one army ant or fifty. This lack of discrimination by Camponotus is adaptive; in the natural habitat there is no such thing as a single army ant. If one warrior is encountered, the rest of the army is surely right behind.

The results of tests with the nonpredatory ants were completely different. Workers of Trachymyrmex and Pheidole

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name or Description</th>
<th>Antipredator Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camponotus festinatus</td>
<td>Relative of carpenter ant</td>
<td>Nest evacuation</td>
</tr>
<tr>
<td>Camponotus vicinus</td>
<td>Relative of carpenter ant</td>
<td>Bites and stings</td>
</tr>
<tr>
<td>Pheidole desertorum</td>
<td>Desert-dwelling ant</td>
<td>Nest evacuation; &quot;MX missile ploy&quot;</td>
</tr>
<tr>
<td>Novomessor albisetosus</td>
<td>Arid plains ant</td>
<td>Nest evacuation</td>
</tr>
<tr>
<td>Novomessor cockerelli</td>
<td>Desert-dwelling ant</td>
<td>Nest evacuation</td>
</tr>
<tr>
<td>Trachymyrmex arizonensis</td>
<td>Fungus-growing ant</td>
<td>Nest evacuation</td>
</tr>
<tr>
<td>Myrmecocystus mexicanus</td>
<td>Honeypot ant</td>
<td>Chemical counterattack</td>
</tr>
<tr>
<td>Pogonomyrmex maricopa and Pogonomyrmex</td>
<td>Harvestier ant</td>
<td>Civil defense; seals nest with pebbles</td>
</tr>
<tr>
<td>desertorum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pogonomyrmex rugosus</td>
<td>Harvestier ant</td>
<td>Bites and stings</td>
</tr>
<tr>
<td>Solenopsis xyloni</td>
<td>Relative of fire ant</td>
<td>Bites and stings</td>
</tr>
</tbody>
</table>

Chemical-warfare ants secrete formic acid and spray invaders with the toxin, often aiming it toward freshly inflicted wounds.
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were virtually ignored, even when hundreds were introduced into the Camponotus arena. The bigger Pogonomyrmex and members of all foreign colonies of Camponotus were occasionally snapped at by individual foragers. But these attacks were not sustained and never resulted in even a partial nest exodus. This relative tolerance of nonpredatory ants demonstrates that prey such as Camponotus ants have evolved the ability to discriminate between a natural army ant predator and other, relatively harmless individual ants.

Research on interactions between army ants and their prey illustrates many of the advantages that social behavior plays in reducing predation. Perhaps foremost is early detection, as when a worker of Pheidole encounters an army column several feet from its own nest and scurries home to spread the alarm. A second line of defense is deterrence, especially useful for species, such as Pogonomyrmex rugosus, that have potent weapons and can use them in concert. And finally, there is the effect of confusion, as when an entire adult worker population of Pheidole desertorum simultaneously flees in unpredictable directions.

Colonies of social insects are organized differently from vertebrate groups. Nevertheless, there are a lot of advantages to group living that have resulted in an evolutionary convergence across many animal species. Predatory behavior, for example, has undoubtedly been a strong selective force in shaping communication and cooperation, whether among colonies of army ants, packs of hyenas, or troops of...
A civil defense measure, sealing the entrance with pebbles turns the nest into a fortress ready to withstand a nocturnal siege.

baboons. The benefit, of course, is that an integrated team can hunt bigger prey more efficiently than could a single individual. But evolution is always a two-sided coin—large groups obviously also require more food. If social integration is good for the predatory “goose,” it is equally beneficial for the prey “gander.” As part of a social group, each individual benefits from the eyes, ears, and noses of all other group members. In my own research, this is illustrated by the early warning system used by many ants to escape from their nest even before the army ant swarm has approached and by the impressive array of counter tactics used during an actual invasion. Thus, although insects such as ants are often depicted as creatures of habit, it is their social habits that finally determine who eats and who gets eaten.

Even panic serves as a survival tactic by prompting ants to bail out of the nest; fleeing workers grab larvae or pupae and, together with the queen, run up the first available grass stalk or shrub. They will regroup later.
Long, Long Ago in Japan . . .

by Edwin O. Reischauer

People today cannot possibly comprehend how much Japan has changed in the past century and a quarter. Equally difficult to appreciate is the radical shift that has taken place in Western attitudes toward Japan. The original title of this beautiful book of photographs of Japan taken between 1863 and 1883, and first published in France in 1984, suggests the vastness of the change in perspective and reality. In France, the book had the Japanese title Mukashi, mukashi, which is perhaps best translated as “Long, long ago” and is the usual opening line of a Japanese fairy tale. The fairy tale quality of the pictures is further stressed by the English title of the present volume, Once Upon a Time. We find ourselves looking through these pictures at a Japan that is incredibly distant from what meets the eye of the traveler today. We are also looking at a Japan that in a sense never existed. It is the make-believe land of japonisme, that enthusiasm for things Japanese that swept the West during the second half of the nineteenth century.

The source of the volume’s contents is explained in a long subtitle—Visions of Old Japan from the Photos of Beato and Stillfried and the Words of Pierre Loti. An informative short introduction gives a fuller explanation. Felice Beato, a great pioneer among combat photographers, came to Japan in 1863, five years before the Meiji restoration started the country on its rapid modernization. Baron Raimund von Stillfried und Ratentitz, an Austrian, was a photographer active in Japan between 1869 and 1883. Pierre Loti, an immensely popular French writer, whose brief descriptions of Japanese scenes are scattered among the pictures, visited Japan in 1885 and 1900-1901.

I was shocked to learn that the life spans of two of these men, who saw a Japan so different from the one I have observed develop since my birth in 1910, overlapped with mine. It seems hard to believe that the Japan of Once Upon a Time is only two lifetimes away from the vibrantly modern industrial giant the country is today. While a few scenes, particularly of nature and architecture, appear as they do today, many others are clearly authentic portrayals of a Japan of another time—even though they may be slightly stylized to accommodate the photographic technology that was then necessary for a prolonged pose and to meet the interests of the European artists. For example, the pictures Kitchen, Carpenter,
DISCOVER JAPAN with a team of Museum experts as you cruise on the world’s highest rated, luxury expedition vessel, the 5-Star M.V. Society Explorer. Experience the remarkable ambiance of the Japanese archipelago: golden temples, ancient traditions, snow-capped volcanic mountains, virgin forests and breathtaking coast lines.

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Fishmongers, Silk Spinner, and Thrashing seem almost like an ethnographer’s display in their somewhat improbable assemblage of now-forgotten tools and utensils.

The japonisme aspect of the book—that is, its peculiarly Western slant—is shown first in its choice of subjects. The highly ornamented, baroque mausoleums of the town of Nikko figure prominently among the examples of architecture, and the one garden depicted is a crowded hodgepodge more akin to Victorian than Japanese tastes. There are a disproportionate number of gaily decked out pretty girls to fit the Madame Butterfly image and a surprising number of prostitutes, mostly bare breasted, posed as examples of everyday life. And while many photographs are of ethnographic interest—of street peddlers, for example—few if any seem to penetrate into normal Japanese home life or catch the Japanese except as they volunteered, or could be hired, for studio portraits.

In other words, Beato and Stillfried were looking at Japan very much from the outside. But this fitted the mood of japonisme, which held that Japan was a never-never land and that no one should try to see behind its quaint façade. Even the composition of many of the photographs emphasizes the sense of remoteness. The curiously cluttered interior in Toilette, the totally improbable pose in Reclining Nude, and the absurdly placed kakemono (hanging picture scroll) in Coiffure could never have been set up by any Japanese, then or now. The amusing errors the two photographers made underline their lack of understanding. The Tea Vendor is carrying two large boxes clearly marked amazake, or “sweet wine.”

I do not mean to trivialize the value or artistry of this book. It is a rich, authentic product of its time. None of its pictures could possibly have been made at any other time, and some give fascinating glimpses of what Japan was like between the 1860s and 1880s. Take, for example, the historically interesting Display of Women in Yoshiwara (The Red Light District), which looks as if it dates from the last years of the collection. And for
those who have any doubts about authenticity, the grisly row of severed heads of criminals in *Executions in the Village of Kizo* will make them realize that they are indeed looking at a real Japan of a very different age.

The greatest virtue of the book, however, lies in the great artistry of many of its photographs. Beato and Stillfried were masters of the budding art of photography. *Portrait of a Woman, Odd Job Men,* and *Young Woman from Niigata* (appearing also on the dust jacket) are masterpieces of their kind. And the care that has been taken in reproducing them makes this a beautiful book, exquisitely designed and printed. The delicate color tinting added to most of the pictures to meet European tastes and match the *japonisme* image of the country provides a sense of subtle mystery, even though it does not always ring true to the daring Japanese use of color. Nevertheless, the restrained elegance of the whole volume admirably mirrors the best in the Japanese aesthetic tradition.

The double focus of the pictures and Loti's text—albeit, frothy—on Japan as it was thought to be by the enthusiasts of *japonisme* is not disturbing but gives a dual interest to the book. There is much to enjoy in this lovely volume.

Edwin O. Reischauer was born in Japan of American missionary parents. He has been on the Harvard faculty since 1939 and professor emeritus since 1981. Reischauer served as the American Ambassador to Japan from 1961 to 1966 and is the author of numerous books on Asia, the most recent being, *My Life Between Japan and America* (1986).
Dolly Sods,
West Virginia
by Robert H. Mohlenbrock

Walking across the flat terrain of Dolly Sods, a tundra-like setting largely within West Virginia’s Monongahela National Forest, people are apt to forget they are on a mountaintop until they reach Bear Rocks at the northeast corner: there they can look straight down 2,500 feet to the valley below. Thirteen miles long by two to four miles wide, Dolly Sods sits atop a ridge of the Allegheny Mountains, which form the eastern section of the 4,000-foot-high Allegheny Plateau. As in the Appalachians to the east, the folds of this ancient mountain terrain run from the northeast to the southwest.

While pine forest covers many of the surrounding mountains and valleys, only a few red spruce trees dot Dolly Sods. They are sometimes called flagged spruces because all their branches are on the east side of the trunk and resemble flags blowing in the breeze. Branch growth on the west side is inhibited by the constant drying force of the wind and abrasion of the buds by windblown ice crystals.

Much of Dolly Sods consists of treeless “balds,” whose shallow, acid soils mainly support shrubby members of the heath family. Blueberries, huckleberries, and cranberries provide ample feasts for wildlife, as well as for hordes of human berry pickers. Some other heaths include the trailing arbutus, which blooms after the snows melt in late April, and mountain laurel, azaleas, and rhododendrons, whose blossoms appear soon thereafter. A smattering of wildflowers grow alongside the heaths. Pink lady-slipper orchids form their pouchedlike flowers in May, and the dainty painted trillium appears by the first of June. Wildflowers continue to bloom throughout the short summer until the deep blue flowers of the wild gentian close out the show. All these plants must survive severe winds and a cold climate. As much as 150 inches of snow may fall in winter, forming drifts that do not completely melt until May. Frost may occur any day of the year, and by September, more snow may be on the way.

Scattered in poorly drained depressions of the high plateau are soggy areas with continuous mounds of sphagnum and haircap mosses. The plant species contained in these sphagnum glades—which include cranberries and tiny insect-eating sundew plants—are similar to those found in bogs much farther north, but the origins of these habitats are different. Northern bogs usually developed from ponds left during the retreat of the last Ice Age glaciers, while the sphagnum glades on Dolly Sods lie over water-impervious rocks that impede the drainage of mountain streams. The cool, cloudy, and often foggy climate also helps maintain the high moisture level.

In a few areas of Dolly Sods, where limestone rock lies near the surface, grass grows in dense mats. Early-nineteenth-century settlers, unable to farm the rocky mountaintop successfully, turned to raising grazing animals to take advantage of these isolated grassy patches. One of the earliest settlers in the region was the Dahlé (“Dolly”) family, and the dense grass on their land claim was referred to as the sod. Although the original grassland settled by the Dahlé family occupied only about one square mile, the name Dolly Sods now applies to the entire tableland.

At the time the early settlers exploited these grass patches, the rest of the mountaintop was nearly covered in forest. Today there are no stumps or other visible traces of this forest, but in 1746, members of the Fairfax Boundary Survey Party reported that as they walked west from Bear

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Rocks, they passed through extensive stands of red spruce so dense that no sunlight reached the forest floor. Underfoot were thick deposits of peaty soil derived from decomposing spruce needles and mosses. The red spruce forest was a remnant of a tongue of northern coniferous forest carried southward along Appalachian crests. When the forest was in this virgin state, its plants and animals consisted of species now typical of Canada—spruces, dwarf dogwoods, northern warblers and thrushes, and snowshoe hares.

In 1884, a railroad was built from Davis, a few miles northwest of Dolly Sods, to the eastern seaboard, opening up the area to lumbering. In a matter of thirty-five years, the entire mountaintop was denuded of timber, leaving a barren landscape covered with slash. The thick mat of spruce needles that had been accumulating for centuries dried out once the canopy was removed, forming ready tinder. Fires became common. Some were started by sparks from logging trains, others by people attempting to create pasture, still others by lightning. Sometimes ground fires smoldered for weeks or months, feeding on the organic soil until they reached bedrock. Only the sphagnum bogs, which occupied the low areas of the tableland and held great quantities of water, were spared, providing sanctuaries for species like the sundews.
Today, although red spruce is making a slow recovery in sheltered coves, only pioneer mosses and liverworts have been able to etch their home on some of the bare boulder fields. And blueberry pickers continue to set fires to retard the growth of the trees invading the blueberry patches.

Thus Dolly Sods is far from being a pristine area. Nevertheless, naturalists have a reason to flock there: to glimpse the same kinds of plants that also grow naturally in the boreal regions of North America. One thousand miles northeast, and 4,000 feet lower in elevation, near sea level along the eastern coast of Canada, there is relatively flat terrain with scattered boulders. In areas where the climate is extreme, growth of vegetation is sparse, and the resultant landscape often appears similarly barren and bleak.

"This Land" highlights the biological phenomena of the 134 U.S. national forests. Robert H. Mohlenbrock is Distinguished Professor of Botany at Southern Illinois University at Carbondale.

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RATES AND STYLE INFORMATION

The following new rates are effective with the February 1987 issue:

$2.50 per word; 10 word minimum. Display classified is $200 per inch. All advertisements must be pre-paid. Rates are not structured for agency or cash discounts. All advertisements are accepted at NATURAL HISTORY's discretion. Advertisements may be paid to NATURAL HISTORY to: The Market, NATURAL HISTORY Magazine, Central Park West at 79th St., New York, N.Y. 10024. Please include your personal address and telephone number, issue preferred, and suggested heading. Deadline—1st of the month, two months prior to publication. For January issue closer Nov. 1). Camera-ready art is required for display ads. A tear sheet or copy of the page with your ad will be sent upon publication.
Two by Two

by Thomas D. Nicholson

Most of the brighter planets are clumped together in pairs in January: Jupiter and Mars in the evening; Saturn and Venus in the morning. Mercury switches from morning to evening about midmonth but is never far enough away from the sun to make an appealing object for viewing.

Jupiter and Mars are low in the sky but easy to see in the southwest at dusk and in the early evening. Jupiter is by far the brighter of the two and the first to become visible; Mars is higher but has become an unpretentious first-magnitude object. They set about two hours after dark early in the month but noticeably earlier by month’s end. When the crescent moon passes them on the 4th and 5th, they are quite close to each other, but the distance between them triples during the month. Their rapid separation reflects Mars’s fast easterly (left) motion through the stars of Pisces. If you were to clock their westerly motion each night (reflecting the earth’s rotation), you would see that Mars is the slower moving of the two, rising slightly later than Jupiter each night.

Morning brings Venus and Saturn into the sky, rising before daybreak. As with Jupiter and Mars, the morning planets also shift easterly through the stars; Venus, closer to the sun than Saturn, moves more rapidly. At the beginning of January, Venus rises an hour or more earlier than Saturn, but as the distance between the planets diminishes during the month, so does the difference in their rising times. By the 24th they rise almost simultaneously; thereafter, as Venus drifts left away from its neighbor, Saturn rises first. As with the evening planets, brightness allows you to distinguish easily between Venus and Saturn. Venus is very nearly five magnitudes brighter than the nearby, first-magnitude Saturn. Comparing them illustrates vividly what this difference means. An accurate light-sensing device would show Venus nearly 100 times brighter than Saturn.

Events in the calendar below are given in local time unless otherwise indicated.

January 1: New moon was less than two days ago; tonight’s sky will be dark and moonless.

January 2–3: The thin sliver of the crescent moon will be in the western sky both nights with bright Jupiter above it. The moon will have set or will be too low before the sky darkens enough to see stars.

January 4: The earth’s is at perihelion, the point on its elliptical orbit that is nearest to the sun.

January 4–6: The fattening moon slides past Jupiter on the 4th, Mars on the 5th, and reaches first-quarter phase on the 6th at 5:34 P.M., EST. Jupiter should be easily seen near the moon on the 4th and below the moon on the next two nights. Mars will be harder to find. Look midway between the moon and Jupiter on the 6th.

January 6: Today’s sunrise is the latest of the year and sunsets are noticeably later than at the December solstice.

January 7–9: A waxing gibbous moon is well up in the south at dusk, moving slowly leftward from night to night through Aries. Hamal and Sheratan, the Ram’s brightest stars, are above it on the 7th; the Pleiades star cluster and the reddish Aldebaran are to its left. The moon moves closer to Taurus on the 8th and 9th.

January 10: The moon is past the Pleiades and above Aldebaran.

January 12: Mercury is at superior conjunction, in line with and beyond the sun, passing it from right to left to enter the evening sky.

January 13: Apogee moon (farthest from the earth) is in Gemini, to the right of its “twin” stars, Pollux and Castor.

January 14: The nearly full moon slides past Pollux and Castor tonight. To the right of Pollux at dusk, the moon is in line with the two stars by midnight. Full moon is at 9:30 P.M., EST.

January 15: Venus’s morning position improves quickly in January as its distance to the sun’s right increases. It is at greatest westerly elongation from the sun today, easily visible at dawn now and for the rest of the month. Saturn is just below Venus, rising later, but the distance between the planets diminishes daily.

January 17: Leo’s bright star Regulus is below the moon as they rise in the east about two hours after sundown.

January 19: The moon slips out of Leo and into Virgo. When you see it in the east about midnight, it will be bracketed by Regulus (Leo’s bright star) above it and Spica (Virgo’s brightest star) below it.

January 21–22: The moon’s stellar companion when it rises late tonight is Spica.

January 22: Last-quarter moon, in Virgo, is at 5:45 P.M., EST. Now a morning object, the moon is up from midnight until about noon.

January 24–25: The “star” near Venus both mornings is Saturn. Venus passes it from right to left at about 3:00 P.M., EST, on the 24th. The moon, rising earlier than the planets, is above them, and the reddish star near the moon is Antares in Scorpius.
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January 26: The slender crescent moon is below Venus and Saturn as they rise in the morning. This is probably the last view of the waning crescent we will have in the January cycle of lunar phases.

January 28: Perigee moon (nearest the earth) primes the spring tide associated with tomorrow's new moon.

January 29: New moon is at 8:44 A.M., EST.

January 31: The early crescent moon may be visible low in the southwest during late twilight tonight.

The winter Sky Map shows the sky for January, February, and March from latitude 40° north at the hours given below. To use the map, hold it vertically in front of you with south (S) at the bottom and match the lower half of the map with the stars you see when you face south. As you face in other directions, roll the map to bring the corresponding compass direction to the bottom of the map. The stars
move westward continuously during the night. By morning (before dawn), stars on the western half of the map will have set, those on the eastern half will have moved into the west, and new stars (those of the spring evenings) will have risen in the east. The map represents the sky at about 2:00 A.M. January 1; 1:00 A.M. on January 15; midnight on January 31; 11:00 P.M. on February 15; 10:00 P.M. on February 28; 9:00 P.M. on March 15; and 8:00 P.M. on March 31. It can also be used for an hour or more before and after these times.

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Native American Month
January is Native American month at the Leonhardt People Center. Each week will be devoted to the Native American traditions of weaving, pottery, jewelry making, storytelling, and dance. In addition, there will be lectures on Northwest Coast Indian culture. These free programs will be repeated several times throughout the afternoon between 1:00 and 4:30 P.M. Seating is on a first-come, first-served basis. For a complete schedule of events call (212) 873-1300, ext. 344.

Women of the Black Diaspora
In cooperation with the Museum's Department of Education, Third World Newsreel presents Journey Across Three Continents—Images of Women of the Black Diaspora, a series of films about the experiences of black women. The following free films will be shown at 7:00 P.M. on three consecutive Thursdays in the Main Auditorium: on January 8, The Road to Accra concerns a debt-ridden driver who shuttles his bus between his village, where his wife and children work the fields, and the city, where money and status seem to abound; on January 15, The Marriage of Mariamu tells of a woman who must confront her childhood fears of traditional doctors, and One Man Several Wives deals with the impact of polygamy on Senegal; on January 22, The Passion of Remembrance details black experiences in the socially divided United Kingdom from 1950 to 1980. For information call (212) 873-1300, ext. 514.

At the Planetarium
Although there were only seven wonders in the ancient world, many more can be found if you look skyward. The Seven Wonders of the Universe, a new show in the Sky Theater, will leave the boundaries of Earth and journey through time and space in search of the greatest wonders of the universe: celestial canyons that could easily dwarf the earth and alien landscapes, where the night sky is ablaze with a million stars, are among the galactic marvels to be explored. This latest Sky Show premieres January 7. For further information call (212) 873-8828.

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A Most Finicky Fruit

Nature cannot take its course with the cherimoya; a human hand is needed

by Raymond Sokolov

Freud did not have fruit in mind when he said, "Anatomy is destiny." But this famous and much-debated epigram probably applies better to fruit than it does to human beings. Indeed Freud's preoccupation with the symbolic and actual importance of human anatomy, in particular with human sexual anatomy, has done much to add to the discontents of civilized life for people who have imbibed the Freudian message in all its enticing yet infuriating imprecision. And yet, even some of the most committed votaries of orthodox psychoanalysis have managed to surmount penis envy and Oedipal conflicts with a flair and originality that defy Freud's biologically deterministic claim.

Fruits, on the other hand, cannot so easily break out of their traditional roles and patterns. Even with much help from federally funded agricultural scientists at land-grant colleges, the apricot has not learned the trick of ripening off the tree. If you think about it, many of the most delicious fruits are finicky by nature. The raspberry is too fragile for machine picking; its shelf life is short. And the most delicious of all fruits known to me is also the most sensitive and biogenetically difficult to coax into fertility outside its normal range. I refer to Annona cherimola, the cherimoya.

This giant pearl of the Andes has the most exquisitely refined climatic requirements. But in the end, what has prevented U.S. growers from producing cherimoyas in commercial quantities is the extremely chaste and all but inviolable shape of this tree's female genitalia. I would not be titillating you with such arcana if the cherimoya were not at last available—at a price, but available nevertheless—to fruit

Cherimoya vendors in Ecuador
lovers across the United States. Total acreage in North America probably does not exceed 200; so we are not on the verge of a cherimoya bonanza. And we probably never will be. But during the season, from now until spring, fancy fruitieres should carry them in sufficient quantity to satisfy the curiosity, if not the appetite of the pomologically alert.

That we have a commercial cherimoya crop at all is due to the efforts of a few determined growers, mostly in California. I visited the largest of the fourteen cherimoya operations in the hills near Santa Barbara. California Tropics has all of twenty-five acres of cherimoya trees in cultivation. The proprietor, Peter Nichols, grew up in the fruit business, but when the family avocado ranch was hit by devastating root rot fifteen years ago, he turned his mind to new crops. There were already half a dozen cherimoya trees on the property, and Nichols, inspired by their success, took the plunge and committed himself seriously to cherimoliculture. "We really rolled our sleeves up eight years ago," he told me. And that was an understatement.

The cherimoya is a subtropical, semi-deciduous tree that is viable along the California coast from Santa Barbara south to Mexico. It originated in Ecuador and Peru, but cultivars have survived in California for at least a century. The moderating sea air soothes these plants, which will not set fruit in temperatures exceeding 85°F. The comparative dryness of the southern California coast helps too, but December rains sometimes make the big green fruits crack open.

This is a minor danger, however. Nichols asserts that the cherimoya's precarious situation in California improves its taste. "It's the same with apples," he says. "They have to struggle a bit."

Nichols knows the meaning of the word

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struggle, since he has to fight the cherimoya's biggest battle for it. He and his laborers must pollinate the trees by hand. Airborne pollination will not deliver a dependable crop. Nichols tried getting bees to carry the pollen from male to female flowers. He set up eighty hives and waited. But the tiny, three-petaled white cherimoya flowers were too small and narrow. Bees couldn't penetrate them. If you are wondering how in the world A. cherimola managed to reproduce itself efficiently in its natural range, the answer is that in South America tiny nocturnal insects do the job. But nothing like them exists in California.

So in midsummer, Nichols and other California growers go out in the late afternoon and do the job themselves, armed with watercolor brushes that have their bristles cut down. They collect the pollen and later apply it to the female flowers, which are receptive for only twenty-four hours—and not all on the same day in the same tree. Ergo, each tree must be visited eight to ten times. To facilitate this process somewhat, the trees are pruned low.

"We pollinate only what we can reach," Nichols says. The same is true for the cherimoya harvest, which is all done by hand. The fruit bruises very easily, and it does not mature all at once. Pickers must be adept at judging when the fruit is ready. They pass through each tree several times, noting slight changes in the color of the rind.

I saw the Nichols trees last spring at the end of the growing season. At first, I thought the season was over because I didn't see any fruit at all, just the big green velvety leaves. You have to walk "inside" the tree, under the canopy, then you see plenty of fruit dangling down, like green hand grenades all covered with indentations that are technically known as carpels. They start as nodules and flatten out when the fruit matures. Experienced pickers can detect a slight yellowing of the thin leathery exterior of the cherimoya. The trick is to collect the fruit a week before it is fully ripe.

At least in this respect, the cherimoya makes life easy on the grower. It gives him the margin of a few days to get his fruit to see it. Then with a rubber spatula scrape the custard into a metal mixing bowl and set that bowl into a larger bowl containing ice and water. This stops the cooking, straightaway and eliminates any risk of scrambling induced by heat retained by the saucepan. Stir in the rest of the cherimoya purée and let the custard cool.

1. Slice cherimoyas in half. Scoop out flesh, remove all seeds, and put flesh in blender or processor. Add lime juice and purée.
2. Combine gelatin and orange juice in a small bowl and let stand, while gelatin softens, for five minutes.
3. Meanwhile, whisk together the granulated sugar and egg yolks in a heavy saucepan. Then whisk in half the cherimoya purée (about 1 cup) and the gelatin mixture. Set over medium heat and whisk constantly until the mixture thickens. As with all custards, the idea is to raise the temperature of the mixture to the threshold of simmering but not beyond. If you heat a custard too far, the egg yolks will scramble. This sounds tricky—and it is, the first time you do it. But it is much better to err on the side of overcooking than undercooking. An unthickened custard is not a custard. A slightly scrambled custard can be pushed through a fine strainer and then used. At any rate, there is no mystery about thickening. When it happens, you will feel it and

**Cherimoya Mousse**

(With thanks to Elizabeth Schneider)

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>ripe cherimoyas</td>
<td>about 2 pounds</td>
</tr>
<tr>
<td>tablespoons lime juice</td>
<td>2</td>
</tr>
<tr>
<td>envelope unflavored gelatin</td>
<td>1</td>
</tr>
<tr>
<td>cup orange juice</td>
<td>¼</td>
</tr>
<tr>
<td>tablespoons granulated sugar</td>
<td>2</td>
</tr>
<tr>
<td>eggs, separated</td>
<td>2</td>
</tr>
<tr>
<td>Salt</td>
<td></td>
</tr>
<tr>
<td>tablespoons superfine sugar</td>
<td>2</td>
</tr>
<tr>
<td>cup heavy cream</td>
<td>½</td>
</tr>
</tbody>
</table>

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the consumer in optimum shape. Cherimoyas picked a tad before they are perfectly ripe really do develop off the tree without loss of quality. But time is still of the essence. It is possible to ship a cherimoya to New York from California and have it ripe and ready. But the job is not simple. Long delays are deleterious to the fruit. So is rough treatment. And so is cold. Just as you must not refrigerate your cherimoya until it is ripe (soft to the touch but not mushy), so the cherimoya shipper must try to protect his still-green fruit from the winter outside the truck. Cold dehydrates the fruit. Over the hill or frozen fruit will be dark all over or splotchy. Frozen fruit will not ripen properly. Growers are acutely aware of this. And because they are in business on a small scale and work through specialty distributors and retailers, their cherimoyas do tend to make it to market in fine fettle. You will pay for the privilege of eating a cherimoya, anywhere from $3.98 to $8.98 a pound, but it is worth it, and compared with the $20 price tag that the fruit-worshipping Japanese have been paying, the American price tag is a bargain.

Here is what to do after you bring your cherimoya home: Let it sit on a counter in the kitchen just as you would an avocado. When it feels a bit soft, chill it. This improves the taste. Take the chilled fruit from the refrigerator. Slice it in half. Give one half to someone you like and keep the other for yourself. Now take a spoon and eat the pure white flesh, discarding the black seeds as you go. The taste of the cherimoya flesh has been compared to the taste of almost all other high-class fruits. The California Tropics cherimoya flier says it has a custardlike texture and a flavor “like a subtle, mouthwatering blend of papaya, pineapple, and banana.” You will come up with your own description.

As you have gathered, I think this fruit is the nuts. I particularly like its texture, which is indeed like a custard. But it is not completely like baby food either. In her book Uncommon Fruits and Vegetables (Harper and Row), Elizabeth Schneider calls attention to a delicate granularity of the sort found in a ripe pear. This is a subtle feature, one you will not probably notice in the first rush of excitement after tasting a cherimoya. Served ice cold, it should seem like sherbet.

Then you should think of this. Peter Nichol's trees are only eight years old. In South America, they say a tree is not at its peak until it's fifty.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

Matthew M. Douglas
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Sit and wait; sit and wait. The bearded chameleon's life style may be low-key but it has its moments. An arboreal lizard native to the cool Kenyan highlands, *Chamaeleo hohnelii* often installs itself on a favorite branch for days on end. But when its swiveling eyes spot an appetizing morsel, the still life then becomes "old lighnin'."

In an instant, muscles propel the tongue to a length equaling the chameleon's, tail included (in this case, six inches). Any insect or spider taking a direct hit with the sticky, club-shaped tongue tip is sure to become a meal.

This enthusiastic diner, caught in midattack by the photographer's special flash system, lunged toward the prey but maintained a grasp on its perch with its hind feet and tail. Like other bearded chameleons, it entered the world already knowing much of its reptilian repertoire. In fact, young of this species can use their laserlike weaponry at the tender age of one hour.—*J.R.*

Photograph by
Bruce Davidson
To reach conclusions about the peopling of the New World on the basis of prehistoric teeth, Christy G. Turner II (page 6) has examined more than 15,000 crania. His travels have taken him to museums, institutions, and archaeological sites throughout North and South America, the USSR, and eastern Asia (the photo shows him in Siberia, describing his methods to Valeri Alexeev, at left, a corresponding member of the USSR Academy of Sciences). Turner was drawn into his field of research in 1961, when he became project supervisor for an Aleutian–Kodiak prehistory and ecology project directed by anthropologist William S. Laughlin. After completing a doctoral dissertation on the dentition of arctic peoples, he went on to determine the dental characteristics of all New World populations and of Siberians. A professor of anthropology at Arizona State University, Turner plans to apply his techniques to the study of another anthropological question, the origin of anatomically modern humans. For further details of Turner's research, readers can consult his chapter, "The Dental Search for Native American Origins," in Out of Asia: Peopling the Americas and the Pacific, edited by Robert Kirk and Emoke Szathmáry (Canberra: Journal of Pacific History, 1985). William S. Laughlin's Aleuts: Survivors of the Bering Land Bridge (New York: Holt, Rinehart, and Winston, 1980) looks at the descendants of what may have been the earliest Asian immigrants to the New World.

They found much to admire in the traditions of these pastoral people, along with much to rue in the intervention of development and aid agencies. McCabe (shown at left with friend and Turkana herdsman Atot in a photo taken by a tribesman who had never used a camera before) is an ex-Peace Corps volunteer. McCabe completed his master's degree in anthropology at the State University of New York at Binghamton in 1976 and worked continuously among the Turkana from 1979 until he received his doctorate in 1985. Now an assistant professor of anthropology at the University of Georgia, he is studying the impact of development efforts on the pastoralists in East Africa. Ellis, who is associate director of the Natural Resource Ecology Laboratory at Colorado State University, studied North American pronghorn, bison, and elk and then began studying how animals and humans deal with each other in an environment. These studies took him from the deserts of Saudi Arabia to the forests of Alaska, and most recently, to the savannas and bushlands of East Africa. For more information on the lives of the pastoralists, the authors recommend The Family Herds, by P.H. Gulliver (London: Routledge and Kegan Paul Ltd., 1955) and Karanojong Politics, by Neville Dyson-Hudson (New York: Oxford University Press, 1966).

Anthropologist J. Terrence McCabe and zoologist and ecologist James E. Ellis (page 32) worked among the Turkana in Africa during the worst periods of drought and famine in recent memory.
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What began for Robert Palmer (page 42) as a sporting venture turned into a scientific pursuit. The sport was underwater cave diving, in which both the risk and the adventure are high. Since so few scientists have explored these deep realms, Palmer quickly found his skills could lead him to undiscovered natural treasures. Soon he was leading research expeditions to the blue hole caves of the Bahamas. He is now director of the Andros Project, an international effort to explore and map the blue holes of Andros Island in the Bahamas. At the same time he is working on his master’s degree in philosophy at Bristol University in Bristol, England, and serving as coastal pollution officer for the Marine Conservation Society of the United Kingdom. For further reading on the Bahamas, Palmer recommends The Ephemeral Islands: A Natural History of the Bahamas, by David G. Campbell (London: Macmillan Education Limited, 1978). His own Blue Holes of the Bahamas was published in 1986 by Jonathan Cape (London).

John W. Schoen, Sterling D. Miller, and Harry V. Reynolds III (page 50) are all research biologists with the Alaska Department of Fish and Game but are working on grizzly bears in different parts of the state. Schoen (above right) finds his bears primarily on Admiralty and Chichagof islands in southeastern Alaska, where his research is greatly helped by his ability to fly a SuperCub and pilot a 38-foot boat. He is particularly interested in the effect of mining and logging activities on the grizzlies. The possible impact of a proposed hydroelectric dam on grizzly and black bears in south-central Alaska has preoccupied Miller (below) for the last five years. Reynolds (far left), whose first professional contact with grizzlies was as a sixteen-year-old working for Frank and John Craighead in Yellowstone, has concentrated on bears of interior and arctic Alaska. In the north, one major concern is how oil exploration might affect the bears. To learn more about grizzlies, readers can turn to Thomas McNamee’s The Grizzly Bear (New York: Knopf, 1984) and Frank Craighead’s The Track of the Grizzly (San Francisco: Sierra Club Book, 1979).

Growing up in New York City, Howard Topoff (page 62) was exposed early to social behavior on a grand scale. Today, as a professor of psychology at Hunter College, where he teaches animal behavior, and as a research associate in entomology at the American Museum of Natural History, Topoff explores the similarities and differences between vertebrate and invertebrate societies. His specialty is the evolution and development of behavior in the social insects, particularly ants. In addition to the predations of army ants, which he reports on in this issue, Topoff studies ant migration (“Ants on the March,” Natural History, December 1975) and slave-making ants (“Invasion of the Booty Snatchers,” Natural History, October 1984). Field research has taken him to the American tropics and to Arizona, where he spends part of every summer, leaving the teeming city to study the ant-hills of the desert. More information on ants and their colonies can be found in E.O. Wilson’s classic, The Insect Societies (Cambridge: Belknap Press of Harvard University Press, 1971).
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Cover: Two olive baboons—a female and her much bigger male friend—spend a cozy minute together. Photograph by Barbara Smuts. Story on page 36.
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Flowers Turned Off Dinosaurs

Robert Bakker, in his article “How Dinosaurs Invented Flowers” (November 1986), suggests coevolution between dinosaurs and angiosperms, resulting in worldwide distribution of the flowering plants. This evolutionary strategy may not have been as pervasive as Bakker intimates. In the Cretaceous, the last period in which the dinosaurs dominated, the most abundant herbivores—the hadrosaurs, or duckbilled dinosaurs—had apparently developed a number of feeding strategies not dependent upon consumption of flowering plants.

At least one group, the so-called non-crested hydrosaurs such as Anatosaurus may well have been gymnosperm foragers. Although interpretation of the evidence has been questioned, preserved stomach contents found with palaeontological specimens of the solid-crested hydrosaurs consist only of conifer debris. Another group of Cretaceous duckbills, the hollow-crested forms Lambeosaurus and Corythosaurus in particular, seem to have had a horny bill exterior to the bony upper jaw. The inner surface of this bill was crossed by at least five vertical channels very similar to those in the bill of the shoveler duck. The forward mobility of the bone in the anterior part of the lower jaw, called the predentary, when opposed against this channeled bill would provide a filtering device. I have conjectured that this system was admirably suited to taking in a slurry of aquatic vegetation, small shellfish, and other faunal eatables. After being ground up, this watery residue would be drained out between the inner bill and opposed dentary. This interpretation negates a low-grazing habit as suggested by Bakker.

In addition, several lineages of hydrosaurs had exceedingly narrow but tall tails, which well may have been adapted as sculling features in an aquatic or semiaquatic form. To my knowledge, with one exception, all unquestioned non-aquatic dinosaurs either among the herbivores or carnivores do not have these vertically flattened tails. This interpretation of an aquatic or semiaquatic environment is consistent with the kinds of sedimentary deposit in which, at least, the hollow-crested duckbill dinosaurs have been found. Without exception all of these forms are found in either channelized or non-channelized deposits of vast ancient deltas analogous to those of the Mississippi or Amazon or in strata formed near ancient seaways. A watery context indeed.

One can be sure that some interaction between dinosaurs and their vegetative diet did take place. To suggest that it was overwhelming, as Bakker has done, is to imply a greater knowledge of dinosaur feeding strategies than we presently have.

William Morris
Emeritus Professor
Department of Geology,
Occidental College
Los Angeles, California

I am pleased that Robert Bakker has proposed “How Dinosaurs Invented Flowers.” Indeed the success of angiosperms in the face of “the intense mowing action of dinosaurs” was probably generally a result of their ability to reproduce and grow faster than the older established groups of plants (ferns, gymnosperms, and cycads). But Dr. Bakker has ignored the fact that flowering plants also possess another important advantage; that is, they produce a far wider range of unique feeding deterrents, which are not found in earlier taxa, aromatic alkaloids, ellagitannins, oxygenated terpenoids, acetylenes, and so on. These protect their seedlings, as well as later stages, from reptilian, mammalian, and insect herbivores. Such phytochemical factors cannot be ignored if we are to understand Cretaceous ecology.

Prof. T. Swain
Jodrell Laboratory
Royal Botanic Gardens
Surrey, England

Nawab of Old

In “Foul Shots and Rifle Fire” (September 1986), R. Lincoln Keiser asserts that one Sharif Khan was made nawab of Dir by the British and that the same Sha-
How high blood pressure can destroy high hopes

The effects of untreated high blood pressure often strike without warning. While high blood pressure (hypertension) by itself might not show any symptoms, there are a range of complications that can result in permanent impairment or death. The complications show up...

Through strokes
Constant high pressure against blood vessel walls in the brain can eventually cause them to break—one form of stroke. High blood pressure seems to speed up atherosclerosis, or hardening of the arteries. As arteries become less flexible and clogged with fatty deposits (cholesterol), it is more and more difficult for the blood to flow. If this happens to the blood vessels supplying your brain, the result can be a blocked artery that will cause a different kind of stroke known as cerebral thrombosis.

Through other problems
Not only are the blood vessels going to your brain affected by high blood pressure, but also the vessels to your heart may be seriously damaged. This results in chest pain (angina pectoris) or a heart attack (myocardial infarction). Hypertension also can trigger problems with the flow of blood to your kidneys, your eyes, or your hands and feet.

Who is at risk?
While individuals of any age can get high blood pressure, it is far more common in older age groups. It affects close to half the population over the age of 64. Under the age of 50, hypertension is more common in men than in women. After 55 or 60, it is more common in women than in men. Yet more men die from hypertension complications than do women.

Statistics also show that blacks, compared to whites, get high blood pressure earlier in life, at higher levels and twice as often.

People of any race who are overweight suffer more often from hypertension. High blood pressure also runs in families and may be aggravated in some cases by consuming too much salt.

What can be done about high blood pressure?
1. Live a healthy lifestyle. Lose excess weight; stop smoking; reduce stress, fat and salt intake; and make sure you get enough exercise, rest and relaxation.
2. If necessary, your doctor will prescribe an appropriate blood pressure medication. While hypertension medicina-
tions available 20 years ago sometimes caused severe side effects, including changes in blood lipid levels, now there is a growing spectrum of medications that provide safe and effective therapy while focusing on the specific abnormalities of hypertension affecting you. Coordinating efforts closely with your doctor will ensure that he or she will prescribe the right medicine or combination of medicines to keep your pressure under control with few significant side effects. The use of anti-hypertensive medicines, together with improved lifestyles has helped cut one type of stroke death in half and reduced heart attacks by one-third.

3. Watch out for other health conditions that may aggravate effects of hypertension. For example, the risk of heart disease increases if both high blood pressure and high cholesterol are present. Your doctor can test your blood pressure and your cholesterol level and interpret the results.

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Sharif Khan was deposed when Pakistan established direct rule in Dir. Since the former event happened in 1897, when the ruler was an adult, and the latter in 1965, this would, if true, indicate an extraordinary longevity. My understanding, however, is that Sharif Khan died or was deposed in 1904, and it was his third successor, Mohammad Shah Khosru Khan, who was deposed in 1965.

Juan Jorge Schäffer
Pittsburgh, Pennsylvania

R. Lincoln Keiser Replies:
The inhabitants of Hindu-Kush/Karakorum Mountains (especially the people living in Hunza) are famous for their longevity. Machbool Khan, a Kohistani friend and informant from the village of Thull, insisted that his grandfather lived to the ripe old age of 160 and participated in events surrounding the invasion of Dir by the Mahmud of Ghazni in the eleventh century. Unfortunately, however, the egg remains on my face because the putative longevity of the area's inhabitants is indeed a myth. Sharif Khan died many years before Dir state was abolished.

Kiwi Company
In his November 1986 article, “Of Kiwi Eggs and the Liberty Bell,” Stephen Jay Gould, whose column I always look forward to, stated that “kiwis, for example, are unique among birds in retaining ovaries on both sides (the right ovary degenerates in all other birds)—and eggs alternate between sides, as in mammals.” The right ovary does not degenerate in some birds of prey, especially in the genera Accipiter, Circus, and Falco. These include various hawks and falcons.

Sharon Milder
Los Angeles County Museum of Natural History
Los Angeles, California

Evolution Goes to the Dogs

As a collector of photos of unusual dogs, I read with some interest Pere Alberch's article on “Possible Dogs” (December 1986). My own informal observations concerning extra or missing digits confirm his [that small dogs will tend to have small embryos and therefore smaller limb buds that are unlikely to produce extra toes]. As the photograph shows, the begging dog, which I came across in San Francisco, has greatly reduced forelegs from, presumably, smaller limb buds, and has no dewclaws.

Also, the greatest cross-over I’ve found between the author’s amphibian research and his dog theories is the curiosity sent to me by a friend in Perugia, Italy. It’s a photograph of a dog belonging to an elderly man named Vittorio Manzione who calls his pet, translated, a “frog spaniel.” The dog has very webbed feet, which Mr. Manzione shaves for effect; he also clips the legs and body. Apparently he’s fond of having the dog sit on lily pads in his water garden.

Gerald Heffernon
Davis, California
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New Dates from Old Bones

Twisted fractures in mammoth bones and some flaked bone tools suggest that humans occupied the Yukon more than 40,000 years ago

by William N. Irving

In the summer of 1966 I was excavating with a crew of six at Klo-Kut, a late prehistoric campsite near the village of Old Crow, in northern Yukon Territory. The work was going well: this was turning out to be one of the largest Athapaskan Indian sites ever found. We were digging through layers of flood-water deposits on which, for the past couple of thousand years, people had camped intermittently to intercept the spring migration of caribou, which crossed the nearby Porcupine River on their way toward the coast. In the sod and uppermost layer we found a pile of ash that contained a jackknife and parts of a harmonica, while in the prehistoric layers below, we unearthed finely made stone projectile points, fish-spear parts made of bone, and a beautiful model of a fish—a graying. And since the Old Crow village—

This is the fourth in a series of articles exploring archeological sites and other lines of evidence that bear on the peopling of the New World.

ers who had directed me to the site were able to tell me something about how their elders and ancestors used it (they recalled it had last been occupied about 1905), I looked forward to connecting my archeological interpretations to a living people.

As a matter of course, I was also aware that we were digging in a region that during the Pleistocene epoch (1.6 million to 10,000 years ago) had been spared by continental glaciers. The fossils of mammoths, giant bison, and other Ice Age animals that once roamed the area had been surfacing near Old Crow since about the turn of the century. Extending to our north was a prime fossil-collecting area, Old Crow Flats, an eighty- by forty-mile basin filled with frozen sand, silt, and mud. Through it flowed the Old Crow River, a tributary of the Porcupine, which in turn now drains into the Yukon River. That any humans might have lived there contemporaneously with Ice Age animals was far from my mind, however, absorbed as I was in the Athapaskan discoveries.

All that changed when, one early August day, paleontologist C.R. Harington and his guide, the late Peter Lord, appeared at my camp with some distracting news. Harington and Lord were spending the summer collecting late Pleistocene fossils on Old Crow Flats. It seems they had discussed the possibility of finding evidence for humans, and then one day, Lord said to Harington, “I guess this is what you’re looking for,” and showed him a caribou leg bone—a tibia. The upper end of it was whittled into a spatula, with the edge indented to make a series of teeth. The foot-long bone was stained the same dark red-brown color as the other fossils found nearby, which were bones of mammoths, giant bison, and the Pleistocene American horse—all extinct since the end of the last Ice Age. The two had stayed up talking about it all that night.

Because I was the only archeologist in the neighborhood, they came to Klo-Kut to show me and my crew the carved caribou bone and also the broken bones of the other animals found nearby, which they felt showed signs of human alteration. As Harington unwrapped his specimens, we were very skeptical. But the caribou bone was unmistakably a fleshed, a tool used to scrape the insides of animal skins. Although it meant a forty-mile journey, I was quickly persuaded to let Harington show me where it had been discovered.

Those forty miles were hard going. We had to drag Lord’s heavy river boat through the braided stream channels of the Old Crow at exceptionally low seasonal water, but eventually we reached the quiet stretch of the river where the fleshers had been found just a few days before. Bones were strewn about on the bank; scraping away at the mud revealed others. They seemed to come from several well-defined layers of gravelly sand, the coarsest deposits anywhere in the vicinity. All were stained a rich, chocolate brown, suggesting they all were about the same age.

Back in Ottawa, where Harington and I both worked at the National Museum of Canada, we puzzled over the fleshers and the fragments of broken mammoth bone found with it. We agreed that the latter were not like the natural animal remains we had occasionally encountered on the forest and tundra landscapes and around wolf dens. Apart from their far higher concentration, some were distinguished by smoothly curved fracture surfaces, which we guessed could only have occurred on fresh bone. Such fractures were especially notable on fragments of mammoth bones, bones that seemed too dense and large to have been cracked by even the largest of carnivores. This suggested to us that they had originally been broken, and probably accumulated, by humans—perhaps the people who had made the fleshers.

Of course, there were other possible explanations to consider. Perhaps someone had fashioned the fleshers from an ancient bone and so the tool as such really wasn’t all that old. Perhaps the staining had taken place rapidly, causing fossils of different ages to appear more alike than they were. Or perhaps we were mistaken in thinking that the unusual fractures could have been caused only by humans. We embarked on two simultaneous lines of inquiry. One was to find out how and why
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mammoth, horse, and bison bones would have been fractured by humans. The other was to establish how long ago the flesher had been manufactured.

Both Harington and I remembered that, under the guidance of Eskimo and Indian mentors, we had broken caribou and moose bones in order to eat the marrow. I got a few fresh beef bones from a local butcher and confirmed my recollection of how they could be broken. This informal experiment produced fragments that resembled those from Old Crow in a very general way. This was encouraging, although we also thought that mammoth bones, with their latticelike interior structure, would have contained little usable marrow.

Turning to our other line of inquiry, we sent samples from the flesher and two fractured mammoth bones, as well as some caribou bone fragments from Kek-Kut (which I knew to be less than 300 years old), to Kenneth Oakley at the British Museum (Natural History), with a request that they be compared chemically to find out if they were of the same or different ages. Oakley's uranium and fluorine testing had been instrumental in the exposure of the Piltdown forgery. But in our case, the results were inconclusive, seeming to show that each of the specimens could be either ancient or modern.

The summer of 1967 brought another development: we learned that all the specimens, including the flesher, must have been redeposited fairly recently by the modern Old Crow River. Radiocarbon dates for twigs and branches found in the bone-bearing layers ranged over most of the last 40,000 years, showing that the layers contained a mixture of materials from different sources. This didn't necessarily mean that the bones themselves were modern, but rather that there was no chance of ascertaining their age through stratigraphic studies at the site of their discovery. Although my crew and I explored many other sites previously recorded by Harington, including one where we saw a few bones buried under many feet of alluvium, it was on the whole a frustrating field season. We realized how much more work would be needed, including the study of upland sites around the valley, if we were ever to answer the most important questions.

Our next recourse was to apply radiocarbon dating to some of the specimens themselves. Samples from the flesher and from two fractured mammoth bones were prepared, using carbon from the bone mineral apatite (more recently, scientists have preferred to use the soft tissue collagen). Enough of the flesher was retained to serve in displays and to permit later analyses with new techniques. The resultant dates were startling. The two mammoth bones and the flesher were determined to be about 27,000 years old. This made them 15,000 years older than nearly all previously dated human artifacts in the New World.

Then, as today, archeologists were more comfortable with artifacts dated no more than 12,000 years old. An association of mammoths and humans, although new for the Yukon, provided no argument for the validity of an earlier date. As known from North American sites farther south, early New World hunters used fluted projectile points (Clovis points) to kill some of the last mammoths, but these animals did not die out until about 10,000 years ago. The conventional wisdom was thus stacked against acceptance of our radiocarbon dates.

And even if our dates could be verified, we still had a lot of explaining to do: why, for example, would prehistoric hunters have smashed elephant bones that, as far as we could see, had very little marrow inside them? (Some suggest that fat can be rendered from such bones, but it is hard to believe this would have been worth the effort.) Another field season, in 1970, moved us a bit further toward solving this problem, as we sought out additional sites both along the Old Crow River and in the uplands around the Old Crow basin. By chance we discovered an enormous deposit of Pleistocene bones on the river, at a location we had boated past many times previously. The 1,500 more interesting specimens selected in the field for later study included a relatively large number of mammoth and horse bone fragments with the distinctive curving fractures that we had previously noted. This was the first large sample of bones collected in the Yukon specifically for archeological study. It promised to reveal both unique specimens and patterns of manufacture and use that would be difficult to infer from a few isolated specimens.

In 1972, I made one of many trips to visit colleagues and solicit their opinions on the nature and purpose of the Old Crow bone-breaking activity. In Edmonton, at the University of Alberta, I happened to encounter Robson Bonichsen, then a graduate student, who had been making thorough studies of paleo-Indian stone tools and their manufacture by percussion and also of the uses of animal bone by modern Indian hunters. He took about a minute to appraise the situation and deliver an opinion: the pieces of mammoth bone that I had presented for his mystifi-
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culation were evidence of the use of percussion to produce cutting, scraping, and other tools from fragments of large mammal bone. The tools were made, not by grinding and polishing, but by chipping and flaking bone in a manner analogous to the manufacture of paleolithic stone tools. As in stone-tool technology, either a flake struck from the material being worked or the piece left after the removal of flakes could serve as the basis for a tool. My reaction time was a little slower than Bonnichsen’s, but his perception of the purpose implicit in the fractured bones soon became the basis for postulating “the Old Crow bone industry,” a type of phenomenon that seems to have occurred in many parts of the world during the paleolithic cultural stage but that until recently has received little attention.

Spurred by the early radiocarbon dates and more focused questions, in 1975 two long-term projects involving as many as forty fieldworkers were initiated to clarify the ecological history of the Old Crow basin and discover evidence for ancient humans. Experimental work also continued. In 1977, using the remains of a dead African elephant (the unfortunate Ginsberg of the Boston Zoo, done in by a poorly administered tranquilizer), Bonnichsen handily replicated several of the bone flakes we had noted as being particularly distinctive among the Old Crow fragments. His work showed me that a tremendous amount of energy concentrated in a very small area is needed to break a fresh elephant bone—a concentration not likely to occur often in nature. Moreover, I learned that the application of a certain sequence of blows to a particular piece of bone is essential in the production of some kinds of edged tools that we have recognized at Old Crow. This, too, could not be expected to occur repeatedly as a result of random natural events.

Although fieldwork findings are still being analyzed, we have begun to describe and interpret the artifacts among the many tens of thousands of bones recovered from Old Crow. For example, about 13 percent of the mammoth long bones exhibit the curvilinear, or “spiral,” fractures that show that the bones were broken while still fresh. Drying changes the properties of bone so that it either crumbles or breaks into roughly rectangular fragments when struck. In the case of mammoth bones, especially those in which the points of impact can be recognized, we are confident in attributing these fractures to humans, even where no particular function or use is apparent. Neither large carnivores, such as bears, nor drifting river ice have ever been observed to cause such fractures. During the Ginsberg experiment, Bonnichsen, hurling a twenty-five pound stone with all his strength, fractured one bone only on his fifth try. This indicated human ability to cause such fractures; it also made it difficult to imagine a similar event occurring repeatedly in nature.

The number of easily recognizable implements is extremely small: a few awls; some hunks of flaked bone that have damaged edges and might therefore be called scrapers; a piece of mammoth bone from which several flakes were struck after one of its sides had been shaped into a suitable striking platform, similar to those made by flint knappers on their cores of stone; and several examples of bone flakes. All these can be explained as results of sequences of operations that could not be duplicated by natural forces. These artifacts can be classified informally as cores for production of flakes, flakes, and implements made by flaking. Most appear to have been used or designed for scraping or chopping. In addition, we found a small number of tools made or at least finished by grinding and polishing; these are all of mammoth ivory. Finally, there are more than fifty examples of flat, polished surfaces on bones and pieces of ivory for which we can propose no utilitarian purpose but which we cannot account for by natural forces.

Even if our interpretations are correct, these finds cannot overcome doubts about our dates. What can is progress in understanding the Old Crow basin stratigraphy. In places, the modern Old Crow River has cut as much as 110 feet down through the basin sediments, exposing them to view. Those of us working in the region have concluded that clay deposits fifteen to thirty feet below the basin floor were left by a lake that filled the basin at the time of the late Wisconsinan maximum ice advance, about 18,000 years ago. In the layers just below this clay, mammoth bone flakes and other artifacts have been excavated, and five of these flakes have been dated by the new radiocarbon technique of accelerator mass spectrometry. They range in age from 22,000 to 43,000 years old. This appears to confirm both the relatively great age and the long persistence of the Old Crow bone industry.

More is in store, however. At the site where we noticed bones in place in 1967, careful excavations over the course of five field seasons have shown bone artifacts to be present in stratified deposits thirty to forty feet below the dated material just mentioned. The stratigraphic position, as well as the presence of extinct kinds of lemmings and other species, indicates ex-
comprises "paralithic specialization, neous basin. Homo sapiens, the Neanderthals, persisted until about 40,000 years ago.

The type of bone industry we have described is not peculiar to the Old Crow basin. For example, percussion-fractured mammoth bones have been found in several parts of Alaska and at sites in Idaho and Texas (in the latter two states, however, the bones appear to be contemporary with 11,000-year-old big-game hunting points of the Clovis type). In addition, during a recent visit to China I was shown several examples of paleolithic bone collections in which stone implements were missing or very scarce; the bone fractures, however, bear a close resemblance to those seen at Old Crow and deserve further careful study. The case is therefore building for a new field of specialization in what might be called "paralithic technology." This technology comprises the hard, but nonlithic and thus usually perishable, parts of paleolithic material culture—what early humans did to make tools when suitable stones could not be found or other materials were more convenient.

In Southeast Asia, an environment totally different from that of the Yukon, Geoffrey Pope has arrived at a similar formulation: he suggests, as have others, that bamboo served as a basic raw material for making edged tools of many kinds, replacing the need for certain stone tools. Because these tools were made of a perishable material, the archeological record is incomplete. Pope's observations and the work at Old Crow seem to show that the paleolithic of Southeast Asia and northern North America cannot be understood by paying attention only to implements made of stone.

A percussion-based bone industry has lurked in the wings of paleolithic archeology since at least as long ago as the 1920s, but it never has been brought to center stage. One reason is that there cannot be a bone industry without at least a few stone tools—hammers, to begin with, and probably scraping and whittling stones as well. But in the Old Crow basin of northern Yukon, dozens of fieldworkers deployed over two decades have found upwards of 200,000 vertebrate fossils, among which I estimate that there may be 5,000 to 10,000 bone artifacts—specimens altered by humans—yet they have found no more than fifty stone artifacts along the river. Hundreds of artifacts and flakes of stone have been found on lookout sites on hills around the northern and eastern margins of the basin, but in most cases no bone has been found with them. These are the statistics; perhaps someday they won't seem so unusual.

One of the ironies of science is that the flesher, when recently redated by accelerator mass spectrometry using the now-favored collagen portion of the bone, gave an apparent age of about 1,400 years. The discrepancy between this figure and the original 27,000 years is the subject of sleuthing by chronology specialists—it seems too great to have resulted from a simple mistake. The ironic part of the story is that the age of the flesher is now relatively unimportant. While most of the flesher has been sacrificed over the years to accommodate all the tests, the Old Crow bone industry does not depend on their results for confirmation. The large quantity of observations that the flesher prompted us to collect constitutes a mass of data that can stand on its own.

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Freudian Slip

What mental blinders caused the master psychologist to make a mistake so hurtful to women?

by Stephen Jay Gould

The Marquis de Condorcet, enthusiast of the French Revolution but not radical enough for the Jacobins—and therefore forced into hiding from a government that had decreed, and would eventually precipitate, his death—wrote in 1793 that “the perfectibility of man is really boundless . . . . It has no other limit than the duration of the globe where nature has set us.” As Dickens so aptly remarked, “It was the best of times, it was the worst of times.”

The very next year, as Condorcet lay dying in prison, a famous voice from across the channel published another paean to progress in a world that many judged on the brink of ruin. This treatise, called *Zoonomia, or the Laws of Organic Life*, was written by Erasmus Darwin, grandfather of Charles.

*Zoonomia* is primarily a dissertation on the mechanisms of human physiology. Yet, in the anachronistic tradition that judges biological works by their attitude to the great watershed of evolution, established by grandson Charles in 1859, *Zoonomia* owes its modern reputation to a few fleeting passages that look upon organic transmutation with favor.

The evolutionary passages of *Zoonomia* occur in item 8, part 4, of section 39, entitled, “Of Generation,” Erasmus Darwin’s thoughts on reproduction and embryology. He viewed embryology as a tale of continuous progress to greater size and complexity. Since his evolutionary speculations are strictly analogous to his concept of embryology, organic transformation also follows a single pathway to more and better:

Would it be too bold to imagine that in the great length of time, since the earth began to exist . . . all warm-blooded animals have arisen from one living filament . . . possessing the faculty of continuing to improve by its own inherent activity, and of delivering down those improvements by generation to its posterity, world without end?

As the last sentence shows, Erasmus Darwin’s proposed mechanism of evolution lay in the inheritance of *useful* characters acquired by organisms during their lifetime. This false theory of heredity has passed through later history under the label of Lamarckism, but the citation by Erasmus (a contemporary of Lamarck) shows the extent of this misnomer. Inheritance of acquired characters was a standard, commonsense belief of the time, used by Lamarck to be sure, but by no means original or distinctive with him. For Erasmus, this mechanism of evolution embodied the concept of pervasive utility. New structures arose only when needed and by direct organic striving for an evident purpose. Erasmus discusses adaptations in three great categories: reproduction, protection and defense, and food. Of the last, he writes:

All . . . seem to have been gradually produced during many generations by the perpetual endeavor of the creatures to supply the want of food, and to have been delivered to their posterity with constant improvement of them for the purposes required.

In this long section, Erasmus considers only one potential exception to the principle of pervasive utility: “the breasts and teats of all male quadrupeds, to which no use can be now assigned.” He also suggests two exits from this potential dilemma: first, that male nipples are vestiges of a previous utility if, as Plato had suggested, “mankind with all other animals were originally hermaphrodites during the infancy of the world, and were in process of time separated into male and female”; second, that some males may lactate and therefore help to feed their babies (in the absence of any direct evidence, Erasmus cites the milky colored feeding fluids, produced in the crops of both male and female pigeons, as a possible analogue).

The tenacity of anomalies through centuries of changing beliefs can be truly astounding. As a consequence of writing these monthly essays for more than thirteen years, I receive hundreds of letters from readers puzzled about one or another apparent oddity of nature. With so large a sample, I have obtained a pretty good feel for what issues and particulars of evolution pose conundrums for well-informed nonscientific readers. I have been fascinated (and, I confess, surprised) over the years to discover that no single item has evoked more puzzlement than the very issue that Erasmus Darwin chose as a primary challenge to his concept of pervasive utility—male nipples. I have received more than a dozen requests to explain how evolution could possibly produce such a useless structure.

Consider my latest example from a troubled librarian. “I have a question that no one can answer for me, and I don’t know where or how to look up the answer. Why do men have nipples? . . . This question nags at me whenever I see a man’s bare chest”

I was fascinated to note that her two suggestions paralleled exactly the explanations floated by Erasmus Darwin. First, she reports, she asked a doctor. “He told me that men in primitive societies used to nurse babies.” Finding this incred-
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ible, she tried Darwin's first proposal for nipples as a vestige of previous utility: "Can you tell me—was there once only one sex?"

If you are committed—as Erasmus was, and as a distressingly common version of "pop," or "cardboard," Darwinism still is—to a principle of pervasive utility for all parts of all creatures, then male nipples do raise an insoluble dilemma, hence (I assume) my voluminous correspondence. But as with so many persistent puzzles, the resolution does not lie in more research within an established framework but rather in identifying the framework itself as a flawed view of life.

Suppose we begin from a different point of view, focusing on rules of growth and development. The external differences between male and female develop gradually from an early embryo so generalized that its sex cannot be easily determined. The clitoris and penis are one and the same organ, identical in early form, but later enlarged in male fetuses by the action of testosterone. Similarly, the labia majora of women and the scrotal sac of men are the same structure, indistinguishable in young embryos, but later enlarged, folded over and fused along the middline in male fetuses.

I do not doubt that the large size and sensitivity of the female breast should count as an adaptation in mammals, but the smaller male version need have no adaptive explanation at all. Males and females are not separate entities, shaped independently by natural selection. Rather the two sex'es are variants upon a single ground plan, elaborated in later embryology. Male mammals have nipples because females need them—and the embryonic pathway to their development builds precursors in all mammalian fetuses, enlarging the breasts later in females but leaving them small (and without evident function) in males.

In a similar case that will help us to understand the general principle, the panda develops a highly functional false "thumb" from the radial sesamoid bone of its wrist. Interestingly, the corresponding bone of the foot, the tibial sesamoid, is also enlarged in the same manner (but not nearly so much), although this increase of the tibial sesamoid has no apparent function.

As D. Dwight Davis argued in his great monograph on the giant panda (Field Museum of Natural History, 1964), evolution works on growth fields. Radial and tibial sesamoids are homologous structures, probably affected in concert by the same genetic factors. If natural selection operates for an enlarged radial sesamoid, a bigger tibial sesamoid will probably "come along for the ride." Davis drew a profound message from this case: organisms are integral and constrained structures "pushing back" against the force of selection to channel changes along permitted paths; complex animals are not an atomizable collection of independent, optional parts. He wrote that "the effect seen in the sympathetic enlargement of the tibial sesamoid... strongly suggests that a very simple mechanism, perhaps involving a single factor, lies behind the hypertrophy of the radial sesamoid."

In my view of life, akin to Davis's concept of constraint and integration, male nipples are an expectation based on pathways of sexual differentiation in mammalian embryology.

At this point, readers might demur with the most crushing of all rejoinders: "Who cares?" Why worry about little items that ride piggyback on primary adaptations? Let's concentrate on the important thing—the adaptive value of the female breast—and leave aside the insignificant male ornament that arises as its consequence. Adaptations are preeminent; their side effects are nooks and crannies of organic design, meaningless bits and pieces. This argument is, I think, the standard position of strict Darwinian adaptationists.

I could defend the importance of structural nonadaptation with a long and abstruse general argument (I have done so in several technical papers). Let me proceed instead by the most compelling route I know—presenting a second example based on human sexuality, a case entirely comparable in concept with the origin of male nipples but differing in its importance for human culture. A case, moreover, where the bias of utility has brought needless pain and anxiety into the lives of millions (where, indeed, one might argue that Freudian traditions have provided a manifestly false but potent weapon, however unintentional, for the subjugation of women). I speak of the anatomical site of orgasm in human females.

As women have known since the dawn of our time, the primary site for stimulation to orgasm centers upon the clitoris. The revolution unleashed by the Kinsey report of 1953 has, by now, made this information available to men who, for whatever reason, had not figured it out for themselves by the more obvious routes of experience and sensitivity.

The data are unambiguous. Consider only the three most widely read of extensive surveys—the Kinsey report of 1953, Masters and Johnson's book of 1966, and The Hite Report of 1976. In his study of genital anatomy, Kinsey reports that the female clitoris is as richly supplied with sensory nerves as the male penis—and therefore as capable of excitation. The walls of the vagina, on the other hand, "are devoid of end organs of touch and are quite insensitive when they are gently stroked or lightly pressed. For most individuals the insensitivity extends to every part of the vagina."

The data on intercourse affirm this pattern. Hite reports a frequency of orgasm with intercourse at 30 percent and often attained only with simultaneous stimulation of the clitoris by hand. She concludes: "not to have orgasm from intercourse is the experience of the majority of women." Masters and Johnson only included women who experienced orgasm with intercourse in their study. But they concluded that all orgasms are identical in physiology and clitoral in origin. These findings led Hite to comment that human copulation "sounds more like a Rube Goldberg scheme than a reliable way to orgasm. . . . Intercourse was never meant to stimulate women to orgasm." As Kinsey had said earlier with his characteristic economy and candor, "The techniques of masturbation and of petting are more specifically calculated to effect orgasm than the techniques of coitus itself."

This conclusion should be utterly unsurprising—that is the whole point of this essay. I don't believe in the mystery style of writing essays: build up suspense but save the resolution until the end—for then readers miss the significance of details along the way for want of proper context. The reason for a clitoral site of orgasm is simple—and exactly comparable with the nonpuzzle of male nipples. The clitoris is the homologue of the penis—it is the same organ, endowed with the same anatomical organization and capacity of response.
Part of the reason, of course, is simple male vanity. We (and I mean those of my sex, not the vague editorial pronoun) simply cannot abide the idea—though it flows from obvious biology—that a woman’s sexual pleasure might not arise most reliably as a direct result of our own efforts. But the issue is more profound. Clitoral orgasm is a paradox not only for the traditions of Darwinian biology but also for the bias of utility that underlies all functionally based theories of evolution (including Lamarck’s and Darwin’s) and, in addition, the much older tradition of natural theology that saw God’s handiwork in the exquisite fit of organic form to function.

Consider the paradox of clitoral orgasm in any world of strict functionalism (I present a Darwinian version, but parallel arguments can be made for the entire range of functionalist thinking, from Paley’s natural theology to Cuvier’s creationism): evolution arises from a struggle among organisms for differential reproductive success. Sexual pleasure, in short, must evolve as a stimulus for reproduction.

This formulation works for men since the peak of sexual excitement occurs during ejaculation—a primary and direct adjunct of intercourse. For men, maximal pleasure is linked with the greatest possibility of fathering offspring. In this perspective, the sexual pleasure of women should also be centered upon the act that causes impregnation—on intercourse itself. But how can our world be functional and Darwinian if the site of orgasm is divorced from the place of intercourse? How can sexual pleasure be so separated from its functional significance in the Darwinian game of life? (For the most divergent, but equally functionalist, view of some conservative Christians, sex was made by God to foster procreation: any use in any other context is blasphemy.)

Elisabeth Lloyd, a philosopher of science at the University of California at San Diego, has just completed a critical study of explanations recently proposed by evolutionary biologists for the origin and significance of female orgasm. Nearly all these proposals follow the lamentable tradition of speculative storytelling in the a priori adaptationist mode. In all the recent Darwinian literature, I believe that Donald Symons is the only scientist who presented what I consider the proper answer—that female orgasm is not an adaptation at all. (See his book, The Evolution of Human Sexuality, 1979.)

Many of these scientists don’t even know the simple facts of the matter; they assume that female orgasms are triggered by intercourse and draw the obvious Dar-
winian conclusion. A second group recognizes the supposed paradox of nonassociation between orgasm and intercourse and therefore proposes another sort of adaptive explanation, usually based on maintenance of the pair bond by fostering close relationships through sexual pleasure. The most widely read exponent of this view is Desmond Morris (The Naked Ape, 1969), who writes that female orgasm evolved for its role in promoting the pair bond by “the immense behavioral reward it brings to the act of sexual cooperation with the mated partner.” Perhaps no popular speculation has been more androcentric than George Pugh’s (Biological Origin of Human Values, 1977), who speaks about “the development of a female orgasm, which makes it easier for a female to be satisfied by one male, and which also operates psychologically to produce a stronger emotional bond in the female.” Or Eibl-Eibesfeldt who argues (1975) that the evolution of female orgasm “increases her readiness to submit and, in addition, strengthens her emotional bond to the partner.”

This popular speculation about pair bonding usually rests upon an additional biological assumption—almost surely false—that the capacity for male orgasm is an especially human trait. Yet Symons shows, in his admirable review of the literature, that whereas most female mammals do not experience orgasm during ordinary copulation, prolonged clitoral stimulation—either artificially in the laboratory (however unpleasant a context from the human point of view) or in nature by rubbing against another animal (often a female)—does produce orgasm in a wide range of mammals, including many primates. Symons concludes that “orgasm is most parsimoniously interpreted as a potential all female mammals possess.”

Adaptive stories for female orgasm run the full gamut—leaving only the assumption of adaptation itself unquestioned. Sarah Hrdy, for example, has taken up the cudgels against androcentrism in evolutionary speculation, not by branding the entire enterprise as bankrupt, but by showing that she can tell just as good a story from a female-centered point of view. She argues—turning the old pair-bond theory on its head—that the dissociation between orgasm and intercourse is an adaptation for promiscuous behavior, permitting females to enlist the support of several males to prevent any one from harming her babies. (In many species, a male that displaces a female’s previous partner may kill her offspring, presumably to foster his own reproductive success by immediate remating.)

Indeed, no one is more committed than Hrdy to the adaptationist assumption that orgasm must have evolved for Darwinian utility in promoting reproductive success. Chosen language so often gives away an underlying bias; note Hrdy’s equation of nonadaptation both with despair in general and with the denigration of women’s sexuality in particular.

Are we to assume, then, that [the clitoris] is irrelevant? ... It would be safer to suspect that, like most organs ... it serves a purpose, or once did ... The lack of obvious purpose has left the way open for both orgasm, and female sexuality in general, to be dismissed as “nonadaptive.”

But why are adaptationist arguments “safer,” and why is nonadaptation a “dismissal”? I do not feel degraded because my nipples are concomitants of a general pattern in human development and not a sign that ancestors of my sex once lactated. In fact, I find this nonadaptationist explanation particularly fascinating, both because it teaches me something important about structural rules of development and because it counters a pervasive and constraining bias that has harmed evolutionary biology by restricting the range of permitted hypotheses. Why should the dissociation of orgasm from intercourse degrade women when it merely records a basic (if unappreciated) fact of human anatomy that happens to unite both sexes as variations of a common pattern in development? (Such an argument would only hold if adaptations were “good” and all other aspects of anatomy “irrelevant.” I, for one, am quite attached to all my body parts and do not make such invidious rankings and distinctions among them.)

I could go on but will stop here for the obvious reason that this discussion, however amusing, might be deemed devoid of social importance. After all, these biologists may be enjoying themselves and promoting their view of life, but isn’t all this strictly entre nous. I mean, after all, who cares about speculative ideas if they impose no palpable harm upon people’s lives? But unfortunately, the history of psychology shows that one of the most influential theories of our century—a notion that had a direct and deeply negative effect upon the lives of many women—was rooted in the false assumption that clitoral orgasm cannot be the natural way of a mature female. I speak, of course, about Sigmund Freud’s theory of transfer from clitoral to vaginal orgasm.

In Freud’s landmark and most influential book Three Essays on the Theory of Sexuality (1905, but first published in complete form in 1915), the third essay on “transformations of puberty” argues that “the leading erotogenic zone in female children is located at the clitoris.” He also, as a scientist originally trained in anatomy, knows the reason—that the clitoris “is homologous to the masculine genital zone of the glans penis.”

Freud continues: “All my experience concerning masturbation in little girls has related to the clitoris and not the regions of the external genitalia that are important in later sexual functioning.” So far so good; Freud recognizes the phenomenon, knows its anatomical basis, and should therefore identify clitoral orgasm as a proper biological expression of female sexuality. Not at all, for Freud then describes a supposed transformation in puberty that defines the sexuality of mature women.

Puberty enhances the libido of boys but produces an opposite effect in girls—a “fresh wave of repression.” Later, sexuality resumes in a new way. Freud writes:

When at last the sexual act is permitted and the clitoris itself becomes excited, it still retains a function: the task, namely, of transmitting the excitation to the adjacent female sexual parts, just as—to use a simple—pine shavings can be kindled in order to set a log of harder wood on fire.

Thus, we encounter Freud’s famous theory of female sexual maturity as a transfer from clitoral to vaginal orgasm:

When erotogenic susceptibility to stimulation has been successfully transferred by a woman from the clitoris to the vaginal orifice, it implies that she has adopted a new leading zone for the purposes of her later sexual activity.

This dogma of transfer from clitoral to vaginal orgasm became a shibboleth of pop culture during the heady days of pervasive Freudianism. It shaped the expectations (and therefore the frustration and often misery) of millions of educated and “enlightened” women told by a brigade of psychoanalysts and by hundreds of articles in magazines and “marriage manuals” that they must make this biologically impossible transition as a definition of maturity.

Freud’s unbiological theory did further harm in two additional ways. First, Freud did not define frigidity only as an inability to perform sexually or as inefficacy in performance, but proposed as his primary definition a failure to produce this key transfer from clitoris to vagina. Thus, a woman who greatly enjoys sex, but only by clitoral stimulation, is frigid. “This anaesthesia,” Freud writes, “may become permanent if the clitoral zone refuses to abandon its excitability.”

Second, Freud attributed a supposedly greater incidence of neurosis and hysteria in women to the difficulty of this trans-
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...fer—for men simply retain their sexual zone intact from childhood, while women must undergo the hazardous switch from clitoral to vaginal. Freud continues:

The fact that women change their leading erogenous zone in this way, together with the wave of repression at puberty . . . are the chief determinants of the greater proneness of women to neurosis and especially to hysteria. These determinants, therefore, are intimately related to the essence of femininity.

In short, Freud’s error may be encapsulated by stating that he defined the ordinary biology of female sexuality as an aberration based on failure to abandon an infantile tendency.

The sources of Freud’s peculiar theory are complex and involve many issues not treated in this essay (in particular his androcentric biases in interpreting the act of intercourse from a man’s point of view and in defining both clitoral and penile stimulation in childhood as a fundamentally masculine form of sexuality that must be shunned by a mature woman). But another important source was the perspective underlying all the fanciful theories that I have discussed throughout this essay, from male nipples as sources of milk to clitoral orgasm as a clever invention to cement pair bonds—the bias of utility, or the exclusive commitment to functionalist explanations.

The more I read Kinsey, the more he wins my respect for his humane sensibility, and for his simple courage. (His 1953 report on Sexual Behavior in the Human Female appeared during the height of McCarthyism in America and led to a withdrawal of funding for his research and the effective end, during his lifetime, of his programs—see my essay of December 1982.) Kinsey was a measured man. He wrote in a dry and clinical fashion (probably more for reasons of necessity than inclinations of temperament). Yet, every once in a while, his passion spills forth and his rage erupts in a single, well-controlled phrase. Nowhere does Kinsey express more agitation than in his commentary on Freud’s theory of the shift from clitoral to vaginal orgasm.

Kinsey locates his discussion of Freud in the proper context—in his section on sexual anatomy (chapter 14, “Anatomy of Sexual Response and Orgasm”). He reports the hard data on adult masturbation and on the continuing clitoral site of orgasm in mature women. He locates the reason for clitoral orgasm not in any speculative theory about function but in the basic structure of sexual anatomy.

In any consideration of the functions of the adult genitalia, and especially of their ability to sensory stimulation, it is important and imperative that one take into account the homologous origins of the structures in the two sexes.

Kinsey then provides a long and beautifully clear discussion of anatomical homologies, particularly the key unit of penis and clitoris and of sites for sensory innervation, concluding that “the vaginal walls are quite insensitive in the great majority of females . . . There is no evidence that the vagina is ever the sole source of arousal, or even the primary source of erotic arousal in any female.” Kinsey has now laid the foundation for a swift demolition of Freud’s hurtful theory. He cites (in a long footnote, for his text is not contentious) a compendium of psychoanalytical proclamations from the Freudian heyday of the 1920s to 1940s. Consider just three items on his list:

1. (From 1936): “If this transition [from clitoris to vaginal] is not successful, then the woman cannot experience satisfaction in the sexual act . . . The first and decisive requisite of a normal orgasm is vaginal sensitivity.”

2. (again from 1936): “The sole criterion of frigidity is the absence of the vaginal orgasm.”

3. (from 1927): “In frigidity the pleasurable sensation is as a rule situated in the clitoris and the vaginal zone has none.”

Kinsey’s sole paragraph of evaluation is one of the finest dismissals by understatement (and by incisive phrase at the end) that I have ever read.

This question is one of considerable importance because much of the literature and many of the clinicians, including psychoanalysts and some of the clinical psychologists and marriage counselors, have expended considerable effort trying to teach their patients to transfer “clitoral responses” into “vaginal responses.” Some hundreds of women in our own study and many thousands of the patients of certain clinicians have consequently been much disturbed by their failure to accomplish this biological impossibility.

I then must ask myself, why could Kinsey be so direct and sensible in 1953, while virtually all evolutionary discussion of female orgasm during the past twenty years has been not only biologically erroneous but also obtuse and purely speculative? I’m sorry to convert this essay into something of a broken record in contentious repetition, but the point is the same, all the way from Erasmus Darwin on male nipples to Hrdy on clitoral orgasm. The fault lies in a severely restrictive (and often false) functionalist view of life. Most functionalists have not misinterpreted male
nipples, for their unobtrusive existence poses no challenge. But clitoral orgasm is too central to the essence of life for any explanation that does not focus upon the role of sexuality in reproductive success. And yet the obvious, nonadaptive structural alternative staves us in the face as the most elementary fact of sexual anatomy—the homology of penis and clitoris.

Kinsey’s ability to cut through this morass right to the core of the strong developmental argument has interesting roots. Kinsey began his career by devoting twenty years to the taxonomy of gall-forming wasps. He pursued this work in the 1920s and 1930s before American evolutionary biology congealed around the Darwinian functionalism of the so-called modern synthesis. In Kinsey’s day, many (probably most) taxonomists accepted the nonadaptive nature of much small-scale geographic variability within species. Kinsey followed this structuralist tradition and never absorbed the bias of utility. He was therefore able to grasp the meaning of this elemental fact of homology between penis and clitoris—a fact that staves everyone in the face, but becomes invisible if the bias of utility be strong enough.

I well remember something that Francis Crick said to me many years ago, when my own functionalist biases were strong. He remarked, in response to an adaptive story I had invented with alacrity and agility to explain the meaning of repetitive DNA: “Why do you evolutionists always try to identify the value of something before you know how it is made.” At the time, I dismissed this comment as the unthinking response of a hidebound molecular reductionist who did not understand that evolutionists must always seek the “whys” as well as the “hows”—the final as well as the efficient causes of structures.

Now, having wrestled with the question of adaptation for many years, I understand the wisdom of Crick’s remark. If all structures had a “why” framed in terms of adaptation, then my original dismissal would have been justified for we would know that “whys” exist whether or not we had worked out the “how.” But I am now convinced that many structures (such as male nipples and clitoral orgasm) have no direct adaptational “why.” And we discover this by studying pathways of genetics and development—or, as Crick so rightly said to me, by first understanding how a structure is built. In other words, we must first establish “how” in order to know whether or not we should be asking “why” at all.

I began with Charles Darwin’s grandpa Erasmus and end with his namesake, Desiderius Erasmus, the greatest of all Renaissance scholars. Of more than 3,000 proverbs from antiquity collected in his Adagia of 1508, perhaps two are best known and wonderfully apt for the point of this essay (which is not a diatribe against adaptation but a plea for expansion by alternative hypotheses and for fruitful competition and synthesis between functional and structural perspectives). First a comment on limitations of outlook: “No one is injured save by himself.” Second, probably the most famous of zoological metaphors about human temperament: “The fox has many tricks, and the hedgehog only one, but that is the best of all.” Some have taken the hedgehog’s part in this dichotomy, but I will cast my lot for a diversity of options—for our complex world may offer many paths to salvation, and the hounds of hell press continually upon us.

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

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The Man Who Cries Wolf

An ethologist decodes the meaning of wolf cries and silences

by Fred H. Harrington

The winter night was perfect for howling. The air was cold and motionless. Light, fluffy snow blanketed the ground, cushioning my steps as I edged closer to the wolf pack. Best of all, a full moon hung in the clear black sky, illuminating my way and perhaps stirring a few primordial howls within the wolves. Soon I came across wolf tracks that crossed the road and headed toward a spruce bog. I tried to follow, but at every third step I broke through the crust and was left floundering midthigh in powdery snow. I stopped trying to walk, set my microphone on its tripod, and switched on my tape recorder. Then I howled.

Within seconds, a pack of radio-collared wolves answered. For nearly a minute the spruce woods reverberated with a cacophony of yips, yaps, and yowls, anchored by an occasional low bass note. Finally, the wolves’ reply ended with a series of staccato, barklike yaps.

At the time, I was studying timber wolf howling in Superior National Forest in northeastern Minnesota. Working in conjunction with L. David Mech, of the U.S. Fish and Wildlife Service, I was trying to test a theory that howling plays a role in the establishment and maintenance of wolf pack territories. Each night I searched a vast network of logging roads from an antenna-equipped truck, patiently listening for radio signals from wolves Dave had radio-collared.

Populating the forest were about forty packs of wolves, each occupying some twenty-five to one hundred square miles. Under normal conditions, a pack could satisfy all its needs within an area that size—there would be an adequate number of dens, for example, and sufficient prey throughout the year. Virtually every square mile in the forest was claimed by at least one pack, so at the edges of adjacent territories, a one- or two-mile-wide overlapping strip was shared. If at all possible, these overlapping areas were typically avoided by neighboring packs and were thus underused compared with the packs’ exclusive territories. Lone wolves accordingly found these areas relatively safe and therefore made frequent use of them. And since the packs tended to stay in their own areas, they rarely met one another or even crossed the path of a lone wolf.

Observing all this led me to wonder if wolves communicate to maintain this quiltlike pattern. So each night I would set out by truck in search of a radio-collared wolf. Once I located one, I would drive as close to the animal as the roads allowed. Then I’d howl.

Most animal-vocalization studies use playbacks of recorded calls to provoke live responses. My studies had started that way too. Using several different taped howls, I had attempted playbacks but had been plagued by poor fidelity and equipment failure. My tape recorder, for instance, became very sluggish as the tem-

A wolf pack sends a signal by howling.

Karen Hollett
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perature dropped toward freezing. When the speed of the machine slowed, pups’ voices deepened and they began to sound like adults. Adult howls took on an unearthly quality that can only be compared to the moaning of lost souls in a horror film. So after three months with no success, I dumped the playback gear and developed my own personal hawl.

Getting a howl that fooled the wolves, I soon discovered, was not at all difficult. After learning to maintain enough wind to sustain a loud, six-second howl, I soon developed a standard series of five howls, which I used for the rest of the study. By this time I had been in the field four months and had not heard a single wolf howl. Soon, however, the wolves began to reply to me, and when I left the forest two years later, nearly five hundred of my howls had evoked some sort of vocal reply.

Once I knew my howls were being interpreted as those of an intruding wolf, I was ready to force encounters with packs and then note the conditions under which they replied.

A pack’s responses, I learned, could be divided into two major categories based on their howling. If a pack responded by howling, it nearly always stood its ground. (Only 3 percent of the time did the pack reply and then retreat.) If it kept quiet, it either stayed put or it fled. Thus, if there is a message to a pack’s reply, it probably reads, “We are a wolf pack, we are here, and we intend to stay here.” Implicit in this message is the threat that “if you get closer, we might attack.”

Of course, there could be a good deal of bluff involved in a reply. I soon found out that there were times when packs would turn tail and run if an intruder ignored their replies and continued to close in. I also learned that if an encounter does occur, a pack’s actual response might depend on a quick appraisal of the odds.

When a pack did not reply, it retreated about a third of the time. These retreats ranged from a fraction of a mile to more than a mile. Dave Mech and I watched one small retreat in progress. I was on the ground, howling to a pack about a mile away, while Dave watched from a circling aircraft as the pack rested on a frozen lake. When I howled, one wolf leaped up and appeared to bark once or twice, perhaps to arouse the rest of the pack. Within minutes the wolves retreated from the open ice and into the woods north of the lake, where they lay down again, less than a mile from shore. Now that the wolves knew my location, and had placed a lake between us, they would have ample warning if I moved closer. In addition, fresh scent from urination, defecation, feet, and bodies would act as an additional olfactory warning.

One probable reason why packs don’t forcibly eject intruders is that direct physical encounters carry the risk of severe injury or even death. Dave has now watched several direct encounters between packs, and in each case at least one animal was seriously wounded.

Howling thus serves the pack as a longdistance defense system. Wolves may be able to hear howls from as far away as five miles, making them aware of one another’s locations long before an accidental encounter can take place. Once aware of a neighboring pack’s position, a pack can avoid traveling into an area where a chance meeting would be likely.

Packs typically tried to avoid other packs that were too far away to be seen. The reason for this seemed clear: encounters between packs could be dangerous if one pack turned out to be larger. Once two packs could see each other, they would quickly discover which had the advantage in size, and usually the larger pack would chase after the smaller. We haven’t been able to determine, however, whether the smaller pack flees first, thus drawing the chase, or whether the larger pack attacks the smaller first.

When a pack does reply, it may “hope” the intruder will go away. But that doesn’t always happen. On an increasing number of occasions, both Dave Mech in Minnesota and researchers elsewhere have watched packs leave their territories and invade those of their neighbors. In some cases, the intruders seemed content merely to filch a deer or moose, eat it hurriedly, and return to their own territory. But other intrusions were different. The invading packs picked up the residents’ trail and excitedly followed it, not repelled by the residents’ scent, as might normally be expected. In several cases in Minnesota, the intruders pressed on until they had located the residents and attacked them. Most of these incursions resulted in at least one mortally wounded resident. What motivated these attacks is unknown.

This introduces the crux of a pack’s howling dilemma. If a pack howls and its neighbors answer, and if each pack is content to leave the other alone, then the howling has served its function: a potentially destructive encounter has been averted. But if one pack intent on attack howls and the other answers, then the second pack has given away its location and has facilitated its potential demise. This may explain why packs only answered me on half of the occasions on which I howled.

On each howling occasion, I tried to
note various kinds of information, such as where I was in relation to the territory edge or center; whether the pack was traveling or stationary; whether it was at a den, a rendezvous site, or out hunting; whether the pups were present; and which adults were there. Despite my sketchy data, a number of striking patterns emerged, which fleshed out an answer to the “howl or not to howl” question.

If replying to intruders carries the risk of attack, then wolves should expect to reap benefits that make the risk worth taking. One such benefit is the advantage of staying put. For the most part, wolves have no overriding reason to stay put. They can afford to get up, move off, and start hunting again, rather than risk an attack. But if a site contains an important resource, such as their favorite prey or their pups, there is no incentive to move.

Just one of the large ungulates that wolves hunt in Minnesota can keep the average pack well fed for a few days to a week or more. The typical wolf needs about four to eight pounds of meat each day to survive. An adult male moose provides about 725 pounds of edible meat, enough to fuel a pack of six wolves for two to four weeks. Packs are understandably reluctant to leave their kills.

But the kills get old, their meat and marrow are consumed, and soon nothing but hair, bones, and pieces of hide remain. When a pack was ready to move on, howls to them often resulted in a silent retreat. Thus an interesting pattern developed at kills. The freshest or largest kills were associated with the highest reply rates. I located one pack feeding on a six- to seven-month-old fawn that had been killed less than four hours before. It replied to my howls nine times in less than one and a half hours. When I returned the following day, the pack was still there but refused to answer any of my howls. It was gone when I checked again a few hours later, leaving nothing but the fawn’s lower jawbone.

Pups also tie a pack to a specific site, but for a much longer period. Once out of the den at three to four weeks of age, the pups spend the next three to four months at rendezvous sites, where they grow and mature as rapidly as the adults can keep them supplied with food. During this period, the pups become increasingly capable of traveling but still cannot match the endurance of an adult. Should danger threaten, while the pups are near the den, they can scamper back into it and take refuge. But most rendezvous sites lack such havens and the pups are more exposed to danger, making them more dependent on protection by the adults.

Packs are therefore quite vocal at ren-
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dezvous sites. For each pack I studied, the highest reply rates were obtained at rendezvous sites during the summer. One pack replied on all twenty-four nights I howled to it in July and August, while another replied on seventeen of twenty nights in July and on all thirty-two howling sessions in August.

During these pack replies, the pups readily joined in. Pups are accustomed to replying to packmates on their return to the rendezvous site. I found that when pups were left alone, they frequently approached me when I howled near the rendezvous site. On one occasion a pup traveled nearly half a mile toward me. It was panting and whimpering when it crashed through the brush a few feet away. Once it caught my scent it circled around me, still looking for the phantom adult wolf it was so anxious to meet. When I couldn't hear it anymore, I howled, and within seconds the pup came panting and whimpering toward me again. To the pups I must have seemed one of the pack's adults, coming back to the rendezvous site with food and perhaps in the mood to play.

The adults, however, made no such errors in identification. To them, I was an intruder and a real threat to their pups. Therefore, replying to my howls was a serious matter. If I pressed the pack by continuing to howl, the adults led the pups several hundred feet away, giving up some ground rather than endanger the pups in a fight.

As their pups grew and developed, however, packs became less and less responsive. Sometime in late November or early December, by which time pups had been traveling with the adults for some two months, packs were unlikely to reply unless they were camped at a kill. Because the pups were now very mobile, there was no need to stay on their account. Silence, and perhaps retreat, might be the best response to an intruder's howling. Accordingly, in December and January, replies came sporadically. If a pack had just made a kill, I could expect a day or two of replies before the pack clammed up. But I soon discovered that more than kills or pups influenced a pack's decision about replying.

When the breeding season approached in late February, reply rates went up for all my study packs; kills at that time made no difference in responses. With the increased production of reproductive hormones at the onset of the breeding season, there is a parallel rise in aggressiveness. Within the pack, wolves of the same sex jealously compete for the privilege of mating. This aggression is directed toward strangers as well. Most fatality-producing encounters between packs occur during the mating season, when the dominant wolves seem unwilling to tolerate a threat to their status from any corner. But the breeding season ends even more suddenly than it begins, and as aggressiveness wanes, the number of replies to howling plummeted. By April, a month after mating activity had ceased, replies were extremely difficult to elicit.

One last factor seemed to influence a pack's decision whether to reply—its size. One pack of seven to twelve wolves replied twice as frequently as a smaller pack with four to six members. This was true at kill sites, around rendezvous sites, and elsewhere in the packs' territories. Being in a group appears to make wolves more confident in replying to an intruder's threat. As the size of the group increases, individuals become bolder and therefore more likely to reply.

Such group support seems to make larger packs more aggressive than smaller ones. They are accordingly more likely to trespass into neighboring territories, to attack their neighbors, and to chase away any strangers they encounter in their own territories. When deer were in short supply recently in Minnesota's Superior National Forest, packs were occasionally forced to trespass in order to find food. Most were content to make brief forays into alien territory and returned home quickly after finishing their filched kills. One pack of four to six members played this form of Russian roulette once too often; the dominant male was killed when the pack was detected and confronted by the residents. But one of the largest packs, numbering nearly a dozen, trespassed repeatedly during this time and prospered.

In my two years of howling, I had some close encounters with the wolves and experienced moments of fear when the mythology about the animals took over and my imagination got the better of me. But only on seven of more than four hundred occasions did a single wolf leave the pack and approach me. Even these approaches happened only when I continued to howl after the wolves had given me one or more vocal indications of their original position.

Another thing. Even after teasing apart my data in as many ways as I could, I was never able to make any connection between wolf howls and the phases of the moon. I found that especially comforting. Why should wolves pay more attention to the moon than to their families, their food, and their foes?

Fred H. Harrington is an ethologist at Mount Saint Vincent University in Halifax, Nova Scotia.
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Windfalls of Dust

For eons, dust has fallen and settled in the ocean, leaving a record of past climates

by David K. Rea

A change in climate can have enormous consequences for our planet. A minor warming of a few degrees would begin to melt icecaps on Antarctica and Greenland and cause a rise in sea level that could displace a billion people. A similar cooling could shorten the growing season in the "bread basket" of the Northern Hemisphere, resulting in severe food shortages. For the past million years, the earth's climate has been as favorable as today's for only a small percentage of the time, and eventually, if left to its own devices, the earth would be expected to return to its "normal" colder state. On the other hand, humankind is now filling the global atmosphere with carbon dioxide (CO₂) from the engines of industry and the burning of forests. Carbon dioxide and other industrial gases in the air trap incoming solar energy, warming the earth in what is known as the greenhouse effect. The result of this will be to raise temperatures, but it is unclear by how much or whether the warming will be the same everywhere. Faced with these potentially countervailing trends, the challenge before scientists is to arrive at an accurate prediction of what lies before us.

The standard basis of any scientific prediction is a detailed record of past performances. To understand when and by how much climate may change in the future, climatologists are assembling the details of past climatic changes. They are probing the Antarctic and Greenland ice sheets, analyzing tree rings, studying pollen preserved in lakes and bogs, and sampling the sediments of the ocean floor in search of patterns from the past. One of the more recent thrusts in this search has been an attempt to read the record of the wind.

At the University of Michigan, we have embarked on a study of dust deposited on the ocean floor during the past seventy million years to see how well sediment patterns correlate with the climate. We had been encouraged to believe such a correlation might exist by previous scientific studies that related the quantity of dust to current global climatic conditions. For example, during the Sahel drought of the early 1970s, two to three times more dust was picked up by the trade winds and deposited in the Caribbean than in previous years. Other work has shown that when dust grains, be they from deserts or from less arid regions, are lifted by the wind, the larger grains begin to fall out of the air immediately until eventually all have settled out. Those grains that remain are small enough—usually smaller than 0.01 mm in diameter—to reach an equilibrium condition with the wind and are transported global distances. The stronger the winds, the larger the grains that will reach the equilibrium state. Most dust moves in the upper troposphere (the lowest layer of the atmosphere) at altitudes of roughly five to ten miles, where sooner or later it acts as nuclei for raindrops and is washed out of the air.

Such studies convinced us that by measuring the quantity and size of dust grains, one could establish the past strength of winds and the dryness of land surfaces. Knowing that winds have deposited dust at sea for as long as much of the planet has been covered by water, and that that dust quickly settled to the ocean floor, we decided to analyze core samples of ocean-floor sediments in an attempt to determine ancient wind patterns.

At first blush, this approach might seem doomed to failure. After all, the dust particles that eventually fall to the ocean surface far from land are so small that it would require, in theory, fifty to one hundred years before they settled to the bottom of the ocean. In that length of time, ocean surface currents, which flow several miles or more every day, would smear out any patterns of dust dropped into the ocean over a wide area.

However, when sea-floor preservation patterns are compared with sea-surface patterns for various components of the sediments, this smearing is not observed. Oceanographers have discovered two processes that account for the rapid removal of particles from the surface of the ocean. First, feeding zooplankton filter the entire contents of the surface waters and package the nondigestible residue, mostly remains of phytoplankton and including...
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dust grains, into relatively large (millimeter scale) fecal pellets, which sink to the sea floor in a matter of days. Second, there are centimeter-size amorphous organic aggregates in the ocean that settle rapidly and sweep small particles along with them. These two processes combine to remove all small particles from the ocean surface very quickly, before the sea currents can transport them any noticeable distance. Instead, they are deposited in orderly sedimented layers, just waiting to be sampled.

We didn’t have to charter boats or lease drilling rigs to do our sampling since that work had already been done for us. For decades oceanographers have taken core samples of such sediments and turned them over to core libraries. Two such collections have proved particularly valuable because they provide a large number of cores from all of the world’s oceans and because they have been well cared for. These include cores taken by the Lamont-Doherty Geological Observatory, which are kept in its archives in Palisades, New York, and cores taken by the Deep Sea Drilling Project and its successor, the Ocean Drilling Program, which are stored at the Scripps Institution of Oceanography in La Jolla, California, Texas A&M University in College Station, and at Lamont-Doherty.

To date, we have worked with two sediment cores from the North Pacific Ocean, each of which records the last seventy million years of earth history, as well as with several shorter cores that provide detailed studies of the last one million years. The history we developed of dust accumulation, or flux, in the two longer cores shows moderate dust flux before fifty million years ago, low but increasing flux from fifty to perhaps ten million years ago, and a five- to ten-fold increase in the amount of dust entering the North Pacific just a few million years ago. We interpret these data as indicating that the Northern Hemisphere continents became more humid, and probably more vegetated, fifty to forty-five million years ago and then gradually became more arid, culminating in a great increase in aridity about the same time that the Ice Age began two and a half million years ago.

The grain-size data also show some important changes. Older grains in the lower portions of these cores are relatively coarse, suggesting strong winds. Fifty-five to fifty million years ago, grains become increasingly fine, indicating that atmospheric circulation had slowed considerably. It remained sluggish for about fifteen million years and then began a slow increase toward present conditions.

This is important data not only for what
it tells us about winds but also because it provides us with clues about global temperatures. The intensity of atmospheric circulation is related to the difference in the earth's temperature at the poles and the equator, as both the oceans and atmosphere circulate in response to this heat imbalance. Thus, we can interpret the fine grain sizes and accompanying sluggish circulation between fifty and thirty-five million years ago as indicating a warm equitable climate produced by a relatively small difference in the temperatures at the equator and at the comparatively ice-free poles. The polar regions are known to have cooled considerably after that, and this jibes with the increasingly coarser grains that were deposited by stronger winds in the period from thirty-five million years ago to the present, with our cold poles and hot equator.

One unusual, or unanticipated, aspect of our data was our discovery of coarser grains indicating fairly rapid atmospheric circulation before fifty-five to fifty million years ago. This phenomenon showed up in all the cores we studied, but our basic interpretation of more vigorous circulation was contrary to the general understanding of that geologic era as a time of warm climate and sluggish atmospheric and oceanic circulation. Indications of the same phenomenon, however, have recently been documented by British scientists studying windblown sediments taken from the North Atlantic, adding validity to our interpretation.

Other than this one discovery of what at first appeared to be a major anomaly, neither the grain sizes nor the flux data from these cores presented any real surprises; geologists have known for a long time that the earth was characterized by a warmer and more equitable climate between fifty and thirty million years ago. The data also emphasize how much more arid the world as a whole has become since the beginning of the Ice Age—also previously determined by geologists. But the lack of surprise is good news, really, because it confirms the reliability of our methodology in "reading" ancient climatic patterns from ocean-bottom dust deposits.

A second aspect of our study is an ongoing investigation of how atmospheric circulation responded to the waxing and waning of the great continental glaciers during the past million years. Paleoclimatologists have shown that the glaciers advance and retreat on roughly a 100,000-year cycle, so we wanted to determine whether the global winds grew stronger and weaker in synchronization with the ice cycles.

To answer this question, we analyzed

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data from two different cores, one containing dust dropped by the North Pacific westerlies and the other holding deposits from the trade winds close to the equator. Results of that work reveal two important features of atmospheric circulation during the last million years. First, variations in the size of the dust in each core are much more frequent than every 100,000 years. It is possible to do a mathematical study of this kind of variability to see if the observed fluctuations are random or occur at some definite time interval. For these data such an analysis shows that the variations in dust-grain size have some randomness but often exhibit well-defined periods of approximately 20,000, 40,000, and 100,000 years. Periods of these durations are of great interest to paleoclimatologists because they match the periods—three kinds of wiggles and wobbles—that the earth makes in its orbit around the sun.

Through geologic time, the earth comes closest to the sun on a 20,000-year cycle, a wobble known as the precession of the equinoxes. A second variation is the tilt of the earth's axis, which changes by a few degrees, on a 40,000-year cycle. And the third variation is in the oval shape of the earth's orbit around the sun, which changes very slightly on a 100,000-year cycle. Each of these orbital variations causes some small change in how incoming solar energy is distributed geographically and seasonally over the earth. These climatic effects of orbital changes were first calculated by Milutin Milankovitch, a Yugoslavian mathematician, who did the work by hand during the twenty-one years between the two World Wars. Milankovitch first proposed that orbital changes caused climate changes, specifically the glaciations in the 1930s, but he was not shown to be generally correct until the mid-1970s, when paleoclimatologists first began to find these orbital signals in their climate-related data sets. We therefore expected to find the Milankovitch cycles in our data and were not particularly surprised that the fluctuations in atmospheric circulation responded to the shorter-period stimuli.

The second important piece of information to be obtained from this dust-grain-size data is the general similarity of the records to each other, in terms of when variations were large, small, long, or short. Since one sample came from the Southern Hemisphere trade winds and the other from the Northern Hemisphere westerlies, these data suggest that the wind circulation in each hemisphere is closely linked. A particularly good example of this similarity is a time of reduced dust-grain size found in both cores in deposits about 300,000 years old. This represents a span of 50,000 to 70,000 years when both the intensity and the variability of the global winds were significantly reduced. This "event" may have important ramifications for other parts of the climate system, such as ocean circulation, but we have yet to fully understand these observations.

Our conclusion, then, at this point in our studies is that analysis of ocean-floor dust sediments provides a clear window not merely on the climatic shifts of tens of millions of years ago but also on shifts taking place during the more recent glacial cycles. Thus, the challenge ahead of us is to apply our understanding to predictions of future climatic change. To do this we must take the following steps.

We must recover and analyze samples from regions of the world other than the Central and North Pacific. The Atlantic Ocean is an obvious place to begin, and scientists from the United States, Germany, and England are now engaged in research on wind-borne dust deposits in the Atlantic. As of this writing, the Indian Ocean seems to be the next most promis-
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What Are Friends For?

Among East African baboons, friendship means companions, health, safety... and, sometimes, sex

by Barbara Smuts

Virgil, a burly adult male olive baboon, closely followed Zizi, a middle-aged female easily distinguished by her grizzled coat and square muzzle. On her rump Zizi sported a bright pink swelling, indicating that she was sexually receptive and probably fertile. Virgil's extreme attentiveness to Zizi suggested to me—and all rival males in the troop—that he was her current and exclusive mate.

Zizi, however, apparently had something else in mind. She broke away from Virgil, moved rapidly through the troop, and presented her alluring sexual swelling to one male after another. Before Virgil caught up with her, she had managed to announce her receptive condition to several of his rivals. When Virgil tried to grab her, Zizi screamed and dashed into the bushes with Virgil in hot pursuit. I heard sounds of chasing and fighting coming from the thicket. Moments later Zizi emerged from the bushes with an older male named Cyclops. They remained together for several days, copulating often. In Cyclops's presence, Zizi no longer approached or even glanced at other males.

Primatologists describe Zizi and other olive baboons (*Papio cynocephalus anubis*) as promiscuous, meaning that both males and females usually mate with several members of the opposite sex within a short period of time. Promiscuous mating behavior characterizes many of the larger, more familiar primates, including chimpanzees, rhesus macaques, and gray langurs, as well as olive, yellow, and chacma baboons, the three subspecies of savanna baboon. In colloquial usage, promiscuity often connotes wanton and random sex, and several early studies of primates supported this stereotype. However, after years of laboriously recording thousands of copulations under natural conditions, the Peeping Toms of primate fieldwork have shown that, even in promiscuous species, sexual pairings are far from random.

Some adult males, for example, typically copulate much more often than others. Primatologists have explained these differences in terms of competition: the most dominant males monopolize females and prevent lower-ranking rivals from mating. But exceptions are frequent.
His eyes shut and mouth open in a relaxed yawn, a young male olive baboon blissfully submits to grooming by a middle-aged female. If all goes well, this budding friendship may last for years.

Barbara Smuts; Anthro-Photo
Among baboons, the exceptions often involve scruffy, older males who mate in full view of younger, more dominant rivals.

A clue to the reason for these puzzling exceptions emerged when primatologists began to question an implicit assumption of the dominance hypothesis—that females were merely passive objects of male competition. But what if females were active arbiters in this system? If females preferred some males over others and were able to express these preferences, then models of mating activity based on male dominance alone would be far too simple.

Once researchers recognized the possibility of female choice, evidence for it turned up in species after species. The story of Zizi, Virgil, and Cyclops is one of hundreds of examples of female primates rejecting the sexual advances of particular males and enthusiastically cooperating with others. But what is the basis for female choice? Why might they prefer some males over others?

This question guided my research on the Eburru Cliffs troop of olive baboons, named after one of their favorite sleeping sites, a sheer rocky outcrop rising several hundred feet above the floor of the Great Rift Valley, about 100 miles northwest of Nairobi, Kenya. The 120 members of Eburru Cliffs spent their days wandering through open grassland studded with occasional acacia thorn trees. Each night they retired to one of a dozen sets of cliffs that provided protection from nocturnal predators such as leopards.

Most previous studies of baboon sexuality had focused on females who, like Zizi, were at the peak of sexual receptivity. A female baboon does not mate when she is pregnant or lactating, a period of abstinence lasting about eighteen months. The female then goes into estrus, and for about two weeks out of every thirty-five-day cycle, she mates. Toward the end of this two week period she may ovulate, but usually the female undergoes four or five estrous cycles before she conceives. During pregnancy, she once again resumes a chaste existence. As a result, the typical female baboon is sexually active for less than 10 percent of her adult life. I thought that by focusing on the other 90 percent, I might learn something new. In particular, I suspected that routine, day-to-day relationships between males and pregnant or lactating (nonestrous) females might provide clues to female mating preferences.

Nearly every day for sixteen months, I joined the Eburru Cliffs baboons at their sleeping cliffs at dawn and traveled several miles with them while they foraged for roots, seeds, grass, and occasionally, small prey items, such as baby gazelles or hares (see “Predatory Baboons of Kekepey,” Natural History, March 1976). Like all savanna baboon troops, Eburru
Cliffs functioned as a cohesive unit organized around a core of related females, all of whom were born in the troop. Unlike the females, male savanna baboons leave their natal troop to join another where they may remain for many years, so most of the Eburru Cliffs adult males were immigrants. Since membership in the troop remained relatively constant during the period of my study, I learned to identify each individual. I relied on differences in size, posture, gait, and especially, facial features. To the practiced observer, baboons look as different from one another as human beings do.

As soon as I could recognize individuals, I noticed that particular females tended to turn up near particular males again and again. I came to think of these pairs as friends. Friendship among animals is not a well-documented phenomenon, so to convince skeptical colleagues that baboon friendship was real, I needed to develop objective criteria for distinguishing friendly pairs.

I began by investigating grooming, the amiable simian habit of picking through a companion’s fur to remove dead skin and ectoparasites (see “Little Things That Tick Off Baboons,” Natural History, February 1984). Baboons spend much more time grooming than is necessary for hygiene, and previous research had indicated that it is a good measure of social bonds. Although eighteen adult males lived in the troop, each nonestrous female performed most of her grooming with just one, two, or occasionally, three males. For example, of Zizi’s twenty-four grooming bouts with males, Cyclops accounted for thirteen, and a second male, Sherlock, accounted for all the rest. Different females tended to favor different males as grooming partners.

Another measure of social bonds was simply who was observed near whom. When foraging, traveling, or resting, each pregnant or lactating female spent a lot of time near a few males and associated with the others no more often than expected by chance. When I compared the identities of favorite grooming partners and frequent companions, they overlapped almost completely. This enabled me to develop a formal definition of friendship: any male that scored high on both grooming and proximity measures was considered a friend.

Virtually all baboons made friends; only one female and the three males who had most recently joined the troop lacked such companions. Out of more than 600 possible adult female–adult male pairs in the troop, however, only about one in ten qualified as friends; these really were special relationships.

Several factors seemed to influence which baboons paired up. In most cases, friends were unrelated to each other, since the male had immigrated from another troop. (Four friendships, however, involved a female and an adolescent son who had not yet emigrated. Unlike other friends, these related pairs never mated.) Older females tended to be friends with older males; younger females with younger males. I witnessed occasional May-December romances, usually involving older females and young adult males. Adolescent males and females were strongly rule-bound, and with the exception of mother–son pairs, they formed friendships only with one another.

Regardless of age or dominance rank, most females had just one or two male
friends. But among males, the number of female friends varied greatly from none to eight. Although high-ranking males enjoyed priority of access to food and sometimes mates, dominant males did not have more female friends than low-ranking males. Instead it was the older males who had lived in the troop for many years who had the most friends. When a male had several female friends, the females were often closely related to one another. Since female baboons spend a lot of time near their kin, it is probably easier for a male to maintain bonds with several related females at once.

When collecting data, I focused on one nonestrus female at a time and kept track of her every movement toward or away from any male; similarly, I noted every male who moved toward or away from her. Whenever the female and a male moved close enough to exchange intimacies, I wrote down exactly what happened. When foraging together, friends tended to remain a few yards apart. Males more often wandered away from females than the reverse, and females, more often than males, closed the gap. The female behaved as if she wanted to keep the male within calling distance, in case she needed his protection. The male, however, was more likely to make approaches that brought them within actual touching distance. Often, he would plunk himself down right next to his friend and ask her to groom him by holding a pose with exaggerated stillness. The female sometimes responded by grooming, but more often, she exhibited the most reliable sign of true intimacy: she ignored her friend and simply continued whatever she was doing.

In sharp contrast, when a male who was not a friend moved close to a female, she dared not ignore him. She stopped whatever she was doing and held still, often glancing surreptitiously at the intruder. If he did not move away, she sometimes lifted her tail and presented her rump. When a female is not in estrus, this is a gesture of appeasement, not sexual enticement. Immediately after this respectful acknowledgement of his presence, the female would slip away. But such tense interactions with nonfriend males were rare, because females usually moved away before the males came too close.

These observations suggest that females were afraid of most of the males in their troop, which is not surprising: male baboons are twice the size of females, and their canines are longer and sharper than those of a lion. All Eburru Cliffs males directed both mild and severe aggression toward females. Mild aggression, which usually involved threats and chases but no body contact, occurred most often during feeding competition or when the male redirected aggression toward a female after losing a fight with another male. Females and juveniles showed aggression toward other females and juveniles in similar circumstances and occasionally inflicted superficial wounds. Severe aggression by males, which involved body contact and sometimes biting, was less common and also more puzzling, since there was no apparent cause.

An explanation for at least some of these attacks emerged one day when I was watching Pegasus, a young adult male, and his friend Cicily, sitting together in the middle of a small clearing. Cicily moved to the edge of the clearing to feed, and a higher-ranking female, Zora, suddenly attacked her. Pegasus stood up and looked as if he were about to intervene when both females disappeared into the bushes. He sat back down, and I remained with him. A full ten minutes later, Zora appeared at the edge of the clearing; this was the first time she had come into view since her attack on Cicily. Pegasus instantly pounced on Zora, repeatedly grabbed her neck in his mouth and lifted her off the ground, shook her whole body, and then dropped her. Zora screamed continuously and tried to escape. Each time, Pegasus caught her and continued his brutal attack. When he finally released her five minutes later she had a deep canine gash on the palm of her hand that made her limp for several days.

This attack was similar in form and intensity to those I had seen before and labeled “unprovoked.” Certainly, had I come upon the scene after Zora’s aggression toward Cicily, I would not have understood why Pegasus attacked Zora. This suggested that some, perhaps many, severe attacks by males actually represented punishment for actions that had occurred some time before.

Whatever the reasons for male attacks on females, they represent a serious threat. Records of fresh injuries indicated that Eburru Cliffs adult females received canine slash wounds from males at the rate of one for every female each year, and during my study, one female died of her injuries. Males probably pose an even greater threat to infants. Although only one infant was killed during my study, observers in Botswana and Tanzania have seen recent male immigrants kill several young infants.

Protection from male aggression, and from the less injurious but more frequent aggression of other females and juveniles, seems to be one of the main advantages of friendship for a female baboon. Seventy times I observed an adult male defend a female or her offspring against aggression by another troop member, not infrequently a high-ranking male. In all but six of these cases, the defender was a friend. Very few of these confrontations involved actual fighting; no male baboon, subordinate or dominant, is anxious to risk injury by the sharp canines of another.

Males are particularly solicitous guardians of their friends’ youngest infants. If another male gets too close to an infant or if a juvenile female plays with it too roughly, the friend may intervene. Other
As a practical and satisfying way to express affection and get rid of dead skin and parasites, grooming is unbeatable. The adult male at left is enjoying the attentions of two of his female friends, one of whom is, in turn, being groomed by a third. Very likely, the three females are related. By befriending them all, the male boosts his chances of mating with them in the future. Females frequently have fewer friends than males, but they and their offspring benefit greatly from the protection of the much bigger males.

The infant below, nestled in the shadow of its mother (whose pale pink rump makes clear that she is not in estrus), has little to fear as long as its mother’s friend is near.

When I returned to Eburru Cliffs four years after my initial study ended, several of the bonds formed between males and the infants of their female friends were still intact (in other cases, either the male or the infant or both had disappeared). When these bonds involved recently matured females, their long-time male associates showed no sexual interest in them, even though the females mated with other adult males. Mothers and sons, and usually maternal siblings, show similar sexual inhibitions in baboons and many other primate species.

The development of an intimate relationship between a male and the infant of his female friend raises an obvious question: Is the male the infant’s father? To answer this question definitely we would need to conduct genetic analysis, which was not possible for these baboons. Instead, I estimated paternity probabilities from observations of the temporary (a few hours or days) exclusive mating relationships, or consortships, that estrous females form with a series of different males. These estimates were apt to be fairly accurate, since changes in the female’s sexual swelling allow one to pinpoint the timing of conception to within a few days. Most females mated with only two or three males during this period, and these males were termed likely fathers.

In about half the friendships, the male was indeed likely to be the father of his friend’s most recent infant, but in the other half he was not—in fact, he had never been seen mating with the female. Interestingly, males who were friends with the mother but not likely fathers nearly always developed a relationship with her infant, while males who had mated with the female but were not her friend usually did not. Thus friendship with the mother, rather than paternity, seems to mediate the development of male-infant bonds.

Recently, a similar pattern was documented for South American capuchin monkeys in a laboratory study in which paternity was determined genetically.

These results fly in the face of a prominent theory that claims males will invest in infants only when they are closely related. If males are not fostering the survival of
For young baboons, friendship with an adult male is not without its dark side. The little baboon at right is being used as a pawn in a game with potentially high stakes: his male friend is holding him tightly, thereby hoping to halt the aggressive approach of another male. The presence of an infant usually cuts off such confrontations before they get rough—the aggressor being reluctant to incur the wrath of the baby’s mother, her relatives and friends—but the infant’s face, screwed up in an expression of panic, reveals its uncertainty about the outcome. Infants also sometimes find themselves caught between their mothers and quarrelsome females, below.

Their own genes by caring for the infant, then why do they do so? I suspected that the key was female choice. If females preferred to mate with males who had already demonstrated friendly behavior, then friendships with mothers and their infants might pay off in the future when the mothers were ready to mate again.

To find out if this was the case, I examined each male’s sexual behavior with females he had befriended before they resumed estrus. In most cases, males consorted considerably more often with their friends than with other females. Baboon females typically mate with several different males, including both friends and nonfriends, but prior friendship increased a male’s probability of mating with a female above what it would have been otherwise.

This increased probability seemed to reflect female preferences. Females occasionally overtly advertised their disdain for certain males and their desire for others. Zizi’s behavior, described above, is a good example. Virgil was not one of her friends, but Cyclops was. Usually, however, females expressed preferences and aversions more subtly. For example, Delphi, a petite adolescent female, found herself pursued by Hector, a middle-aged adult male. She did not run away or refuse to mate with him, but whenever he wasn’t watching, she looked around for her friend Homer, an adolescent male. When she succeeded in catching Homer’s eye, she narrowed her eyes and flattened her ears against her skull, the friendliest face one baboon can send another. This told Homer she would rather be with him. Females expressed satisfaction with a current consort partner by staying close to him, initiating copulations, and not making advances toward other males. Baboons are very sensitive to such cues, as indicated by an experimental study in which rival hamadryas baboons rarely challenged a male–female pair if the female strongly preferred her current partner. Similarly, in Eburru Cliffs, males were less apt to challenge consorts involving a pair that shared a long-term friendship.

Even though females usually consort with their friends, they also mated with other males, so it is not surprising that friendships were most vulnerable during periods of sexual activity. In a few cases, the female consorted with another male more often than with her friend, but the friendship survived nevertheless. One female, however, formed a strong sexual bond with a new male. This bond persisted after conception, replacing her previous friendship. My observations suggest that adolescent and young adult females tend to have shorter, less stable friendships than do older females. Some friendships, however, last a very long time. When I returned to Eburru Cliffs six years after my study began, five couples were still together. It is possible that friendships occasionally last for life (baboons probably live twenty to thirty years in the wild), but it will require longer studies, and some very patient scientists, to find out.

By increasing both the male’s chances of mating in the future and the likelihood that a female’s infant will survive, friendship contributes to the reproductive success of both partners. This clarifies the evolutionary basis of friendship-forming tendencies in baboons, but what does friendship mean to a baboon? To answer this question we need to view baboons as sentient beings with feelings and goals not
Unlike our own in similar circumstances. Consider, for example, the friendship between Thalia and Alexander.

The affair began one evening as Alex and Thalia sat about fifteen feet apart on the sleeping cliffs. It was like watching two novices in a singles bar. Alex stared at Thalia until she turned and almost caught him looking at her. He glanced away immediately, and then she stared at him until his head began to turn toward her. She suddenly became engrossed in grooming her toes. But as soon as Alex looked away, her gaze returned to him. They went on like this for more than fifteen minutes, always with split-second timing. Finally, Alex managed to catch Thalia looking at him. He made the friendly eyes-narrowed, ears-back face and smirked his lips together rhythmically. Thalia froze, and for a second she looked into his eyes. Alex approached, and Thalia, still nervous, groomed him. Soon she calmed down, and I found them still together on the cliffs the next morning. Looking back on this event months later, I realized that it marked the beginning of their friendship. Six years later, when I returned to Eburru Cliffs, they were still friends.

If flirtation forms an integral part of baboon friendship, so does jealousy. Overt displays of jealousy, such as chasing a friend away from a potential rival, occur occasionally, but like humans, baboons often express their emotions in more subtle ways. One evening a colleague and I climbed the cliffs and settled down near Sherlock, who was friends with Cybelle, a middle-aged female still foraging on the ground below the cliffs. I observed Cybelle while my colleague watched Sherlock, and we kept up a running commentary. As long as Cybelle was feeding or interacting with females, Sherlock was relaxed, but each time she approached another male, his body would stiffen, and he would stare intently at the scene below. When Cybelle presented politely to a male who had recently tried to befriend her, Sherlock even made threatening sounds under his breath. Cybelle was not in estrus at the time, indicating that male baboon jealousy extends beyond the sexual arena to include affiliative interactions between a female friend and other males.

Because baboon friendships are embedded in a network of friendly and antagonistic relationships, they inevitably lead to repercussions extending beyond the pair. For example, Virgil once provoked his weaker rival Cyclops into a fight by first attacking Cyclops's friend Phoebe. On another occasion, Sherlock chased Circe, Hector's best friend, just after Hector had chased Antigone, Sherlock's friend.

In another incident, the prime adult male Triton challenged Cyclops's possession of meat. Cyclops grew increasingly tense and seemed about to abandon the
At nine months or so, young baboons often begin seeking out their male friends whenever their mothers are not around, at times seeming almost to worship them. While looking up adoringly, this little baboon, right, grunts softly, hoping to engage his friend in a duet. Barbara Smuts. Anthro-Photo

prey to the younger male. Then Cyclops's friend Phoebe appeared with her infant Phyllis. Phyllis wandered over to Cyclops. He immediately grabbed her, held her close, and threatened Triton away from the prey. Because any challenge to Cyclops now involved a threat to Phyllis as well, Triton risked being mobbed by Phoebe and her relatives and friends. For this reason, he backed down. Males frequently use the infants of their female friends as buffers in this way. Thus, friendship involves costs as well as benefits because it makes the participants vulnerable to social manipulation or redirected aggression by others.

Finally, as with humans, friendship seems to mean something different to each baboon. Several females in Eburru Cliffs had only one friend. They were devoted companions. Louise and Pandora, for example, groomed their friend Virgil and no other male. Then there was Leda, who, with five friends, spread herself more thinly than any other female. These contrasting patterns of friendship were associated with striking personality differences. Louise and Pandora were unobtrusive females who hung around quietly with Virgil and their close relatives. Leda seemed to be everywhere at once, playing with infants, fighting with juveniles, and making friends with males. Similar differences were apparent among the males. Some devoted a great deal of time and energy to cultivating friendships with females, while others focused more on challenging other males. Although we probably will never fully understand the basis of these individual differences, they contribute immeasurably to the richness and complexity of baboon society.

Male–female friendships may be widespread among primates. They have been reported for many other groups of savanna baboons, and they also occur in rhesus and Japanese macaques, capuchin monkeys, and perhaps in bonobos (pygmy chimpanzees). These relationships should give us pause when considering popular scenarios for the evolution of male–female relationships in humans. Most of these scenarios assume that, except for mating, males and females had little to do with one another until the development of a sexual division of labor, when, the story goes, females began to rely on males to provide meat in exchange for gathered food. This, it has been argued, set up new selection pressures favoring the development of long-term bonds between individual males and females, female sexual fidelity, and as paternity certainty increased, greater male investment in the offspring of these unions. In other words, once women began to gather and men to hunt, presto—we had the nuclear family.

This scenario may have more to do with cultural biases about women's economic dependence on men and idealized views of the nuclear family than with the actual behavior of our hominid ancestors. The nonhuman primate evidence challenges this story in at least three ways.

First, long-term bonds between the sexes may evolve in the absence of a sexual division of labor or food sharing. In our primate relatives, such relationships rest on exchanges of social, not economic, benefits.

Second, primate research shows that highly differentiated, emotionally intense male–female relationships can occur without sexual exclusivity. Ancestral men and women may have experienced intimate friendships long before they invented marriage and norms of sexual fidelity.

Third, among our closest primate relatives, males clearly provide mothers and infants with social benefits even when they are unlikely to be the fathers of those infants. In return, females provide a variety of benefits to the friendly males, including acceptance into the group and, at least in baboons, increased mating opportunities in the future. This suggests that efforts to reconstruct the evolution of hominid societies may have overemphasized what the female must supposedly do (restrict her mating to just one male) in order to obtain male parental investment. Maybe it is time to pay more attention to what the male must do (provide benefits to females and young) in order to obtain female cooperation. Perhaps among our ancestors, as in baboons today, sex and friendship went hand in hand. As for marriage—well, that's another story.
Leaping Lepus

Wild hares may show signs of March madness throughout the year

Photographs by Stefan Meyers

Scooting about in open fields, hopping, thumping, and boxing, *Lepus* has come to embody the more harebrained spirits of spring. But the hare’s fancy is not bound to any one season, turning fitfully to thoughts of rutting for up to ten months of the year. This persistent ardor (along with its prodigious results) has fired the imagination of many cultures, for hares are indigenous to North America, Africa, Europe, and Asia. In *The Leaping Hare* (published by Faber and Faber, London, 1972), George Ewart Evans and David Thomson document images of hares on Grecian wedding rings, hares consorting with cupids on Attic vases and frolicking on kraters with Aphrodite and her satyrs. In the Far East, the Buddha commanded that the image of the hare adorn the face of the moon as a symbol of longevity. The Algonquin Indians of North America attributed the earth’s procreative powers to the Great Hare. In Egyptian hieroglyphs, the hare stood for existence itself, its image common on Theban coffins. In northern Europe, the hare, as attendant spirit to the Anglo-Saxon dawn goddess, Eastre, merged images of death and resurrection with carnal pleasure and fecundity. A thirteenth-century Welsh poem, a bowhunter’s hopeful prayer, enlarged upon the attributes of the hare, especially its elusive nature.

The man who encounters the hare
Will never get the better of him,
Except he lay down on ground
The weapon he bears in his hand
And with sincere devotion
Utter this one prayer
In praise of the hare.

Hunters and photographers are well aware of the keenness of the hare’s senses. (Photographing the sequence shown on these pages took five shooting sessions.) Studies show that ten feet is about as close as anyone can get to a wild hare before it leaps, “explodes” as one zoologist put it, shooting up to seven feet into the air and reaching fifty miles per hour in its not-so-mad dash for cover. The thirteenth-century hunter called his prey

... the springer, the jumper, the get up quickly, the way beater, the swift-as-the-wind...

Although the hare’s eyesight is not good, the placement of its eyes on the sides of its head allows a wider field of vision. And its nose and ears are constantly assessing the smells and sounds around it.

The quick and cunning hare,

... the one who doesn’t go straight home

never runs directly to its den. It hops toward it, then past it, turns around, hops back a little way, then suddenly jumps to the side and runs back parallel to the first track, hops back to the original path, and then repeats the movements a few times before finally leaping into the den. Animals tracking a hare spend so much time following the false tracks that the hare sees them before being found itself. Such an elusive quarry made the frustrated Bowman change his run. Hare is now

... old big bum, the lurker in ditches, the filthy beast, the coward, the slink-away, the nibbler, the traitor, the friendless one, the cat of the wood....

Hares rarely burrow into holes. Instead, they dig shallow depressions, called forms, that serve as camouflage blinks from...
which they keep an eye on their surroundings. The European hare is most at home on open terrain, along forest edges and clearings. As furious farmers will attest, the hare feeds only on vegetation and turns cultivated fields into year-round sources of wild forage.

... the stag of cabbages, the cropper of herbage, the animal that dwells in the corn, the clear-eyed one, the wall-eyed one, the dew-hopper... 

Hares appear in the damp fields just before sunrise or just after sunset, and on moonlit nights they may be out all night. When rutting, hares throw much of their caution to the wind. They groom themselves by rubbing their forepaws across scent glands located between the corners of their mouth and their cheeks, then spreading the secretions over their bodies. Females in heat shake their tails as they run, displaying their colors and releasing odors that stimulate the males. The chase is often frenetic. Several males pursue one or two females over open fields, and males challenge each other for the right to mate.

When confrontations occur, the challengers thump their back legs, stand, hop, and box the air with their front paws. (If it has to, a hare will turn and fight, standing up to protect its young from the attacks of hawks. One gamekeeper told Evans and Thomson that to protect her leveret, he had seen a hare stand up and punch a bullock on the nose.) The battles between hares are tests of endurance rather than fights to the finish, and they punch the air more often than each other. Copulation, however, can get rough, with the male struggling to hold the female in place.

The leverets are born after six weeks, then concealed in dense vegetation. Unlike newborn rabbits, they are covered with hair and their eyes are open—the leveret shown is only some two weeks old. The female visits once a day for five to ten minutes of nursing. Hares mature quickly, are ready to mate at seven months, and usually deliver two litters of two to five young each year.

And all the young are

... smart-tailed, long eared, white-bellied, and fidgety-footed... And now, good day to you, Sir Hare!

Bruce Stutz
This place is really nowhere.

This mountain exists inside a computer, and can be seen on a computer screen. It was built only with numbers. And it exists only because of one man’s idea.

The man is Benoît Mandelbrot, a mathematician and an IBM Fellow. And his idea is known by the name he gave it: fractal geometry.

This geometry is a new, non-traditional area of mathematics. Now scientists and artists can create computer images—like this mountain—that have all the quirks and irregularities of natural objects. That wasn’t possible before fractals, and it’s changing the way we look at the world.
Of course, ideas like fractal geometry don’t just happen. It takes support and encouragement, which is one reason why the IBM Fellow Program was created. It’s a program that gives a select group of IBM scientists and engineers the freedom to take risks, and pursue their ideas wherever they may lead.

Today, there are over 50 IBM Fellows. Their influence on science and computer technology doesn’t stop with their innovative thinking.

Because they’ve also shown us that the freedom to explore ideas can lead to places never imagined before.
In the Absence of Men

Centuries of male emigration have changed the economic roles and sexual mores of Portuguese women

by Caroline B. Brettell

On a recent airplane trip from Lisbon to New York, I sat across the aisle from a Portuguese man in his mid-thirties. At first, we simply exchanged smiles, but when I indicated that I could speak Portuguese, he began a conversation. He told me that he was from the district of Vila Real in north-central Portugal and that this was his first trip to America, where he was to begin a new job. His wife and two daughters had remained behind in his village, and when he called them from Lisbon just prior to boarding the plane, "there was lots of crying."

He then launched into a discussion of the "dream of every Portuguese boy—to emigrate to America," with an eloquence that was remarkable for someone with only a few years of schooling. "My father," he said, "could neither read nor write, and yet he sent me to school. Now I want more for my children—a proper house and even more education. It is impossible to give them this with what I earn in Portugal, so I am on an adventure, going to America."

For more than two centuries, both single and married men from the provinces of northern Portugal have left their villages seasonally, temporarily, or permanently to find work in other regions of the world. The impact of this predominantly male migration stream on the lives and roles of women has been enormous, affecting the economics of both the family and the society, marriage and residence patterns, inheritance practices—even morals and fertility rates. The story recounted by the man on the airplane was one I had heard many times before during the course of an ethnographic and historical study that I conducted in the village of Santa Eulália de Lanheses. (I was there because I had worked with Portuguese migrants in France and wanted to study the effects of this male migration on the women left behind.) The words of the migrants may have been different but the meaning was always the same, and I imagine that similar stories were told among third-class passengers sailing to Brazil in the 1880s.

Lanheses is located in the extreme northwestern concelho (municipality) of Viana do Castelo, a district in the province...
Northwestern Portugal abounds in single young women. So many men emigrate to other countries to find employment, that many women may never marry. These three women are dressed in costume for a local festival; the candle they carry is decorated with tinfoil flowers.

Marion Kaplan
of Minho, bordered by the Atlantic on the west and Spain to the north. This region was the birthplace of the Portuguese nation in the twelfth century. While Lisbon in the south is now the focus of population and government, in the Middle Ages the northwestern area of Portugal was the most heavily populated. Land here was divided into smaller and smaller plots over the centuries in contrast to the south of Portugal, where large estates farmed by day laborers were the rule. In Minho today, a peasant family is likely to own or rent numerous fields dispersed throughout a village and perhaps even in neighboring villages. The essayist Ramalho Ortigão once remarked in jest that the ownership of land in several villages gave the Minhotan peasant the right to be buried in all of them, but the right to vote in only one. Today, Viana do Castelo has the greatest percentage of owner-proprietors in Portugal's agricultural population. It also has a highly unusual culture. As early as the eighteenth century, travelers noticed Portuguese peasant women digging, plowing, hauling, and carrying heavy loads on their heads. Even today, few tasks are considered to be outside the female realm. Women prepare and till the fields and participate in all forms of harvesting. Those over seventy can still be found among the limbs of olive trees,
Women have long been the mainstay of the agricultural labor force, plowing the ground, hauling loads, and harvesting the crops. A group of women, left, dig potatoes that are planted among cabbages, and several generations of females, below, pick grapes in early fall.

_— Caroline B. Brettell_

Women, young and old, assemble to pick grapes and husk corn.

But women in Viana do Castelo do far more than hard labor. The Lanheses peasant women, for example, assume virtually all domestic responsibilities, and until just after World War II, they had the laborious task of linen making to occupy them during the winter months. Even two of the most traditional male tasks—buying and selling oxen at the regional feiras (markets) and spraying the vines—have in recent years fallen frequently into female hands. In fact, a woman is admired for being able to do the “work of a man.”

What brought about this remarkable phenomenon? Low family incomes, minimal mechanization, and the high instances of male emigration explain, in large part, the predominance of women in agricultural tasks. Male emigration was necessary to supplement the yields from small plots of land that were rarely sufficient to sustain a peasant family. Men from Lanheses, like men elsewhere in this region of Portugal, emigrated to Brazil and Spain throughout the eighteenth, nineteenth, and early twentieth centuries.

More recently, and especially since 1960, the major destination for emigrants has been France, and to a lesser extent, West Germany, the United States, Canada, Venezuela, and Australia. In 1970 alone, more than 88,000 Portuguese were given legal entry into France, and to this figure one must add immigrants who entered France clandestinely.

Many Lanhesans claim that if it had not been for France, Portugal would still be a poor country. While the money sent home by the emigrants to Brazil during the period just prior to World War I was substantial enough to provide a period of semiprospertity, it was nowhere near the amount that Portuguese men in France have been able to send home. One of the most visible results is the _casa estilo maison_ (a house in the _maison_ style)—the new homes built by the emigrants on the model of French bourgeois houses. In contrast to the older single-story houses of gray stone, these two-story houses of colorful stucco and tile, trimmed with wrought
An older generation of women, like the peasant woman below, accepted spinsterhood or if they did marry and their husbands emigrated, resigned themselves to a life of hard agricultural labor. Working in front of a typical peasant stone house, an old woman, right, spreads corn out to dry.

Ernest R. Manewal; Black Star

Iron, have brought to the Lanhesan landscape, and to northwestern Portugal in general, an air of modern living. For some Lanhesan women, the houses have fulfilled their dream of becoming donas de casa (homemakers). Frequently, these houses have two kitchens—on the upper level, a spic-and-span one appointed with marble counter tops and modern appliances and used mainly for show, and a more traditional one on the ground floor, where the family feels more comfortable and where sausages and hams can be smoked in a large stone chimney.

But centuries of male emigration have affected more than just the economic roles of women or the style of houses in Lanheses. Prospects for marriage, inheritance practices, residence patterns, fertility, and attitudes toward virginity—so highly valued elsewhere in southern Europe—have also been markedly altered by the continual absence of men.

The proportion of spinsters in the female population of Lanheses is high. These women have been left out of the marriage market because so many eligible men leave the village. In the 1860s, 34 percent of the women dying over age fifty had never been married, compared with 10 percent of the men; in the 1920s, comparable proportions were 37 percent and 4 percent; and in the 1960s, 31 percent and 10 percent. High proportions of women left out of the marriage market were not uncharacteristic of Western Europe in the nineteenth century, but that these high figures persisted in northern Portugal well into the 1960s is highly unusual.

Swinging singles aside, our tendency in North America is to view spinsterhood as an unfortunate state of affairs. For example, a much publicized recent study has pointed with doom and gloom to the supposedly minimal marriage prospects for unmarried women in the United States who reach thirty-five. In Lanheses, however, where spinsterhood is both prevalent and historically rooted, the negative connotations of this status are absent. Indeed, numerous popular proverbs and verses tend to laud celibate bliss over marital misery. "When I was single, I used ribbons and ties; now that I am married, I
have tears in my eyes,” goes one. And another: “When I married and entrapped myself, I exchanged silver for copper. I bartered my freedom for money which does not flow.”

Spinsters interviewed during the course of my study tended to corroborate this attitude. If some remained single simply because there were no men available, others claimed they chose the unwed status because they or their fathers felt they were better off without the hunger and poverty that might accompany the task of establishing a new household and having to nurture “an endless stream of children.” Said one woman, “My father would rather have seen his daughters dead than married and in misery. And pretty soon you have passed the age for marrying anyway.” Another spinster talked about having grown up with a stepfather who abused her mother. She preferred to retain her independence and freedom rather than make the mistake her mother had made. Although these statements may rationalize the lack of opportunity to marry, the important point is that since a shortage of men made it impossible for all women to marry, those who chose not to marry were not anomalies. The spinsters of Lanheses lead full and meaningful lives, supporting themselves through agricultural labor, domestic service, or more
recently, employment in a small local clothing factory. The easy transition from
girlhood to spinsterhood is marked in the
village in terms of address. A woman is a
menina (girl) until marriageable age is
passed and then becomes a tia (aunt), a
generic term used to address all unat-
tached women within the village.

Spinsters have had an important role to
play in caring for aged parents in a society
that has only recently introduced a social
security plan for its rural population. They
remain in the home where they help with
the household and increasingly take over
as parents become infirm. In return, un-
marr id daughters are frequently design-
nated as the recipients of the terço (third
share) of their parents’ property, which
generally includes the parental home. The
remaining two-thirds are then divided
equally among all offspring. Evidence
drawn from an analysis of eighteenth- and
nineteenth-century testaments clearly in-
dicates the deep-rootedness of this prac-
tice, which is based on a concern for wel-
being in old age, rather than for keeping a
family patrimony intact. And it contrasts
greatly with inheritance practices in other
Western European societies, where sons
are generally the preferred heirs. There,
spinsters are often dependent on their
brothers, but in Portugal, the unmarried
daughter can generally support herself af-
after the death of her parents, and when she
dies, the property she inherited reverts
back to her family in the form of a legacy
to a niece or nephew who is often also a
godchild.

In general, daughters were and are fa-
vored over sons for two reasons. They are
likely to be more caring than daughters-in-
law, and they tend to remain in the village
or region, whereas sons tend to leave the
parish either temporarily or permanently.
Furthermore, blood-related women are
more likely to work compatibly in the
fields. This preference is most obviously
reflected in the names of children, who are
often referred to by nicknames derived
from their mother’s, rather than their fa-
ther’s, side of the family. All the descen-
dants, male or female, of a certain Clara
de Sousa, who died in Lanheses in the
early twentieth century, are still referred
to as “the Claras.” Official naming prac-
tices also reflect an element of matri-
lineality. In the late nineteenth century,
there seems to have been a tendency for
sons to receive the family names of their
fathers and for daughters to receive the
family names of their mothers. Only re-
cently have children been given two fam-
ily names: first their mother’s and then
their father’s. Nor was it common until
recently for a married woman to append
her husband’s name to her own. Previ-
ously, she would use only her own family
name, even after marriage.

The frequent designation of daughters
as major heirs has also created unusual
residence patterns. Marriages take place
in the bride’s village, and while there are
exceptions, a groom from a neighboring
village generally moves to Lanheses to live
with his wife’s family or in a separate
household nearby. Even when both bride
and groom are natives of Lanheses but are
from different luges (hamlets) within
the village, the young couple is more likely
to live with or near the bride’s kin than the
groom’s. If the young husband then emi-
grates, he leaves his wife in the familiar
environment of her own kin rather than in
the more estranged environment of in-
laws. The emphasis on bonds of kinship
between women, rather than men, is also
evident in the tendency of unmarried sib-
lings to live with sisters rather than broth-
ers, and when nuclear family households
are formed by marriage, married sisters
are more likely to live in proximity to one
another than are married brothers.

While the emigration of single men has
played a role in the emergence of a signifi-
cant population of spinsters, the emigra-
tion of married men has had its own im-
portance on the lives of women in Lanheses
by creating viuvas dos vivos (widows of the
living). These “widows” are wives whose
husbands are absent for great lengths of
Even though they may take part in traditional festivals, today's young women, like the one below, are less likely to accept the traditional female role. New homes modeled after French bourgeois houses, left, are built with money sent by male emigrants and reflect more modern tastes.

Caroline B. Breuel

Olivia's story also says much about the effect of emigration on fertility. She was twenty-four when she wed, but with her husband absent she had only one child. The reproductive rate of women in Lanheses during the last two and a half centuries has been drastically reduced because emigration has acted as a surrogate method of birth control, decreasing the need for more modern methods.

While some widows of the living move in with their parents, many reside in their own homes and are the recognized heads of households. Consequently, they bank the money their husbands send from abroad, supervise the education of their children, and make other important family decisions. Unlike other parts of southern Europe, in Lanheses it is not unusual to find widows recorded in official lists as the heads of three-generation households. A widow who may have taken over as household head during her husband's absence, remains in charge after his death until extreme old age makes it no longer possible. At that point, authority may be turned over to a son-in-law or, in his absence, to a daughter residing with her. Of course, this position of authority is informal. Within the country as a whole, enormous legal restrictions on the social and political roles of women have changed only in the past decade with the unraveling of rules and regulations enforced during Antonio Salazar's dictatorial reign.

With so many single women in Lanheses, sexual mores were altered from the European norm. Not surprisingly, the rate of illegitimacy in Lanheses, and throughout northwestern Portugal in general, although it has declined since the 1930s, has been extremely high compared with other southern European countries. (At the turn of the century, roughly 13 percent of all births were illegitimate.) Some of these births were the result of young women being abandoned by fiancés who got them pregnant. Emigration was an easy escape route in a country that has only recently obliged fathers of illegitimate children to assume some responsibility for their actions. Other births were the result of a population of women who, as the daughters of landless day laborers or of small-scale peasant farmers, had fewer opportu-
nities to marry or were exploited by employers in domestic service. Because marriage prospects were somewhat better for a girl whose family owned land, the daughters of peasant families had lower rates of illegitimate births than the daughters of landless day laborers.

Yet another factor contributing to high rates of illegitimacy was the high marriage age, which extended the length of time in which an out-of-wedlock birth might occur. Throughout the twentieth century, however, the marriage age has declined and with it, illegitimate births. Simultaneously, however, the proportion of premarital pregnancies has risen. This has not necessarily reflected a change in morals, but rather the increased facility with which young couples can get married. Throughout Lanheses, older villagers describe rigorously controlled courtship in the past and condemn the sexual license of the present generation. But the extent of both illegitimacy and premarital pregnancy indicates that in this region of Portugal the "vigilance of virgins" was never as rigorous as in other areas of southern Europe. Attitudes toward out-of-wedlock motherhood varied depending on the social status of the girl (from a day-laboring or a peasant family) and upon her behavior and sense of shame. Mulheres sem vergonha (women with no shame) were those who had several illegitimate children—not uncommon in Lanheses' history, although unknown today.

All the distinguishing characteristics of Lanhesan life discussed to this point have been continuous for nearly 200 years. But changes in the world at large do affect this remote corner of Portugal and are gradually altering some of these centuries-old patterns. For example, beginning in the mid-1960s, and particularly with changes in French and American immigration policies, increasing numbers of Lanhesan women have begun to emigrate, either before or after marriage. Among the newest generation of young wives, there are many who find it no longer acceptable to remain behind while their husbands emigrate, and if they do, it is often a very temporary measure. They, and their teen-age daughters, are increasingly unwilling to work in the fields and accept the slave's life that has been the fate of Portuguese women for generations.

Another major shift occurring in recent years can be seen in the increased status of emigrants' children, which has in turn erased some of the former class distinctions in northwest Portugal. In the 1800s, for example, the daughters of the more well-to-do landowning peasant families held a special status in the community. But in recent years, money earned by Portuguese men in France has paid not only for new houses in the village (which for many families have become vacation or retirement houses) but also for high school educations for the emigrants' children. In Lanheses' annual religious festival, Senhor dos Necessidades, which has been revived and elaborated through the contributions of French francs sent home, emigrants' daughters now often serve in the prestigious role of mordoma (patron) for the five images of saints that are carried during the procession. Dressed in the traditional marriage costume, which includes dozens of gold chains draped over her chest, and carrying on her head, a tabuleiro (tray) laden with food and drink, which will later be auctioned off, and in general bid on by the young woman's father or fiancé, the emigrant's daughter publicly displays the success her father has had abroad.

Dressed in the traditional black wedding costume, with dozens of gold chains draped around her neck, a young woman, right, takes part in the annual religious festival. Her costume proclaims her to be a mordoma—a patron for the images of the five saints carried during the procession. The mordomas at the village festival, below, carry tabuleiros (trays) filled with food and drink on their heads. These will later be auctioned off, usually to fathers and fiancés.

Caroline B. Brette
Grouse and Spouse

Ptarmigan dads don’t grouse about taking care of the youngsters

by Kathy Martin

July 5, 1982, dawned sunny, warm, and full of promise for male willow ptarmigan B2226, but he suddenly lost his mate and was faced with the prospect of raising his ten energetic day-old offspring alone. Within minutes the chicks started to peep insistently; this called for immediate parental action, since a noisy chick is a liability that could attract the attention of a passing predator. A half hour later, after many soft “bees” and gutteral “ga-ga-gas,” B2226 had all ten chicks under control, even the adventurous youngster that had persisted in ignoring him and wading in a nearby puddle.

One hour later, peril approached from the air as a female harrier arrived on the scene, swooped repeatedly two to three feet above the brood, and finally landed on a low bush. B2226’s defense was a fearsome and energetic attack, especially impressive because harriers can kill adult ptarmigan. He inflated his neck feathers, fanned his tail feathers, dragged his wings, hissed, and screamed urgent “growl-bees” and “arroos” as he flew up repeatedly at the hawk. The harrier dropped to the ground, then swooped over the brood six times before leaving the scene empty-clawed. Five minutes later, B2226 discreetly moved his chicks away from the area, and I was not privy to any other life-threatening encounters experienced by this family. Nevertheless, I later observed that B2226 proved to be an able single parent, successfully raising five of his ten chicks to independence.

Unlike the males of all other North American grouse, male willow ptarmigan are active parents, heavily involved with the care and defense of their young during incubation and after the hatch. I began my study of willow ptarmigan because I wanted to investigate the importance of two-parent care in this species. In particular, I wanted to know why male willow ptarmigan appear so helpful and if their care contributed to the welfare and survival of their offspring.

From 1981 to 1984, I conducted my fieldwork on about four square miles of subarctic tundra near La Perouse Bay, twenty-five miles east of Churchill, Manitoba, Canada. The major shrub cover con-
Compared with other grouse species, the willow ptarmigan male (upper right) is an unusually attentive parent. He remains with and cares for his family long after the offspring fledge in July. Ptarmigan and their precocial chicks leave their ground nest within a day of the hatch. The young quickly adopt the basic survival skill of scattering and crouching to elude predators.

Kathy Martin
sisted of knee-high willow with occasional strips of taller willow, five or six feet high, and scattered patches of arctic birch.

In this landscape, ptarmigan are classic examples of crypticity, or camouflage. In any season, they can melt into backgrounds almost devoid of protective ground vegetation. In summer and fall, ptarmigan plumage is a mottled brown, while in winter and spring the birds are white, slightly brighter than their snow-blanketed surroundings and slightly rounder in silhouette than the peaked snowdrifts they sometimes use for shelter. But when ptarmigan nestle into the snow below the crest of a drift, their vision is reduced, and they become vulnerable to the stealthy approach of arctic foxes and red foxes, which depend heavily on unwaried grouse for meals in winter.

Other mammals such as wolves and occasionally even polar bears consider these arctic grouse delectable. And ptarmigan scan the skies constantly for a host of aerial predators, including harriers, snowy owls, rough-legged hawks, peregrine falcons, and bald and golden eagles. Herring gulls and ravens also present a lethal threat to ptarmigan of all ages. A nestful of vulnerable eggs or hatchlings requires even greater watchfulness by parents.

There are a number of prerequisites for attaining ptarmigan parenthood. Although on occasion, nonterritorial males may sneak copulations and become parents, the usual procedure is for males to first claim and successfully defend a territory. Even then, hen ptarmigan reject some males as mates, and males may reject certain females. Mate choice may be an important factor in reproductive success as some pairs produce no offspring, while others fledge more than ten young in a season. Monogamy is the usual pair bond for willow ptarmigan, but about 5 to 9 percent of males have two mates simultaneously (5 percent in my study), and in rare cases, males have three.

The opportunity to watch the chaotic, noisy process of willow ptarmigan staking out territories and acquiring mates lures me back to the Arctic each summer. In mid-April, the silence of the tundra is shattered continually by a ptarmigan cophony of "aerial beaks," "rattles," "growls," and "arroos," as each male advertises his presence to all. The contested areas are under total snow cover, and one wonders how ptarmigan evaluate their real estate. Males are constantly on the lookout for acceptable visitors (hens), intruders (usually other males), and predators. I observed one male ptarmigan fly toward a snowy owl, successfully driving it off. After any such conquest, the male returns to his territory or his mate and usually performs the aerial beck, a conspicuous flight and song display.

Hens may appear on the breeding site singly or in small flocks. Typically, they "meow" and "cluck" loudly, and when approached by the resident male, they run away, expecting to be followed. The ensuing chases, aerial and terrestrial, often erupt into border disputes between neighboring resident males.

"Ring around the willow" is a common courtship display. A hen flies away from her prospective mate, often leaving his territory. The male pursues her and tries to push or guide her back to his turf. When the pair land, the hen often races around a willow bush ten or twelve times, with the male in close pursuit. If the hen lands on a male neighbor's territory, that male also takes up the chase. Occasionally, the threesome is joined by the neighbor's mate. The sight of four plump birds noisily chasing one another around a small willow bush provides much-appreciated entertainment for an ornithologist trudging through the melting arctic spring. But sometimes such chases have bittersweet endings. In one instance, I saw a female desert her mate, which had to return to his territory alone. The hen chose to become the second mate of the male occupying the territory where she landed.
After twenty-two eggbound days, a ptarmigan is born. Hens tend the eggs diligently, regularly turning them and responding vocally to their prehatch peeps.

Timothy Scones

Once mates are chosen, considerable effort is put into maintaining the pair bond during the month-long precopulatory period. Males repel other male intruders, and sometimes female intruders, although more often than not they will court these hens. A paired hen is loath to share her mate, and when a strange hen appears on the territory, she may directly attack or chase the intruder. In other instances, the resident hen may simply vie for her own mate’s attention by calling loudly and exhibiting precopulatory behavior, such as head wagging and squatting in front of him. In this way she usually succeeds in leading her mate away from the intruder.

In late May or early June, the conspicuous advertisement phase draws to a close, and ptarmigan pairs begin the serious business of nesting. Hens become sedentary, doing little more than eating and visiting their nests once a day to lay a single egg. During laying, pairs are inseparable. Males follow their mates everywhere, usually remaining within fifteen feet of them. The reason is simple: an unaccompanied hen does not remain alone for long. Unmated males search continuously for opportunistic matings, and even already mated males are alert for such opportunities.

Single Parent Prospects

From 1981 to 1984, I performed a series of experiments near my camp at La Perouse Bay in Manitoba to compare the parenting performance of single ptarmigan to that of pairs. I created “widows” and “widowers” by temporarily removing males or females from pairs and retaining them in net cages. After the experiment, the removed birds were released. The five parental categories included unmanipulated control pairs and four experimental types: “incubation widows,” which had their males removed at the beginning of incubation (these hens matched the parental condition for all other species of North American grouse); “incubation widowers,” which were created naturally when predators killed six incubating hens but left the clutches intact; and “hatch widows” and “hatch widowers,” which had their mates removed on the day of hatch.

In this way, I was able to measure the performance of single parent females, single parent males, and pairs. I looked for possible effects in the number and health of offspring raised by parental types and also for any additional breeding costs incurred by single parents, such as loss of health or lower survival in the current season or subsequent years.

My two English setters braved the bugs and polar bears and displayed boundless enthusiasm for questing ptarmigan, regardless of weather. They assisted in locating birds for capture early in the season, pointed nests and males at roosts during incubation, and found more than 90 percent of the broods after hatch. My canine field assistants were largely responsible for the quantity and quality of data I obtained from these experiments.

I discovered that it was very difficult to create a ptarmigan widow. From 1981 to 1984, I removed 61 male parents after the onset of incubation. But other male ptarmigan filled vacancies rapidly, usually within twenty-four hours but sometimes within five minutes. Widows were not aggressive toward the replacements. In fact, when widows left their nests, they often flew to and willingly landed beside their new mates.

So to compare the nesting success of single parents and pairs, I found that I had to remove not only male parents but all replacements to cages until nesting efforts ceased. Fifty-three percent of thirty-four incubation widows hatched nests successfully, compared with 55 percent of forty-seven intact ptarmigan pairs. I found no differences in length of incubation periods, partial predation of clutches, or hatchability of eggs between widows and pairs.

A very different result could be seen with incubation widowers. Of the six males widowed during incubation, three continued to defend their nests for several days, but none were observed incubating the eggs. None of these nests hatched, and none of these males obtained another mate in that season. Thus, while single parent hens defended eggs and incubated clutches as successfully as pairs, lone males failed totally.

After hatch, both pairs and widows raised about 60 percent of their chicks to fledging, but widowers fledged only about 40 percent of their chicks. Most of the chicks that disappeared were probably killed by predators. The best test of parental success is the number of offspring that survive and return to breed the following year. Here again, I recorded no differences between pairs and single parent hens in offspring return to La Perouse Bay.

All returning hen offspring breed in their first year, but male offspring vary in their breeding status. I wondered if the amount of care provided by parents could conceivably influence the future mating status of their male young. I found that 52 percent of male offspring raised by single parents acquired territories and mates in the first year of their return compared with 47 percent raised by two parents. The breeding status of returning male offspring did not vary between widows and widowers.

Having determined that two ptarmigan parents did not produce more or better offspring than single parent females, I set out to discover whether females raising their brood alone were at greater physical risk than hens accompanied by males. I found that mortality of hens during the breeding season was not altered by the removal of their mates or by the presence of replacement males. During the four years of my study, 6 percent of paired hens were killed during incubation compared with 3 percent of lone incubation widows, and none of the incubation widows with replacement males.

Males returned to the study area in subsequent years at significantly higher rates than did hens, but the rate of return of either sex was not altered by the mate having been removed in the previous season. Single parents of either sex did not differ from pairs in their survival during the breeding season or in their rate of return in subsequent years.

Although it is very tempting after watching male willow ptarmigan defend their mates, nests, and chicks to conclude that such behavior is vital, my experiments have shown that the defense activities of male parents simply are not necessary or even helpful to their mates or offspring. Thus, I had to conclude that two-parent care in willow ptarmigan generally is a luxury and not of sufficient importance to force all male willow ptarmigan to be dedicated parents. My next step would be to test other possible explanations for the behavior of willow ptarmigan: which sex had the most to gain from their parenting patterns?
chances. Males wishing to insure that the offspring they raise are their own have little choice but to remain very close to their mates before and during laying.

Hens lay nine to eleven eggs, but sometimes as many as fourteen. Upon laying the penultimate egg, they begin incubation. Abruptly, the tundra quietens. Discretion and secrecy reign. For twenty-two days, hens sit on their eggs, taking only one or two short recesses a day to feed, drink, defecate, and dust bathe. Incubating hens are remarkably tenacious and abandon their nests only when predators or humans approach to within inches.

Unlike the hens, males are not confined to one location during incubation, but they too become less active. They often ignore trespassers unless these behave aggressively. Males spend much time sitting at one or several roosts near their nests. Their parental duties consist of accompanying hens during incubation recesses, warning them of predators, and occasionally deflecting intruders from the nest.

Keeping predators from the eggs demands constant vigilance. Males attempt to lead potential marauders away from the nest by flying or running away. The behavior of most males during incubation is so predictable that I was able to find nests by searching in the opposite direction when they left the site. But even this decoy behavior and the hen's remarkable camouflage and lack of distinguishing scent when she is immobile do not succeed in staving off the many bird and mammal predators inhabiting the tundra. Each year at La Perouse Bay, about 60 percent of the first nests started by ptarmigan fail. Hens reluctant to leave their nests also risk death, and annually, about 6 percent of incubating hens are killed on or near their nests. I once observed three herring gulls detect a nest, and despite vigorous protests from the male, they killed and ate the incubating hen as well as her clutch. In fact, despite the defenses mounted by parents, ptarmigan are often unable to defend themselves from predators that have discovered their nests.

Willow ptarmigan seem to cope with the high rate of nest failure by renesting up to three times in a season. If an incubating hen loses her clutch, she will often begin another within four to six days. Replacement clutches are smaller, the first renest usually containing seven to nine eggs. The second results in four to six eggs, and occasionally hens attempt a third renesting. In my study, 40 to 60 percent of pairs succeeded in hatching only after hens laid replacement clutches. The frequent nest failure and the ability of hens to replace lost clutches rapidly provides considerable incentive for males to remain with their mates throughout incubation.

As hatching approaches, males station themselves closer to the nest, and hens spend more time turning the eggs and talking to the "peeping" ones. Chicks can be heard tapping and peeping after they have broken through the membrane under the shell. About twenty-four hours after a crack appears on the shell surface, a wet chick emerges, kicking and ready for action. The precocial chicks dry off and become fluffy in a matter of hours.

The orderly, sedentary life of ptarmigan parents changes abruptly as impetuous chicks emerge from "well-behaved" eggs. The vigor and energy of chicks can result in disaster if a few simple rules are ignored. Within hours of the hatch, the hen instructs her brood on the essentials of survival: following, hiding, and freezing. Moving a few feet from the nest, she calls for her chicks to follow and may gather them under her for a short period of brooding. Then she goes back to the nest, summoning them to return. When a predator is observed in the vicinity, she or the male gives an alarm call. On hearing this note, even tiny chicks still wet from the egg will scatter and then freeze.

Within twelve to twenty-four hours after hatching, the parents and chicks leave the nest permanently. The rush to desert the area is probably adaptive: A predator that happens on a nest of eggs usually eliminates the entire clutch, but once chicks have hatched and mobility is an option, predators are less successful. Only 7 percent of ptarmigan parents suffer total brood loss after the hatch. Chicks have almost no body scent and, like the hens,
are cryptically colored, able to "disappear" in areas that seemingly offer little chance of concealment. Even newly emerged chicks can scatter instantly into sparse vegetation and roots or dive into crevices. After danger has passed, hens give a special "come hither" call and the brood regroups.

Eating calls for less urgent instruction as ptarmigan chicks carry about four days' nourishment in their yolk sacs. At first, chicks peck indiscriminately at leaves, sticks, their mother's back, and one another. Other galliforme, or chickenlike birds use a food call that summons chicks to locations with suitable food. Willow ptarmigan parents may provide their young with similar dietary guidance.

For the first week, the chicks are unable to regulate their body temperatures and require brooding, although how much is somewhat dependent on the weather. At ten to thirteen days of age, chicks fledge. The family unit remains intact until September or later, but after fledging, usually by mid-July, the offspring can survive on their own.

Although ptarmigan parents appear to be specialized in their roles—with males undertaking surveillance duties and hens diligently brooding, instructing, and disciplining chicks—these gender roles are interchangeable. My studies revealed that one parent of either sex can perform all duties necessary to raise offspring after the hatch. Why do male willow ptarmigan depart from the rule of one-parent care followed by other grouse species? While we can never be sure of the precise reason for the establishment of any behavior, we can examine experimentally the advantages of alternative behaviors, such as the number of offspring raised by two parents and by a single parent. If, for example, two parents fledge more or healthier offspring than one parent, this would offer an explanation for the evolution and maintenance of this behavior.

For four years, I conducted a series of experiments to find out whether two ptarmigan parents are more successful than one. Although at first I seemed to be settling to demonstrate the obvious, the ptarmigan had a few surprises in store for me. My experiments have shown that the defense activities of male parents are not necessary or even particularly helpful to their mates or offspring. Single parent hen willow ptarmigan produce just as many offspring and are not at greater physical risk than paired hens (see box, page 65).

Thus after 118 experimental trials, I was again faced with the basic question: why do willow ptarmigan provide two-parent care? I considered the question from another angle. Because ptarmigan parents may have several motives for their behavior, and as each sex may not have identical goals, I decided to examine the activities of each parent separately, to find out which had most to gain at various periods during the breeding season.

After the onset of incubation, hens do not appear to benefit from male help in caring for young. But if a first nest is destroyed, having a mate on hand (although replacement males seemed readily available) to fertilize her eggs will enable a hen to start a new nest quickly. Hens may benefit from a mate's presence chiefly before and during laying, periods not tested in this study. After incubation is under way, the male's activities may be helpful to himself, but of little consequence to the hen's success.

Since a male willow ptarmigan can raise hatched offspring alone, a hen could possibly leave her first brood for her mate to raise—as happens in northern phalarope—recoup her body condition, and
A grown brood gathers around dwarfed spruce trees. In fall, willow ptarmigan migrate from their subarctic nesting grounds to the boreal forest, up to five hundred miles south.

Sharon Cummins

perhaps start a second clutch to raise on her own. But the occasional bad record of single parent males makes desertion a risky business for females. Furthermore, early broods contain more chicks than do those of renest attempts, and in subsequent years, “early” offspring return to the breeding area at higher rates than do those from replacement broods. Thus, hens benefit most from raising their first clutches by themselves, with or without a mate.

Males, in contrast, would benefit most from having several mates, but opportunities to acquire more than one female are limited, and great effort is required to keep even one mate. Neighboring males and unmated males exert considerable pressures, and if a male does not or cannot guard his hen, he risks losing her. After a loss, he usually does not acquire another hen in that season. In light of the heavy nest failure, I concluded that the reason a male remains with his mate throughout incubation is to insure paternity in renesting attempts.

Early in the season, a mated male’s best interests dictate that he remain with his mate until the nest hatches. If a clutch is destroyed, he will be ready to start another. By remaining after the hatch, the male is available to care for the brood should his mate die.

Raising ptarmigan offspring may appear at first to be a cooperative venture. Upon closer scrutiny, however, each parent has a different point of view and at times has conflicting goals, in terms of breeding opportunities, what each must contribute, and how much each stands to gain. Consequently, each sex provides its young with the amount of care that contributes the most to its own reproductive success. The total care provided by willow ptarmigan parents may, in most cases, be more than is required for offspring survival. But B2226 would probably have a very different opinion on that subject. He was willing to assume full parental responsibility after he lost his mate, and as a consequence, he has offspring and grandoffspring that continue the annual tradition of pairing and parenting on the northern Manitoba tundra.
At the American Museum

Black History Month
Honoring the contributions of blacks to both American and worldwide culture, the American Museum of Natural History will celebrate Black History Month throughout February.

Each weekend will be devoted to a different aspect of black culture. Slide-illustrated discussions will focus on the pioneering political works of Marcus Garvey, the poetry of Langston Hughes, and other significant contributions by black Americans to the development and advancement of society. Demonstrations of basketry, hair braiding, gospel singing, and traditional African dance will also be part of this month-long celebration. These programs will be repeated several times from 1:00 to 4:30 p.m. in the Leonhardt People Center.

In addition, the following special performances will be presented in the Kaufmann Theater:

Music of Two Worlds, February 7, at 2:00 and 4:00 p.m. This program of music, song, and dance will demonstrate how African-Americans have retained and drawn upon their heritage to create their music and dance styles.

Harlem Renaissance, February 15, at 2:00 and 4:00 p.m. This puppet show will celebrate such noted personalities as Langston Hughes, Zora Neale Hurston, Eubie Blake, and others who were at the heart of this black cultural movement.

The Harlem Mosaic, February 18, at 7:00 p.m. Sponsored by the Metropolitan Museum of Art, this slide-illustrated lecture, featuring the work of photographer James Van Der Zee and others, chronicles Harlem's changing spirit over the past century.

Rhythms, Rhymes and Rituals, February 22, at 2:00 and 4:00 p.m. The Caribbean Theater of the Performing Arts will combine traditional song, dance, and poetry in an exposition of the rich diversity of the island cultures.

The Ubu Repertory Theater, February 25, at 7:30 p.m. The Second Ark, a play by African playwright Sony Lab'ou Tansi, will transport the audience into a surrealistic world as it focuses on a wise man—a contemporary Noah—who believes the onslaught of industry will soon ruin the world.

All the above programs are free to the public and seating is on a first-come, first-served basis. For a complete schedule of events call (212) 873-1300, ext. 503.

Hawaii Story
Through puppets, skits, and songs, The Story of Hawaii explores the cultural and ecological development of the fiftieth state. Open only to members, the program will be presented in the Kaufmann Theater at 1:30 and 3:30 p.m. on February 8. For ticket information and prices call (212) 873-1327.

Sword Dance Festival
Sword dancing, a traditional winter celebration in the coal mining regions of northern England, will be presented by the Half Moon Sword Dance Team at 1:00 and 3:00 p.m. on February 14 in the Kaufmann Theater. The program will also include morris dancing and other English folk dances, as well as a seventeenth-century mummer's play based on the legend of Saint George and the dragon. This winter festival is free to the public, but seating is on a first-come, first-served basis. For further information call (212) 873-1300, ext. 559.
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15
On the Other End of the Binoculars

by Michael Harwood

Considering the bird-watching boom in the United States—reflected by, among other things, the recent freshest of field guides—you'd think that before now someone would have written a popular history of American birding. But very little, either popular or scholarly, has been published on the subject. So Joseph Kastner, whose book is particularly welcome. *A World of Watchers* starts with a nice touch, a survey of bird watching and bird naming as practiced by North American Indians. Moving along at a brisk pace, Kastner carries us past the beginnings of formal American ornithology, through the era of the specimen collectors and early conservationists, and into the Age of Peterson, with its millions of active birders. The major mileposts on this journey are not scientific discoveries or the establishment of museums or the blossoming of university ornithology departments. Kastner directs our gaze instead to the exploits of individual birders, and he produces a lot of interesting characters for our observation.

Not all of these bird-crazy folks are famous today because of their bird watching. They include small-town school teachers as well as two U.S. presidents named Roosevelt and another named Jefferson. But then there are some true ornithological luminaries in the cast. Among them is Spencer Fullerton Baird, around whom Kastner builds a chapter called "The Recruiter." When Baird was still a boy—in the 1830s—he was a natural prodigy and a protegé of John James Audubon. The teen-aged Baird, wrote an admiring Audubon, proved that "an old head may be found from time to time on young shoulders." At the age of twenty-seven, Baird became assistant secretary of the new Smithsonian Institution, bringing with him (as a scientist's version of a dowry, one supposes) his own natural history collection. Kastner describes it as "two freight-car loads of specimens: four thousand bird skins, several thousand eggs and nests, five hundred jars and kegs of reptiles and fish, innumerable boxes of insects . . ."

For thirty-seven years, as assistant secretary and secretary of the Smithsonian, Baird created and supervised one of the most unusual networks of natural historians ever seen. U.S. military officers, particularly physicians, who were interested in wildlife, were, through Baird's influence, assigned by their superiors to posts in the West where they might do the most good for science. "The string of scientific expeditions which I have succeeded in starting is perfectly preposterous," Baird once wrote in amazement. His military cooperators supplied the Smithsonian with multitudes of specimens and careful observations that, among other things, helped establish solid scientific foundations for American ornithology.

Through Baird we meet people with names that became part of the bird watchers' vocabulary but are otherwise unknown to most birders today. Key examples are James Graham Cooper, whose name is now borne by a major western organization, the Cooper Ornithological Society; U.S. Surgeon General William Alexander Hammond and a one-time member of his staff, the Hungarian John Xantus, who named a new flycatcher after his boss and in turn had three bird species named after him; and Charles Emil Bendire, a German immigrant who wrote reams of commentaries on birds and nests and eggs and whom Baird eventually appointed as the Smithsonian's honorary curator of oology, the study of eggs (like Baird, Bendire then gave his entire collection of 8,000 eggs to the Smithsonian). Kastner does much greater justice to
Q. Would you buy a pair of shoes from this man?

A. Thousands of Lands' End customers do, for reasons this interview makes clear.

Above is a rare photo of Jim Jennings, the "old shoe dog" who governs the buying and selling of Lands' End shoes. Rare, because Jim is seldom caught in repose. But Carol Sadler, one of our resourceful creative people, cornered him one day, and what follows are excerpts from an interview that may lead you to rethink whatever prejudice you may have against ordering shoes from a catalog. Even ours.

Carol: How long have you been in the business, Jim? And how does that affect your buying shoes for your customers?

Jim: Let's see...about 20 years, I guess. When you've been around that long, you see a lot of companies come and go. You get to know the good, reliable ones. The ones that make the Lands' End kind of shoe.

Carol: And what kind of shoe is that?

Jim: The kind of shoe that goes with the clothing we sell. Not "high fashion", or a "hot seller". But classic. We offer casual shoes, as you know, and a very controlled line of dress shoes. Always in style. And as well made as possible.

Carol: What steps do you take to get that kind of quality?

Jim: Extra steps, frankly. When we look at a shoe, we'll see what we can add to it to give it more quality. Like a leather lining instead of vinyl, so the shoe wears longer and breathes better. Or a wool lining instead of acrylic in a pair of slippers. Or we'll add a better sole.

(JIM PAUSES. RUMMAGING AROUND IN SOME SHOE BOXES AND COMES UP WITH A PAIR OF LANDS' END "DUSTY BUCKS".)

Here's a perfect example. We took these traditional Bucks. Nice suede leather, but the rubber soles wore out in a big hurry. And they were heavy. So we added a lightweight Vibram sole, with a real tough skin to make it long-lasting. Now, instead of a Buck, we give you a Buck-and-a-quarter.

Carol: They warned me about your puns, Jim. Let's get serious again. I'm told you visit manufacturers quite often. Right? What do you look for?

Jim: Actually, as a company we probably do make more factory visits than most. That's really the only way to maintain quality. You just can't run our business from an "ivory tower". And when we do visit, we look to see how things are organized. And at how many points the shoes are inspected. After a while, you can tell how neat and careful the work is at every step.

Carol: Do you literally look over a handsewer's shoulder?

Jim: You bet. You look to see how neat and even the stitches are.

Carol: That kind of quality control must take a lot of travel.

Jim: It does. But we're fortunate in having built up a very strong domestic structure of suppliers. Which means for the customer that we can keep an eagle eye on quality, and keep the shoes they want in stock too.

Carol: But you buy shoes overseas, too?

Jim: Yes, indeed. We go where we can get the best shoe. Italy, for example, for the fine leathers and excellent craftsmanship for some of our dressier shoes.

Carol: How do you do all these extra things and still keep prices as low as they are?

Jim: We have several things going for us. We don't operate on the normal 50% retail mark-up. We're direct merchants, with no middlemen to raise costs. Also, we order in large quantities. And we have long-standing relationships with our suppliers, which helps.

Carol: What would you say to the person who hesitates to order shoes from a catalog because of fit?

Jim: We make an extra effort to standardize sizes within our offerings. We've used the same lasts—which determine fit—for ten years or more in many of our shoes. And we fit-test a shoe on 20 to 25 people before we offer it.

Carol: Gee, you seem to have things all worked out. Don't you have any problems?

(JIM PAUSES. JIM LAUGHS A LITTLE NERVOUSLY. Finally, HE ANSWERS.)

Jim: Frankly, the hardest thing to do is managing the variety of sizes and colors we offer in each style. We try our darndest to fit everybody, and that means we have to keep track of something like 1863 offerings.

Carol: That ought to keep you busy. And your customers happy.

Jim: Well, Carol...that's the idea.

* * * *

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Baird and his colleagues than I can here, but that gives the flavor of the author’s approach. In like fashion he focuses on William Brewster, one of the founders of the American Ornithologists’ Union, a scientist and author, whom Kastner describes as “the model watcher”; on the gifted, headstrong, eccentric Elliot Coues, a “prodigious trouble-maker”; on Witmer Stone, the affectionate chronicler of the birdlife at Cape May, New Jersey; on Edward Howe Forbush, the lyrical and learned chief author of a great American ornithological work, Birds of Massachusetts and Other New England States; Margaret Morse Nice, North America’s most famous amateur ornithologist; John Burroughs, the poet, teacher, and popularizer; and Roger Peterson, who was the author of the first of the great modern pocket guides to birds.

He also looks at some historical issues that in their day ruffled many a birder’s feathers. There was, for example, the matter of the house sparrow. Most birders today simply look down upon the house sparrow, first because it is very common and second because—through no fault of its own—it invaded North America “unnaturally,” having been transplanted to Brooklyn from Europe in 1853. That transplant, however, was paid for and organized by a committee of upright, good-doing citizens. Many other such committees were formed in the next several years, in communities from Maine to Texas, for the purpose of transplanting house sparrows. This was one of man’s many crude attempts to warp the environment for his benefit, and like many efforts of that sort, it produced unintended and unwanted results. The house sparrow was introduced in the belief it was a great eater of insects and would wipe out destructive cankerworms, measuring worms, and the like. It did no such thing. In fact, the house sparrow showed a distinct preference for grain, much of which it picked up in the horse manure found on American streets. Meanwhile, it bred liberally, competed successfully with many native bird species, including such favorites as bluebirds and purple martins, and in some places became a downright pest.

Although it is now completely fashionable in American birding circles to snoot the house sparrow, in the late 1860s and 1870s the value of the species had not been agreed upon, and this produced the enlightening spectacle of the big names in American ornithology going after each other hammer and tongs, stirring up a furious public argument—over a small bird. Kastner tells us that Elliot Coues called the house sparrow “a nuisance with-
out a redeeming quality." Thomas Brewer suggested that Coues was a liar. Henry Ward Beecher, the great Unitarian preacher, came into the fight by accusing Coues of "treason" for having "incited a riot" against the house sparrow, and Henry Bergh, founder of the American Society for the Prevention of Cruelty to Animals, called Coues "a murderer." And that, believe me, wasn't half the tempest.

Another issue that embroiled the birders was the matter of collecting bird skins and eggs. As the conservation movement formed in the late nineteenth century, people began to question the logic of protecting birds from market gunners and plume hunters while not protecting them from bird students. The collecting of specimens had always been considered central to the science; in fact, it still is. It also was believed to be the only sure way to identify a bird in the field. A developing conservation ethic, combined with numerous technological advances in optical equipment, sharply reduced the amount of collecting and revolutionized the behavior of birders in the field. Meanwhile, for decades birders shouted at each other about this topic and called each other bad names.

On the obverse of that coin are the friendships and fraternities that evolved with, and often helped transform, the science and pastime of ornithology. There we find young William Brewster and his birding buddy Henry Henshaw getting together with like-minded contemporaries at Brewster's home in Cambridge in 1873 to form the Nuttall Ornithological Club, which led directly to the organization of the American Ornithologists' Union. In this century another gang of tyro birders, up in the Bronx in New York City of all the places, started the Bronx Bird Club, which included several future leaders in American ornithology and soon helped transform field birding from a sport of gunners to a sport of watchers.

A great deal of the information in A World of Watchers was new to me, and I know it will be new to most American birders. I often found myself grinning at the novelty of the material, at the variety of personalities, and at Kastner's sprightly anecdotal way of displaying it all. The book doesn't cover everything or everyone that it might, and here and there, it delivers more fizz than substance, but those are minor cavils. There was a void in the literature on this subject, and Joseph Kastner has gone a long way toward filling it.

Michael Harwood, who has written several books on birds, is coauthor with his wife, Mary Durant, of On the Road with John James Audubon.
El Yunque Rain Forest, Puerto Rico

by Robert H. Mohlenbrock

Coqui! Coqui! The high piping of the inch-long tree frog that sings its name lulled me to sleep each night during my stay near El Yunque, a mountain peak of the Caribbean National Forest in the northeastern corner of Puerto Rico. El Yunque is one of the high summits in the Luquillo Mountains, the only area in the United States national forest system to harbor a tropical rain forest. There are twelve species of coquis. Sounding more like birds than frogs, they pipe their loudest on rainy evenings, which are frequent. The Caribbean National Forest is less than ten miles from the ocean, and the steep terrain rises from 330 feet near the coast to 3,281 feet. As the moisture that the northeastern trade winds take from the sea strikes the Luquillo Mountains, it condenses into rain. In some places, rain falls an average of 350 days each year, with a yearly accumulation of 200 inches.

Climbing the slopes of El Yunque is like moving rapidly north from the equator. Every 350 feet ascended in the tropics is roughly equivalent to moving 100 miles toward the pole. Distinct plant communities are encountered on the way. The forest that extends above the hot agricultural lowlands up to about 2,000 feet is the rain forest proper, also called the tabanuco forest because of the dominance of the white-trunked tabanuco tree. Tabanuco belongs to the tropical Burseraceae family, a group of plants that includes the gumbo-limbo of southern Florida, the elephant tree of southern Arizona and Mexico, and the trees of biblical fame that produce frankincense and myrrh.

Between 2,000 and 2,500 feet, where evaporation is often inhibited by a heavy, foglike cloud cover and a cooler climate, a forest known as a montane thicket generally prevails, characterized by palo Colorado trees. In the same altitude range, where the drainage is especially poor, nearly pure stands of sierra palms attain heights of up to fifty feet. Finally, above 2,500 feet, on the highest ridges, is an elfin forest, where the thick growth of vegetation is dominated by gnarled trees no more than twelve feet tall.

The El Yunque rain forest is all that is left of a rain forest that covered much of...
Puerto Rico’s mountains more than a century ago. Agricultural practices and heavy timbering have reduced it to the 10,000-acre preserve that makes up one-third of the Caribbean National Forest.

My preconceived idea of a tropical rain forest was of an impenetrable, vine-entangled jungle that could be traversed only with machete, and with venomous reptiles watching and waiting at every step. In the El Yunque rain forest, nothing could be further from the truth. The trees form such a dense, closed canopy that scarcely any sunlight penetrates to the forest floor. As a result, there is little brushy undergrowth, and the vines grow quickly and vertically to the tops of the trees, seeking the sunlight they need for optimum leaf, flower, and fruit production. Only near streams, or where a tree has fallen, opening the canopy to sunlight, does a junglelike growth of plants develop. As for poisonous snakes, there are none in the El Yunque rain forest, although the Puerto Rican boa, which may grow thirteen feet long, lives here. Since this snake is rare enough to be considered endangered, the casual visitor is not apt to encounter it.

The tabanuco forest nevertheless provides a new experience for persons accustomed to temperate regions. The trees form a continuous canopy about eighty or ninety feet above the forest floor, with an occasional tree projecting even higher. The first side branches appear about halfway up the trunks, contributing to the openness of the understory. I was surprised to learn that growth of the tall rain forest trees is not like that of Jack’s beanstalk but is relatively slow for some
species. Foresters from Puerto Rico's Institute of Tropical Forestry have shown that in the mature rain forest, tabanuco stems may increase in diameter by only one-eighth of an inch per year.

The leaves of most rain forest trees and of the shade-loving plants in the understory are remarkably thin, facilitating photosynthesis in the diffused light that filters through the canopy. The bark of most rain forest trees is mottled by the growth of lichens, while their branches are crowded with epiphytes (air plants) of all sizes and shapes. Giant "bird's-nest" bromeliads and small, delicately flowering orchids share the upper branches.

Although the trunks of the tall trees are usually relatively slender, most of them flare out dramatically at the base to form buttresses. Much of the root system creeps over the ground, which is usually covered by fallen leaves that are rapidly broken down by microorganisms and fungi. These nutrients, along with those released by decomposition of the bedrock material, are absorbed by the feeder roots lying on or near the surface of the soil. Eventually these nutrients are replenished when leaves and other plant parts drop. Thus, the tropical rain forest plants set up a cycle of nutrients that enables them to thrive even when soil fertility is low.

To a botanist, perhaps the most interesting, as well as the most overwhelming, feature of the tabanuco rain forest is the great diversity of trees present. Although the tabanuco is the dominant species, 167 other kinds of trees have been recorded in this forest, with 33 different kinds of trees appearing in any given acre. No forest anywhere in the mainland United States approaches this diversity, and only seven of the Puerto Rican species are also native to the mainland (all but one confined to southern Florida).

Above the tabanuco forest, in the cooler realm of the palo colorado tree, I observed one behemoth that stood sixty feet tall and had a trunk circumference of nearly twenty-one feet. The palo colorado's red-barked trunk is often hollow, serving as a favorite nesting site for the nearly extinct Puerto Rican parrot. Curiously, the tree is the same species (Cyrrila racemiflora) that grows as a native shrub from Florida to Virginia. Called the titi bush in the United States, it typically grows in coastal plain swamps. The reason for its very different stature in Puerto Rico is not known.

"This Land" highlights the biological phenomena of the 154 U.S. national forests. Robert H. Mohlenbrock is Distinguished Professor of botany at Southern Illinois University at Carbondale.
Stellar Old-timers

Where are the oldest stars in our galaxy?

by Stephen P. Maran

Astronomers are searching the Milky Way for signs of what they call Population III, a collective title for the oldest stars in the universe. Population III formed so long ago and appears to be so hard to find that it has been termed a cosmological Atlantis—the mythical island mentioned by Plato, which was believed to have vanished beneath the sea. These objects, if they still exist, may have been created even before the Milky Way itself, more than twelve billion years ago, and were later incorporated in the great spiral galaxy that contains our own earth and sun.

Much has been theorized, but nothing proved, as to the nature of Population III. Thus, it is not clear to some of us what the seekers should be looking for, although that does not seem to deter them. Various astronomers say that the stars of Population III shine no more and that they exist today only as massive black holes. According to this view, Population III originally consisted only of huge stars, a race of celestial Titans that has since collapsed into invisibility.

Another opinion about Population III as it exists today suggests that its most numerous members are not black holes or true stars but brown dwarfs. True stars are powered by the steady nuclear burning of hydrogen during a large part of their lifetimes. Brown dwarfs, in contrast, are too small to generate the high temperatures and pressures needed to sustain hydrogen nuclear reactions in their interiors. Lacking a continuing energy supply from nuclear energy, brown dwarfs fade rapidly. Therefore, if there are brown dwarfs that formed billions of years ago as part of Population III, they would be very cool and dark by now, and like black holes, extremely hard to see. Only one generally accepted brown dwarf has been found (see “A Telltale Wobble,” Natural History, January 1986), but the brightness and temperature of this object, VB8B, prove that it is too young to be a member of Population III.

Population III is so named to distinguish it from Populations I and II. Population I includes the sun, the bright blue-white stars in Orion, and more generally, the stars that have formed or are forming at present in the spiral arms of the Milky Way or of other galaxies. Population II includes the stars in globular clusters, those compact, round aggregations of hundreds of thousands to millions of stars, such as omega Centauri, a cluster that can be seen with the naked eye from the Southern Hemisphere. The globular clusters of the Milky Way form a huge spherical system, with its heart at the center of the galaxy. So-called halo stars, which also form a great round system—the halo, or galactic corona—around the center of the Milky Way, are likewise members of Population II. Astronomers generally believe that the members of Population III, whether visible stars, black holes, or brown dwarfs, would be located in the halo, which probably arose early in the formation of the Milky Way. Some Population III members may be present in the galactic bulge, a dense concentration of stars in the Milky Way.

Thus, location helps to discriminate between the members of the two identified stellar populations. Chemical composition constitutes a second differentiation. Population I stars contain greater amounts of heavy elements (in astronomy, that means all elements heavier than the lightest two, hydrogen and helium) than do stars of Population II. According to cosmologists, hydrogen and helium were created in the Big Bang that gave rise to the expansion of the universe. Also created, although rarely mentioned in popular accounts of the Big Bang, was a slight trace of lithium, the next heaviest element after helium, and perhaps infinitesimal amounts of substances even heavier. As an upper limit, according to one calculation, the mass of heavy elements created in the Big Bang amounted to no more than one hundred-millionth of the mass of hydrogen and helium. Population III, formed from the primordial products of the Big Bang, would therefore be almost totally lacking in heavy elements.

If virtually no heavy elements were made in the Big Bang, where did all the carbon, oxygen, iron, and other elements heavier than lithium come from? Physicists believe that these elements were made for the most part in stars, in these same nuclear furnaces mentioned above. In fact, in 1983, astronomer William Fowler of the California Institute of Technology shared the Nobel Prize in physics for his work in helping to establish that elements were made in this way. Some of the heaviest elements could not be made in the stellar interiors, according to astrophysical calculations by Fowler and others, but were instead created in the supernova explosions that disrupt some stars.

In a supernova explosion the heavy elements made within the stars and in the explosions themselves are ejected into space. Heavy elements formed in stars that don’t become supernovae are carried into space by stellar winds, by smaller explosions called novae, and by the expulsion of atmospheric layers. These layers form expanding nebulae such as the ring nebula in the constellation Lyra. New stars, in turn, condense from the interstellar medium. In this way, each successive generation of stars forms from gas that contains more heavy elements than the gas from which the preceding generation was formed. Stars of Population III were
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made less than a half billion years after the Big Bang, from a primordial medium that consisted, according to most calculations, of about 75 percent hydrogen and 25 percent helium. Stars of Population II, in contrast, were formed from a medium enriched by heavy elements that were created inside other stars that belonged to Population III or even to Population I. (Both Population II and Population I probably consist of several stellar generations.)

Observations show that in many Population II stars, the heavy elements are less plentiful by a factor of one hundred or even a few hundred than they are in the sun. (The solar composition is taken as a standard of comparison for the chemical makeup of objects in space.) This circumstance led Howard E. Bond, an expert on stellar populations who is now at the Space Telescope Science Institute in Baltimore, Maryland, to adopt a working criterion for recognizing Population III stars. He proposed that any star with a deficiency in iron of at least a factor of 1,000, with respect to the abundance of iron in the sun, be identified as a Population III star. He then spent a decade in a heroic search of more than one-half of the sky, examining the spectra of several hundred thousand stars for signs that any one of them met his criterion for membership in Population III. In September 1981, Bond reported that his search had turned up only two stars that passed the test, and even in those two cases, the available observations were not sufficient to prove that the iron contents of the stars were less than one-thousandth of the sun. Two courses of action were indicated: better observations of these two stars should be made, and a further search should be conducted for other stars lacking or deficient in iron and other heavy elements.

Of the two stars identified by Bond as possible members of Population III, one was later shown to exceed his search criterion substantially. This object, a red giant known by its catalog number, CD -38 245, had actually been noted in 1971—independently of Bond's survey—as a heavy-element-deficient object. Later, it was observed repeatedly over several years by two astronomers from the Mount Stromlo and Siding Springs Observatories using the 3.9-meter Anglo-Australian Telescope, the second largest telescope in the Southern Hemisphere. The spectra that they obtained were analyzed to define the star's iron content with high precision. Australian observers M.S. Bessell and John Norris reported in October 1984 that CD -38 245 has about 30,000 times less iron than the sun, making it the most
heavy-element-deficient star known. Bessell and Norris concluded, however, that although CD-38 245 "readily satisfies Bond's criterion," the data are "consistent with the view that this object is an extreme member [one that is exceptionally deficient in heavy elements] of Population II." If they are right, then Bond's criterion is useful for identifying stars for further study, but it is not a sure test of membership in Population III.

Another search for stars with a very low content of heavy elements has been under way since 1979. Astronomers from the Mount Wilson and Las Campanas Observatories, with headquarters in Pasadena, California, and from the California Institute of Technology, also in Pasadena, took seventy-two wide-angle survey photographs with a telescope in Chile. The photographs were made through a large prism mounted at the top of the telescope tube, so that each photograph recorded the spectra of about 5,000 stars.

Those astronomers used calcium, rather than iron, as the telltale element. Calcium lines were identified in the spectra, and stars with weak calcium lines were categorized as objects deficient in heavy elements. In this way, 1,800 stars were identified as candidates for membership in Population III.

To establish whether any candidate is so deficient in heavy elements that it can be assigned to Population III, the object must be observed with a more powerful telescope in order to obtain a more detailed spectrogram, which also reveals the iron content. Such observations of the 1,800 candidate stars are in progress. In October 1985, the Pasadena team of Timothy C. Beers, George W. Preston, and Stephen A. Schectman reported on the follow-up studies of 450 of the 1,800 stars. Of the 450 stars, they found that 134 have at least one hundred times less iron than the sun. However, only one star, CS 22876-32, was found with an iron deficiency approaching that of CD-38 245, the red giant studied by the Australians Bessell and Norris. The exact quantity of iron in CS 22876-32 remains to be determined, and thus for the moment CD-38 245 is the record holder—the star with the least amount of heavy elements among all stars of known chemical composition. If Bessell and Norris are correct in their conclusion that CD-38 245 is not a member of Population III, then presumably the stars found so far in the continuing search by the Pasadena astronomers are not Population III members either, and the search must go on.

Given the existing technology, a direct search for the hypothesized huge black
hopes of Population III is not practical. Nevertheless, there is indirect evidence that is consistent with the existence of these objects. (But that does not prove they exist.) Specifically, the mass of the galactic halo appears to be greater than the sum of the masses of all the visible stars in the halo. This is deduced from motions of stars in the Milky Way, which reveal the total mass of that galaxy just as the motions of the earth and other planets tell us the mass of the sun. (The sun’s mass determines the speed at which the planets revolve around it, under the action of its gravitational force. If the sun’s mass were greater than its present value, the earth would complete each orbit in less than the present period of one year.)

The difference between the visible mass in the galactic halo and the total mass of the halo is known as the missing mass, although “unseen mass” would be a better term. Since the missing mass is not visible, it could well consist of large black holes. On the other hand, the ancient brown dwarfs of Population III, if there are any, could also make up the missing mass. They, too, cannot be detected by present means. The only difference is that far more brown dwarfs than black holes would have to be present to make up the calculated missing mass, since the hypothesized black holes are individually much more massive. Of course, the missing mass may consist of both black holes and brown dwarfs or it might be something quite different, such as a huge number of subatomic particles, that might have nothing to do with Population III.

Since both Bond’s search and the ongoing survey by the Pasadena astronomers have so far failed to positively detect Population III in our galaxy, perhaps we should look beyond the Milky Way. Investigations of distant quasars show that their spectra often contain absorption lines due to the passage of light from the quasars through clouds of gas in intergalactic space. Some of these clouds, judging from the spectra, have primordial or near-primordial composition; they lack heavy elements. Hence the existence of clouds that may resemble the parent clouds of Population III stars has been established.

At one time, some cosmologists believed that clouds of primordial composition would not have given birth to stars with a wide range of stellar masses, as gas clouds in the spiral arms of the Milky Way do. Instead, it was thought that the primordial hydrogen-helium clouds would form only very massive stars, so huge that they would collapse into enormous black holes. This conclusion came from the hypothesis that the presence of heavy ele-
ments is necessary for small clumps to form in a gas. (Clumps, in turn, condense into stars.) More recent calculations, which appear to be more accurate, show that gas clumps, and hence stars, should have formed from primordial gas with a wide range of masses, ranging from very massive stars to stars like the sun and to even smaller stars, including red dwarfs.

Since Population III was born so long ago, and the most massive stars exhaust their nuclear fuel with the greatest rapidity, the very massive stars of that population should long ago have collapsed into black holes. Less massive stars, but still much larger than the sun, would likewise have ended their lives by now, probably through supernova explosions. Even the stars with the mass of the sun would now be dead. They would be white dwarfs like the companion star of Sirius but much cooler and dimmer than that object. From Population III, only stars significantly less massive than the sun (with masses of 80 percent of the sun’s or less) would still be shining brightly, since their nuclear furnaces burn slowly. These are the stars the Bond and Pasadena searches have looked for and have thus far failed to identify unambiguously. The red giant CD -38 245, although much larger than the sun, is less massive. Thus, the Australians don’t rate it as a member of Population III, but I would not exclude that possibility.

If the Population III stars less massive than the sun cannot be found (or cannot be positively identified) and those of solar or greater mass no longer exist as detectable objects, what can be done to find them?

Looking far out into space, at quasars and distant galaxies, we are in effect looking way back in time, since the light that we receive nowadays with our telescopes left those objects long ago. A quasar seen from a distance of, say, eight billion light-years is seen as it was eight billion years ago. (A light-year is the distance about 5.8 trillion miles, that light travels in one year.) Thus, I suggest we search for Population III in galaxies in their formative stages, early in the history of the universe. Then, in the first billion years or so after the Big Bang, the massive stars of Population III were still shining. Perhaps NASA’s forthcoming Hubble Space Telescope or one of the currently planned huge telescopes on the ground will enable astronomers to detect this cosmological Atlantis.

Stephen P. Maran is a senior staff scientist in the Laboratory for Astronomy and Solar Physics at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. The opinions expressed here are his own.

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Lunar Tunes by Thomas D. Nicholson

The moon passes directly in front of four bright objects in February—two planets, Jupiter and Mars; and two stars, Spica and Antares—covering them as it moves easterly. The number may seem high but is not really unusual. This year there are also four occultations (as these events are known) in September and three each in March, April, July, and August. With either one or two in each remaining month, the total for the year will be twenty-eight. Unfortunately for us, three of this month's four occultations occur over the Eastern Hemisphere at times when the moon is below our horizon, and the only one in North American skies (Spica on the 8th) will be in daylight or early twilight when we can't see the star.

The bright planets are evenly divided in February between evening and morning. They are, in fact, closely gathered around the sun: Jupiter and Mars a short distance to its left; Venus and Saturn to its right. Jupiter and Mars are the evening stars; being on the sun's left, they remain in the sky after sunset. The other two are morning stars, rising first, to the sun's right. Mercury plays it both ways. It moves from the sun's left to its right (from evening to morning) on the 27th but never in a really good position to be observed.

Jupiter and Mars will be visible in the evenings during early February: Jupiter will be very bright; Mars will be above and to its left. Both are in Pisces on the 1st, but Mars moves into Aries at midmonth. By month's end, Jupiter will set too early to be easily seen; Mars will be lower and even harder to see. Jupiter leaves the evening sky in March; Mars dawdles along as a poor evening object until August.

Venus and Saturn, however, are becoming easier to observe in the morning sky. Venus is actually past its maximum morning brilliancy and also past maximum distance to the sun's right. But come spring it will be in a better position in its orbit, causing it to rise earlier and climb higher in the sky before daylight overpowers it. Saturn, on the other hand, is separating rapidly to the sun's right and brightening as well. Its morning configuration will improve steadily through February. Low in the east and very close to the brighter Venus at early dawn in the month, by month's end Saturn will rise shortly after midnight, appearing much higher than Venus when the latter comes up just before daybreak.

Events in the calendar below are given in local time unless otherwise indicated.

February 1: It's a good bet that the new crescent moon (now three days old) is visible in the southwest tonight. If so, it guides you easily to the brilliant Jupiter, below and to its right. The moon occults the planet over the Eastern Hemisphere when passing it earlier today.

February 2-3: Had you seen the moon and Jupiter the evening of the 1st, you would also have found Mars coming into view about half an hour later. The moon is closer to and a bit below Mars on the 2d, above it on the 3d. The brighter Jupiter is well below and to the right of both. Mars is also occulted over the eastern part of the world when the moon passes it on the 3d.

February 4-5: The moon is in Aries, marked by the two bright stars Hamal and Sheratan above and to the right. The brighter Mars and Jupiter are positioned farther to their right and lower. First-quarter moon is at 11:22 A.M., EST, on the 5th.

February 6-8: The gibbous moon is an easy mark in locating the constellation of the Bull as it swings through Taurus. The Pleiades (a tight little star cluster) is close to the moon's right on the 6th, while red-dish Aldebaran and the V-shaped Hyades (another cluster marking Taurus's face) are below the moon on the 7th and 8th.

February 9: The gibbous moon is at apogee (farthest from the earth) in the constellation Gemini.

February 10: Pollux and Castor (Gemini's twin stars) are to the moon's left at dusk. The moon slides toward them during the night and slips into line with the two stars in the early morning of the 11th.

February 11-13: On the 11th and 12th the gibbous moon marches through Cancer, easily outshining the constellation's inconspicuous stars. But the brighter Leo waits to the left of the moon to drift into it. Full moon is at 3:58 P.M., EST, on the 13th. Later that night the moon passes between Regulus below and a circle of stars above, together marking the Lion's heart and head.

February 15-18: The moon is a morning object, rising after sundown (later each night) and remaining in the sky past sunrise. It slips into Virgo on the 15th, then night by night moves off the distance from Leo's Regulus (to its right) toward Spica (Virgo's brightest star), finally drifting past the latter on the 18th. On its way past, the moon occults Spica over North America, but in daylight or early evening twilight.

February 19: Mercury stands still, relative to the stars around it, and begins its retrograde (westerly) motion, quickly bringing to an end its sojourn as an evening object.

February 21: Last-quarter moon is at 3:57 A.M., EST, in Scorpius. During the morning hours, the reddish star Antares (part of our summer evening scene) is close by the moon's left. Antares is occulted over the Eastern Hemisphere when the moon goes by in the late afternoon.

February 22: Saturn is found above and to the left of the moon at dawn, near the border between Ophiuchus and Sagittarius. By the morning of the 23d, the crescent moon is nestled in Sagittarius's "Teapot," well to the left of Saturn.

February 24: Bright Venus is just to the left of the crescent moon about dawn.

February 25: Perigee moon (nearest the earth) is in Capricornus, virtually below Venus. If the eastern sky is clear this morning, you might still see the moon during early twilight.

February 27: Mercury passes between the earth and the sun (inferior conjunction) and enters the morning sky. New moon is at 7:52 P.M., EST.

February 28: This is the third year in succession that February ends in 28 days, creating a deficit of approximately 18 hours in the average duration of our solar year. That is why we add an extra day to February in the leap year of 1988, when the deficit will total about 24 hours.

Editor's Note: The Sky Map in the January issue shows the evening constellations and stars for this month and gives the times and dates for use.
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The Natural Moment
Posing motionless for the eye of the camera? No. It's the owl's lack of facial musculature that accounts for the stony expression. Actually, it's feeding hour in the family nest atop a coniferous stump in Oregon's Cascade Range, where dinner has been momentarily delayed while an adult great gray owl displays the catch of the day to its two chicks. Three or four feedings a day are the rule for an adult, which will eat insects and centipedes to supplement its diet of rodents. Mice, shrews, and young squirrels are all fair game, but the favorite feast, by far, is meadow vole.

Feasting means hunting, which can be a taxing chore when there are hungry mouths to feed. Gliding on its five-foot wingspan through the coniferous forest in the low light of early morning or late afternoon, an owl will cover an area of about one square mile in search of the best perch from which to watch and listen. Great grays depend on their acute hearing to locate prey. A circle of feathers, fanned out around each eye, protects the opening of the inner ear without blocking sound waves, and a dense wall of stiff feathers and flattened quills creates a semicircular trough near each ear that helps pick up the slightest vole scamper. Swooping down from its hiding place, the owl will snatch the prey with its talons.

Once a vole has been caught, the owl will kill it with a snap of its beak to the rodent's skull. Back at the nest the great gray holds the rodent in its claws and with its beak rips it into strips for the young. Both sexes share the hunting, but when the female broods, the responsibility falls solely on the male. A female great gray can lay up to three eggs during May. But only the one or two chicks that monopolize the food the parent brings will survive.

These owlets may not be beak-fed much longer. At four weeks, when test flying begins, adults will still supply rodents, but the owlets will swallow them whole, as their parents do. The family nest will remain the fledglings' home until they are four to five months old and their hunting skills have been perfected. Then it will be their turn to bring home their own dinner.

Sharon Mulligan
Homage to Anatolia

_A forbidden cult is the driving force behind an international food conference_

by Raymond Sokolov

Alexander the Great crossed the Bosporus on his way to world conquest. Crusaders took this route to face the infidel usurpers of Jerusalem. Byron swam this storied channel in a romantic stunt that merged his personal myth with an ancient Greek story about a lover swimming across the Hellespont from Europe to Asia.

Or was it from Asia to Europe? When you are at this symbolic crossroads, the actual differences do not loom so large. Istanbul everywhere straddles so many worlds and states of mind that the arriving gastroethnographer feels himself in Europe and Asia all at once, wherever he turns. The swimmer who really matters at the Bosporus is Kemal Ataturk, the Turkish George Washington, who established modern Turkey in the twenties and did his best to extinguish the archaic culture that had made Ottoman Turkey the proverbial sick man of Europe. I speak of Ataturk as a swimmer because of the photograph of him in bathing trunks, half-submerged, that I recently saw on display in the ornate lobby of the Pera Palas Hotel in Istanbul. Ataturk is not alone in the picture. There are women with him, also in bathing suits. Even today, that photograph makes a political statement. It shows the father of the Turkish republic flaunting his disregard for traditional Moslem modesty.

The Pera Palas is in some sense a shrine to Ataturk's radicalism. His room there is preserved as a secular shrine, with its period furniture and memorabilia. And yet it was also in that glamorous if slightly faded hotelery that I and several other foreign food journalists and scholars first encountered a strain of Islamic tradition that Ataturk suppressed. Among Ataturk’s reforms had been the total suspension of the religious practices of the Mevlana cult, a form of Sufism. But were it not, in fact, for the cleverness and determination of certain highly cultivated descendants of this proscribed cult, none of us visiting food people would have been invited to Turkey. And the _Milletlerarası Yemek Kongresi_ (International Food Congress) would not have held its extraordinary proceedings in Istanbul, Ankara, and Konya from September 25 to 30 of last year.

Konya is a landlocked provincial town south of Ankara. It was the capital of the Seljuks, the original Turks to invade Anatolia, the Turks the Crusaders faced. Konya today has its modern blocks of apartments. And in your hotel, you can watch color television or drink vodka. But Konya is also a center of Turkish-Islamic conservatism. Its streets are dotted with theological seminaries and many historic mosques. In downtown Konya, the electronically amplified muezzin calls the faithful to prayer before daybreak. There is a long street, a bazaar, of shops selling religious books and garb. Although the veil is nowhere seen, because Ataturk forbade it, many women cover themselves ostentatiously, in overcoats and other full drapery, and shroud their hair in tight, prim, pinned-on turbans.

One such woman is the heroine of our story. Her name is Nevin Halici. A well-born spinster, she has led a sheltered life with her mother. While one brother went into politics and also wrote poetry and another ran the family rug business, Nevin confined herself to the traditional concerns of women—and she wrote a Turkish cookbook. Ms. Halici might easily have continued her quiet life at home in Konya if it had not been for another woman with a stake in Turkish food traditions. I speak of Claudia Roden, author of _A Book of Middle Eastern Food._

Mrs. Roden makes her home in London, but she grew up in Cairo in a family that had moved there from Aleppo. And she is descended directly from a chief rabbi of the Ottoman Empire. So there was a certain historical piquancy surrounding a research trip that led her to Turkey in search of local food experts. An
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inquiry put to the relevant authorities in Istanbul resulted in an appointment in Konya with Ms. Halici. Up to that time, Ms. Halici had not ever eaten in a restaurant. But as Mrs. Roden’s guide to Turkish food, she soon found herself assisting at interviews with male chefs, and somewhat later, urged by Mrs. Roden, she traveled to England to attend the annual Oxford Food Symposium at Saint Antony’s College, Oxford.

The Halici family knew a good thing when they saw one. They planned a food symposium of their own, inviting a full complement of Turkish food scholars to meet with a delegation of Oxford Symposium alumni picked by that event’s founder and sashem, Alan Davidson. When my invitation to the Konya congress came, I was aware of none of this. And it seemed to me an eccentric miracle that a Feyzi Halici of the Culture and Tourism Association of Konya should have conceived of, and found the local support for, an international food conference. Indeed, it took a day or two in Turkey before I fathomed the somewhat subtlety explanation that lies behind the Halici family’s involvement with official culture and tourism in Turkey.

It was obvious from Ms. Halici’s dress that she was a traditional Moselem woman. But it transpired only gradually that she and her family, and many other Turks associated with the organization of the congress, were partisans (I hesitate to say members) of the cult of Mevlana. This thirteenth-century Islamic sage was the inspiration for an ascetic sect based in Konya. Its adepts, called Melevi, practiced an ecstatic form of dancing worship. They are still known throughout the world as the whirling dervishes. But ever since the reforms of Atatürk, whirling and other Melevi practices have been illegal—at least insofar as they are carried out with religious intent.

For decades, the Melevi were in decline and almost disappeared; the dervish dances all but forgotten. But then, various determined enthusiasts of Mevlana in Konya revived the dervish cult under the guise of folklore—perfectly legal cultural entertainment. The holy convent, or dergah, of the Melevi in Konya, containing the tombs of Mevlana and the cult leaders, was secularized as a museum by Atatürk and continues as such today. In other words, the dissolved mystic cult of Mevlana has survived as an artifact or relic. True believers can no longer worship at Mevlana’s tomb, but they can serve him in what you might call a curatorial capacity. And dervishes can continue to whirl so long as they do it as if they were entertainers. In practice, this means that there must be non-Melevi in the audience.

In effect, then, since the dissolution of the cult in 1925, the Melevis and their adherents have been forced to practice show business in order to practice their religion. They have also found it necessary to encourage tourists to visit their shrine, and they have organized a variety of dervish events both in Turkey and abroad. Over time, such Mevlana followers as the Halics and Celaliddin B. Celebi (who would have taken his hereditary place at the head of the cult if the post had not been abolished by Atatürk) spread their influence through the official and commercial worlds of tourism and culture in Turkey. They did not limit themselves to activities promoting the Mevlana cult. The Konya Culture and Tourism Association has recently fostered poetry, chess, classical music, and folk art, as well as Melevi events in Algeria, Greece, and Italy. So it was entirely natural for her brothers to see, in Nevine Halici’s newfound international connections as a food writer, an opportunity to hold a food congress of their own. This was especially true because the lore of Mevlana and his traditions included many food associations.

The kitchen of the Konya dergah were a central part of Melevi life. They were restored and expanded in 1584 under Sultan Murad III and again in 1867. Potential novices spent 1,001 days wearing the “pelt of the water carrier” and helped out

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in the kitchen. A brick oven associated with Mevlana has been restored at a location just outside the center of Konya. Food played a crucial role in Melevi life, as Mr. Celebi explained in his address to the congress. He outlined the kitchen duties of the cult's aspirants and read an elaborate and metaphorical passage from a holy book in which the cooking of the chickpea symbolized the mystic enlightenment of Melevi Sufism. Finally, he repeated Mevlana's most important statement, the watchword of his philosophy: "I was raw, cooked, and then burned."

Most of the group's time was divided between official sessions of the congress, at which learned papers were read (in English and Turkish) or in general tourism or making practical contact with Turkish food. The groaning buffet at the Restaurant Konyali next to the Topkapi Palace in Istanbul had every imaginable variation on the standard vocabulary of kebabs and dolmas and sarmas. Here were the clichés of every Turkish and Greek and Syrian and Armenian and Lebanese restaurant in the world, but they were produced with a finesse and in a profusion and variety one could hardly have guessed at. Exposed, as we were, to the overwhelming refinement of this vigorous cuisine, in detail and on its home ground, we were able to sense the once-commanding vigor of Ottoman civilization. Even in a few days, you could begin to see that what looked at first like a collection of familiar dishes-cracked wheat, grilled meat, meatballs, and vegetables stuffed with rice—was in fact a subtly graded array of quite separate recipes defined within these large categories.

This came home to me most clearly at a lunch prepared in an elegant new private home at the edge of Konya. Whole lambs had been roasted in an old-fashioned outdoor oven and then laid on the table to be pulled apart and consumed. Hardy congressists competed for the privilege of eating the eyeballs. This primitive feast took place in a most refined garden. The lamb was entirely delicious, but the accompanying dishes were of perhaps even greater interest. They included firik pilavi, a mixture of chickpeas and a distinctive form of bulgur (cracked, steamed wheat; see recipe, left) and four kinds of kebabs—standard shish kebab marinated overnight in yogurt, eggplant kebab (meatballs alternated with sliced eggplant on a skewer), parsley kebab (ground meatballs heavily flavored with parsley), and bulgur kebab (ground meat patties mixed with cooked bulgur, chopped mint, and other spices).

In five days, I cannot recall eating the same dish twice. Moreover, along with the other congressists, I happened upon a small flock of the legendary fat-tailed sheep of the Middle East, I learned to count to ten in Turkish, and I collected copies of learned papers that I will discuss next month.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.
In 1966, having concluded that research on the earliest human presence in the New World was "barren of humanistic rewards," archeologist William N. Irving (page 8) was happily ensconced in the Yukon, excavating a site that could be related to local living inhabitants. As he describes in this issue, however, he was soon plunged into a world of Ice Age mammals and prehistoric bone tools. Additional information about these finds appears in "Pleistocene Archaeology in Old Crow Basin: A Critical Reappraisal," by Richard E. Morlan, in New Evidence for the Pleistocene Peopling of the Americas, edited by Alan L. Bryan (Orono: Center for the Study of Early Man, 1986). The same volume contains a chapter by Irving and chapters on a number of other sites in both North and South America. Irving is a professor of anthropology at the University of Toronto. Having done fieldwork in Canada, the United States, and Mexico, he is currently planning a project on Ice Age archeology in northern China.

Stefan Meyers (page 46) specializes in shooting game animals and birds with a camera and travels widely from his home in Konstanz, West Germany, in search of subjects. The European hare has been one of his favorite subjects for the past several years. And his favorite spot for seeing them is in southern Austria, near the Hungarian frontier, where he took these photographs using a Canon F-1 with an 800-mm lens. Meyers found the best way to get close to the excitable hares was to stay inside his car, some hundred feet away from his rutting subjects. Meyers will be visiting the United States later this year to take photographs of wild game in California and Arizona.

Barbara Smuts's passion for primates goes back to childhood, when she was inspired by Jane Goodall's work with chimpanzees. Smuts (page 36), in fact, began her dissertation work on chimpanzees, but in 1975 she and three other students were kidnapped from Goodall's research station in Gombe, Tanzania. After being released unharmed, she shifted to studying baboons in Kenya since Gombe was no longer open to non-Tanzanian researchers. Smuts was disappointed at first to find herself among baboons rather than chimps but soon learned that social relationships among these large, gregarious monkeys were every bit as fascinating as those among apes. Assistant professor of psychology and anthropology at the University of Michigan, Smuts extends her interest in primates to humans as well; one of her research and teaching goals is to encourage more women to become naturalists and to encourage feminists to incorporate concern for protection of wildlife into programs for social and political change. Readers wanting to learn more about baboons can turn to her book Sex and Friendship in Baboons (New York: Aldine, 1985). Smuts also recommends Sarah Hrdy's The Woman That Never Evolved (Cambridge: Harvard University Press, 1983), a general account of female-female and female-male relationships in nonhuman primates.
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While conducting research for her doctoral dissertation among Portuguese immigrants in Paris, Caroline B. Brettell (page 52) became curious about the impact on Portuguese society of emigration. Her interest in the Portuguese dates back to graduate school at Brown University in Rhode Island and the presence in that state of significant communities of Portuguese immigrants. In the late 1970s, the growing field of family history led Brettell (below, right) to launch a historical demographic project to complement her ethnographic research. This work resulted in a book, *Men Who Migrate, Women Who Wait: Population and History in a Portuguese Parish* (New Jersey: Princeton University Press, 1986), on which her present article is based. Brettell is project director and lecturer at Loyola University of Chicago. For further reading she suggests *Sons of Adam, Daughters of Eve*, by João Pina-Cabral (London: Oxford University Press, 1986).

"I wanted to work in the north, and I fancied working on a species of grouse," says Kathy Martin (page 62). "That pretty well narrowed it down to ptarmigan." Martin chose the willow ptarmigan as the subject of her dissertation and earned her doctorate in biology from Queen's University in Ontario in 1985. At that time, male parenting was the most notable and least explained aspect of ptarmigan behavior. Martin is continuing her study as a postdoctoral fellow jointly at the Boreal Institute for Northern Studies and the Zoology Department at the University of Alberta in Edmonton. She is shown here with her ptarmigan-spotter and field companion Tasha, an English setter. Her future plans include a comparative study of the white-tailed ptarmigan in the Colorado Rockies. Martin, who can hold her own on squash and basketball courts, is the author of several natural history articles and a book on a river system, *Watershed Red*. Although her heart is in the Arctic, she says that, "after a three- or four-month stint in the north, I savor such urban comforts as going to the theater, drinking cappuccino, and walking in my bare feet." Further sources of information on ptarmigan are Paul A. Johnsgard's *The Grouse of the World* (Lincoln: University of Nebraska Press, 1983) and A. C. Bent's classic *Life Histories of North American Gallinaceous Birds* (Mincola: Dover, 1932).

Art Wolfe's (page 92) interest in photography began with his first snapshot in 1968, but he didn't start photographing professionally until 1975, after he had received degrees in painting and art education from the University of Washington. For this month's "Natural Moment," he stationed himself some twenty-five feet away from the owls' nest and used a 300-mm lens. Wolfe, who lives in Seattle, spends eight months of the year in the field searching for prospective subjects. His first book of photographs was *Imagery of Art Wolfe*, and he is currently working on another devoted solely to owls. When not traveling or photographing, Art paints watercolor landscapes.
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Cover: A Hindu maid in northwestern Nepal pounds grain for a family wedding in which five Tibetan brothers will take one bride. Photograph by Thomas L. Kelly. Story on page 38.
A Puzzle Solved

Your article "Airlifting the Oaks" (October 1986) has solved a puzzle for me. Our farm was originally prairie, except the south edge, which was woodland. Even now we have three bur oaks in our south field, one-quarter mile from our homestead. What puzzled me for some time has been the number of bur oak seedlings and acorns found around our homestead, while the oak trees are so far away across open fields. Our squirrels plant our walnuts not over 200 feet out in the fields so I do not think that they would cross open fields so far and bring back acorns.

Twenty-five years ago I planted a row of American chestnuts and in ten years they had started to bear. For a few years we could harvest the nuts from a ladder by picking the open unopened burs. About eight years ago we harvested more than forty pounds of chestnuts from the nine trees by mounting a ladder on a loader attached to a tractor. Since then the burs have been out of reach, so we pick up the nuts as they ripen and fall. When the ripening season is hot and dry, the nuts ripen quite fast, and any wind will whip the branches enough to dislodge the nuts, which then fall to the ground. Our usual crop is about ten pounds, as the jays pick them from the opening burs. I thought that they were eating all of them. This past autumn the ripening season was cool and wet and not windy so the jays had plenty of time to harvest most of the crop, and we picked up only about a couple of pounds. The jays must have carried off more than fifty pounds!

For the last few years I have found chestnut seedlings, probably planted by the jays, coming up alongside stumps and trees, while the few planted by the squirrels come up in the open lawn.

William G. Frame
Northfield, Minnesota

This article made fascinating reading to a forester who has practiced for more than twenty-five years in Ohio. It explains the transport of oak acorns by birds to renesting areas that we have been seeing. But how to explain the northward travel of other heavy-seeded species like hickory and walnut? Birds don’t carry these far. Water transport can’t be the entire answer, as just about all major streams run north to south, against the grain of northward migration of these trees from their southern Ice Age sanctuaries.

I suggest that these and other species were carried northward and planted by a two-legged creature that moved them in giant steps covering hundreds of miles instead of the five and ten mile transport provided by the birds.

Tom Hennessy
Service Forester
Ohio Division of Forestry
Carey, Ohio

Jackdaws Versus Foxes

Stephen Jay Gould’s essay “The Panda’s Thumb of Technology,” with its accompanying history of QWERTY (January 1987), was both informative and humorous. Nonetheless, his concluding sentence is not the shortest sentence containing all twenty-six letters of the alphabet. The record holder is “Jackdaws love my big sphinx of quartz.” Somehow, knowing this seems to justify my extensive collection of The Guinness Book of World Records.

Ted Leather
Washington, D.C.

Plant and Animal Biases

As a longtime fan of Stephen Jay Gould (I assign many of his writings in my courses), I’m disappointed to see his zoological bias mar one of his articles: He says, “Biological evolution is a system of constant divergence without any subsequent joining of branches” (“This View of Life, January 1987). Alas, this declaration ignores much of plant evolution via amphiploidy. Some of the best direct evidence for speciation comes from chromosomal studies in plants. In fact, at least one new plant species has been “created,” via amphiploidy, and established in the wild.

My own bias, as a botanist, would be to say that since plants use all the evolutionary strategies that animals do (even altruism), plus many additional ones, we might better use plants as the main focus for teaching evolution.

Michael Wirth
Associate Professor of Biology
New England College
Henniker, New Hampshire

Getting the Author’s Goat

Robin Dunbar’s story about the goats of Rhum (November 1986) gave a nice comparison of ecology on Rhum with that of those islands where goats have become a nuisance. I raise goats and enjoy watching their behavior, day and night. Whether snug in caves, barns, or even sleeping outdoors at night, their eyes do not remain slitted like, but like other species, their pupils dilate and consequently become round. I realize it would be almost impossible to observe the eye of a feral goat at night!

Dorothy G. Tompkins
Charlottesville, Virginia

The author replies:

Of course, goats’ pupils do dilate in the dark, like everyone else’s! Having spent many a night peering at them through binoculars and with the naked eye under a low torch light, not to mention at those of several species of antelope in Africa, I should have known otherwise. You catch me fair and square, and I stand corrected, with nothing but a moment of literary enthusiasm as a defense.

The claim by Robin Dunbar that goats in the tropics have an easy time is simplistic. Goats on tropical islands, by virtue of
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greater forage production, achieve higher densities. However, they too stop growing in numbers as the habitat is filled (and destroyed). What does Dunbar assume happens to those individuals born into such a situation? Clearly, they perish, and presumably in even greater numbers than the goats on Rhum. In fact, if his claim that a nanny leaves four surviving young during her lifetime is correct, then the goats on Rhum are increasing at a rapid rate.

The claim that feral goats can produce twins twice a year and that the average nanny can produce forty-eight young during her typical lifetime is preposterous, as is his assumption of a typical twelve-year life span. In the literature on feral goats there are only a few instances reported of female goats giving birth twice within a twelve-month period, and it is by far the exception rather than the rule.

Feral goats in the tropics do not kid throughout the year with little sign of marked seasonality. In fact, in most areas they seem to kid in one to several distinct peaks with only a few stragglers during the intervening periods. There is some mention of this in the literature, and I have seen it on Santa Catalina Island ("Wild Goats of Santa Catalina," Natural History, June 1976), in the Galápagos, and on Curacao and Saint John's in the Lesser Antilles.

The anecdotal story about the "crazed he-goat" was pure science fiction. Snorting and foot stamping are part of the suite of alarm behaviors that goats employ. They are usually done when potential danger is observed but the precise identity of that danger is unknown. The "barely disguised intent" of this goat was purely in the imagination of the researcher. Furthermore, it is doubtful that this goat traveled clear across a bay to check out a huddled shape that it had seen. Goats are practically blind to distant figures that are not silhouetted or moving, unless there are bright colors involved. I've used knowledge of this scores of times by pressing myself against a tree trunk and allowing distant goats to approach within a few yards.

The author fails to demonstrate cognizance of the difference between density and population growth. Worse yet, giving legitimacy to feral goats in environments where they are not native is ecologically irresponsible.

Bruce Coblentz's comments on my analysis of population growth rates have little bearing on the point I was making. My point concerned the reproductive potential of goats in tropical habitats, not how they actually perform once density-dependent effects have stabilized the population. The problem with goats in benign habitats is precisely that they can achieve extraordinarily high reproductive rates. For habitats like those of many isolated tropical islands that lack large predators and whose plants have lost (or never had) the capacity to respond to the grazing impact of large herbivores, this is clearly a recipe for disaster. It would be biologically naïve, however, to insist that the reproductive characteristics of goats in such situations apply universally. Reproductive rates in any given population depend on both local predation levels and on the nutritional quality of the available forage. They may also depend on environmental factors such as climate. Tropical populations will often only be limited by food, but our very careful analyses of life history data from known animals in the Rhum population shows that this particular population is limited primarily by the severity of the winter weather. Even with optimal foraging conditions, they would be unable to match the reproductive potential of tropical populations. Thus, whether or not goats on tropical islands breed seasonally and whether or not these populations are at their carrying capacities is irrelevant to the point I was making. Incidentally, in his comments on my rough illustrative calculations of female reproductive rates, Coblentz seems to forget that half a female's offspring are male: population growth rates are a function of an individual's ability to replace itself by producing offspring of the same sex.

Coblentz objects to one of my "stories," insisting that a goat's eyesight is too poor to see a human being at 400 yards. He apparently confuses the ability to detect objects at such distance with an ability to recognize those subjects for what they are. This was precisely the point of my story: during the rut, males will go to anything that attracts their attention if there is the slightest chance that it might be a female. I might add, just for the record, that it was generally unnecessary to go to such lengths as Coblentz describes to conceal ourselves during fieldwork on Rhum: the population, all of whom were known individually, was moderately tame, and males in particular would often tolerate observers at fairly close range. Coblentz's objections to my deliberate anthropomorphisms in the sequel to this story are quaint but uninteresting: the second part of the story clearly has less to do with goats than with my own personal reaction to an unexpected predicament.

Finally, Coblentz asserts that I am being ecologically irresponsible by "giving legitimacy to feral goats in an environment where they are not native." Aside from the fact that at no point did I make any such implication (indeed, I made it quite clear that goats can and do cause considerable damage when conditions are favorable to them), it is unclear just what counts as a "native" habitat for a species that has never been "wild." Much of the goat's reputation for destructiveness is based on circumstantial evidence, presumption, and plain myth. Feral goats have not always been responsible for the destruction of habitats where they have been living, and it is biologically naïve to assume, as many do, that they must inevitably destroy any habitat in which they happen to occur (Rhum being an obvious case in point). Such simplistic views reflect badly on biologists, for they seriously underestimate the role that goats can (and do) play both in improving habitat productivity and as a source of protein in the Third World, where the human population is perpetually on the brink of starving to death. A little more sensitivity to the complexity in biological systems would make a major contribution to our ability both to conserve what little remains of the natural resources of this planet and to preserve human life.
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Voices from the Past

Beneath the seeming confusion of American Indian tongues lie clues to the migrations that populated the New World

by Merritt Ruhlen

When European explorers first reached the New World, almost five centuries ago, they found islands and continents already inhabited by a multitude of ethnic groups, most of which spoke their own distinctive language. In 1492 there were an estimated thirty to forty million Native Americans and more than one thousand different native languages. Today about six hundred of these languages are still spoken, although in many cases by only a few older speakers, the younger generation having switched to a national language (English, Spanish, or Portuguese).

During the past five hundred years, Native Americans have been studied by anthropologists, biologists, archeologists, linguists, and other scholars, who have asked, When did the ancestors of these people arrive in the New World? Where did they come from and how did they get here? (More precisely, How many different migrations were there, and how did each migration break up into smaller groups once in the New World?) The work of archeologists and biologists generally supports the conclusion that humans first entered the New World relatively recently, most likely by walking across the Bering land bridge, which linked East Asia and North America at various times between 20,000 and 10,000 years ago. Both disciplines have contributed to determining the relationships among living and prehistoric groups and to answering the question of how many migrations there were from East Asia. But these are areas in which linguistics excels.

The technique for grouping languages into families, and these families in turn into higher-level (that is, more ancient) families, was discovered more than two centuries ago. The technique is quite simple, involving nothing more than comparisons of basic vocabularies in a search for words that are similar in sound and meaning. A basic vocabulary includes those words, such as pronouns and the names for parts of the body, that linguists have found to be highly stable, often being used for thousands of years with little change in sound or meaning. For example, the English word hand is almost identical in both sound and meaning with German Hand, Dutch hand, Swedish hand, Danish hånd, and Gothic (now extinct) handus.

There are three possible ways in which to explain the similarities in this example: coincidence, borrowing, or common origin. Although a few such resemblances might be the result of coincidence, the parallels in numerous other words in these same languages make coincidence mathematically improbable. Borrowing is unlikely (although not impossible) since basic words such as hand are seldom borrowed. Conceivably such a word might be borrowed from one language to another, but it is unlikely that it would be borrowed into many different languages. Instead, the usual explanation for these similarities is that the different words for hand have a common origin, that is, they are all cognates derived from a single word in a single language that was spoken in the past. On historical grounds, linguists estimate that this language was spoken more than two thousand years ago. They call it Proto-Germanic, and the languages that are its descendants, including those mentioned above, are said to belong to the Germanic family of languages. (The similarities among cognates are generally not as obvious as those in this example, but linguists, who are aware of the common paths of change in sounds and meaning, can often recognize cognates that, to the lay person, seem different.)

Further examination of the basic vocabulary in the Germanic languages reveals that there are also words that are similar in sound and meaning to words in other language families, such as the Romance family, which contains the modern-day descendants of Latin (including Rumanian, Italian, French, Spanish, Portuguese); the Slavic family (including Russian, Polish, Bulgarian); the Celtic family (including Irish, Welsh, Breton); Greek, Albanian, Sanskrit, and others (a single language such as Albanian can also be a family in this sense). In all these different families, the first-person pronoun is characterized by the consonant m (for example, English me, French moi, Russian men'я, Old Irish -m, Greek eme, Albanian mua, Sanskrit mām, Hittite annuₖ). In these same languages, the second-person pronoun usually begins with r (for example, English thou, French tu, Russian ty, Old Irish tú, Greek su, Albanian ti, Sanskrit tuvāṃ, Hittite tuk₆). In addition to such fundamental grammatical resemblances, many of the basic lexical words in these families are also related. For example, all the following words are commonly accepted as cognates: English heart, Latin cord-, Russian сердце, Old Irish cride, Greek καρδία, Hittite kart-. As a result, linguists have concluded that all of these language families—Germanic, Romance, and so on—belong to an even more ancient language family known as Indo-European. Linguists estimate that the common language from which they all derive, Proto-Indo-European, was spoken more than five thousand years ago. As is apparent from these examples, Germanic cognates are easier to recognize than Indo-European cognates. This is not surprising, inasmuch as Indo-European languages have had five millennia to change in various directions, while Germanic languages have had less.
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than half that time to develop their own idiosyncrasies.

The details of the Indo-European family were worked out during the nineteenth century. At the same time that European scholars were classifying the languages of Europe and Asia, similar research was going on in the New World—and not without success. Many low-level groups, comparable to Germanic, Romance, or Slavic, were recognized. Such groups include Siouan, Athabaskan, Iroquoian, Chibchan, Arawakan, Ge, and dozens of others. During the first three decades of this century, anthropologist Alfred Kroeber and linguist Edward Sapir proposed sweeping consolidations in the classification of North American languages, uniting many lower-level families into more ancient groupings, comparable in time depth to Proto-Indo-European or even earlier. Examples of these more ancient groupings include Na-Dene, Penutian, and Hokan. In 1929 Sapir proposed, without explicit evidence, that the languages of North America belonged to only six independent families.

During the ensuing decades, however, a reaction against Sapir’s 1929 classification set in until, by the 1970s, specialists in American Indian languages were almost unanimous in dismissing his proposals, returning to a taxonomic position little altered from that of the nineteenth century. For South America, meanwhile, no higher-level groupings had even been proposed. The number of independent families there grew ever larger as more and more tribes were contacted, and there were more than one hundred by the 1950s, all supposedly unrelated to one another.

In 1950, although European and Asian languages had been reduced to a fairly small number of well-circumscribed families, the number of such families in both Africa and the New World measured in the hundreds, and the overall classification in both areas was poorly understood. At this point linguist Joseph Greenberg took a fresh look at African classification and concluded that all African languages could be grouped into but sixteen families. In 1955 he reduced these sixteen to nine, and in 1963, to only four. Despite some initial criticism, this scheme has formed the basis for all subsequent work on the classification of African languages and has proved reliable in all but a few details. Greenberg’s method was conceptually simple but enormously time-consuming. What he did was to collect word lists (roughly three hundred of the most stable words) for as many languages as possible, comparing them to identify cognates. Upon completing the first round of African classification in 1954, Greenberg decided to apply the same techniques to the languages of the Americas. After surveying the available evidence, he announced at an international congress in 1956, although without giving supporting data, that in his view the native languages of the New World belonged to only three separate families: Eskimo-Aleut, Na-Dene, and Amerind. During the next three decades Greenberg continued to collect word lists from as many New World languages as possible, and just this year he has published his evidence, both for the tripartite classification of New World languages and the division of the large Amerind family into eleven branches.

The evidence consists of grammatical peculiarities and some two thousand etymologies, or sets of cognate words. Of the

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**Linguistic Families in the Americas**

![Map of Linguistic Families in the Americas](image)

*New World languages fall into three families: Eskimo-Aleut, Na-Dene, and Amerind. Amerind is the most diverse (and probably most ancient) of the three families, each of which originated from a different tongue. The Amerind subdivisions of South America (oranges, reds, and pinks) are closely related to one another, as are the majority in North America (greens); Central Amerind (yellow) is in a class by itself.*

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etymologies, 329 serve to connect two or more of the Amerind subgroups and some roots are in fact found in every Amerind subgroup. Just as the Indo-European languages are characterized by first-person \(m\) and second-person \(t\), Amerind languages are characterized by first-person \(n\) and second-person \(m\).

**Some Basic Vocabulary in the Amerind Language Family**

**Woman:** Sahaptin asam, Huastec irum (woman, wife), Central Sierra Miwok 'asaa (wife), Cayapa suna (wife), Chilanga sung, Eten sonang.

**Dig:** Seneca oka (make a hole), Kutenai k'u (hole), Tullamook kuji, Toa ko, Motilon oka (hole), Pedraza kui, Bintuca kui (dig up), Paez xxw, Shipaya ikua (hole), Meinacua aeo (hole).

**Good:** Biloxi cema, Southeast Pomo rama, Santa Barbara suna, Chiquimulilla cama, Canichana cemač (beautiful), Apolista suna, Mekens t'ame (beautiful).

**Finger:** Karok tiik (finger, hand), North Pomo tek, Santa Rosa dixi, Jibaro tikij (one), Itene taka (one), Katembrì tikà (toc), Yuracare tečé (thumb), Yagua tik (one), Kukura tikùa, Tri'o tinki (one), Botocudo ēkù (one).

**Dog:** Achomawi kwan (silver fox), Yana kuwan (lynx), Tonkawa e'kuwan, Yurimagui kwun, Popoloça kuniña, Ixcaté 'uninni, Chatino chêni, Chilanga ak'uan (deer), Tarascan axunti (deer, animal).

The major result of Greenberg's work has been the demonstration that all the languages of the New World for which there is sufficient documentation may be classified into three families (if other languages, unrelated to these, were once spoken in the Americas, they have vanished). Since, with the exception of a few Eskimo dialects that have migrated back to Asia, all the subgroups of these three families are confined to the New World, a further conclusion is that all the internal divisions in each of the families took place in the Americas.

The relative positions and sizes of the distributions suggest that there was first an Amerind migration, followed by Na-Dene and Eskimo-Aleut migrations, in that order. The fact that the Amerind family is more disparte than the Na-Dene family, which in turn is more disparte than Eskimo-Aleut, points in the same direction. Linguistic analysis does not, however, provide a reliable estimate of the absolute dates these migrations took place.

The tripartite classification does not in itself prove that there were three distinct migrations from Asia. A single migration, with subsequent differentiation into three families in the New World, is a logical possibility. So, too, are two migrations, with one of them later splitting in two. At most we can conclude that there were not more than three. Yet, there is strong evidence for three migrations in that each of the three New World families appears to be more closely related to language families in the Old World than to either of the other two New World families.

Specifically, Eskimo-Aleut is most closely related to the Indo-European, Uralic, Altaic, Aino, Gilyak, Chukchi-Kamchatkan, Japanese, and Korean languages, all members of an ancient linguistic family that Greenberg calls Eurasiatic. Some other scholars recognize a similar, but not identical, language group that was originally postulated by the late Soviet scholar V.M. Illich-Svitych, who called it the Nostratic language family.

The Na-Dene family appears to be genetically closest to a different set of Old World language families, namely Sino-Tibetan, Yeniseian, (North) Caucasian, Bursushaski, Basque, and possibly the extinct languages Etruscan and Sumerian. Evidence in support of this family, which is known as Dene-Caucasian, has only recently been published by Soviet scholars.

The origins of the Amerind family are the most baffling, but there are a number of apparent cognates with language families in Africa, Europe, Asia, Australia, and Oceania. For example, the root *tiik*, meaning "finger, one, to point," is found in Africa, Europe, and Asia, as well as in the Americas. The Amerind words for dog bear a striking resemblance to the Proto-Indo-European word, which is usually reconstructed as *kwon* (reconstructed forms are customarily marked with an asterisk). Illich-Svitych cited similar forms from Uralic (*küünä*, "wolf") and Afro-Asiatic (*k'ijin*, "dog, wolf"). Other Amerind roots also found in the Old World include *mumu*, "bee, fly," which may be compared with Proto-Indo-European *mu,* "fly," and Amerind *pal,* "two, dual," which is also widespread in Africa, Europe, Asia, and Australia. The significant number of such global cognates leads some linguists to conclude that all the world's languages ultimately belong to a single language family. Research in support of this bold hypothesis is currently being carried out by Greenberg, Vitaly Shevoroshkin of the University of Michigan (in collaboration with other linguists in this country), Aaron Dolgopolsky of the University of Haifa, and a team of Soviet scholars working in Moscow under the leadership of Vladimir Dybo.
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This View of Life

Hatracks and Theories

*What* don't stamp collecting, *Trivial Pursuit,* and the science of taxonomy have in common?

by Stephen Jay Gould

Since people so easily confuse names with meanings, a motley horde—including bureaucrats, profiteers, and the merely insecure—have tried to elevate the ordinary to the sublime by timely redesignation. Ed Norton, pal of Ralph, the bus driver in "The Honeymooners," liked to call himself a "subterranean supervisor" but would admit, when pressed, that he worked in the sewers.

Hobbyists also like to construct fancy names derived from classical sources for their avocation—in part to promote the aura of arcane knowledge, but largely to justify the devotion of such passion to an enterprise that the rest of humanity might regard as trivial. Stamp collectors are philatelists; coin collectors, numismatists.

Perhaps the hobbyist can justify his tactic of hiding behind fancy names after all, for the ordinary designations are often used as terms of reproach. When the purveyors of modernism in molecular biology wish to play the parochial game of one-upmanship against naturalists who pursue the science of taxonomy, they often dismiss us as "stamp collectors"—a designation deeply resented by this former philatelist (hinge licker).

The image called forth by this derogatory metaphor compares stamps with organisms and stamp albums with systems of classification. The activity of classifying organisms cannot be real science, for it reduces to the simple mechanics of pasting stamps into their proper, pres-
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signed locations. Nature is a hatrack or a system of pigeonholes; taxonomists merely place objects upon their proper hooks or into their designated cubicles.

Taxonomists respond that this image not only denigrates but also completely misrepresents what we do. Places are not preassigned in an unambiguous and easily identifiable natural order. Systems of classification are not hattracks, objectively presented to us by nature. They are dynamic theories developed to express particular views about the history of organisms. Evolution has produced a set of unique species ordered by differing degrees of genealogical relationship. Taxonomy, the search for this natural order, is the fundamental science of history.

I suggest a test for my claim that taxonomies are dynamic theories, not neutral hattracks for hanging the products of nature: study the history of classification for a given group. Do changes through time merely record the discovery of new items added to an unaltered objective framework (the hatrack or, if you will, philatelic model) or do the alterations of history reflect basic changes in our understanding of the causes of natural order?

A common claim seems to support the philatelic model—and this essay therefore focuses on a case that refutes the claim. We are often told that the introduction of evolutionary theory in the midnineteenth century provoked little or no change in systems of taxonomy. Evolution merely supplied a different cause for a structure previously attributed to God’s direct will—but Darwin’s revolution did not alter the structure itself. We didn’t need evolution to learn that whales are mammals and not fish; Darwin’s world did not change the classes of vertebrates or the phyla of animals.

If this claim were true, the philatelic model would win strong support. After all, if the greatest conceptual transformation in the history of biology did not alter the structure of classification, then taxonomies must only record some basic facts of nature, so evident in their objectivity that they stand impervious to the deepest theoretical debates about their cause.

I propose to test the philatelic claim by examining one of the greatest works of creationist taxonomy and asking whether the author’s underlying belief in creation led to taxonomic procedures and conclusions different from those that evolution would later suggest.

Louis Agassiz’s Recherches sur les poissons fossiles ("Research on Fossil Fishes") was the most comprehensive pre-Darwinian work in vertebrate palentology. As a hyperenergetic beginner seeking both fame and truth, the young Swiss naturalist conceived an audacious plan to describe all the world’s fossil fishes. Agassiz and his artists worked for more than a decade (1833–43) to produce a massive work in five oversized volumes of text, accompanied by an even larger atlas of 391 plates, including some of the finest work in the entire history of scientific illustration (and representing one of the earliest uses of color lithography).

For a bad reason that distorts history—the differential change of perceived value in text and plates—Les poissons fossiles is generally regarded today in a purely antiquarian context as a superb objet d’art (for its plates), burdened with a superficial and unreadable text. As such, Agassiz’s work has become one of the great collectibles among bibliophiles of natural history and complete copies can command five-figure sums.

Such a view misrepresents both Agassiz’s status and the impact of Les poissons fossiles. Agassiz was a young man on the make—the Watson and Crick of his time all rolled up into one man who spent a decade coursing through Europe seeking the meaning of life in nature’s divinely created order. Agassiz, in his day, never had to face the Dangerfield dilemma of getting no respect. Taxonomy was the forefront science of his time; any ambitious neophyte could tell you that the order of life’s history through time represented the language and logic of God’s own thoughts.

Les poissons fossiles was the cornerstone of Agassiz’s remarkable career, and the immediate cause of his relocation to America, where he established natural history as a front-rank science and built the museum that I now inhabit. Moreover, the plates that we now view only as works of art, done with precision and beauty for aesthetic or commercial motives, were the chief tool of his scientific modernism—the analogue of computers and scanning electron microscopes today.

Taxonomy is a comparative science; species are unique historical entities linked together by differing degrees of relationship. Since you can scarcely transport all fossil fishes to one center, you must visit various museums and private collections armed with accurate illustrations of material from other places. Today, we carry photographs for this primary activity of comparison; Agassiz used the scrupulously accurate drawings that later became plates of Les poissons fossiles. Just as the cost of, and indenture to, fancy equipment often directs or ruins scientific careers today, the plates of Les poissons fossiles were Agassiz’s undoing.
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He established his own lithographic press and printing business in Neuchâtel and brought all his artists and lithographers to live in his house and share his meals. The press eventually went bust, and his first marriage crumbled as his wife became progressively embittered by the conversion of their home into a scientific factory. Agassiz relocated in America to escape his creditors and his domestic troubles.

*Les poissons fossiles* describes 1,700 species of fossil fishes, more than ten times the total of all fossil vertebrates enumerated before Agassiz began his work on fishes alone. His new classification of fishes is the ordering principle of his five volumes—one of introduction, and one for each of the four great groups that he recognized in his taxonomy.

Agassiz presents the epitome of his system in a chart at the end of volume one. This chart follows the conventions of palaeontological illustration. The vertical dimension is time. The width of each lineage is a measure of its abundance at any past time. Lineages are placed on the chart by order of natural relationship—proximity for close connection, greater distance for progressive disparity.

Charts like this often fool readers into thinking that Agassiz stood poised on the verge of accepting evolution. After all, we reason, if he simply had connected the groups, he would have produced an evolutionary chart. And he does come ever so close—as if he longed to be an evolutionist, allowing the groups to curve lovingly toward each other but never quite making that final connection. Agassiz even calls his chart a "genealogy of the class of fishes."

It has become something of a tradition in the popular literature on Agassiz to lament that such a great thinker came so close to the truth but could not make the final break with tradition. Lynn Barber, for example (in *The Heyday of Natural History*, Doubleday, 1980), writes that Agassiz’s work “positively shrieked with evidence of evolution.”

This common claim is quite off the mark. (I can sympathize with its misguided motivation as a desire to view a fine man with a tragic flaw in a better light, but past scientific greatness is not measured by consonance with modern ideas. Agassiz deserved his status for the coherence of his own system, even though we reject its premises today.)

In fact, this final chapter presents one of Agassiz’s most spirited and consistent defenses of creation as the basis for a “natural” arrangement of organisms. He directly defends his decision not to join his subgroups into a tree of true descent (vol. 1, p. 170):

Nevertheless, I have not tied the lateral branches to the principal trunks because I believe that they do not descend, one from the other, by paths of direct procreation or successive transformation, but that they are materially independent, one from the other,
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Safe energy for a secure future

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although each forms part of an integrated taxonomic ensemble. The links in this ensemble can only be sought in the creative intelligence of its author.

Agassiz defends creationism by an argument that he maintained steadfastly throughout his life, from this expression as a biological consensus of his youth to his lonely support as an old man, abandoned by his own students but bitterly keeping the faith against a Darwinian tide (Agassiz died in 1873). Agassiz argues that species of fossil fishes occupy fixed geological ranges that never extend beyond one major unit of our time scale. Species appear without ancestors, remain stable throughout their range, and die without descendants, often in catastrophic moments of mass extinction that may exterminate all life prior to a subsequent divine restoration in new form. Agassiz writes (vol. 1, p. 172):

The more than 1500 species of fossil fishes that I have come to know tell me that species do not pass insensibly from one to another, but that they appear and disappear without direct connection to their predecessors in time, Agassiz means, not ancestry . . . . All these species have a fixed time of appearance and disappearance; their existence is even limited to a determined time.

As for varying degrees of taxonomic affinity (rays standing closer to sharks than either do to trout, for example), Agassiz interpreted the entire Linnaean system, with its hierarchies of interrelated groups, not as an expression of historical change, but as a manifestation, or material embodiment, of the structure of God's mind. Each species is the incarnation of a single divine idea, and the interrelationships of species therefore display the order of God's thoughts. Taxonomy is the highest science because it provides our clearest insight into the mentality of divine power.

Do we not have [in the taxonomic and geological order of fossil fishes] the manifestations of a thought as powerful as it is fruitful; the acts of an intelligence as sublime as it is foreseeing; the marks of a goodness as infinite as it is wise; the most palpable demonstration of the existence of a personal God, the first author of all things, governor of the entire world, and dispenser of all welfare? This, at least, is what my feeble intelligence reads in the works of the creation when I contemplate them with a thankful heart [vol. 1, p. 172].

Agassiz certainly pours out his creationist convictions, but did they influence his chosen taxonomy directly? Did his creationism impose a taxonomic order different from one that evolutionary theory could support? If the answer to this question is no, then the philatelic model may hold, and taxonomy may not transcend the assignment of species to proper places in the album of nature. But if the answer is yes, then taxonomic schemes are theories of relationships that provide insight into the causes of natural order.

Agassiz divides all fishes into four orders, primarily on the basis of differences in the structure and pattern of their scales: placoids for sharks and their relatives; ganoids for fishes with heavy, and usually angular, scales, covered by enamel; ctenoids for higher bony fishes bearing scales with comlike dentifications at one edge; and cycloids for higher bony fishes with round and thin scales (as in our "ordinary" view of a quintessential fish scale).

We all recognize today that this system embodies several key mistakes. Agassiz included the earliest jawless fishes with sharks, but jawless fishes are probably the ancestors of all later fishes. His ganoids are a "wastebasket" of generalized forms, falsely linked by the negative criterion of lacking certain features evolved by later groups (we do not unite cats with rats because neither evolved wings, but bats did). His cycloids and ctenoids represent an invalid division of the single great group of teleosts, or higher bony fishes. But these, and several others not detailed here, are not the errors directly inspired by creationist convictions. Rather, they are the kinds of mistakes that any pioneer must risk. Nobody can hope to get anything so complex completely right the first time. Our general verdict on Agassiz's basic system must be, not bad for a first try.

However, Agassiz's taxonomy of fishes also includes two deeper errors of procedure that did flow directly from his creationist view of life: his criteria for arranging subgroups within each of his orders, and the justification for his fundamental decision to use scales as the basis of classification.

The arrangement of subgroups: Note, on Agassiz's chart, that one or two groups within each order are distinguished as "central" by their more prominent letters, their middle position in the array of names, and the drawing of their lineage through time as a straight stick, toward which other lineages bend. We might easily be fooled by our own evolutionary assumptions into viewing these central, or focal, groups as ancestors, or at least as primitive and generalized designs from which other groups might be derived by specialization of certain parts. If Agassiz had designated his focal groups by these criteria (however differently justified in his creationist view of life), we might conclude that evolution makes no difference in classification but merely of-
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fers a new interpretation of central status. But Agassiz defined these focal groups by a creationist criterion that no evolutionary taxonomist could follow in principle. These foci are neither precursors nor hypothetical models (archetypes) of ancestors; they are, rather, groups that lie closest to the essence, or abstracted ideal form, of the larger group. Thus, although we might be tempted to read Agassiz's focal and lateral groups as ancestors and branching descendants (and therefore view his taxonomy as prone to a later evolutionary reinterpretation), Agassiz's arrangement cannot be translated into such Darwinian language—for focal and lateral, to him, are essences and progressive degrees of departure, and these definitions cannot be recast in evolutionary terms.

Consider, as examples, the two focal groups for his "highest" orders, the cycloids and eocentids. Agassiz lists "Gadoïdes" (codfish and their relatives) as the focus of cycloids. But note that Agassiz's gadoïdes have no fossil record at all, and the lateral groups do not converge toward a potential ancestor but toward an ideal form for the order as a whole. The "Percoïdes" (perches and their allies), focus of the eocentids, do have a fossil record predating all lateral groups within the order—and could be read as ancestral on this basis. But Agassiz's own justification for focal status precludes such an interpretation. Perches, to him, are central because they are the actual eocentids closest in design to the "common species," or abstracted ideal for the group. Agassiz writes (vol. 4, p. ix) that the perches' "more or less intimate affinity with the common species...has guided me in all the successive degrees of approach that I have established [for other groups to this focus]."

Scales as the basis of classification: To understand Agassiz's key decision to base his taxonomy of fishes on the form of scales, we must document a major change in conviction that occurred early in his own career. During his university studies in Munich, Agassiz became enthralled with the teaching of Lorenz Oken. He wrote:

[Oken] exercised an almost irresistible influence over his students...It seemed to us who listened that the slow, laborious process of accumulating precise detailed knowledge could only be the work of drones, while a generous, commanding spirit might build the world out of its own powerful imagination.

Oken was a leader of the romantic movement in biology known as Naturphilosophie. These scientists based their view of life, and their classifications of organisms, upon a search for simple laws of change that would unite creatures as steps along pathways of progressive elaboration. (Some interpreted these pathways as ladders of evolutionary descent; others, like Oken, as unconnected stages of an ideal sequence.)

Oken's classification of fishes reflects his preoccupation with simple laws of progressive advance (yet another example of taxonomies as theories of order). In his *Lehrbuch der Naturphilosophie* (1808—11), Oken arranges all fishes in a single ladder of thirteen steps placed into five orders, each higher than the one before. Since fishes form the rung that connects invertebrates with reptiles on life's larger ladder, Oken arrays his fishes into a sequence marking successive stages in this progressive transformation. The jawless lampreys occupy rank one "since they remind us in every respect of the worms by their naked, mucous, and lineiform body, with indistinct head, almost devoid of bones..." Sharks inhabit the summit at rank thirteen because their complicated genitalia and ovoviviparous reproduction (eggs hatched within the mother's body) recall the shape of things to come in advanced vertebrates.

Agassiz regarded his later rejection of this tradition as the turning point in his maturation as a scientist. The instigator of Agassiz's academic crisis was the greatest zoologist of the early nineteenth century, Georges Cuvier. Agassiz owed more to Cuvier than mere intellectual inspiration. For years, Cuvier had planned and partly executed the complete monograph of fossil fishes that Agassiz later produced. With the audacity of youth, Agassiz arrived in Paris at age twenty-five to seek audience with Cuvier, in the hope that he might induce the Aristotle of French biology to surrender his project in Agassiz's favor. (Agassiz, at that time, had written one work on the fishes of Brazil and had cleverly prepared for his Parisian assault by spending several months at German museums, drawing and describing fossil fishes that Cuvier had never seen.) Agassiz's plan worked. Cuvier was captivated by Agassiz's rare combination of intelligence, loyalty, dedication, charm, and chutzpah. He also realized, no doubt, that he never would have time to complete such a project himself (in fact, Cuvier died a few months later). After a few weeks of probing and testing, Cuvier surrendered his project to Agassiz and gave all his descriptions and drawings to his younger colleague.

Cuvier vigorously opposed Oken and the entire romantic school. He regarded
their search for simple laws of organic progress as a misguided venture in untestable speculation—as a fitting of facts to preconceived theory. He advocated instead a rigorous empiricism, based on careful observation. One cannot, however, observe properly without some theory to test (if only to guide a diligent search for exceptions that might disprove the theory itself).

Cuvier’s theoretical convictions centered upon the strict correlation of organic design with the functions performed by each animal. To Oken, function was a diversion from the noble aim of linear progress. A giraffe might grow a long neck, an aardvark a long snout, for reasons related to feeding or some other immediate function. But such particulars are peripheral to life’s true goal of advancing order. To Cuvier, function was the essence and cause of design. Anatomies are precise reflections of function—and classifications must therefore be based upon functional groupings.

Moreover, Cuvier developed this functional perspective as the centerpiece of his creationist convictions. Animals are so precisely and optimally designed for their designated functions that any change is impossible. If one part changed in order to perform a different function, absolutely every other part would require a redesign in order to insure functional optimality for the new role. Since such pervasive alterations are unthinkable (and small changes in single parts impossible), evolution cannot occur.

Agassiz—for reasons of loyalty and conviction—became a disciple of Cuvier’s system. He was determined that the cornerstone of his career, his legacy from the great Cuvier himself, would reflect the true philosophy of his benefactor. Agassiz therefore set out to establish a functionally based classification of fishes that, following Cuvier, would be rooted in the impossibility of evolution.

Agassiz defended on these functional grounds his primary decision to use scales as the basis for a classification of fishes. He wrote, following Cuvier’s dictum, that “the entire [morphological] organization is only the manifestation of the mode of life appropriate to each being” (vol. 4, p. xv). He claims that he chose scales as a key character because they are the boundary between external environment and internal design. Since they face the outside world directly, scales must record the intricate functional adaptation of each fish to its environment. But, following Cuvier’s principle of the “correlation of parts,” scales must also determine the internal structure of skeleton and organs. “A very
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Intimate correlation exists between the
conformation of the scales and that of the
skeleton” (vol. 4, p. xvi). Scales therefore
mediate between the morphological en-
semble inside (the data of taxonomy) and
the functional needs of the outside envi-
ronment. They “may be envisaged as the
surface reflection of everything that
passes from the interior to the exterior of
the fish” (vol. 1, p. 59). Agassiz explicitly
defends this functional view against a
charge that classification by scales is an
artificial device for imposing false order
upon unresolvable complexity:

I insist primarily upon the structure of the
scales, a character which might appear to
be of little importance at first approach, but
which I hope to be able to establish as the
exterior reflection of all organization, by
showing the intimate relationship that ex-
ists between the structure of scales and the
form of certain parts of the bony skeleton;
at the same time, I shall make known how
the skeleton is the frozen expression of the
phenomena of life [functions] manifested
in the formation of species (vol. 4, p. x).

For all of Agassiz’s brave words, he
presents very few arguments for specific
ties of correlation between scales and in-
ternal bones. We suspect that taxonomy
by scales may have been more for conven-
ience than by proven conviction—yet
Agassiz’s personal need for incessant jus-
tification on (somewhat hokey) functional
grounds does record the strength of his
dedication to Cuvier’s program. (The ex-
tent of a bias, after all, is best demon-
strated when arguments in its favor must
be forced upon unwilling data.)

The practical imposition of Agassiz’s
functional views upon his classification
lies in a domain more detailed than his
criterion of division into four orders by
scales. We see the direct impress of his
creationist conviction (in the Cuvierian
mode) in the hundreds of smaller deci-
sions that he makes for the formation of
subgroups within his four orders. Many of
Agassiz’s subgroups are functional associ-
ations of fishes that work in the same basic
way, not the genealogical groups that
modern taxonomists seek to establish.

The error of basing taxonomic associa-
tions on functional groupings is easy to
grasp from an evolutionary point of view.
Ways of making a living (function) are
few; lineages are many. Consequently,
organisms of radically different descent of-
ten look very similar—a phenomenon
known as convergence—because they
have adapted to a similar mode of life in
the same basic way. Most of the classical
dilemmas of taxonomy arise when we mis-
take similarities evolved separately by
correlate evolution for historical ties of
genealogy. When converging organisms
are sufficiently unlike, we sort them out
with little trouble—we recognize bats as
mammals and pterodactyls as reptiles,
even though their wings share strong simi-
larities of aerodynamic design with those
of birds. But when converging organisms
are closely related, the separation of simi-
larities by descent from similarity by con-
vergence can be very tricky. (One recent
report, for example, argues that the
Megachiroptera, large fruit-eating “bats,”
are actually closer by descent to primates
than to true bats.)

Agassiz, in the absence of this frame-
work based on evolutionary theory, often
defined his subgroups explicitly by com-
mon function—the greatest no-no of mod-
ern taxonomy. Many of his associations
are mixtures of members from radically
different lineages, incorrectly united by
their superficial similarity of function.
Yet Agassiz purposely used this criterion
and even defended groups so defined as
the most securely established of all.

For example, he unites as Anguil-
iformes (eels) all teleost fishes that have
come elongated by reason of functional
similarity. He notes important differences
among the several kinds of “eels” but de-
defends their union by writing (vol. 5, p.
129):

But as all these differences are subordi-
nated to a more preponderant general char-
acter—the length of the body—that deter-
nines the general physiognomy of the
family, I envisage the family of the
Anguilliformes as one of the most natural.

Yet, by modern reckoning, Agassiz’s
eels are a frightful mixture of creatures
from all over the proper taxonomic map of
teleosts—including the gymnoids (knife
fishes) of the carp and catfish lineage;
synbranchids (swamp eels); members of
the percomorphs, or perchlike, fishes; and
Ophidium (the cuskeel), of uncertain affin-
ity, but not close to true eels. (I thank
Melanie Stiassny for these details of aqua
incognita to me.) In fact, Agassiz’s het-
rogenous “eels” represent a classic case of
improper grouping by functional conver-
gence rather than by genealogy.

Evolutionists, of course, are interested
in function. Natural selection works by
adapting the forms of organisms to altered
environments. But evolutionists explicit-
ly avoid such functional characters in their
classifications because they realize that
separate lineages may be similarly modi-
fied by common directions of adaptation.
Evolutionary taxonomists work in a pre-
cisely opposite way from Agassiz. We
avoid marks of immediate function as
sources of convergence; Agassiz sought
these very characters as signs of deepest affinity in the light of Cuvier's creationist principle that function determines the essence of organization. Thus, Agassiz's creationism did structure his taxonomy—and the introduction of evolutionary theory did establish new goals and procedures that altered both the practice and content of classification. No one ever put the central issue more clearly than Darwin himself in the chapter of the Origin of Species (1859) devoted to the influence of evolution upon taxonomy:

On my view of characters being of real importance for classification only in so far as they reveal descent, we can clearly understand why analogical or adaptive character, although of the utmost importance to the welfare of the being, are almost valueless to the systematicist. For animals, belonging to two most distinct lines of descent, may readily become adapted to similar conditions, and thus assume a close external resemblance; but such relationships will not reveal—will rather tend to conceal their blood relationship to their proper lines of descent [p. 427].

In direct contradiction to Agassiz's fundamental belief about classification, Darwin argues that taxonomy must be based on nonadaptive characters that reveal historical connection:

We choose those characters which, as far as we can judge, are the least likely to have been modified in relation to the conditions of life to which each species has been recently exposed [p. 425].

My message is not the wishy-washy relativism of "I'm OK, you're OK"—a good position for the ethics and sympathy of human relationships, but scarcely a motto for science. I do not say, "Agassiz had his way, we have ours, our descendants will have theirs. Each will reflect its own theoretical assumptions, as taxonomies must because they are not stamp collections—and isn't it nice that the human mind can invent so many different but coherent systems?" My own reading is more stark and, I fear, less forgiving. Agassiz was wrong—and he was wrong because he based his classifications on an incorrect principle for the ordering of life: a brand of creationism that defined natural affinities by common function. We will never attain final truth, but our classifications are better than his—not only because we have learned many details about fishes in the intervening century but primarily because evolution is both true and also the underlying cause of order among organisms.

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

* A microscopic ménage à trois may be responsible for a major step in evolution

by Dorion Sagan and Lynn Margulis

Named for its flowing, ever-changing form, *Amoeba proteus*, a one-celled microbe with a nucleus, represents in its tiny body a whole modern tale of transmutation. A writhing, jellylike mass, such an organism probably inspired that genre of low-budget horror films exemplified by *The Blob*. In real life, amoebas are usually predictable creatures. So it came as some surprise to Prof. Kwang Jeon of the University of Tennessee when, upon looking through his microscope, he realized his amoeba collection was going through a major epidemic. Approximately 150,000 dots were seen in each amoeba, and each dot was a perfectly normal-looking bacterium. These bacteria had not been there before. Now they were growing inside the amoebas and killing off Jeon’s collection. He picked out the least sick amoebas and kept a record of their progress over the next several months. Those that were apparently more resistant to the invaders returned to health and began growing by division at almost their former rates. Jeon examined these survivors and found that each still contained the foreign bacteria but far fewer of them—some 40,000 in each amoeba. Had *A. proteus* somehow transmuted, incorporating the invaders into its own system? Had infector and infected merged?

To the question, “Can the nucleus of the amoeba cell now live without the former pathogenic bacteria?” the answer turned out to be “No.” When Jeon transplanted the nuclei of infected amoebas to amoebas lacking the bacteria, the hybrid amoebas died in about four days. Yet if at the very last moment he reinjected these hybrids with the once-lethal “parasites,” the amoebas revived and grew. Today, the mutual beings are alive and well and living in Knoxville, Tennessee.

Jeon caught evolution in the act. What is more, the evolution of a new organism occurred by symbiosis, not by accumulation of mutations. Furthermore, the new amoebas evolved not over millions of years but in eighteen months, which geologically speaking is instantaneous. Natu-
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ral selection eliminated not competitors but competition itself. After the smoke had cleared, only symbionts—bacteria and amoebas that could work and live together—survived. (We should not be surprised. The deadliest parasites destroy not only their hosts and habitats but also their own chances for continued survival.)

Jeon’s tale of two microbes hints at the answer to a major evolutionary puzzle. Of all the missing links in evolution none is more profound than the gap between eukaryotes, cells with nuclei, and all bacteria, which lack nuclei. The difference between bacteria and any nucleated cells makes the difference between people and apeslook negligible. Plant and animal cells have far more in common than do bacteria and nucleated cells. Cells with nuclei contain up to a thousand times...
more genetic material than their smaller relatives. This material is tightly coiled into chromosomes that are contained in a membrane-bounded nucleus.

Nucleated cells divide by a complex “dance of the chromosomes,” during which the chromosomes pull the hereditary material to opposite ends of the cell and then divide. Bacterial cells simply split apart: they don’t form chromosomes. They indulge in a wide range of metabolic variations, consume nitrogen and sulfur, produce methane, precipitate iron and manganese while breathing, and grow in boiling water and brine. Bacteria obtain their food and energy by using every sort of plant fiber and animal waste. If they did not, we would be living in a mounting heap of garbage.

A microscopic look at the waters of the earth of the Proterozoic eon 2,500 million years ago would have revealed flotillas of bobbing purple, blue-green, red, and yellow spheres: colonies of organisms crowding on rocks, gliding on water, or darting about with whipping tails. Shoals of bacterial cells waved with the currents, coating pebbles with brilliant hues. Bacterial spores blown by breezes showered the muddy terrain. Their genetic material, DNA and RNA, was not bound up; their genes were not packed into chromosomes wrapped by a nuclear membrane. They reproduced asexually by growing to twice their size, replicating their single strand of DNA, and then dividing, with one copy of the DNA going to each offspring cell. Or a small cell containing a complete set of genetic material budded on the parent and then broke off. They also encased their DNA in spores that survived long periods of dryness, waiting to come alive when conditions became wetter or more generally favorable. By 1,500 million years ago, the earth’s modern surface and atmosphere were largely established and the bacteria flourished. Microbial life permeated the air, soil, and water, recycling gases and other compounds as they do today.

From this low-lying milieu came new forms of life. A new kind of cell formed, larger and more complex than bacteria. This cell had circuitous channels of internal membranes, including one enveloping the nucleus. It had parts called mitochondria: dark bodies providing the cell surrounding them with energy derived from oxygen. Some would soon have plastids, chlorophyll-bearing packets capable of photosynthesis, suspended in their cytoplasm.

What brought about this new cell? As with other evolutionary puzzles, the solution to the mystery of the origin of the nucleated cell lies first in the circumstantial

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evidence. History must be reconstructed from clues. If the ancestors of mitochondria were themselves bacteria without nuclei that raided and reproduced inside their hosts without killing them—in a fashion similar to Kwang Jeon’s “dots”—an ancestral line of complex cells could have become established. There would be no record of transitional forms because the new entity would have evolved rapidly, the result of interspecies merger.

Imagine the ancestor of the mitochondria: a bacterial attacker, capable of breathing oxygen or even doing without it when necessary. Such microscopic predators still exist. Bdellovibrio (the Greek bdello means leech; vibrio refers to their vibrating comma shape) burst asunder bacterial prey, eating them from the inside out. Daptobacter (the “gnawing bacterium”) enters both the inner and the outer membranes of its victim’s cell walls. Then it divides, again and again. The mitochondrial ancestor’s original prey may have been a larger bacterium like modern-day Thermoplasma. The DNA of Thermoplasma is unlike that of other bacteria and similar to that of eukaryotes. This rugged bacterium can survive very hot and acidic water such as that found in the hot springs of Yellowstone National Park.

When they were first invaded, occupied hosts like Thermoplasma probably couldn’t survive, and when they died, they took the invaders with them. Eventually, some of the prey evolved a tolerance for their aerobic predators, which then remained alive and well in the food-rich interior of their hosts. As they reproduced inside the invaded cells without causing harm, the predators gave up their independence and moved in for good. The two organisms thrived on internal leftovers—the products of each other’s metabolism. Invaded victims and tamed mitochondria recovered from the attack and have lived ever since, for 1,000 million years, in dynamic alliance. Because of the mitochondria, all earthly beings made of nucleated cells—which includes fungi, plants, animals, humans, and all organisms except bacteria—have remarkably similar metabolisms.

The presence of DNA in mitochondria helped tip off scientists to the possibility that these cells used to be free-living bacteria. When this DNA was examined, it was found to resemble the DNA in certain free-living bacteria far more than it resembled the DNA in the nucleus of the cell from which the mitochondria had come. Mitochondria have their own genes, their own reproductive timetable, and they often divide out of step with the rest of the cell. The bacteria that became mitochondria in our cells can be thought of as raiders that took over their hosts and formed cells with nuclei—cells ancestral to every plant and animal on the planet.

If we know where to go and how to look, we can see that these kinds of mergers are still occurring today.

In a scene from a beautifully colorful silent film called Intimate Strangers, Oxford University botanist David C. Smith stands on a beach on the Brittany coast of France. Beneath his feet is what appears to be seaweed. But as Smith begins stepping on the spinachy green matter, it squirms straight down into the sand. Very soon all that’s left is a cleared patch of beach.

Where did it go? Actually, “it” is “they.” Convoluta rossoffensis are flatworms within whose translucent bodies live grass-green algae. Annoyances to bathers, they long baffled biologists. The flatworms and algae have merged into a composite creature. They lie in dense green masses on the shore, and instead of eating, make their own food from sunlight and air. They resemble plants until bothered by pounding surf or a predator, at
which point they burrow for cover. The algae not only live inside the tissues of the flatworm and produce food for it but also recycle the worm’s waste products, such as uric acid, into additional food. Due to this symbiotic relationship, adult worms do not have to eat and their mouths remain permanently closed.

Symbiosis—the living together in intimate association of different kinds of organisms—is more than an occasional oddity. It is a basic mechanism of evolutionary change. Some plants and animals would long ago have become extinct were it not for the help of their partners: blind shrimps are led around by sighted fish, flowering plants need to be pollinated by specific insects, cows and other ruminants cannot digest grasses without the aid of gut bacteria. Humans also need live bacteria in their intestines. We have trillions of animal cells—and ten times as many bacterial cells.

Although many plant and animal symbionts are known, symbiosis and its fundamental role in evolution really become conspicuous in the microcosm.

Perhaps a hundred million years after mitochondria had become established, a new type of organism joined them in the cytoplasm of certain cells. But the genesis of the union was not through infection but ingestion. Like Jonah swallowed by the whale, the forebears of the photosynthetic parts of nucleated cells were engulfed by larger bacteria but, far from being destroyed, found shelter within, resided being digested, and kept their valuable light-trapping pigments alive. Today, locked inside every plant, these organelles, or plastids, make food from water and sunlight. Chloroplasts are green plastids and are even larger and more like bacteria than are the mitochondria. Plants turn toward sunlight because without it the plastids within would die.

Plastids provide the biosphere with food and oxygen. From a planetary point of view, the major role of mammals may be as fertilizers of plants and carriers of mitochondria. But if all mammals were to die in one instant, insects, birds, and other organisms would carry mitochondria and fertilize plants. If plants with their plastids were to suddenly disappear, the output of food on the planet would be so severely hampered that all mammals would certainly die. A cell that didn’t exist before would soon become indispensable to future generations. The new evolving cell now had mitochondria for oxygen metabolism and plastids to provide food. Both were the products of bacterial mergers. The question that remains is whether the cell’s ability to move—even within its own...
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Proving the spirochete connection is difficult. As bacteria merge, promiscuous genes ultimately blend, and it becomes very difficult to sort out the original partners. The integrity of individual partners

... — the product of yet another symbiotic merger.

If you look at a living eukaryotic cell under the microscope, you may be startled by the vigorous movement within it. In sharp contrast to a bacterial cell, whose contents are motionless or drift passively about, the interior of eukaryotic cells is swarming like a city. The cytoplasm streams. Many cells rhythmically expand and contract. For example, in a chameleon that is changing color, particles of pigment are carried from the surface to the interior of cells when the animal’s skin becomes lighter. We believe that cellular motion by nucleated cells may be the result of a symbiotic merger between still other kinds of bacteria: rapid, whiplashing bacteria called spirochetes. Close study of the tiny cell whips on many kinds of cells with nuclei shows an amazing uniformity. These filaments have traditionally been called flagella if they are long and few like sperm tails, or cilia if they are short and numerous like hairs. Since there is no basic difference between them, they are all called undulipodia. Nearly all algae and ciliates — the earliest organisms with nucleated cells to have evolved — have them. We are currently exploring the idea that undulipodia come from spirochetes, among the tiniest, fastest, most mobile members of the microcosm.

Shaped like corkscrews or bits of fusillini pasta, spirochetes thrive everywhere, from garden soil to people’s gums. Some use oxygen; others are poisoned by it. They tend to attach to things, living or not. They form a major part of the microbial community that lives inside the swollen intestines of termites. There they can be seen attached to and feeding at the surfaces of larger organisms.

When, 2,000 million years ago, an organism with spirochetes propelling it found more food and reproduced more often, natural selection would have favored the alliance. A certain modern amoeba, for example, that draws in its whiptail and gorges itself when food is plentiful, grows a tail when food is scarce in order to swim in search of a meal. The advent of spirochete alliances would have altered the microcosm, leading to the first animal cells — a sort of symbiotic ménage à trois formed of Thermoplasma, mitochondria, and spirochetes. Plant cells may also be multispecies assemblies, composed of these plus plastids.
is sacrificed to the formation of a new cell. As Smith puts it, what remains after the living merger, after billions of years of life within a supporting living habitat, is only the smile of Lewis Carroll's Cheshire cat: "the organism progressively loses pieces of itself, slowly blending into the general background, its former existence betrayed by some relic."

New techniques of molecular genetics confirm that parts of organisms dwindle within the life support system of other living cells. Bacteria can donate and receive varying numbers of genes, not only from each other but also from viruses and cells with nuclei. The free transfer of parts and pieces of living things from one area of a cell to another may explain how symbiotic organisms became streamlined into mere semblances of their former selves.

The malleability of microbial life is exploited by genetic engineers who identify proteins they want to produce in large quantity, such as human insulin, and put the genes for them inside bacteria capable of rapid and prodigious reproduction. Not to belittle the human effort, it is worth pointing out that bacteria have been using "genetic engineering" techniques—transferring genes among themselves for their own purposes—for billions of years.

In the traditional view of a cutthroat Darwinian world, merged life forms have always seemed a bit odd, aberrations from the law of the jungle that the poet Tennyson characterized as "red in tooth and claw." Yet it now seems plants and animals never would have evolved at all were it not for attacks and defenses followed by symbiosis and reciprocity. Uneasy alliances are at the core of our very many different beings. Individuality, independence—these are illusions. We live on a flowing pointillist landscape where each dot of paint is also alive. Earth itself is a living habitat, a merger of organisms that have come together, forming new emergent organisms, entirely new kinds of "individuals" such as green hydras and luminous fish. Without a life-support system none of us can survive. It is in this light that we are beginning to see the biosphere not only as a continual struggle favoring the most vicious organisms but also as an endless dance of diversifying life forms, where partners triumph.

Lynn Margulis is professor of biology at Boston University and a director of NASA's Planetary Biology Internship Program. Dorion Sagan is a science writer who specializes in geology and evolutionary biology. They are coauthors of Microcosmos, published in 1986 by Summit Books, New York.
World Without Design

by Douglas J. Futuyma

Like Jacques in As You Like It, who could moralize each spectacle "into a thousand similes," Richard Dawkins is a master of metaphor. For Jacques, "All the world's a stage"; for Dawkins, all of life's a computer, a magnetic disk, a radar unit, a stretched DC-8, an arms race, as his lively imagination leaps from analogy to analogy in the service of explaining evolution. Lecturer in animal behavior at Oxford and author of two previous popular books (The Selfish Gene, The Extended Phenotype), Dawkins has an unpretentious style and a command of the well-turned, sometimes funny, sometimes outrageous and arrest-}

The Blind Watchmaker, by Richard Dawkins. W.W. Norton and Company, $18.95, 332 pp., illus.

ing phrase. "It is raining DNA outside," he says in reference to the seed fall from a willow tree; "it's raining programs; it's raining tree-growing, fluff-spreading, algorithms. That is not a metaphor, it is the plain truth. It couldn't be any plainer if it were raining floppy discs."

I could heartily recommend The Blind Watchmaker just for the pleasure it will afford the reader who is looking for a treatment of evolution that is not only educational but fun. But the more important reason for reading Dawkins's book is that this is his answer, in clear and often insightful terms, to the opponents of neo-Darwinian evolutionary theory. Dawkins takes as his theme the adaptive complexity of organisms and sets out to show not only that neo-Darwinian theory successfully explains complexity but that even in principle it is the only theory that could explain this complexity. He is highly successful in his aim.

In the last ten years or so, evolution has been under severe attack, especially in the United States. It is important here to recognize the distinction between the proposition that evolution has occurred and the theory that describes the causes of evolutionary change. That evolution has occurred—that diverse organisms have descended from common ancestors by a history of modification and divergence—is accepted as fact by virtually all biologists. "Fact" here means a proposition, like the proposition that the earth revolves about the sun, supported by so much evidence that to disbelieve it would require disbelieving a large, successful edifice of scientific achievement. The historical reality of evolution is doubted chiefly by creationists, mostly on doctrinaire religious grounds.

The theory of evolution, on the other hand, like the atomic theory of chemistry, is a complex, ever-growing body of statements intended to describe mechanisms—of chemical reactions in the case of chemistry, of evolutionary change in the case of biology. The neo-Darwinian theory, to which not all biologists subscribe in full, has at its core the principle that adaptive evolution takes place through the action of natural selection on genetic variations that arise from mutations that are random with respect to adaptive utility. There is much more to neo-Darwinian theory, but this is what Dawkins is chiefly concerned to defend.

Dawkins notes that there are three main classes of people "who desperately want not to have to believe in Darwinism": those who, like the creationists, want evolution itself to be untrue; those who find the Darwinian mechanism ideologically or aesthetically offensive; and those who, often out of self-serving motives, like to see applecarts upset. Among the lay public, individuals in all three categories have been cheered by challenges to neo-Darwinian theory from within the halls of biology, which they often interpret as attacks on the historical reality of evolution. But few if any of the biologists who challenge neo-Darwinian theory deny the reality of evolution, even though creationists and certain noncreationist journalists selectively quote them to that effect.

Traditionally, the chief argument against evolution has been the argument from design: that complexity cannot arise by chance, but implies a designer. William Paley's (1802) famous analogy—that a watch implies a purposeful watchmaker—is the starting point for Dawkins's book and the inspiration for its title. With the aid of computer simulations, natural examples such as the eye, and plentiful analogy, Dawkins ingeniously develops the meaning of complexity, improbability, and chance, and he graphically shows how natural selection, the antithesis of chance, makes the improbable probable. En route, he explains why complex organs must arise in successive small steps (Darwinian gradualism) rather than by single mutations and shows how coevolution ("arms races") among species provides direction in evolution. He ranges over a great variety of fascinating topics, such as a recent mathematical theory of sexual selection that explains why peacocks are so absurdly overburdened with feathers. This
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theory, incidentally, is so complex that even Dawkins's verbal skills do not entirely succeed in making it clear—which I take as testimony to the importance of mathematical theory in evolution. It also highlights Dawkins's point that even though evolutionary theory seems so simple that "it is regarded as fair game for critics with any degree of ignorance," it is in reality a subtle and complex theory.

Dawkins's discussion of adaptive complexity is larded throughout with refutations of creationism, which he finally dispatches with the observation that special creation cannot be a serious alternative to Darwinism because it assumes, in the form of a complex deity, the existence of the very thing we want to explain, namely, organized complexity. In the last chapters, he turns from his theme of adaptive complexity to a general treatment of the challenges that have arisen from within biology. I will mention three, two of which are peculiarly appropriate for the pages of Natural History.

One is the contention of a few developmental biologists that "the neo-Darwinian concept of random variation carries with it the major fallacy that everything conceivable is possible." Obviously everything conceivable—grasshoppers with vertebral and opposable thumbs, for example—is not possible. But that does not violate neo-Darwinism because, as Dawkins says, this interpretation of "random variation" is a caricature to which no neo-Darwinian has ever subscribed. Mutations are random with respect to adaptive advantage, but their morphological effects are constrained by developmental processes, and neo-Darwinians have always recognized this.

Another challenge is punctuated equilibrium, which Dawkins views as a rhetorically overblown, "interesting, but minor wrinkle on the surface of neo-Darwinian theory." I must agree with most of Dawkins's treatment of this controversial issue. He rightfully distinguishes punctuations from saltationism (evolution by discrete mutational jumps), argues that punctuationalists confounded true Darwinian gradualism with constant evolutionary rates (which no neo-Darwinian has believed in), and concludes that punctuationalists are just as gradualist as Darwin.

"What needs to be said now, loud and clear, is the truth: that the theory of punctuated equilibrium lies firmly within the neo-Darwinian synthesis." Absolutely.

The most bizarre attack on not only neo-Darwinism but the entire Darwinian tradition has been launched by a tiny handful of taxonomists, the so-called transformed cladists. These curious mutations have arisen from the ranks of true cladists—whose approach to inferring evolutionary relationships among species both Dawkins and I applaud. Transformed cladists claim, through pure casuistry, that ancestral forms have no objective reality, so that "Darwinism . . . has been put to the test and found false." According to the philosophy of classification that transformed cladists have adopted, ancestral forms (such as the therapid ancestors of mammals) should not be recognized as formal, named categories in classification. They deduce, by a curious logic that Dawkins analyzes as well as anyone bound by real logic can, that if ancestors are not formally recognized by names, they cannot be real. We could dismiss this attack as a trivial nuisance, were it not that transformed cladists have gained the attention of antievolutionary popular writers. For example, Tom Bethell (Wall Street Journal, December 9, 1986) quotes the transformed cladist Gareth Nelson as saying that fossils are designated as ancestors because paleontologists "know they have to be there, and these are the best candidates." Nelson must know that this is simply not what paleontologists—or true cladists—do. Dawkins concludes that transformed cladists may really only mean that it is hard to fit ancestors into classifications, "but to make statements that encourage others to conclude that there never were any ancestors is to debauch language and betray truth."

Dawkins analyzes these and other objections to neo-Darwinism with insight and clarity, and with a refreshing absence of pedantry. He emerges, contrary to his reputation in some quarters, as fully aware of the complexity and integration of the development and function of organisms. He makes a few errors (for example, the cessation of response to artificial selection is typically not due to exhaustion of genetic variation); he phrases a few things misleadingly (as by saying that among living species there are no intermediate forms); and I disagree with some of his emphases (as in his implication that only molecular data can yield reliable phylogenies). But these are minor points. If you want to know why neo-Darwinian theory is valid, and powerful beyond all contenders, this is the book to read.

Douglas J. Futuyma is professor of ecology and evolution at the State University of New York at Stony Brook. He has published several books on evolution (including the widely used textook Evolutionary Biology), served as editor of the journal Evolution, and is president of the Society for the Study of Evolution.
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Among ethnic Tibetans who have lived along the Tibet-Nepal border for centuries, a form of polygamous marriage called fraternal polyandry is a traditional and widespread practice. This twelve-year-old bride from the village of Brassi, in northwestern Nepal, stands with three of her five husbands-to-be. The grooms, ages nineteen, seventeen, and seven, are brothers from the village of Bargaon (the other two brothers, ages fourteen and twenty-two, are off on trading trips).
When Brothers Share a Wife

Among Tibetans, the good life relegates many women to spinsterhood

Text by Melvyn C. Goldstein • Photographs by Thomas L. Kelly

Eager to reach home, Dorje drives his yaks hard over the 17,000-foot mountain pass, stopping only once to rest. He and his two older brothers, Pema and Sonam, are jointly marrying a woman from the next village in a few weeks, and he has to help with the preparations.

Dorje, Pema, and Sonam are Tibetans living in Limi, a 200-square-mile area in the northwest corner of Nepal, across the border from Tibet. The form of marriage they are about to enter—fraternal polyandry in anthropological parlance—is one of the world's rarest forms of marriage but is not uncommon in Tibetan society, where it has been practiced from time immemorial. For many Tibetan social strata, it traditionally represented the ideal form of marriage and family.

The mechanics of fraternal polyandry are simple. Two, three, four, or more brothers jointly take a wife, who leaves her home to come and live with them. Traditionally, marriage was arranged by parents, with children, particularly females, having little or no say. This is changing somewhat nowadays, but it is still unusual for children to marry without their parents' consent. Marriage ceremonies vary by income and region and range from all the brothers sitting together as grooms to only the eldest one formally doing so. The age of the brothers plays an important role in determining this: very young brothers almost never participate in actual marriage ceremonies, although they typically join the marriage when they reach their midteens.

The eldest brother is normally dominant in terms of authority, that is, in managing the household, but all the brothers share the work and participate as sexual partners. Tibetan males and females do not find the sexual aspect of sharing a spouse the least bit unusual, repulsive, or scandalous, and the norm is for the wife to treat all the brothers the same.

Offspring are treated similarly. There is no attempt to link children biologically to particular brothers, and a brother shows no favoritism toward his child even if he knows he is the real father because, for example, his other brothers were away at the time the wife became pregnant. The
The children of a polyandrous marriage regard all of their mother's husbands as their fathers, even if specific paternity is known. Children from the village of Brassi, above, toss drying diced radishes into the wind. Right: Representatives of the grooms dance in front of the bride's house. They are encircled by her representatives, who carry pussy willow staffs as mock protective weapons.
Family Planning in Tibet

An economic rationale for fraternal polyandry is outlined in the diagram below, which emphasizes only the male offspring in each generation. If every wife is assumed to bear three sons, a family splitting up into monogamous households would rapidly multiply and fragment the family land. In this case, a rule of inheritance, such as primogeniture, could retain the family land intact, but only at the cost of creating many landless male offspring. In contrast, the family practicing fraternal polyandry maintains a steady ratio of persons to land.

Joe LaMinn

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Fact, divorce traditionally was relatively simple in Tibetan society. If a brother in a polyandrous marriage became dissatisfied and wanted to separate, he simply left the main house and set up his own household. In such cases, all the children stayed in the main household with the remaining brothers, even if the departing brother was known to be the real father of one or more of the children.

The Tibetans' own explanation for choosing fraternal polyandry is materialistic. For example, when I asked Dorje why he decided to marry with his two brothers rather than take his own wife, he thought for a moment, then said it prevented the division of his family's farm (and animals) and thus facilitated all of them achieving a higher standard of living. And when I later asked Dorje's bride whether it wasn't difficult for her to cope with three brothers as husbands, she laughed and echoed the rationale of avoiding fragmentation of the family and land, adding that she expected to be better off economically, since she would have three husbands working for her and her children.

Exotic as it may seem to Westerners, Tibetan fraternal polyandry is thus in many ways analogous to the way primogeniture functioned in nineteenth-century England. Primogeniture dictated that the eldest son inherited the family estate, while younger sons had to leave home and seek their own employment—for example, in the military or the clergy. Primogeniture maintained family estates intact over generations by permitting only one heir per generation. Fraternal polyandry also accomplishes this but does so by keeping all the brothers together with just one wife so that there is only one set of heirs per generation.

While Tibetans believe that in this way fraternal polyandry reduces the risk of family fission, monogamous marriages among brothers need not necessarily precipitate the division of the family estate: brothers could continue to live together, and the family land could continue to be worked jointly. When I asked Tibetans about this, however, they invariably responded that such joint families are unstable because each wife is primarily oriented to her own children and interested in their success and well-being over that of the children of the other wives. For example, if the youngest brother's wife had three sons while the eldest brother's wife had only one daughter, the wife of the youngest brother might begin to demand more resources for her children since, as males, they represent the future of the family. Thus, the children from different
wives in the same generation are competing sets of heirs, and this makes such families inherently unstable. Tibetans perceive that conflict will spread from the wives to their husbands and consider this likely to cause family fission. Consequently, it is almost never done.

Although Tibetans see an economic advantage to fraternal polyandry, they do not value the sharing of a wife as an end in itself. On the contrary, they articulate a number of problems inherent in the practice. For example, because authority is customarily exercised by the eldest brother, his younger male siblings have to subordinate themselves with little hope of changing their status within the family. When these younger brothers are aggressive and individualistic, tensions and difficulties often occur despite there being only one set of heirs.

In addition, tension and conflict may arise in polyandrous families because of sexual favoritism. The bride normally sleeps with the eldest brother, and the two have the responsibility to see to it that the other males have opportunities for sexual access. Since the Tibetan subsistence economy requires males to travel a lot, the temporary absence of one or more brothers facilitates this, but there are also other rotation practices. The cultural ideal unambiguously calls for the wife to show equal affection and sexuality to each of the brothers (and vice versa), but deviations from this ideal occur, especially when there is a sizable difference in age between the partners in the marriage.

Dorje's family represents just such a potential situation. He is fifteen years old and his two older brothers are twenty-five and twenty-two years old. The new bride is twenty-three years old, eight years Dorje's senior. Sometimes such a bride finds the youngest husband immature and adolescent and does not treat him with equal affection; alternatively, she may find his youth attractive and lavish special attention on him. Apart from that consideration, when a younger male like Dorje grows up, he may consider his wife "ancient" and prefer the company of a woman his own age or younger. Consequently, although men and women do not find the idea of sharing a bride or a bridegroom repulsive, individual likes and dislikes can cause familial discord.

Two reasons have commonly been offered for the perpetuation of fraternal polyandry in Tibet: that Tibetans practice female infanticide and therefore have to marry polyandrously, owing to a shortage of females; and that Tibet, lying at extremely high altitudes, is so barren and bleak that Tibetans would starve without resort to this mechanism. A Jesuit who lived in Tibet during the eighteenth century articulated this second view: "One reason for this most odious custom is the sterility of the soil, and the small amount of land that can be cultivated owing to the lack of water. The crops may suffice if the brothers all live together, but if they form separate families they would be reduced to beggary."

Both explanations are wrong, however. Not only has there never been institutionalized female infanticide in Tibet, but Tibetan society gives females considerable rights, including inheriting the family estate in the absence of brothers. In such cases, the woman takes a bridegroom who comes to live in her family and adopts her family's name and identity. Moreover, there is no demographic evidence of a shortage of females. In Limi, for example, there were (in 1974) sixty females and fifty-three males in the fifteen- to thirty-five-year age category, and many adult females were unmarried.

The second reason is also incorrect. The climate in Tibet is extremely harsh, and
At a polyandrous wedding in the village of Halje, in Nepal's Limi district, wedding guests, below, enjoy salt-butter tea and barley beer inside the bride's ceremonial hall. Incense smoke swirls around one of the guests, right, who drinks from a traditional Tibetan wooden teacup.

ecological factors do play a major role perpetuating polyandry, but polyandry is not a means of preventing starvation. It is characteristic, not of the poorest segments of the society, but rather of the peasant landowning families.

In the old society, the landless poor could not realistically aspire to prosperity, but they did not fear starvation. There was a persistent labor shortage throughout Tibet, and very poor families with little or no land and few animals could subsist through agricultural labor, tenant farming, craft occupations such as carpentry, or by working as servants. Although the per person family income could increase somewhat if brothers married polyandrously and pooled their wages, in the absence of inheritable land, the advantage of fraternal polyandry was not generally sufficient to prevent them from setting up their own households. A more skilled or energetic younger brother could do as well or better alone, since he would completely control his income and would not have to share it with his siblings. Consequently, while there was and is some polyandry among the poor, it is much less frequent and more prone to result in divorce and family fission.

An alternative reason for the persistence of fraternal polyandry is that it reduces population growth (and thereby reduces the pressure on resources) by relegating some females to lifetime spinsterhood. Fraternal polyandrous marriages in Limi (in 1974) averaged 2.35 men per woman, and not surprisingly, 31 percent of the females of child-bearing age (twenty to forty-nine) were unmarried. These spinster women continued to live at home, set up their own households, or worked as servants for other families. They could also become Buddhist nuns. Being unmarried is not synonymous with exclusion from the reproductive pool. Discreet extramarital relationships are tolerated, and actually half of the adult unmarried women in Limi had one or more children. They raised these children as single mothers, working for wages or weaving cloth and blankets for sale. As a group, however, the unmarried woman had far fewer offspring than the married women, averaging only 0.7 children per woman, compared with 3.3 for married women, whether polyandrous, monogamous, or polygynous. While polyandry helps regulate population, this function of polyandry is not consciously perceived by Tibetans and is not the reason they consistently choose it.

If neither a shortage of females nor the fear of starvation perpetuates fraternal polyandry, what motivates brothers, particularly younger brothers, to opt for this system of marriage? From the perspective of the younger brother in a landholding family, the main incentive is the attainment or maintenance of the good life. With polyandry, he can expect a more secure and higher standard of living, with access not only to his family's land and animals but also to its inherited collection of clothes, jewelry, rugs, saddles, and horses. In addition, he will experience less work pressure and much greater security because all responsibility does not fall on one "father." For Tibetan brothers, the question is whether to trade off the greater personal freedom inherent in monogamy for the real or potential economic security, affluence, and social prestige associated with life in a larger, labor-rich polyandrous family.
A ten-year-old bride, left, from Halje village, is adorned with mother-of-pearl earrings, turquoise-inlaid charm boxes, and a traditional headdress. She is marrying a man from the same village, in a union that will include any other males born to his parents.
In Halje village, representatives of the bride assemble to respond to a sing-song test of cleverness and worthiness by representatives of the groom.
A brother thinking of separating from his polyandrous marriage and taking his own wife would face various disadvantages. Although in the majority of Tibetan regions all brothers theoretically have rights to their family’s estate, in reality Tibetans are reluctant to divide their land into small fragments. Generally, a younger brother who insists on leaving the family will receive only a small plot of land, if that. Because of its power and wealth, the rest of the family usually can block any attempt of the younger brother to increase his share of land through litigation. Moreover, a younger brother may not even get a house and cannot expect to receive much above the minimum in terms of movable possessions, such as furniture, pots, and pans. Thus, a brother contemplating going it on his own must plan on achieving economic security and the good life not through inheritance but through his own work.

The obvious solution for younger brothers—creating new fields from virgin land—is generally not a feasible option. Most Tibetan populations live at high altitudes (above 12,000 feet), where arable land is extremely scarce. For example, in Dorje’s village, agriculture ranges only from about 12,900 feet, the lowest point in the area, to 13,300 feet. Above that altitude, early frost and snow destroy the staple barley crop. Furthermore, because of the low rainfall caused by the Himalayan rain shadow, many areas in Tibet and northern Nepal that are within the appropriate altitude range for agriculture have no reliable sources of irrigation. In the end, although there is plenty of unused land in such areas, most of it is either too high or too arid.

Even where unused land capable of being farmed exists, clearing the land and building the substantial terraces necessary for irrigation constitute a great undertaking. Each plot has to be completely dug out to a depth of two to two and a half feet so that the large rocks and boulders can be removed. At best, a man might be able to bring a few new fields under cultivation in the first years after separating from his brothers, but he could not expect to acquire substantial amounts of arable land this way.

In addition, because of the limited farmland, the Tibetan subsistence economy characteristically includes a strong emphasis on animal husbandry. Tibetan farmers regularly maintain cattle, yaks, goats, and sheep, grazing them in areas too high for agriculture. These herds produce wool, milk, cheese, butter, meat, and skins. To obtain these resources, however, shepherds must accompany the animals on a daily basis. When first setting up a monogamous household, a younger brother like Dorje would find it difficult to both farm and manage animals.

In traditional Tibetan society, there was an even more critical factor that operated to perpetuate fraternal polyandry—a form of hereditary servitude somewhat analogous to servodom in Europe. Peasants were tied to large estates held by aristocrats, monasteries, and the Lhasa government. They were allowed the use of some farmland to produce their own subsistence but were required to provide taxes in kind and corvée (free labor) to their lords. The corvée was a substantial hardship, since a peasant household was in many cases required to furnish the lord with one laborer daily for most of the year and more on specific occasions such as the harvest.

Left: The bride is led into the groom’s ceremonial grounds by her attendants. Below: Representatives of the groom are served barley beer. By custom, each recipient declines the offer a couple of times before giving in.
This enforced labor, along with the lack of new land and the ecological pressure to pursue both agriculture and animal husbandry, made polyandrous families particularly beneficial. The polyandrous family allowed an internal division of adult labor, maximizing economic advantage. For example, while the wife worked the family fields, one brother could perform the lord's corvée, another could look after the animals, and a third could engage in trade.

Although social scientists often discount other people's explanations of why they do things, in the case of Tibetan fraternal polyandry, such explanations are very close to the truth. The custom, however, is very sensitive to changes in its political and economic milieu and, not surprisingly, is in decline in most Tibetan areas. Made less important by the elimination of the traditional serf-based economy, it is disparaged by the dominant non-Tibetan leaders of India, China, and Nepal. New opportunities for economic and social mobility in these countries, such as the tourist trade and government employment, are also eroding the rationale for polyandry, and so it may vanish within the next generation.
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WE SPEAK YOUR LANGUAGE
Grass Roots of the Maned Wolf

Life on the Central Highlands of Brazil has turned one unusual canid into a long-legged, fruit-eating, mouse-chasing chicken thief

by James M. Dietz

Ask any of the hill people from the interior of Minas Gerais State, Brazil, What is a maned wolf? and they will tell you, in the melodious Portuguese of the region, that it is a wild animal as big as a small horse. They'll explain how it wanders alone through the scrub forest in search of fruits and how it barks at night when the weather is going to change. And they will surely say it seems to be supernaturally efficient at killing chickens.

During my two-year study of the ecology and social organization of this elusive canid, I discovered that the hill people were largely right.

Maned wolves (*Chrysocyon brachyurus*) are spectacular animals: an adult typically weighs about fifty pounds and stands about three feet tall, roughly 50 percent larger and heavier than a coyote. Its fur is gold-red, with black on the muzzle, feet, and scapular region and white on the throat, tail, and large ears. During confrontations with others of its kind, the maned wolf takes complete advantage of its size and striking color by standing broadside to its adversary, arching its back like a Halloween cat, and fully erecting the hair on its throat, back, and tail. It accompanies this spectacle with an equally impressive vocalization: a series of loud roar-barks delivered at about four-second intervals. These conspicuous visual and auditory signals help keep individuals apart, something that maned wolves are very concerned about.

During my first visit to my study area in the Serra da Canastra National Park, I rode with park guards to a hilltop overlooking an immense sea of grassland and scrub forest, excited about the prospect of seeing a maned wolf in the wild. But in the several square miles that I searched with binoculars, the entire visible mammal fauna consisted of a single giant anteater. I saw a small band of rheas streaking across the savanna and guessed that wolves, fast as they might be, would have a hard time running these big birds down. As we bumped back to the village below, I wondered where the wolves might be and how this large carnivore could make a living in a grassland environment so obviously devoid of large prey.
Its gold-red fur glowing against the brown grass, a maned wolf freezes in a position of alertness. During the dry season, a wolf uses its large ears, sharp eyes, and sensitive nose to spot mice in the grass. Once the prey's position is pinpointed, the wolf lunges forward, pinning the victim to the ground with its long legs.

François Gohier
I spent the next few weeks setting up camp and traveling over the 270-square-mile park looking for wolves—and finding none. Ranchers had been grazing their cattle in those hills for more than one hundred years, burning the grasslands to “improve” pasture and systematically investigating every clump of cover looking for lost calves. At the time of my study, the rangeland was being converted to park, but the transition was not yet complete. And for a while, ranchers actually drove more cattle than ever into the hills of the Serra da Canastra to take advantage of the last days of free pasture. Maned wolves had learned to be wary of these cowboys and their dogs, and they were equally apprehensive of me. But in this age of high technology, even shy mammals, if caught, can be fitted with a radio collar and then tracked. The trick was to catch them. I planned to appeal to the gourmand in them, but to do that, I had to discover their eating habits.

Until I began roaming the Serra da Canastra, no one knew precisely what maned wolves found to sustain themselves in the high grasslands. As it turned out, resolving this mystery involved somewhat primitive techniques: collecting, drying, and analyzing their feces, or scats. But it also opened the door to understanding several aspects of the species’ unusual morphology and social system.

Collection of the scats was not difficult because maned wolves habitually deposit their strong-smelling feces in the same places, prominences fifteen inches or so above the ground. Once I had learned these locations—which probably serve as “no trespassing” signs for neighboring wolves—I simply made the rounds each month to gather samples.

The scats revealed that, as I had come to suspect, maned wolves were not preying on large vertebrates. During the rainy season, they concentrated on the wild fruits that were abundant then; during the dry season, they switched to small mammals, principally field mice. Insects turned up now and then, as did the remains of birds, armadillos, and other slightly larger animals. In terms of volume and frequency of occurrence in scats, one fruit—*Solanum lycocarpum*—was the most important item in the diet of the maned wolves I studied. The regional common name of this softball-sized relative of a tomato is *lobeira*, which means “fruit of the maned wolf.” Scientists may have known little about the wolf’s diet, but the local inhabitants clearly did.

The wolves were obviously getting plenty to eat on the grasslands, but they often had to travel fair distances for a meal. As nutritious as a field mouse might be, one is not enough for such a large animal, and the next one may be miles away. Even the thorny *lobeira* bushes on which the maned wolves depend are sparsely distributed in open areas of the Serra da Canastra. Indeed everything that the maned wolf eats is in short supply and spread over large areas, and this is where its long legs come in handy. Of the seven

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**Taxonomic Tangles**

Science has long found almost everything about maned wolves a mystery. Not only have few scientists spotted them in the wild, but over the years maned wolves have been assigned to three different genera and five different species. Untangling the evolutionary and taxonomic relationship of this species to the rest of South America’s canids has not proved an easy task. The other species include the crab-eating fox, common throughout most of South America south of the Amazon rain forest; about five species of foxes in a different genus, also living south of the Amazon; and the bush dog and small-eared dog, two little-known and endangered species found from the rain forests of northern South America to southern Central America. Most of these small canids feed mainly on small vertebrates, insects, and fruits. One exception seems to be the bush dog; its strong jaws and legs are

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*Crab-eating fox  Maned wolf  Small-eared dog*
Maned wolves and humans generally go their separate ways, but in Minas Gerais, Brazil, the priests of Caraça Church regularly leave food out to attract a family of wolves onto church property. To tourists, however, the priests say the wolves are drawn by more spiritual fare: the presence of God.

Luiz Claudio Margo

presumed to be adaptations for hunting large prey in thick forest.

Maned wolves, as we know them today, first appeared in the fossil record for South America roughly half a million years ago. However, the incompleteness of the fossil record for South America casts some doubt that the maned wolves evolved so recently. The maned wolf differs morphologically from the other South American canids: it has a considerably larger body and relatively reduced canine and incisor teeth. But there are also some disconcerting similarities. The feet, nose pad, and eccum of the maned wolf, for example, are very similar to those of the bush dog. And the number and structure of chromosomes in the cell nucleus suggest that maned wolves have a relatively close relationship to the true wolf-like canids—the gray wolf, coyote, and African hunting dog. Although the taxonomic significance of these similarities and differences is not yet fully understood, most experts have agreed that the maned wolf is distinct enough to be placed by itself in its own genus.

With the arrival of the era of modern cellular genetics, new information is becoming available. Robert Wayne, researcher at the National Cancer Institute, is now applying electrophoretic techniques to blood proteins to calculate the genetic distances between the maned wolf and other canids. Simplistically put, the farther apart species are genetically, the longer ago they are assumed to have diverged. According to these studies, the lineage from which the maned wolf and the South American foxes evolved branched off from wolflike canids some seven million years ago, most likely in North America. The maned wolf lineage appears to have split from that of the South American foxes shortly thereafter, about six and a half million years ago, making it the oldest of the modern South American canid lines. The bush dog also belongs to an ancient lineage, having diverged from primitive canid stock some six million years ago. Thus both the maned wolf and bush dog lines were distinct long before the Panamanian land bridge connected North and South America three million years ago, at the end of the Pliocene epoch. Wayne's work suggests that the South American foxes evolved into their modern forms only after the two continents were joined.
Maned wolves are also fond of—some would say obsessed with—domestic chickens. I will never forget my own experience, watching with mixed emotions as a pair of subadult wolves made off with the last two hens (their seventeenth and eighteenth) from my chicken house. This taste for poultry puts the wolves at the mercy of armed farmers trying to protect their flocks. Of the twenty-one wolves whose deaths I documented during my study, 76 percent were killed while stealing chickens. But chickens were also the key to my noninjurious capturing and radio collaring the eight wolves residing in my study area. I constructed large hardwood box traps in areas where wolf tracks and scats were seen, placed a chicken supplied with food and water inside each trap, and worked a deal with local cowboys to check the traps twice a day: one week's wages for each new wolf trapped.

With the help of radiotelemetry, I tracked the wolves daily, often hiking or riding horseback over rugged terrain, sometimes mindlessly following beeps in the headphones, sometimes watching the animals from a favorable vantage point. As my familiarity with the movements of the maned wolves of the Serra da Canasstra increased, their patterns of land use gradually became evident. Monogamous male–female pairs of wolves defended permanent territories averaging ten square miles, larger than those for most canids (exceptions would be the gray wolf and the African hunting dog, which travel in large packs and occupy territories of up to several hundred miles). Resident maned wolves liberally deposited urine and feces along their territorial boundaries, often a total distance of some forty miles. The large territories are undoubtedly a reflection of how far the animals commonly must go for food and how small each item, once found or caught, may be.

Distant neighbors occasionally exchange vocalizations, but incursions into strange territories are rare. The male seems to shoulder most of the burden of territory defense, but the female's partici-
pation is also crucial. On three occasions during my study, vacancies opened up. In all three cases, the missing wolves, who had either died or left the area, were replaced within a few weeks by what I believe were unlanded nomads that wandered the edges of occupied territories waiting for an opportunity to find an unpaired mate. Finding a new mate quickly seemed to be important to the remaining member of the pair, too. As long as the vacancy remained open, neighboring pairs encroached on the territory. It is likely that ranges not occupied and defended by both a male and a female would soon be swallowed up. Again, diet seems to have determined an important part of maned wolf life, in this case, the nature of the bond between male and female.

As essential as it may be, the bond between members of a mated pair is not a particularly sociable one. Male and female travel and forage over their common range, but they associate closely with each other only during the breeding season. Copulation usually takes place in April, and the birth of from two to five pups about August. None of my radio-collared animals produced a successful litter, but when I returned to the States at the end of my fieldwork, I was able to study the reproductive behavior of maned wolves in captivity at the National Zoological Park’s Conservation and Research Center in Front Royal, Virginia. My work there suggested that there is an element of female choice in the extent to which males participate in rearing of the young. In the wild, this, too, may be a function of how much food is available. In a good year, the female may not require the aid of her mate to hunt for food, and he may best contribute to the survival of his offspring by defending and expanding territorial boundaries, thus insuring an ample food supply during the year or so before the pups disperse from their parents’ territory.

Unfortunately, there are few large and undisturbed tracts of land within the present geographical distribution of the maned wolf—central South America, south of the Amazon forest. And every year, more and more grassland and savanna are converted to fields, cattle pasture, and plantations of exotic trees. In Brazil, the maned wolf is considered an endangered species, but the situation may not be as grim as it first appears, at least not yet. Maned wolves are relatively flexible in their habitat requirements. They currently live in a variety of habitats, including grasslands, flood plains, several types of cerrado scrub forest, as well as part of the caatinga spine forest of northeastern Brazil—all characterized by a grass understory and an open overstory. In one recent instance, the species even expanded its range into the deforested zona da mata of southeastern Brazil, suggesting that in the short term, the maned wolf may actually benefit from the destruction of closed tropical forest.

Prospects for the long term may be less rosy, however. With the mediocre success of colonization and exploitation of the Amazon Basin, the Brazilian government is now initiating development of the more fertile savannas of the Central Highlands to increase agricultural exports. As Brazil shifts to more efficient and intensive modern agricultural practices, there will be
The maned wolf is the only canid that routinely uses a pacing gait, that is, simultaneously moving first the front and back legs on one side of the body and then both legs on the other side.

Francisco Erize, Bruce Coleman Ltd.

less unused land between ranches and farms. The large areas required by each pair of wolves will be increasingly difficult to acquire, both by wolves and by conservationists interested in establishing parks and reserves. Surviving wolves will be divided into smaller and smaller populations, each reproductively isolated from the other, and with an increasingly greater probability of suffering the deleterious effects of inbreeding.

But for now, wolves and ranchers generally go about their business much as they have for decades. The wolves' habits vary somewhat from region to region. In the Serra da Canastra, they are almost entirely nocturnal, perhaps as a result of human activity in this region. In the Pampas del Heath in Peru, where there is little human disturbance, maned wolves are reportedly active during the day. Throughout their range, the wolves pose no physical threat to humans or to livestock—except chickens. The occasional wolf that is caught invading a chicken yard is simply and quietly disposed of.

In the chicken yard, the maned wolf may be a nuisance; in the folk culture of the Serra da Canastra, it holds a more respectable position. Rural residents consider the animal to have supernatural and medicinal powers. For example, I was informed that the right eye of a maned wolf—plucked from the living animal—brings luck with women and in games of chance. Many cowboys in the region tied a piece of wolf hide to their saddles to treat backaches, and on several occasions I saw young children with a wolf's canine tooth on a string around their neck. I later found out that parents attached these amulets to prevent dental problems. One cough remedy that I never had the courage to try was a hot tea brewed from the feces of a maned wolf.

Whether through science or folk culture, humans everywhere try to understand the animals around them. Perhaps animals, in their way, also seek to know us. One cool evening toward the end of my two years in the Serra da Canastra, I was rinsing off in the creek behind my field headquarters in the park, and as I was about to leave the water I was startled to see a large maned wolf appear eerily out of the dusk to examine my bar of soap. I had never been this close to a wolf without the unfair advantage of radiotelemetry, and as the wolf ambled off I stood shivering—wondering who had really been observing whom during the years of my study. Is it possible that the maned wolves of the Serra da Canastra learned as much about me as I did about them?
In the rainy season, the wolves’ environment takes on a greener hue, and the animals live mainly on wild fruits.

James M. Dietz
In the waters of Puget Sound, a female sea cucumber (Cucumaria miniata), below, extrudes a pencil-thin pellet of green eggs, which are fertilized as they drift through waters clouded by sperm (the white plumes in the photo at right).
Sex Among the Sessile

With the onset of spring in cool northern Pacific waters, even sea cucumbers bestir themselves

Text and photographs by Ronald L. Shimek

Spring brings a resurgence of color to the cool, rich waters around the San Juan Islands just north of Puget Sound. On the surface, there is a dense bloom of green phytoplankton taking advantage of the longer days, clearer skies, and warmer seas. Below, the rocky ocean bottom becomes a waving carpet of colored tentacles—red, white, orange, black—as sea cucumbers reach out from their burrows to feed on the tiny floating plantlife.

The sea cucumbers here are among the most numerous of the animals adapted to feed on the phytoplankton. Relatives of the rigid sea stars and hard, spiny sea urchins, sea cucumbers have a much-reduced skeleton beneath their leathery skin. They have abandoned the radial symmetry found in the rest of the echinoderms and have become elongated, with a mouth and tentacles at one end. Although some sea cucumbers may burrow through sediment or move over the ocean bottom on small tube feet, most are sedentary and let their food come to them.

Of the several species of sea cucumbers in the San Juan Islands, none is more resplendent than the orange Cucumaria miniata, which reaches lengths of six to twelve inches and lives in dense aggregations of one hundred or more per square yard. When feeding, C. miniata extend the crowns of their mucous-laden tentacles from their burrows and then stick the tentacles, one by one, into their mouths to remove the adhering plankton. When other species of sea cucumbers are feeding nearby, the show of tentacle crowns is spectacular.

In the winter, microscopic planktonic plants are uncommon in the waters of the San Juan Islands, so the cucumbers do not feed. They remain retracted in their burrows and may spend this time repairing damaged tentacles while their gonads mature and ripen. As spring approaches, the sea cucumbers become more and more laden with mature gametes. An ebb tide on a sunny day is often the best time to catch the action.

Usually a single male spawns first: crawling clear of its burrow, it releases a plume of sperm into the water. As this sperm suspension drifts downstream, it causes other males and females to stretch from their burrows and spawn. The genital aperture of both sexes is located between a pair of feeding tentacles. In the female, the membrane covering the genital pore ruptures and a pencil-thin strand of green eggs is extruded. These are soon fertilized by sperm swimming around in
Different species of sea cucumber often spawn simultaneously, filling the waters with eggs and sperm. The eggs of Cucumaria piperata, below, are nearly the same color as C. miniata. Strands of eggs may get as long as four inches before the strong tidal currents begin to break them up, right.

The egg strand gradually breaks up, and the buoyant eggs drift slowly away to develop alone among the plankton.

While watching one or two Cucumaria spawn is interesting, a whole population spawning together is a far more impressive sight. The gamete suspensions can be so dense that they cloud the water.

Scott McEuen of the University of Alberta found that simultaneous spawning is common in many local populations. This insures that sperm and eggs are released together so that fertilization may occur. The spawning of the male of one species of Cucumaria often causes the spawning of both sexes of other related species. The echinoderm fauna of this region is so diverse and abundant, that on the right spring day, a diver may find five or more species, including sea stars, spawning. Whether they spawn independently, in response to the same seasonal cues, or in response to the spawning of the sea cucumbers is still uncertain. But the immense numbers of eggs released means that many will survive.

Cucumaria eggs are yolky (the fat in them colors them green). Although the eggs are toxic to fish, certain invertebrates seem to be immune to the poison. One of those invertebrates is a small predatory crustacean, Parapleustes pugettensis, the saddleback amphipod. These fast-moving amphipods are often abundant (20,000 per square yard) where Cucumaria are common. Parapleustes will swim up off the bottom, grab Cucumaria eggs and carry them away. Predation by amphipod swarms could wipe out the spawn of one or a few individual sea cucumbers, but the huge number of eggs released during one of the simultaneous spawns insures that most eggs survive. (Parapleustes is not above being a generalist predator and, in fact, during a feeding frenzy will bite a diver’s face.)

The young cucumber embryos and larvae, small green dots about one millimeter in diameter, float in the waters of the San Juan Islands for several weeks after spawning ends. Then they settle to the ocean bottom and take up the sessile existence of adults.

Throughout the spring and early summer, many other groups of marine animals in the San Juan Islands reproduce by liberating gametes that will develop into planktonic larvae. While always interesting and occasionally impressive, these spawning events seldom rival the synchronous spawnings of sea cucumbers.
Hard Times on Mussel Beach

Survival is a learning experience for oystercatchers on an English estuary

by John D. Goss-Custard

On the coast of Devon in southwest England, where the Exe River meets the sea, a broad estuary serves as the wintering ground for 15,000 shorebirds, among them 3,000 European oystercatchers. From my blind on a tower fifteen feet above mussel beds exposed by the receding tide, I watch as a young oystercatcher spies an older bird breaking into a mussel. Before the adult can extract the flesh, the young bird launches a vicious attack from behind. Caught unawares by the lunging beak of the juvenile (a bird in its first year), the adult squawks and runs away, leaving the morsel behind. By the time the adult realizes the attacker is just a youngster, the juvenile has snatched the mussel and dashed off to gulp down the stolen shellfish at a safe distance. This scene happens often in August and flouts the rule that avian youngsters are subordinate to older birds. By winter, however, the young oystercatchers will have learned to imitate and even respect their elders.

Oystercatchers are large wading birds found throughout the world. Up to twenty-one inches long, the European species sports a handsome black-and-white plumage offset by a big, bright orange bill. Toughened and shaped according to how

Surrounded by oystercatchers, a sheep grazes on the shore.

G. and H. Denzau
an individual gets its prey, the bill is sculpted to pry open or break the barricades of the toughest shellfish. The birds on the Exe are migrants that have traveled from their breeding grounds in Norway, the Faroe Islands, and Scotland in the north and Holland in the east. Unlike other shorebirds, oystercatchers feed their young, and siblings compete for food in a contest that is often one of life and death.

A few weeks after the chicks hatch, the family disbands as adults migrate from the breeding area. The young leave about two weeks later, and many eventually gather in August on the Exe. Although not often harvested now, most of the mussels on the Exe were originally laid down decades ago by fishermen. Each bed covers several hundred square yards, and each square yard holds up to a few hundred of the larger mussels favored by the oystercatchers. A mussel provides enough flesh to satisfy 2 percent of a bird’s daily requirements. The mussels cling in dense clumps to stones and dead shells, and above all to one another, with tough threads growing out from their lower surface. They form thick black mats, or “scars” as they are often called in England, on the surface of the flats, visible at
great distances. But this apparently abundant source of food does not prove to be easy pickings for the oystercatchers.

For the majority of young birds, the river and estuary are a new world. Some have been brought up on farmland far from the sea and its resources; still others come from coastal areas offering different fare than the Exe's beaches. Consequently, when the novices arrive and first follow the adults onto the feeding grounds at low tide, they are faced with a challenge: the tasty, nutritious mussel is encased in a hard shell. Because only some juveniles will have had any experience with this kind of shellfish, most of the young will be inept feeders. Even with hundreds of mussels to the square yard, the beginners usually fail to find the occasional one that can be pried open easily. I have seen them attack empty shells and get their beaks stuck in living ones. Much of their portion comes from cleaning out those mussel shells sprung by adults and abandoned with a bit of meat left inside. The juveniles are so incompetent in August that they secure food at less than half the rate of adults.

I first became interested in the education of young oystercatchers as I observed those on the Exe learning to penetrate mussels. The thick shell protecting the fleshy morsel is designed to keep the prying bills of birds like oystercatchers out. During high tide, mussels open their shells slightly to suck in food. But when the tide recedes and birds arrive on the beds, most shells are clamped shut. The birds must break down this barrier, and they do it in several ways. Sometimes they stalk an unwary mussel that is feeding with its shell slightly agape. The bird swiftly stabs its sharp beak into the gap and severs the strong adductor muscle that holds the two parts of the shell together. The mussel is then defenseless. Another method the birds use is to jam their beak persistently into a closed mussel until it eventually gives way. Both these techniques are called stabbing. Another way of getting into a mussel is by hammering a hole in the shell. This can be done on the dorsal, or upper, shell, where continual abrasion from tide-swept sand wears some mussels...
thin. An oystercatcher shops around, tapping each mussel until it finds a thin-shelled one, then uses its beak as a jackhammer to drill a hole. Or a mussel can be carried to firm ground, turned upside down, and hammered on the ventral, or lower, shell. Remarkably, the birds are able to select mussels with vulnerable shells, perhaps by their outward appearance. Mussels with thin shells on the underside have grown quickly; they tend to be brown rather than black and to have few barnacles adhering to them.

Although each grown bird can usually deal with mussels in several ways, most specialize in a single technique and, if they breed along a coast where mussels are available, they relay that one method to their young. The specialty is carried through into mate choice: an adult pairs only with another that uses the same method. Adults may also concentrate for long periods on a single kind of prey—mussels, clams, worms, or cockles (on the Exe, 80 percent favor mussels). Although oystercatchers are more flexible in their diet than was once thought, there is little doubt that individuals often specialize. Despite their name, few European oystercatchers are able to find oysters readily because these shellfish are farmed commercially, often in cages.

When oystercatcher families break up at the end of summer, only some of the young, then, are equipped with knowledge gleaned from their parents. For oystercatchers reared in fields and on different coastal food, the introduction to mussel hunting has to take place in August on the Exe. When the initiates spot a nearby adult that has opened a mussel, they attack the older bird and try to steal the prey. Theft is fairly common between adults, but newcomer juveniles are driven to it by desperation far more often, and they are surprisingly successful at first. Their impunity lasts only a short time, however. First, the juveniles quickly learn how to find mussels for themselves. By October, they are scoring ones as large as those caught by adults, and by February, they can feed just as fast as the adults. Second, the older birds become increasingly intolerant of thieving juveniles, resisting them more often and more violently, and sometimes even attacking the young first. The improved foraging skills of the juveniles make it increasingly worthwhile for adults to turn the tables and steal from them. In this way, an adult can double its intake rate. But after their early forbearance with the young, adults seem to reassert their dominance, teaching the juveniles a painful lesson that has been well learned by January or February. Feathers literally fly when an adult grabs a youngster and won't let go. The juveniles become the least aggressive group on the mussel beds. They suffer theft of prey more than any other group, especially when the estuary is crowded. Under these conditions, the by now skillful juveniles actually consume no more food than they did in August as neophytes.

Oystercatchers feed at the mussel beds during the approximately five hours of low tide. So with two tidal cycles per day, the birds have access to the beds for about ten hours in every twenty-four, year-round. They feed for 50 to 100 percent of this ten hours, depending on season and age. Juveniles feed almost continually and hardly
Unlike most shorebirds, oystercatchers actively teach their young how to forage. A two-week-old chick, below, watches its parent demonstrate the finer points of shellfishing. The young birds learn two main ways of penetrating the tough shell. An adult, right, extracts a mussel for its brood.

Both photographs by Jan van de Kam

ever rest; it's a rare sight to see one taking a break. Adults rest far more often, especially in autumn when life is easier.

As winter comes on, juveniles need from fifty to one hundred mussels a day to survive. Although subfreezing temperatures are usually short-lived in this part of Britain, the birds' energy requirements soar from the heat loss brought about by the cold temperatures and increased winds. Juveniles often leave the mussel beds, where their intake rate is forced down by almost half by the dominant adults. They may go to the mud flats to feed on clams, to the nearby seacoast to forage for a variety of prey, or to the fields bordering the estuary to eat earthworms, using their bills as probes. In fact, worms are an important source of winter food for young oystercatchers and for inefficient adults, usually stubbers. Winter rains draw the worms to the surface, and if the fields are not frozen, worms can be easily caught. Some juveniles remain to feed on worms all day, whereas many birds feeding at low tide on the shore fly to the fields at high tide to supplement their diet. Without earthworms, many fewer oystercatchers would see the spring.

In most winters, 10 to 15 percent of the juveniles die on the Exe compared with 2 to 3 percent of the adults. In colder estuaries subject to more frost, the toll is much higher. Snow-covered fields yield no earthworms. When forced to remain on the estuary, juveniles lose much of their prey to aggressive adults and to crows. During lengthy cold spells, a high proportion of the juveniles and the immature, or second-to-fourth-winter, birds starve.

In spring, two thousand adults leave the Exe for the breeding grounds to the north and east. The few hundred immature birds now in charge of the estuary seize the opportunity to retake the mussel beds. Here their education in edibles continues by trial and error. Juveniles start feeding on mussels by stabbing, but from spring onward, more and more of them switch to hammering. This changeover carries through until the young become adults at the age of four or five. By then, only a third of them stab, while the rest use one of the two hammering techniques. Why do juveniles stab? Perhaps because their beaks are not hard enough for hammering for a year or so. And how do they choose a feeding method when they mature? Many no doubt pick a method by watching other birds on the Exe. The high proportion of juveniles reared inland know nothing, at first encounter, about eating bivalves. But the possibility exists that young that are taught to hammer by their parents recall these early lessons and revert to this method later in life.

An occupational hazard of oystercatchers that probably accounts for some of the deaths on the Exe is an injured or deformed beak. To compensate for the severe wear brought on by cracking into dozens of shells a day, bills must grow continually. Birds that hammer, for example, might end up with a completely flat-tipped bill, but normal regrowth will provide a new, pointed tip within two or three weeks. Bill deformity or failure to regrow can be fatal.

Recent research on the Exe has revealed some subtleties in feeding strategies related to competition. In crowded conditions, fighting between oyster-
catchers intensifies, and for individual birds, frequent squabbling means less time spent searching for prey. Only a minority of raids result in the attackers actually winning a mussel. Often a potential victim sees the attack coming and runs off with the shellfish. Even when the target panics and leaves its prize behind, the attacker frequently fails to find it. So the rate at which the average bird consumes mussels drops as bird density increases. How much a particular bird is affected by competition depends on its dominance and its feeding efficiency. Aggressive, dominant birds gain more opportunities to steal, while the intake of low-ranking oystercatchers plummets when overall bird numbers rise. But if we compare birds of the same dominance, a finer level of competition emerges. Ironically, the most capable birds suffer the most. The more they earn, the more they are “taxed” by the others. This means that the average hammering bird, being able to locate food items 50 percent faster, is affected more by competition than the average stabbing bird. So subdominant, very efficient hammering birds drop to the bottom rung, losing out to stabbing individuals that are both dominant and poor food finders.

The role of competition became clearer when I looked at exactly where the birds were feeding. The estuary has more than thirty mussel beds, most of them in its lower reaches, that vary enormously in ways that matter to the oystercatchers. While the birds prefer beds tightly packed with thin-shelled mussels, they also opt for mussel beds that are firm underfoot and close to the roosts they use at high tide when the mussels are covered by seawater. Each choice increases efficiency and helps cut energy costs. Even a captive bird refused to walk across two yards of sloppy mud to reach its food and instead took a firmer route over sand. Presumably, wading through mud is not worth the effort, even for a wading bird.

When the adults are away breeding in the summer, the young birds that remain on the Exe concentrate on the two or three best beds. But as the adults return, from July to October, the young birds gradually retreat to the less preferred areas. The
least dominant are the first to go, but by October, most immatures have been driven from the most productive beds. By the time winter really begins to bite, the young birds are, on average, feeding on much poorer beds than the adults, one reason why more young birds die. Not until they are on the verge of adulthood, at age four, does the dominance of a young bird match that of a full adult.

Many estuaries in the United Kingdom are being "claimed" for agriculture, building, rubbish dumps, or recreational beaches. With the loss of mud and sand flats, birds will be forced to feed at higher densities. This could heighten competition, increase mortality, and thus reduce population size. Juveniles are currently the most vulnerable group. Because juveniles are the foundation for future generations, an increase in the mortality rate of just this small subgroup (usually 10 percent of the population) has a disproportionate effect on the size of the entire population in the long run. The present higher mortality rate of juveniles seems to be linked to their lack of feeding success. But is this due to poor foraging skill or low competitive ability? If low food intake is a byproduct of competition, land reclamation and higher bird densities would hit juveniles hard. But if the young's lower intake rates stem from inexperience and incompetence at feeding, then increasing bird density might not have much effect on them. We now know that competition already reduces their intake rate very substantially in winter, and this would certainly worsen if bird densities were to be forced up by further land reclamation. Loss of habitat is likely to make life difficult for these birds.

Competition, bird density, weather, and physical traits, such as bill shape, all interact in the life of the Exe oystercatchers. But vitally linked to a bird's success in securing adequate food are its age and experience. If early lessons from parents and actual practice on the mussel beds greatly improve a bird's stabbing or hammering, then learning must supplement oystercatchers' innate knowledge, at least about feeding. From its first clumsy jabs at an empty mussel, to its frenzied theft of food, and its subsistence on shellfish scraps, a young oystercatcher, if it survives, will perfect its technique, become an expert in either stabbing or hammering, choose a mate that uses the same method, and perhaps pass on that skill to its own young. A breeding adult that returns to spend the winter on the one or two most prized mussel beds has really made it on the Exe.

Oystercatchers scour a rocky shoreline for vulnerable mussels, below. Adult birds that monopolize the best mussel beds can afford to rest occasionally, right, before winter sets in, while young birds driven to less bountiful areas must search incessantly for food and still may starve.

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Ancient Mansions of Chaco Canyon

With its leaders divided and its armies defeated, Mexico ceded two-fifths of its territory to the United States at the end of the Mexican War in 1848. A small American army occupied this vast area, mainly to keep the peace and to survey the land for roads and natural resources.

In 1849, en route to sign a peace treaty with the Navahos, a military force passed through Chaco Canyon in New Mexico. James H. Simpson, a young lieutenant with the U.S. Army Corps of Topographical Engineers, heard reports about some large Indian ruins nearby and obtained permission to explore them. A small party, including an artist and a cartographer, spent several days studying the site and collecting potsherds. Simpson’s Journal, published three years later, is the oldest eyewitness account we have of the great buildings and vast ruins of Chaco. Simpson estimated (correctly) that the buildings were about 700 years old and speculated they were an outpost of the Toltec civilization of the Valley of Mexico, although Indian guides with the army disagreed. They claimed (correctly) that the buildings had been built by the Anasazi ancestors of the local Pueblo Indians.

Nearly a half century later, Richard Wetherill, a rancher and trader who had developed an interest in archæology earlier at the Mesa Verde cliff dwellings, visited Chaco and sparked the first methodical

study of the ruins. He sent off a letter to Talbot Hyde in New York City:

Not having anything important on hand this winter I have taken the opportunity to visit the ruins of New Mexico. Those of Chaco Canyon being the greatest in New Mexico and almost unknown—every one so far having tried to get relics there making a total failure of it—for that reason more than any other I wished to examine them— I was successful after a few days search in finding relics in quantity—the ruins there are enormous—there are 11 of the large Pueblos or houses containing from one hundred to 500 rooms each and numerous small ones—how many I do not know but there must be more than 100. I stayed there until I had gotten 40 pieces of pottery . . . . Grass
When workers of the Hyde expedition excavated a room of Pueblo Bonito, they found baskets and pottery on the floor.

...and water is plenty—wood is scarce. A wagon can be driven to the Ruins in 5 or 6 days from our Ranch.

Talbot and his brother, Frederick Hyde (a trustee of the American Museum of Natural History), funded the Hyde Exploring Expedition, under the scientific direction of Frederick W. Putnam of the American Museum of Natural History. A 23-year-old Museum researcher, George H. Pepper, supervised the fieldwork, and Wetherill was named foreman.

The Hyde Exploring Expedition, helped by local cowhands, hauled a load of supplies to Chaco Canyon and set up a tent camp behind Pueblo Bonito. The kitchen consisted of an ironwood stove propped up on rocks against the pueblo wall. Some Navaho Indians were hired as laborers, and in May of 1896, excavations began on two large rubbish middens, where Wetherill hoped to find burials. After a month of fruitless digging of trenches, Pepper shifted the diggers to some smaller sites across the canyon. There they found thirty graves and many pots. Several Indians quit when they uncovered human skeletons.

From July to September, the workers excavated thirty-seven rooms and one kiva within the Pueblo Bonito ruins. Artifacts and building features were measured, mapped, and photographed. Pepper kept detailed field notes.

In the first season, the expedition recovered enough artifacts to fill a freight car. These included 114 pieces of cylinder-shaped pots, a quiver containing 81 arrows, some 375 carved wooden staffs that probably served as prayer sticks, a basket encrusted with shells and turquoise, 6 wooden flutes, several stone figures of
birds, frogs, and tadpoles, and many turquoise beads and pendants. All were shipped to New York, and the Hydes subsequently donated more than 1,200 items to the American Museum.

In the remaining three years of the Hyde expedition, Pepper and Wetherill laid the groundwork for all succeeding archeological investigations of Chaco Canyon. They started the studies of Great Houses—the pinnacle of Anasazi architecture and the largest buildings in North America until the construction of skyscrapers in the late nineteenth century. These community houses contained up to 800 rooms and could hold 1,000 inhabitants. To construct a single Great House, the Chaco builders cut more than 200,000 trees for beams and rafters. They excavated tons of sandstone for walls that were up to six feet thick and forty feet high. They did all this without the aid of domesticated draft animals.

The grand-scale construction might have led, in part, to the disappearance of the Chaco people. Some scientists contend that the overexploitation of local woodlands for fuel and building caused permanent deforestation of the region, transforming it into an arid wasteland. Tree-ring samples taken in the canyon also show evidence of a twenty-three-year drought, which may have forced the Indians to abandon the site.

While no written record of the Anasazi Indians remains, many traces of their once-flourishing civilization can be found in Chaco Canyon, in private collections, and in museums. The Maxwell Museum of Anthropology in Albuquerque, New Mexico, has created an exhibition, entitled "The Chaco Phenomenon," which includes many items borrowed from the American Museum of Natural History. It will be on view at the Museum in New York from March 6 through June 1.

At the American Museum

Japan Month
March is Japan Month in the Leonard H. Schaeffer Foundation at the American Museum of Natural History. Each weekend will celebrate the cultural achievements of that nation, including the martial art of Aikido, classical and folk dancing, a tea ceremony, and the traditional music of flute and koto. Calligraphy, kite making, doll making, and floral arranging will be demonstrated. The free programs will be repeated several times throughout the afternoon between 1:00 and 4:30 P.M. Seating is on a first-come, first-served basis.

In addition, a special performance by Soh Daiko, a drum group affiliated with the New York Buddhist Church, will be presented in the Kaufmann Theater on Sunday, March 14, at 2:00 P.M. Soh Daiko's music is inspired by Buddhism but also draws upon the older Shinto drum tradition.

At the Planetarium
Laser beams of colored light will dance across the Planetarium's sky of 9,000 stars to the beat of Phil Collins, Peter Gabriel, and the rock group Genesis. This new show will take place Fridays and Saturdays at 7:30, 9:00, and 10:30 P.M. Admission is $6. For more information call (212) 724-8700.

Alvin Ailey Repertory Ensemble
Performing both original compositions and classic works from the repertoire of Alvin Ailey's first company, the Repertory Ensemble will appear Wednesday, March 25, at 7:30 P.M. in the Main Auditorium. Tickets are $6 for members and $7 for nonmembers. Advance ticket purchase by mail is urged. Please enclose a stamped, self-addressed envelope and a check (or money order) payable to American Museum of Natural History. Send ticket requests to: American Museum of Natural History, Community Programs, Department of Education, Central Park West at 79th Street, New York, New York 10024-5315.

The Rollin' Kin' Dinosaur Review
Participatory theater and music (including singing) are planned for the latest discoveries about dinosaurs in a special program designed for children ages 4 to 10. This family program costs $3 and is open only to members. Performances will take place on Saturday, March 28, and Sunday, March 29, at 11:30 A.M. and 1:30 and 3:30 P.M. in the Kaufmann Theater. For more information call (212) 769-5600.

Underground Elephants
Because the soil of Kenya's Mount Elgon, a vast, dormant volcano, is devoid of salt, the elephants of the region go into underground caves to feast on salty rocks. In this program, biologist Ian Redmond will describe his studies, which find that the elephants not only explore the caves but also play, sleep, and bathe in them. Illustrated with Redmond's photographs, the lecture costs $3 for members and $6 for nonmembers. Show time is Wednesday, March 18, at 7:30 P.M. in the Main Auditorium. For more information call (212) 769-5600.

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Unexplained Blazing Objects

There are strange faraway energy sources. Are they naked quasars, cosmic jets aimed at the earth, or images formed by light bent by gravity?

by Stephen P Maran

Almost seventy years ago, a German astronomer included in a routine list of 354 newly discovered variable stars one called BL Lacertae. In the 1960s, Canadian radio astronomers found that BL Lac, as it is known for short, is neither routine nor a star, but a powerful source of energy that originates far beyond our galaxy. Today, about 120 similar BL Lacs are known, but investigators are not sure what they are. On a short-exposure telescopic photograph, a BL Lac resembles a star, but longer-exposed photographs may reveal dim fuzz around the starlike object. Spectra show that the fuzz is an elliptical galaxy, which is a system of hundreds of billions of stars.

Since BL Lacs are located in elliptical galaxies, are they related to radio galaxies like Cygnus A, which is also elliptical? Radio galaxies produce powerful radio waves that usually emerge from twin lobes flanking the galaxies. In addition, there is often a weak and small radio source at the radio galaxy’s center. Radiotelescopes sometimes detect thin jets of radio emission that connect the central energy sources with the distant lobes. Energy is apparently transferred from the centers of radio galaxies through the jets and is then released copiously from the lobes in the form of radio waves. BL Lacs, however, seem to differ from radio galaxies in obvious ways: the BL Lacs are never accompanied by twin radio lobes, and their central radio sources are strong. BL Lacs also have small, bright, central nuclei as seen in visible light.

As compact, powerful light emitters at the centers of galaxies, BL Lacs seem to resemble quasars more closely than they do the central powerhouses of radio galaxies. BL Lacs, however, fail to satisfy the usual criterion for identification as quasars, namely, the presence of strong, broad, highly red-shifted emission lines (emission lines at much longer wavelengths than normal) in the spectrum.

They differ from most quasars in several other ways as well. For example, their visible light and radio wave emissions have a noticeable polarization, that is, the light and radio waves they emit vibrate preferentially in specific directions. The emissions of most quasars are not polarized, vibrating equally in all directions. Thus, if you look at a typical quasar through a telescope and a sheet of Polaroid (a material transparent to light that is vibrating in a specific direction with respect to the top and bottom of the sheet), the quasar will look equally bright regardless of how you turn the Polaroid. But when you look at a BL Lac object in the same way, it will seem to brighten and fade as you rotate the Polaroid.

BL Lacs are also highly variable; their brightnesses in optical, radio, infrared, and X-ray emissions change by large amounts in weeks, days, or even hours. A BL Lac can double or halve its brightness overnight. By contrast, most quasars vary slowly, taking months or years to increase or decrease by 50 percent.

Yet another difference between BL Lacs and quasars is in the amount of X-rays each emits. An X-ray telescope on NASA’s Einstein satellite revealed that BL Lacs are strong sources of X-ray emission. Further, they are brighter in X-rays, in proportion to their light-bright- ness, than quasars. And finally, contrary to the implication of the word quasar, which was originally derived from quasi-stellar radio source, the vast majority of known quasars are not sources of detectable radio emission, while all the roughly 120 known BL Lacs are radio sources.

One unusual type of quasar, the OVV (optically violently variable quasar) is an exception, however, and in fact OVV’s have several similarities to BL Lacs: their radiation is polarized, they are strong radio sources, they undergo large, rapid changes in brightness (as the name OVV implies), and they emit far more X-rays than most quasars. Richard Mushotzky, of the Goddard Space Flight Center, in Greenbelt, Maryland, where I work, told me that OVV’s are stronger X-ray emitters than other quasars in proportion to their visible light, although not quite as strong as BL Lacs. Nevertheless, OVV’s differ from BL Lacs because they produce the bright emission line characteristic of quasars. But despite this difference, many astronomers lump BL Lacs and OVV’s together as “blazars,” a contraction of “BL” and “quasars.” This is an appropriate term, because some BL Lacs and OVV’s, when at the peak of their changing brightness, are among the brightest objects in the universe.

Another distinguishing characteristic of BL Lacs is that their spectra show no signs that their X-rays have been partially absorbed by interstellar matter in the host galaxies where they are located, whereas quasar X-rays are often so absorbed. Furthermore, the visible light of quasars is frequently reddened by interstellar dust in the host galaxies, just as airborne dust makes the sun seem red.

The X-ray emission from BL Lacs is also variable. An extreme case in point is the BL Lac H0323+022, located about two billion light-years from the earth. A 1983 report that observations with the HEAO 1 (High Energy Astronomy Ob-
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Astronomical observations at the Kitt Peak National Observatory in Tucson, Arizona, have revealed very rapid changes in the X-ray brightness of this BL Lac was greeted with some skepticism. Last March, however, a team of astronomers under Eric D. Feigelson, a Presidential Young Investigator at Pennsylvania State University, announced that detailed analysis confirmed that on one occasion the X-rays from H0323+022 decreased by at least 300 percent within thirty seconds. In energy terms, that was the equivalent of a lamp 250 billion times brighter than the sun being suddenly switched off.

One problem in studying BL Lacs and other blazars is that since they are so variable, individual observations may be misleading. Two astronomers at the Kitt Peak National Observatory in Tucson, Arizona, recently reported pronounced changes in the spectrum of the BL Lac object OJ 287, which Feigelson has called "perhaps the most rapidly variable extragalactic object known." Their observations were made with the fifty-inch telescope on Kitt Peak between late November 1984 and late March 1985. During that time OJ 287 reached the faintest magnitude at which it has yet been seen. The two astronomers found that as the brightness of OJ 287 dropped, emission lines of hydrogen and oxygen became visible in its spectrum. Thus, spectra of the same object, recorded at different times when the object is at different brightnesses, would yield different results in terms of emission lines. Since BL Lacs are regarded as lacking strong emission lines and quasars as having them, confusion might result from random observations. Accordingly, organized monitoring programs, in which astronomers repeatedly observe the same BL Lac objects, may be needed in order to unravel their mysteries and draw sound conclusions.

One such program, under way for more than six years, draws on the services of astronomers from about twenty institutions in the United States and Europe to monitor a dozen blazars. These blazars include some objects that have been observed to produce clouds of radio-emitting electrons that seem to travel through space at several times the speed of light but may actually move at only a substantial fraction of that speed. (A geometric illusion can magnify the apparent speed of the clouds to above the speed of light if they are hurled out from the blazar in almost exactly the direction of the observer. This is what seems to be occurring in some OVVs and BL Lacs.) Many attempts to understand BL Lacs involve speculating on how their powerful emissions are produced, based on what we believe about quasars. A quasar, we think, is produced by the release of huge amounts of energy from gas that is drawn into a supermassive black hole, a collapsed object with extremely strong gravitational pull at the center of a galaxy. Around the black hole, in a region perhaps not much larger than the solar system or at least significantly smaller than the distance from the sun to the next nearest star, the swirling, infalling gas somehow generates intense light. That light is bright over a great range of wavelengths, rather than concentrated in emission lines at only a few wavelengths. This emission continuum, which is particularly intense in ultraviolet light, heats and ionizes gas clouds in a region of space around the black hole much larger than the zone that produces the continuum. The hot clouds, stimulated by the ultraviolet light, produce the characteristic quasar emission lines.

If quasar emission lines are produced by gas clouds, one might conclude that a BL Lac is a quasar that is not surrounded by clouds. That is the "naked quasar" theory of BL Lacs. It accords with the observation that BL Lacs are in elliptical galaxies, where there seem to be few gas clouds, while quasars are mostly in spiral galaxies. The gas in elliptical galaxies is so hot and thin that it is unsuited to the production of strong emission lines that can be detected in the visible-light spectrum. But the naked quasar theory doesn't even begin to explain certain other differences between quasars and BL Lacs. For example, it does not predict or account for the observation that BL Lacs are much brighter in X-rays, in proportion to their visible-light emission, than quasars are.

Another explanation for BL Lacs, the "gravitational lensing theory," was recently proposed independently (and in slightly different forms) in three papers: one by Jeremiah P. Ostriker and Mario Vietri, cosmologists at the Princeton University Observatory; a second by an astronomer at the Meudon Observatory, near Paris; and a third by Jeno and Madeleine Barnothy, a married team of freelance astrophysicists in Evanston, Illinois. Gravitational lensing is the production of images of distant objects when their light is bent by the gravity of an intervening object, known as a gravitational lens. The intervening object may be a galaxy or a cluster of galaxies.

Although Ostriker's paper has attracted the most interest, the Barnothys deserve special mention because they have maintained for more than twenty years, despite some scoffing, that the radiation from quasars and related objects may be intensified by gravitational...
lensing. During that time, several gravitationally lensed quasars have been discovered, although I find little reason to believe that most quasars are lensed. In the Ostriker theory of BL Lacs, the gravitational lenses are not whole intervening galaxies but individual stars or small black holes in such galaxies. These lenses are therefore called minilenses. According to Ostriker's view, at least some BL Lacs are really OVVs quasars that happen to be located behind minilenses in intervening galaxies. As the minilenses orbit in their own galaxies, they pass in front of the OVVs, rapidly intensifying and dimming the OVVs' light as the lenses pass on and off the line of sight to the more distant objects.

The theory readily accounts for one crucial difference between BL Lacs and OVVs, namely, the deficiency of emission lines in the former and their prominent presence in the spectra of the latter. Because emission lines in quasars arise in the large region of clouds around the central continuum light source, they are not imaged or intensified efficiently by the minilenses, which are only effective at lensing the pointlike central sources. Thus, the theory explains, the light from a central source is enhanced by means of minilenses and appears bright that the emission lines from the surrounding region are lost in its glare. However, since both the visible-light continuum and the X-rays of OVVs are generated in a small region at their center, the visible light and X-rays would be amplified by gravitational lensing. Therefore, as pointed out to me by Mushotzky, one stumbling block for the minilens theory is that X-rays are proportionately brighter with respect to the visible-light radiation in BL Lacs than in OVVs or other quasars.

The explanation for BL Lacs that seems to have the most advocates is the "directed jet theory" proposed by astrophysicists Roger D. Blandford, of the California Institute of Technology, and Martin J. Rees, of Cambridge University in England. According to them, BL Lacs are radio galaxies in which the jets that run from their centers to their radio lobes are aligned toward the earth. Therefore, when we observe a BL Lac, we are in effect looking down a jet. If you think of the lobes of a radio galaxy and their connecting jets as a huge transparent dumbbell, this theory postulates that our radio-telescopes are viewing along the long axis, so that one lobe is superimposed on the other as seen by us, and therefore they do not appear as separate lobes. This is consistent with radio maps of BL Lacs, which sometimes reveal large, faint radio halos, but which never show twin lobes.

According to one version of the jet theory, high-energy particles stream out along the putative jet in a BL Lac at a large fraction of the speed of light, glowing as they go. The narrow confines of the jet make it seem exceptionally bright when seen end-on in this way, just as the beam from a lighthouse looks much brighter when it sweeps across you than when it is pointing in another direction. If BL Lacs are radio galaxies, this would account for the brightness of their central radio sources in contrast to the central sources in other radio galaxies, which are usually dim, presumably because their jets are not observed end-on.

Doppler boosting, an effect that intensifies the radiation from matter that is streaming rapidly toward the observer, would further amplify the apparent brightness of the BL Lac as seen from the earth. Boosting also shifts radiant energy seen by the observer from longer to shorter wavelengths, an effect known as blue-shifting. Since X-rays have shorter wavelengths than visible-light rays, blue-shifting makes the X-ray emission from BL Lacs brighter at the expense of their visible light. This may account for the high X-ray brightness of BL Lac objects. Slight shifts in the jets, which make them point slightly more or slightly less accurately at the earth, could explain the rapid variations in the brightness of the BL Lacs. The more accurately the jets are aligned with our line of sight, the brighter the objects would seem to be. However, since the jets in radio galaxies are narrow, the odds that the jet in any given galaxy will point right at the earth are very small. Thus, it is hard to understand why so many BL Lacs are observed.

Another problem with the directed jet theory is that as you look further back in time (farther out in space), you find that there were many more quasars and radio galaxies in the past than there are now, but that the abundance of BL Lac objects was not greater in the past. If BL Lacs are radio galaxies whose jets point at the earth, one would expect that with more radio galaxies, there would have been more BL Lacs. If looking back in time doesn't tell us what BL Lacs are, we will have to look to the future. Perhaps further observations with new telescopes and future X-ray satellites will provide us with the answer.

Stephen P. Maran is a senior staff scientist in the Laboratory for Astronomy and Solar Physics at NASA's Goddard Space Flight Center in Greenbelt, Maryland. The opinions expressed here are his own.

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A Promising Morning Sky

by Thomas D. Nicholson

There is little planetary activity in the sky in March. Mars is the only planet still above the horizon at sunset, but it is just barely a first-magnitude object. At the beginning of the month, it is close to Hamal and Sheratan in Aries, which might help to identify it. For those familiar with Aries' stars, the constellation will look as though it has grown a third bright object. During March, Mars moves toward Taurus; by the end of the month it is closer to the Pleiades than to the stars of Aries. Once again, Mars will stand out for experienced star watchers because there is no equally bright star near the Pleiades. Unfortunately, the sun is too close to the right of the Pleiades for easy viewing. Because Mars and the stars near it are very low in the west at dusk and set soon after dark, you will need an exceptionally clear western horizon to see them.

The morning sky holds more promise. Saturn, in Ophiuchus, rises about midnight (plus or minus an hour or so, depending on the time of the month) and will be readily seen in the southeast until morning twilight. Venus rises before daybreak but doesn't get very high before twilight begins. Fortunately, the planet is exceptionally bright, so it should be clearly visible toward the east-southeast until shortly before sunrise.

The most exciting events in the March skies are the lunar occultations of Jupiter, Spica, and Antares and the annular/total annular eclipse of the sun late in the month. Unfortunately, however, none of these occurrences will be visible from North America.

Events in the calendar below are given in local time unless otherwise indicated.

March 1: The moon occults Jupiter above the southern continents, but mostly in daylight, since it is only one day past new.

March 2: Twilight could include a crescent moon, low in the west just after sun-down, to the left of the sun in the ascending branch of the ecliptic.

March 4: Brighter and fatter tonight, the moon is much higher at dusk, and Mars is the reddish object to its right. Both are in Aries.

March 5–7: The moon moves into Taurus on the 5th, very close to the Pleiades at dusk but not yet bright enough to hide the cluster's dim stars. Taurus' bright reddish star Aldebaran is below the moon on the 6th. First-quarter moon is at 6:58 A.M., EST, on the 7th, and that night the moon passes close to Alnath, the star that marks the tip of the Bull's right horn.

March 9: Apogee moon (farthest from the earth) is in Gemini.

March 10: The gibbous moon is in line with Pollux and Castor, the twin stars of Gemini, but moves out of line during the night.

March 11: Mercury completes its swing between the earth and the sun when it ends its retrograde loop and returns to direct motion. It begins to follow the sun in an easterly direction today, to the sun's right, in the morning sky.

March 12–15: The moon is in Leo, near Regulus on the 12th and 13th, switching from the right to the left of the star from one night to the next. It moves out of Leo before reaching full phase at 8:13 A.M., EST, on the 15th. Just barely past full on the night of the 15th, the moon is about midway between bright Regulus to its right and Spica (in Virgo) to its left. At about 7:00 P.M., EST, its position coincides almost exactly with the autumnal equinox—where the sun crosses the equator on its way north next autumn. The sun is now very near the vernal equinox, of course, on the opposite side of the sky.

March 17: When the moon rises tonight, after 8:00 P.M., it will be very near Virgo's Spica. Just a few hours earlier, at about 1:00 P.M., EST, it occulted Spica over northeastern Asia and Japan.

March 18–19: The morning moon (rising before midnight but remaining in the sky almost until noon) is in Libra, pacing off the distance between Spica and Scorpius' Antares. The interval between sunrise and sunset is about twelve hours on the 18th, marking the point in the year when days in the Northern Hemisphere begin to exceed the nights in duration.

March 20: The third occultation of a bright object by the moon occurs, this time of the reddish star Antares. But the event takes place below our horizon.

March 20–21: The first day of spring in the Northern Hemisphere takes place on the 20th or the 21st—depending on where you are located. The sun arrives at the vernal equinox (where it crosses into the northern half of the sky) at 10:52 P.M., EST, on the 20th, so spring begins on that date throughout the Americas. But in Europe, it will already be the 21st.

March 22: The evening sky was moonless on the 20th, but the moon rises after 1:00 A.M. on the 22d.

March 23: Sagittarius rises shortly after 1:00 A.M., the moon about an hour later.

March 24–26: The moon is at perigee (nearest the earth) on the 24th at about the time it crosses into Capricornus, where it joins Venus. The moon rises before Venus on the morning of the 24th and 25th but closes on the planet by the 26th, when they rise virtually together.

March 26: Mercury is at its greatest westerly elongation (to the sun's right), placing it in its best viewing position as a morning star during this cycle. Jupiter is in conjunction with the sun today and finally leaves the evening sky.

March 29: The news today is good and bad. The good news is that the new moon, occurring at 7:46 A.M., EST, crosses directly in front of the sun and causes an annular and total eclipse of the sun. The bad news, as you might suspect, is that we will not see it. The path of the total, or annular, phase (it starts out annular, becomes total, and then annular again) begins in southern South America, crosses the South Atlantic Ocean and Central Africa, and ends in the Indian Ocean just south of Saudi Arabia. The much larger area of partial eclipse extends halfway up the South American continent and includes all of Africa. A lot of people are going to enjoy this eclipse, especially those in Africa, but North America will miss the event.

March 31: Tonight is probably too early to see the new crescent moon; it may not show up until tomorrow. Saturn is beginning to rise before midnight, however; it starts its retrograde (westerly) drift today, a sure sign that it will soon be an interesting evening object.
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Scattered within the forest on Mount Graham and nearby peaks are several cold, wet alpine meadows, known in southern Arizona as cienagas.
Mount Graham, Arizona

by Robert H. Mohlenbrock

“This is a great Pleistocene museum,” exclaimed Tom Waddell, as we neared the 10,720-foot summit of Mount Graham, in southeastern Arizona's Coronado National Forest. A seasoned wildlife biologist with the Arizona Fish and Wildlife Department, Tom has hiked and ridden horseback over most of the surrounding Pinaleno mountain range during the past several decades. He was referring, for one thing, to the glacial till that has been found on the north and east sides of the mountain, the southernmost location of such features in the United States.

The Pinalenos became isolated from other mountains when the last Ice Age ended, about eleven thousand years ago. The Canadian type of spruce-fir forest that formerly occupied the surrounding valleys was stranded on the steep mountain peaks as the glaciers retreated and the Sonoran Desert advanced into lowland areas. Various small mammals, reptiles, birds, insects, and mollusks that could not tolerate the desert heat and aridity were also confined to the top of Mount Graham and other Pinaleno peaks. These included some, such as the Clark nutcracker and the Arizona black rattlesnake, that had originally migrated down from the north across the Colorado Plateau and others, such as the twin-spotted rattlesnake and Yarrow's spiny lizard, that had moved up from Mexico’s Sierra Madre Occidental.

Through the subsequent period of isolation, Rusby's mountain fleabane and a number of other plants have developed into distinct species, and animals such as the Mount Graham spruce squirrel, the white-bellied vole, and the Mount Graham pocket gopher have become recognizable subspecies. The fleabane, squirrel, vole, and pocket gopher live only above 9,400 feet in the Pinalenos, and nowhere else in the world.

Thought to be extinct in 1965, the Mount Graham spruce squirrel was rediscovered a few years later and now numbers fewer than two hundred individuals. It is the smallest and southernmost subspecies of the red squirrel, a common animal that ranges all the way into boreal Canada and Alaska. Unlike other red squirrels, which chatter incessantly, the
Mount Graham spruce squirrel is mute except in the most life-threatening situations. Some zoologists believe that the 11,000-year isolation of this subspecies in the absence of mammalian predators—namely, the pine marten—has eliminated its need for being vocal.

During the first three decades of this century, the spruce squirrel ranged down the mountain slopes to about 6,500 feet, where at least some spruces and Douglas firs were available to provide seed cones for food. But intensive logging, which began in the 1930s, confined the squirrel to higher elevations. When, in the 1940s, the Abert's squirrel was introduced into the adjacent elevations of ponderosa pine for hunting purposes, the spruce squirrel was driven even farther upland.

Today the Mount Graham spruce squirrel lives only within the closed forest canopy above 10,000 feet on Mount Graham and on some nearby peaks. Here the squirrel selects a tree with a cavity for its nest and begins to compete with band-tailed pigeons and crossbills for spruce cones on the trees and with chipmunks for cones on the ground. The squirrel will perch on a branch with a cone, devouring the seeds and dropping the inedible cone debris to the ground. In time, deep layers of this debris build up, and the squirrel uses this midden as a cache in which to bury fresh cones and even mushrooms for future consumption. The squirrel builds the midden in dense forest stands, sometimes in hollow logs and stumps, where sunlight cannot penetrate and dry out the cache of food.

Although the Forest Service is not now logging the spruce-fir forest, and the spruce squirrel seems to have adapted to the occasional intrusion of the Abert's squirrel, its existence is still threatened. Some biologists believe that any organism reduced to fewer than two hundred individuals may lack the genetic diversity needed for survival. In addition, the University of Arizona's Steward Observatory has an $86 million proposal pending with the Coronado National Forest to place eighteen sophisticated telescopes in a 3,500-acre area encompassing most of the terrain above 9,400 feet on Mount Graham and the other Pinaleno peaks. At least 113 of the remaining spruce squirrels live in this high-impact area. If such an astrophysical complex is constructed, the relict Pleistocene spruce-fir forest and the plants and animals that depend on this habitat will be destroyed.

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Talking Turkey

Food congressists experience total immersion in things Turkish

by Raymond Sokolov

Güzel kokolu ekmek!
Sensin yemeklere bas.
Olma seni sevmemek.
Her yemeye arkadas.
—H. Ali Yücel

Even after a week in Turkey last fall at the International Food Congress, I have no clear idea what Mr. Yücel’s quatrain means. But since the congress provided daily opportunities to listen to Turkish gastronomic experts lecture on their subject, I did pick up enough of the language to know that ekmek means bread and that yemeklere is built on the noun yemek, meaning food.

I mention this to give you a direct sense of what much of the scholarly portion of the meeting was like for the non-Turkish participants, all of whom had been selected on the basis of their previous participation at the food symposiums held annually in Oxford, England. For us Anglophones, the meeting offered total immersion in things Turkish but not enough time to acquire mastery. Indeed, for all I really know, the Yücel quatrain may not be Turkish. It was quoted at the beginning of a paper on Kazan Tatar diet and Russia by the English specialist R.E.F. Smith. And since Smith was forced to remain at home in Birmingham because of a personal emergency, he was unavailable to provide a gloss on the poem or to say if it was written in Turkish or Tatar. And yet, after attending the congress here, I am certain that the words are from a Turkic language and that their subject is food.

For many of the more Turkologically inclined veterans of the Oxford symposiums, the Turkish language aspect of the congress was far less a matter of seeing through a glass darkly than it was for neophytes like me. And these cross-cultural experts were, for me, the intellectual core of the meeting (just as the various meals were its practical high point). Smith, the author of Peasants Farming in Muscovy, clearly roams where he likes in the watershed of the Volga and points east and south. But he inevitably writes from the perspective of an Englishman, and after twelve pages on Tatar influence on Russian cooking, he concludes with a nod to Tatar influence on the West. Steak tartare is unknown to his (mostly Russian) sources, he says, but he has managed to locate two recipes for tartar sauce, both
using raw egg yolks, not hard-boiled eggs. The first combines beaten yolk, sugar, oil, vinegar, and horseradish. The second has no sugar or horseradish but does employ finely chopped onion and salt.

Many of the symposiums' papers had nothing to do with Turkey at all. One of the most interesting of these, by Rudolf Grewe, collected fascinating evidence about the arrival of the tomato in Spain and Italy. Grewe’s hypothetical explanation for the origin of the Italian word for tomato, pomodoro, is extremely elegant. The apparent meaning, golden apple, is utterly fanciful unless the term was applied to a yellow tomato. On the other hand, sixteenth-century herbalists knew that tomatoes were related to eggplants—both are in the Solanaceae family. The eggplant had been brought to Europe by the Moors, so it might easily have been called pomme des Maures in French, the apple of the Moors, or in Italian, pomodoro—easily contracted into pomodoro. Since the tomato was considered a kind of eggplant, and since it spread throughout Italian cooking, it eventually took over the misnomer.

Several other valuable papers were delivered that might just as easily have been presented in Oxford. But the Turkish location of this extraordinary event did provoke a few notable contributions, in English, that discussed the effect of the Ottoman preponderance on European neighbors and European subject peoples.

The triumphant example of this was Maria Johnson’s “Notes on Turkish Contributions to Balkan Flour Confectionery.” Johnson is a Bulgarian, now residing in England, who has long been at work on a Balkan cookbook. Her grasp of materials in the many languages of her chosen area is nothing short of dazzling. But pedantry is not her line. When she explains in a footnote that the Turkish proconsuls, called spahis in English, owe their title to a Turkish word (sipahi) derived originally...
from Hindi, she has explained something specific but has also conveyed the global reach of the Ottomans. Similarly, by letting drop in passing that “during the centuries of occupation,” the Christian population of the Balkans referred to Istanbul as Carigrad, the king’s town, she deftly recreates the world in which the imperial cuisine of the capital “became part of the national cookery tradition of the present-day Balkan countries.”

The body of her paper catalogs “some of the most popular flour confections of Turkish origin which are well established in the Balkans. Many of them have departed considerably from their Turkish prototypes” after having been “modified by generations of Balkan cooks.” This simple statement conceals extraordinary complexity and gives no sense of the intricacy of Johnson’s erudition. Here, by way of example, is her entry for kadaif: “(Alban., Bosn., Bulg., Maced., Serbo-Cr.), kandaja, kantafi (Gr.), cadaif (Roman.) from Turk. kadayif, from Arab. The dough for this rather extraordinary confection could be termed ‘spun dough,’ because it is drawn out into long threads as thin as button cotton. Its full Turkish name, tel kadayif (tel meaning wire, thread, a single hair) is used to differentiate it from ekmek kadayif, which is a fairly large, disc-shaped kind of rusk, and from yassi kadaif, which is similar to ekmek kadaif but smaller.

“In the Balkans, tel kadayif has been prepared in small workshops and in the home for years by pouring a flour-and-water paste through a special saucepan with a few holes in the base (each hole approximately 2 mm in diameter), onto a shallow, circular, tinned-copper tray (tepsi, Turk.) lightly coated with beeswax or butter and set well above glowing charcoal. The threads of dough thus produced were allowed to dry on the heated tray before they were put away.

“Nowadays, however, spun dough is an industrially manufactured product. To make the confection itself, the dough is laid in a baking tray, unfilled or, most commonly, with a layer of nuts in the middle, butter is poured over it, and the composition baked until the dough is pale brown or, as in Greece, until it just barely turns color. (This is the esteemed white kanda, filled with green pistachios, which can be bought by weight in some pastry shops in Athens; I came across it recently in Piraeus.) After baking, the pastry is moistened with syrup and served garnished with kaymak (Turk.)—a kind of thick, ripened clotted cream.”

Johnson goes on to explain that “an alternative presentation in Bulgaria is to bake the dough in two identical trays, then sandwich the syrumped pastries together with toasted nuts and stiffly whipped cream, topping the whole assemblage with more cream.

“Yet another variation is the Bulgarian mlechen kadaif, in which the syrup is made with milk rather than with water. Individual-sized, oblong rolls of kadayif, filled with nuts, are the sort mostly served in restaurants and pastry shops throughout the Balkans.”

Ottoman cuisine never much affected northern Europe. But it did get there at least as an idea. In her paper, Gillian

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Two recipes from *Turkish Cookery Book*, by Turabi Effendii (London, 1864), with thanks to Jane and Alan Davidson.

**Kawun Dolmassi**

Procure a musk-melon, or any other one; cut out the part where the stalk is, twice the size of a crown piece, so as to form a lid; take out the seeds, and part the inside; then fry a nice brown a sufficient quantity of raw minced mutton in fresh butter, with two onions chopped fine; then add half a teacup of rice well cleaned, sufficient salt and pepper, a tablespoon of curdants, two or three tablespoons of almonds, skinned, and the same of pistachios; stir three or four minutes longer, and take it off; then stuff the melon with this mixture; put the piece over that you have previously cut out for a lid, and pin it round with a few wooden pins; then put it in a baking-dish, and bake it nicely in the oven; then dish it up and serve.

Sweet pumpkin may be done in the same way. If the pumpkin is not sweet, half a teacup of honey is added.

**Ekmek Kadayif**

Put a pound of white sugar in a clean saucepan with two pints of water, set it to boil until it becomes a syrup; then cut open four or five muffins and put them in the syrup for two or three minutes, take them out carefully, . . , lay half of them in a baking-tin, sprinkle some pound ed pistachios or almonds over, then a layer of clotted cream over, a quarter of an inch thick, again pistachios or almonds, and cover them with the other half of the muffins; then pour three-quarters of a pint of the syrup over, and put it in the oven, or on a moderate charcoal fire, until the syrup is nearly absorbed; . . serve hot or cold.
Goodwin of London looked at “Turkish” recipes in seventeenth-century English cookbooks. The small collection of self-described Turkish dishes are mostly inauthentic turquoiseries, full of pork, called Turkish mainly for their pine nuts or pistachios. Indeed, the authentic recipe for dolma from the manuscript cookbook of a certain Ann Blenowe is the anomalous exception.

The first serious Turkish cookbook appeared in English translation only in 1864. Turabi Effendi’s Turkish Cookery Book was “A Collection of Receipts dedicated to those royal and distinguished personages, the guests of His Highness the late Viceregal of Egypt, on the occasion of the banquet given at Woolwich, on board His Highness’s yacht the Faiz-Jehad ...”. To my inexpert eye, this looks like a serious work. Photocopy editions of the 82-page, 253-receipt book were distributed to congressists by Jane and Alan Davidson, for purposes of research and study.

If much of this smacks more of the library than the kitchen, at least one British congressist had her research subject brought vividly before her in the flesh, so to speak. Jill Tilsley-Benham contributed a paper on the legendary fat-tailed sheep of the Middle East. It was an amusing and yet serious piece of work, collecting loci classicæ on beasts said to have tails weighing as much as thirty pounds, tails so rich in delectable fat that they had to be supported in two-wheeled carts. Lo, as we walked toward town from a disabled bus, which had taken us to the site of a thirteenth-century Sufic oven in the rural hinterland of Konya, we encountered a bevy of bona fide fat-tailed sheep. Tilsley-Benham, in fighting trim because of lessons in traditional belly dancing in London, gave chase. The sheep, surprisingly nimble, escaped, literally dragging their tails behind them.

It was often in this way, between meals and official sessions, that we congressists learned the most about the food and life of our host country. But the more one learns, the more one thirsts to learn. 1, for one, look forward to the much larger international food meeting scheduled to be held in Istanbul in 1988. In the meantime, I find myself left with many questions, some reconduit, one of more mundane nature. On the bilingual laundry list at the elegant Pera Palas Hotel in Istanbul, the Turkish column listed something called a Montgomery. The English translation was Montgomery. What is a Montgomery?

Raymond Sokolov is a writer whose special interests are the history and preparation of food.
Jumping Blues

This photo of a common European frog in midhop provoked the question, Just how far can these amphibians leap? A few phone calls to experts provided some answers.

It turns out that official frog jumping isn't measured on a per jump basis, but by adding up three consecutive jumps. “That's just the way we've always done it,” said Mike Polaszak, manager of Frogtown, U.S.A., the fairgrounds in Angel City, California, where the Calaveras County frog-jumping contest—inspired by Mark Twain’s story of “The Celebrated Jumping Frog of Calaveras County”—is held every May. The world’s record of 21 feet 5⅛ inches was set in Frogtown last year—triple jumped by a “basic pond-variety frog” named Rosie the Ribiter.

Scientists, however, measure jumps in multiples of body length. George Zug, a herpetologist at the Smithsonian Institution, has calculated that little, long-limbed eastern cricket frogs leap up to forty-eight times their body length.

Frogs hop primarily to escape enemies; their muscles aren't made for sustained leaping. “To a frog, how high is not as important as how far, and how far is not as important as how quick,” explained Richard Wassersug, herpetologist at Dalhousie University in Nova Scotia. “So from the frog's point of view the whole emphasis on how far kind of misses the point.”

But since the management of Frogtown, U.S.A., still rewards length of jumps and not quickness, we wanted to know whether modern science could help Rosie break her own record, if she hasn't yet gone into retirement and started endorsing a line of jumping shoes. Indeed, one recent discovery is pertinent. Frogs have bad vision and when they jump they apparently aim for patches of blue, whether water or sky. And so Wassersug suggested that next May, Rosie's friends and supporters should wear sky blue running suits and stand at the far end of the jumping field.

Then he reconsidered. “Actually,” he said, “the running suits might be a little obvious. I'd try everyone in blue jeans first.”

—Charles C. Mann

Photograph by Stephen Dalton
Authors

families.

Ruhlen continues

to investigate

the internal divisions in the largest of

—Amerind—with

a view

to clarifying prehistoric events.

Many

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clude The Languages of Native Ameredited by Lyle Campbell and
ica,

Marianne Mithun, and South American
Linguist Merritt Ruhlen (page 6) ex-

Indian Languages, edited by Harriet E.

amined the major groups of Native
American languages and their relationship to Old World languages while he
was researching his book A Guide to the
World's Languages, Volume 1: Classifi-

Manelis Klein and Louisa R. Stark (pub-

cation (Stanford: Stanford University
Press,

1

987).

Ruhlen

also provided edi-

torial assistance in the publication

of Jo-

seph H. Greenberg's Language in the
Americas (also just issued by Stanford),
which contains the evidence for grouping all New World languages into three

Melvyn C. Goldstein (page

38),

now a

professor of anthropology at Case West-

ern Reserve University in Cleveland,

has been interested in the Tibetan pracof

tice

fraternal

polyandry

(several

brothers marrying one wife) since he was

a graduate student in the 1960s. "The

custom is synonymous with Tibetan society," he says, "but has been difficult to
study, since Tibet was closed to anthropologists until 1985. 1 was forced to
do research among Tibetan refugees in
India and then among Tibetans who traditionally lived in northwestern Nepal
and in Ladakh." As a result of China's
new "open door" policy, however,
Goldstein has been able to begin a seven-

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ton.
ers

golfers,

honeymoon-

teen-month study of nomads living at
elevations of 16,000 to 17,800 feet on Tibet's northern plateau. Part of this study
deals with the role of marriage and family

in

human

adaptation to the harsh

environment. Goldstein's other current
projects
Addr<

include

writing

a grammar-

reader of literary Tibetan and a history

modern Tibet from 1933 to 1951. For
recommends The
Cultural History of Tibet, by David L.

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Natural History 3/87

Island,

SC 2945

additional reading, he

by the University of Texas Press
1979 and 1985, respectively). Ruhlen,

lished
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who lives

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Palo Alto, California,

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rently preparing the second
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Guide, to

data on roughly 2,000 languages.

He

is

compiling a worldwide set of words whose resemblances in sound and meaning suggest links between presumably indealso involved with other scholars in

pendent language families.

Snellgrove and

Hugh

E.

Richardson

The Hidden Himalayas, a book of photographs by
Thomas L. Kelly, with text by Carroll
Dunham, will be published this fall by
(Boston: Prajna, 1980).

Abbeville Press.


Fifteen years ago, James M. Dietz (page 52) spent several months in the Isle Royale National Park, Michigan, participating in a long-term study of wolf-moose ecology. Inspired by that research, he searched for a similar predator-prey situation in Brazil and settled on the maned wolf, only to find the Brazilian canid to be a solitary creature quite fond of fruit—just the opposite of the gray wolf in its foraging behavior and social organization. Nevertheless, he persevered and has, in fact, spent eight of the last thirteen years in Brazil studying endangered animals. Dietz is currently a research associate at the Smithsonian Institution and director of field research for the National Zoological Park’s Golden Lion Tamarin Conservation Project in Brazil. This comprehensive project includes studying free-living animals, reforesting degraded habitats, and efforts to reintroduce captive-born tamarins into suitable areas. For more on the maned wolf and other members of the family Canidae, he suggests The Wild Canids, edited by Michael W. Fox (New York: Van Nostrand Reinhold and Co., 1975) and The Carnivores, by R. F. Ewen (Ithaca: Cornell University Press, 1985).

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Gut Busters

Flaten your stomach in just minutes a day!
Ronald L. Shimek's fascination with the colorful marine life of the rocky intertidal zone of the northern Pacific coast led him to the subject of this month's photo essay (page 60). Patience and nearly a thousand dives in the waters of Puget Sound got him the photos and the story. A zoologist with a doctorate from the University of Washington, Shimek has forsaken full-time teaching for the free-lance life of nature photographer, biological illustrator, and marine researcher. A course in invertebrate embryology piqued his interest in sexual reproduction among scissile creatures. Diving among them, he says, made him aware of their beauty and diversity. Shimek studies and dives in Vancouver, British Columbia, where he will teach at the Bamfield Marine Station this coming summer. For more on life in the intertidal zone, he recommends *Seashore Life of the Northern Pacific Coast*, by E.N. Kozloff (Seattle: University of Washington Press, 1983) and *Between Pacific Tides*, edited by Edward F. Rickleffs et al. (Stanford: Stanford University Press, 1985).

John D. Goss-Custard (page 64) earned his doctorate in ecology from Aberdeen University in Scotland in 1966 and has spent the better part of the last twenty-five years observing shorebirds on the estuaries of southern Britain. He is now the principal senior staff officer at the Institute of Terrestrial Ecology in Dorset, England. A special interest in the impact of habitat loss and change on shorebirds led to his current study of European oystercatchers. In the future, he plans to investigate the effect of the spread of the marsh plant spartina on shorebirds. Spending wet winters on open mud flats has not dampened Goss-Custard's enthusiasm for other enterprises. He is learning to speak French and play the saxophone and enjoys brewing beer and practicing the English art of gardening. A good overview of shorebirds worldwide can be found in W. Hale's *Waders* (London: Collins, 1980). *Coastal Waders and Wildfowl in Winter* (New York: Cambridge University Press, 1984), edited by P.R. Evans and John D. Goss-Custard, contains papers on shorebirds and winter food resources. Peter Matthiessen's *The Wind Birds* (New York: Viking Press, 1973) is an account of migrating shorebirds on the North American side of the Atlantic.

As a child, Stephen Dalton was fascinated by the natural world, but his love affair with high-speed photography began later, when he was an adult. With the assistance of a military engineer, Dalton designed and constructed the special equipment with which he took this month's "Natural Moment" (page 96). Jumping, the frog breaks a beam of light, triggering a flash that goes off for about 1/20,000 of a second, freezing the subject in midflight. "I took this one in the pond below my house," says Dalton, who lives in Sussex, England. "It took some persuasion to get the frogs to jump—most of the time they seemed to want to sit there." Dalton is the author-photographer of *Caught in Motion*, a book of his high-speed photographs.
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   By the Banks of the Chinchihuapi

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   Life's Little Joke

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   A Civilization's Remains

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30 Life upon the Permafrost Text and photographs by Fred Bruemmer
   Summer is only skin deep in the Arctic.

50 Arctic Seas That Never Freeze Maxwell J. Dunbar
   Without these persistent ice-free patches, most birds and mammals could not
   survive the harsh northern winter.

54 Seabird Citadels of the Arctic Tony Gaston
   Why—with empty lands and vast oceans around them—do millions of thick-billed
   murres gather in noisy, odoriferous colonies?

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   A missing link turns up in a Japanese riverbed.

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Cover: At sunset, a polar bear walks along the ice at the edge of North Water, the
largest of the permanently open seas between northwestern Greenland and Elles-
mere Island. Photograph by Fred Bruemmer. Story on page 50.
Ardent Adaptationism

Stephen Jay Gould argues, in “Freudian Slip” (“This View of Life,” February 1987), that we should not worry about the possible adaptive significance of female orgasms in humans. This claim is based on an analogy between the nipples of males and the clitoris of females. Male nipples are small, functionless structures that arise “because females need them”; the embryonic plan that produces useful female breasts has as an incidental byproduct—the formation of nipples in males. Similarly, the basic mammalian plan of development leads to identical organs in male and female fetuses, the penis and the clitoris: the one eventually becomes large and capable of generating functional orgasms for males; the other is destined to remain small, a nonadaptive side effect of the genes and developmental system that are “needed by males” if they are to develop penises. This is a variant on one of Gould’s familiar themes, namely, that knowledge about the developmental bases of a trait often make adaptive explanations unnecessary. The “just-how” stories of Gould are presented as part of a plea for a pluralistic evolutionary biology, one that promotes a more complex, and more realistic, world view than that of the ardent adaptationist, who insists on searching for the reproductive value of every evolved character.

The plea for pluralism seems reasonable and wholesome. So why do so many one-sided adaptationists still stubbornly speculate on why this or that trait increases an individual’s chances of producing surviving offspring? I think I have an explanation.

No evolutionary biologist has bothered to advance adaptationist explanations for male nipples, yet many have proposed an adaptive basis for female orgasm. Male nipples do not do anything. Male nipples do not yield even one percent of the milk of female breasts. In contrast, the clitoris does something—not in every copulation, but often enough and dramatically enough to engage the attention of most women, many of their male partners, and assorted students of psychoanalysis and reproductive biology. Female orgasm is not an imperfect, half-hearted imitation of male orgasm, but a strong physiological response that is different in pattern and timing from male orgasm. The pleasurable sensation of female orgasm is accompanied by a host of correlated muscular contractions of the uterus and vagina. The clitoris is not an utterly inert structure; it is an active participant in a complex and extraordinarily involving event. Viewed in this light, the clitoris—male nipple analogy is an exceedingly crude one.

Female orgasm is not a guaranteed aspect of sexual intercourse for women, and a certain (modest) amount of cooperation with a partner is generally required for its occurrence. In sharp contrast, intercourse is an extremely reliable cause of orgasm in men. Because Gould assumes that orgasm must serve the same function in women as in men, he takes the “failure” of women to reach orgasm 100 percent of the time as evidence for this imperfect and nonfunctional nature of the clitoris. But why make this assumption? As many biologists have pointed out, a male’s reproductive success is often correlated with the frequency of copulations (and diversity of partners). The indiscriminate nature of male orgasm may encourage frequent and indiscriminate copulation.

A woman’s reproductive success, however, is rarely simply a function of the number of copulations she experiences in her lifetime. The long gestation period per embryo limits the number of babies she can produce. The survival of the babies she does have will depend far more on the paternal assistance she receives from her partner(s) than the sheer number of matings. Couldn’t female orgasm have more to do with increasing the probability of having children who receive paternal care than with increasing the probability of forming embryos?

There are several testable predictions that follow from these adaptationist speculations, which Robert L. Smith of the University of Arizona has already outlined in his chapter in Sperm Competition and the Evolution of Mating Systems (Academic Press, 1984). For example, females should reach orgasm more frequently with partners who offer parental care to their children than with casual or explicitly nonpaternal partners. For example, orgasm should motivate a woman to have sexual intercourse more frequently with a male who cares enough about her to attend to her sexual enjoyment. For example, female orgasm should act as a mechanism of discriminating mate choice and paternity control by females.

The clitoris is most definitely not an analogue of the male nipple, and therefore adaptive possibilities should not be written off. The adaptationist position is an invitation to scientific investigation. The speculations presented here could be tested by examining the predictions associated with them. If the predictions fail, then we can rule out the hypothesis. But let’s not reject plausible possibilities out of hand. I suspect that the last word has not been written on female orgasm, and rightly so, for there are still plenty of ideas, including Gould’s favorite hypothesis, that need to be rigorously tested against the competition.

JOHN ALCOCK
Department of Zoology
Arizona State University
Tempe, Arizona

Stephen Jay Gould Replies:

John Alcock has misunderstood my major point—but quite instructively; for in so doing, he has demonstrated beautifully, if unconsciously, the force and restrictiveness of adaptationist bias. As with many constraining biases, one must step outside for correction; tinkering from within will not suffice.

Alcock thinks that in identifying clitoral orgasm as probably nonadaptive, I have asserted the “imperfect and nonfunctional nature” of the clitoris itself. This false inference exemplifies my major complaint about adaptationism—its logically incorrect equation of current utility with reasons for historical origin. The range of biological utility is vastly greater than the domain of function for immediate reproductive success in the Darwinian game of natural selection. The bias of adaptationism equates the two and proclaims as interesting, important, and worth the attention of evolutionary biolo-
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...gists only those structures that natural selec-
tion builds or maintains for current function.

But consider the importance and vital utility of structures that arise for nonadaptive reasons. The male-mimicking genitalia of female spotted hyenas are undoubtedly, even crucially, useful in the so-called greeting ceremony that readmits solitary hyenas to their clans, but these structures probably arose as nonadaptive, developmental byproducts of high testosterone levels in large-bodied females (see my essay of February 1981). The enormous eggs of the kiwi are clearly useful in permitting the hatching of large and capable offspring, but their large size is probably a developmental byproduct, given well-studied rules of scaling for egg sizes among birds, of kiwi evolution from larger moa-sized ancestors (see my essay of November 1986). Similarly, no one can deny the utility of such human skills as writing and reading (or the glory of their great works of art, literature, and music), but natural selection did not act specifically for these foci of technological societies. They are nonadaptive structural consequences of a large brain, built by natural selection for other reasons.

Alcock, equating “origin as adapta-
tion” with “current utility,” apparently
thinks that I downgrade the significance of the clitoris—as if nonadaptive meant useless. He points out that “the clitoris is not an utterly inert structure; it is an active participant in a complex and extraordinarily involving event.” But this same claim is the very premise of my original essay. Of course the clitoris has vital utility—and I spent half my essay trying to explain just why it does in developmental terms (as the homologue of the penis). Adaptations are features built by natural selection that enhance reproductive success; the domain of biologically useful structures is vastly greater.

Such probable nonadaptations as clito-
ral organs, large eggs of the kiwi, and
male-mimicking genitalia of hyenas are eminently useful (and absolutely fascinating) phenomena, co-opted for later utility following an origin as developmental consequences of changing patterns in embryonic and postnatal growth. If anything, such developmental explanations are more expansive and operational than the necessarily fruitless and untestable adaptationist speculations that continue to permeate our literature.

Good science needs, above all, testable hypotheses of all feasible types—including developmental and adaptationist—last one restrictive mode, transiently favored by momentary fashion, come to define the range of the conceivable.

A Duckbill Out of Water

In his response to Robert Bakker’s article, “How Dinosaurs Invented Flowers” (November 1986), William Morris asserts that the duckbill dinosaur’s beak was built for filtering aquatic organisms (“Letters,” February 1987). In so doing, he ignores the goose’s fluted bill, which is very like the duckbill’s, yet geese are terrestrial grass eaters. Morris also fails to mention the duckbill’s fantastically well-developed grinding dental batteries, a serious omission because such teeth are found only in eaters of tough land plants, never in living filter feeders, which do not need them. If duckbills were filter feeders they probably would have been toothless—like blue whales and flamingos. Duckbills may have occasionally grazed upon aquatic plants, but their teeth prove they were land herbivores.

In his recent book, Robert Bakker shows that the duckbill’s weakly muscled stiff tail was not adequate for swimming. Other terrestrial adaptations in duckbills include their extremely short fingers and
toes, exactly the opposite of those found in mud-walking and swimming animals. Skin impressions and footprints show that, contrary to past opinions, duckbill hands and feet were not webbed. One interesting thing that I rediscovered (it had been published more than once earlier in this century) is that the American Museum's duckbill mummies show that they had long, deep, vertical skin folds around the shoulders. Hardly the streamlining that one expects in swimmers. Finally, Morris's claim that hollow-crested duckbills are found exclusively in river delta environments is incorrect; they are also known from highland areas. Simply put, duckbills show no more adaptations for an aquatic existence than do deer or black rhinos and probably spent about the same amount of time in the water. There is little doubt that, as Bakker explains, they must have had a strong influence on the evolution of land plants at that time.

GREGORY S. PAUL
Baltimore, Maryland

Underwater Errata
Although delighted to see an article about submerged caves ("In the Lair of the Lusca," January 1987), I was disappointed to find some errors. The Remipedia represent a new class of crustaceans, not a new order. These graceful swimming creatures reminded me of the ancient Greek and Roman warships called triremes, and I therefore named the class Remipedia, meaning "paddle- or oar-footed," not "many-legged." The fossil relative of living remipedes was found in rock from the lower Pennsylvanian, making it not 150 million, but 300 million years old!

JILL YAGER
Old Dominion University
Norfolk, Virginia

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By the Banks of the Chinchihuapi

Well-preserved dwellings and artifacts, unearthed from a Chilean peat bog, show that hunter-gatherers settled South America more than 13,000 years ago

by Tom D. Dillehay

Caves and rock-shelters with confined habitation space, hunting grounds where prey was killed, quarries from which stone for tools was extracted—these are the kinds of sites that have told us most of what we know about how New World people lived when the last Ice Age drew to a close, between 12,000 and 10,000 years ago. Generally, these sites are in grassland plain, desert, or tundra environments. Often preservation is poor, so that only stone tools and perhaps some bones and plants remain. As a result, more is known of hunting and butchering technology than of domestic life for these times, and little is known about what went on at uncovered occupation sites in America’s forests.

In 1976, however, while surveying the cool, forested country west of the Andes in south-central Chile, my colleagues and I discovered an open-air, wetland site that yielded not only stone tools and the bones of extinct animals but also well-preserved wooden artifacts, dwelling foundations of both earth and wood, and the remains of useful plants. We even unearthed a human footprint and a hunk of mastodon flesh. A sequence of eighteen radiocarbon dates on the two- to six-inch-thick deposits containing these materials and on the adjacent layers, all in stratigraphic order, placed these finds about 13,000 years ago. Five feet deeper we found features and modified stones that belong to an even earlier culture.

The site, which we call Monte Verde, is on Chinchihuapi Creek, a thirteen-foot-wide tributary of Rio Mauíli, a large river that descends to the Pacific Ocean, some thirty miles to the west. The shallow stream (never more than one foot deep) drains a boggy area in a cool rain forest that has existed since late Ice Age times. After the inhabitants abandoned their settlement, a shallow peat bog formed on the banks of the creek and—where the creek modified its course—in the old creek bed itself. Thanks to this water-saturated bog, in which the lack of oxygen inhibited decay and the moisture maintained a constant degree of humidity, a wide range of artifacts was preserved. To prevent deterioration of these perishable materials on exposure to air, we soaked them in chemicals on the spot and later transferred them to a laboratory for further conservation treatment.

Partial excavation of the site (less than one-third of the total area, but about four-fifths of the main occupied section) has revealed settlement remains on either side of Chinchihuapi Creek. To the south we found a scattering of stone tools, wooden artifacts, and plant remains, while on the

This is the sixth in a series of articles exploring archeological sites and other lines of evidence that bear on the peopling of the New World.

Wooden foundations mark the location of huts occupied 13,000 years ago at Monte Verde. Food pits, hearths, and tools have been found within the floor areas.
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north side we identified two distinct activity areas. One consisted of residential huts, as defined by crude logs and branches laid out in rough rectangular forms about six feet wide by seven feet long. The logs apparently provided architectural stability for pole-frame huts draped with animal hides. There were two large hearths and a dozen smaller, shallow clay braziers, on which the inhabitants presumably piled coals from the main hearths.

The second area was downstream and featured a wishbone-shaped foundation that enclosed a space about seven feet wide and nine feet long. The foundation was made of sand and gravel, hardened with a mixture of animal fat. It contained vertical wood stubs, which we take to be the remains of walls made of branches. Fronting the entrance was a rectangular yard outlined with branches and containing a small salt cache, a few stone tools, and braziers. Clusters of mastodon bones, fragments of animal skin, stone tools, worked wood, and the leaves and seeds of several varieties of medicinal plants lay in and around the structure. This second area was apparently a place where the prehistoric inhabitants prepared meat and animal hides, manufactured stone tools, and perhaps cured bodily ailments.

Many of the artifacts we have discovered are of wood, including digging sticks, mortars, a lance, and other implements, as well as the logs, stakes, and poles used to define architectural spaces. Bone items include a baton for striking flakes off stones, mastodon-tusk gouges, and digging and prying tools. Three different stone technologies are evident. Some stones were flaked by percussion—a widespread method familiar to archeologists. Others were shaped by pecking or grinding, with results that also resemble early tools previously described for South America. The third type of stone tools are simply naturally fractured pebbles with one or more sharp edges, which the people selectively scavenged from creek beds and sand and gravel bars. No similar collection of “found” tools has been identified elsewhere in the Americas.

Monte Verde is located in a region made up of deciduous and coniferous forests, lagoons, marshes, bogs, and river bottoms. A wide variety of edible plants, along with small game animals, freshwater mollusks, and fish, are abundant year-round. The Pacific coast also offers many edible species of plants and animals. Studies of the excavated organic remains from hearths, living floors, and small storage pits reveal that all these sources of food were used by the prehistoric inhabitants. Monte Verdeans foraged in thirteen different ecological zones, including nearby forests, bogs, lagoons, and flood plains, as well as farther away on rocky shore points, sandy beaches, salt marshes, and bogs in the delta of the Rio Maullín.

Mastodons and smaller game were
scavenged or hunted for their meat, hide, and bones. Almost all of the animal bones excavated at the site are from seven mastodons. Most are broken ribs, but there are also a few fragments of skulls, teeth, and legs. The bone surfaces exhibit various drying cracks, rootlet scars, patinas, and soil coatings indicative of exposure to a variety of weathering conditions in different environments. The bone samples suggest that the residents scavenged or killed the mastodons elsewhere and carried home only bones for tools and the lighter meat-bearing bones.

One shoulder blade from an extinct relative of the llama, some small rodent and amphibian bones, and fragments of crayfish were also found. Other evidence of hunting consists of round, sometimes grooved, bola stones. This type of projectile weaponry—still used by the local Mapuche Indians—appears all through the later archaeological record of the southern cone of South America. There are also a few lanceolate (tapered-leaf-shaped) wooden and bone points that could have tipped stabbing or throwing spears.

The botanical remains indicate that the past environment at Monte Verde was very similar to today’s. Plants were found that mature during all months of the year, providing direct archeological evidence that the site was occupied throughout at least one full year—a living pattern already implied by the relatively elaborate and permanent architecture. Carlos Ramirez, a botanist from the Universidad Austral de Chile, has reconstructed a diet based primarily on tuberous and rhizomatous plants and secondarily on seeds, stalks, mushrooms, berries, nuts, fruits, and soft leafy vegetables. A total of forty-two edible species have been recovered, including one type of wild potato. Aquatic plants from the freshwater marshes, bogs, and lagoons of the flood plain and from the brackish marshes of the river delta provided the greatest variety and, along with meat, the bulk of the diet.

In addition to food plants, the remains of sixteen medicinal plants were identified at Monte Verde. Their use is inferred from the observation that only the medicinal parts are present. Mapuche Indians still gather many of these today and use them to treat skin ailments or pulmonary diseases. For example, boldo leaves are used in an herbal tea to treat common colds, congestion, and stomach disorders.

Some of the medicinal plants are natural to the site vicinity, but about half come from coastal environments, and one is found only in arid regions to the north. The presence of salt, beach-rolled pebbles used as tools, and bitumen (used to attach...
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Stone tools to wooden hafts) at the site also show that coastal habitats provided important nonfood items to the Monte Verde economy. These prehistoric people either regularly traveled the thirty miles to the coast and to other distant environments or they were part of a web of social and exchange relationships. This area of economic exploitation is far greater than any that can be documented at most other early New World sites.

Specialized skills and a division of labor were probably needed to use the wide range of resources. This is confirmed by the separation of residential from nonresidential areas at the site and by the association of distinct activity areas and household units with different tool types and food items. Tools manufactured from a coastal quartz, for example, along with edible seeds and fruits of two varieties of plants that grow in sand dunes, were recovered from the living floor of one hut, suggesting that the residents specialized in exploiting resources from the coast. In another area of the site, stone scrapers and tree branches were found in a wood-working zone. The multiple dwellings, which we believed were simultaneously occupied, accommodated as many as thirty to fifty individuals. This large group size may have both permitted and required the mixed economy and heavy exploitation of plants from different ecological zones.

The most important implication of Monte Verde is that humans must have entered the New World sometime before the appearance of the big-game hunters that archeologists have identified by their distinctively fluted stone projectile points (Clovis points, generally dated to no more than 12,000 years ago). If Monte Verde is any indication, these earlier Americans relied on a mixed economy and technology, centered on gathering plants as much as on hunting animals.

How long ago this may have been is revealed by additional discoveries at Monte Verde. In the deeper, sandy levels, where the preservation of organic remains is poor, we found three apparent hearths containing charcoal. Radiocarbon dating of the charcoal showed it to be about 34,000 years old. Associated with the hearths were twenty-four fractured pebbles, seven of which have clear percussion scars. Four of these stones exhibit polish and striations on their sharp edges, resulting from scraping and cutting plants, hide, and meat. There is no reason to believe these artifacts filtered down from above, since the strata between them and the higher occupation level of the site are culturally sterile, and there is no evidence of geological disturbance.

The scholarly reception of the Monte Verde findings, especially regarding these older remains, has been mixed. Skepticism with respect to the scant 33,000-year-old material is understandable. The 13,000-year-old cultural episode, instead, is intimidating because of the preservation of wooden artifacts, the early radiocarbon dates, and the architecture; most New World scientists have never seen, much less excavated, such a site. In fact, when my students and I first began to excavate Monte Verde in 1976, we ourselves were overwhelmed and slightly confused. The stone tools and cut mastodon bones presented a familiar picture, but we were less confident about interpreting the concentrations of burned and cut wood. We had doubts that the site was actually a human settlement.

The preservation was so good at Monte Verde that it presented us with an archeological quandary. On the one hand, the presence and clearly human patterning of charred and uncharred food remains, cut wood and logs, and fragments of animal hide made it easy to imagine the kinds of domestic activities carried out at the site. On the other hand, the insects, leaves, twigs, small branches, and other organic debris that were present at times made it difficult to determine whether some of the wooden objects and other materials were modified and spatially patterned by human forces or by natural ones.

To better understand how natural forces, such as stream deposition, animal burrowing and trampling, tree fall, and plant growth, can alter the context and the physical appearance of perishable materials, a thirty-member interdisciplinary research team was challenged to study Monte Verde in a way that no other early site had ever been researched in the Americas. Much of the field, laboratory, and experimental work was oriented toward comparing the composition and distribution of inorganic with organic materials in the buried settlement, in buried areas outside of the site within the natural present-day environment, and in controlled experimental areas. This research has elucidated many detailed differences and similarities in the way natural forces and human actions alter materials and deposit them on the landscape, providing a framework for interpreting some of the more ambiguous materials excavated from the site. Equipped with this knowledge, archeologists will be better prepared to identify and excavate other early wetland sites that otherwise might have been overlooked and to reexamine previously excavated stone collections that have not been accepted as cultural artifacts.
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Aspirin risk vs. aspirin benefits.
Although aspirin is still among the most effective treatments for arthritis, it is far from harmless in the high doses that are needed (as many as 8 to 20 tablets a day). It can cause a variety of unwanted effects ranging from nausea and vomiting to stomach ulcers. Doctors treating arthritis have always had to consider whether the benefits of aspirin outweigh these risks.

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Life's Little Joke

The evolutionary histories of horses and humans share a dubious distinction

by Stephen Jay Gould

I still don't understand why a raven is like a writing desk, but I do know what binds Hernando Cortés and Thomas Henry Huxley together.

On February 18, 1519, Cortés set sail for Mexico with about 600 men and, perhaps more importantly, 16 horses. Two years later, the Aztec capital of Tenochtitlan lay in ruins, and one of the world's great civilizations had perished.

Cortés's victory has always seemed puzzling, even to historians of an earlier age who did not doubt the intrinsic superiority of Spanish blood and Christian convictions. William H. Prescott, master of this tradition, continually emphasizes Cortés's diplomatic skill in making alliances to divide and conquer—and his good fortune in despoiling Mexico during a period of marked internal dissension among the Aztecs and their vassals. (Prescott published his History of the Conquest of Mexico in 1843, and it remains among the most exciting and literate books ever written.)

Prescott also recognized Cortés's two "obvious advantages on the score of weapons"—one inanimate and one animate. A gun is formidable enough against an obsidian blade, but consider the additional impact of surprise when your opponent has never seen a firearm. Cortés's cavalry, a mere handful of horses and their riders, caused even more terror and despair, for the Aztecs, as Prescott wrote,

had no large domesticated animals, and were unacquainted with any beast of burden. Their imaginations were bewildered when they beheld the strange apparition of the horse and his rider moving in unison and obedient to one impulse, as if possessed of a common nature; and as they saw the terrible animal, with "his neck clothed in thun-
der," bearing down their squadrons and trampling them in the dust, no wonder they should have regarded him with the mysterious terror felt for a supernatural being.

On the same date, February 18, in 1870, Thomas Henry Huxley gave his annual address as president of the Geological Society of London and staked his celebrated claim that Darwin's ideal evidence for evolution had finally been uncovered in the fossil record—a sequence of continuous transformation, properly arrayed in temporal order:

It is easy to accumulate probabilities—hard to make out some particular case, in such a way that it will stand rigorous criticism. After much search, however, I think that such a case is to be made out in favor of the pedigree of horses.

Huxley delineated the famous trends to fewer toes and higher-crowned teeth that we all recognize in this enduring classic among evolutionary case histories. Huxley viewed this lineage as a European affair, proceeding from fully three-toed Anchi-
therium, to Hipparion with side toes "reduced to mere dew-claws [that] do not touch the ground," to modern Equus, where, "finally, the crowns of the grinding-teeth become longer . . . . The phalan-
ges of the two outer toes in each foot disappear, their metacarpal and metatarsal bones being left as the 'splints.'"

In Cat's Cradle, Kurt Vonnegut speaks of the subtle ties that can bind people across worlds and centuries into aggregations forged by commonalities so strange that they must be meaningful. Cortés and Huxley must belong to the same karass (Vonnegut's excellent word for these associations)—for they both, on the same date, unfairly debased America with the noblest of animals. Huxley was wrong and Cortés, by consequence, was ever so lucky.

Horses evolved in America, through a continuity that extends unbroken across 60 million years. Several times during this history, different branches of this evolving bush migrated to Europe, where Huxley arranged three (and later four) separate incursions as a false continuity. But horses then died in America at the dawn of human history in our hemisphere, leaving the last European migration as a source of recolonization by conquest. Huxley's error became Montezuma's sorrow, as an animal more American than Babe Ruth or apple pie came home to destroy her greatest civilization. (Montezuma's revenge would have to come in another way.)

During our centennial year of 1876, Huxley visited America to deliver the principal address for the founding of Johns Hopkins University. He stopped first at Yale to consult the eminent paleontologist Othniel C. Marsh. Marsh, ever gracious, offered Huxley an architectural tour of the campus, but Huxley had come for a purpose and would not be delayed. He pointed to the buildings and said to Marsh: "Show me what you have got inside them; I can see plenty of bricks and mortar in my own country." Huxley was neither philistine nor troglodyte; he was simply eager to study some particular fossils: Marsh's collection of horses.

Two years earlier, Marsh had published his phylogeny of American horses and identified our continent as the center stage, while relegating Huxley's European sequence to a periphery of discontinuous migration. Marsh began with a veiled and modest criticism (American Journal of Science, vol. 7, 1874, p. 255):
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Huxley has traced successfully the later genealogy of the horse through European extinct forms, but the line in America was probably a more direct one, and the record is more complete.

Later, he stated more baldly (p. 258): "The line of descent appears to have been direct, and the remains now known supply every important intermediate form."

Marsh had assembled an immense collection from the American West (prompted largely by a race for priority in his bitter feud with Edwin D. Cope). For every query, every objection that Huxley raised, Marsh produced a specimen. Leonard Huxley describes the scene in his biography of his father:

At each inquiry, whether he had a specimen to illustrate such and such a point or to exemplify a transition from earlier and less specialized forms to later and more specialized ones, Professor Marsh would simply turn to his assistant and bid him fetch box number so and so, until Huxley turned upon him and said, "I believe you are a magician; whatever I want, you just conjure it up."

Now T.H. Huxley had coined a motto and meant to live by it: "Sit down before fact as a little child, be prepared to give up every preconceived notion." He capitulated to Marsh's theory of an American venue. Marsh, with growing pleasure and retracting modesty, reported his impression of personal triumph:

He [Huxley] then informed me that this was new to him, and that my facts demonstrated the evolution of the horse beyond question, and for the first time indicated the direct line of descent of an existing animal. With the generosity of true greatness, he gave up his own opinions in the face of new truth and took my conclusions.

A few days later, Huxley was, if anything, more convinced. He wrote to Marsh from Newport, his next stop: "The more I think of it the more clear it is that your great work is the settlement of the pedigree of the horse." But Huxley was scheduled to lecture on the evolution of horses less than a month later in New York. As he traveled about eastern America, Huxley rewrote his lecture from scratch. He also enlisted Marsh's aid in preparing a chart that would show the new evidence to his New York audience in pictorial form. Marsh responded with one of the most famous illustrations in the history of paleontology—the first pictorial pedigree of the horse.

Scholars are trained to analyze words. But primates are visual animals, and the key to concepts and their history often lies in iconography. Scientific illustrations are not frills or summaries; they are foci for modes of thought. The evolution of the horse—both in textbook charts and museum exhibits—has a standard iconography. Marsh began this traditional display in his illustration for Huxley. In doing so, he also initiated an error that captures pictorially the most common of all misconceptions about the shape and pattern of evolutionary change.

Errors in science are diverse and have a taxonomy just as organisms do. Some make me angry, particularly those that arise from social prejudice, masquerade as objectively determined truth, and directly limit the lives of those caught in their thrall (scientific justifications for racism and sexism, as obvious examples). Others make me sad because honest effort ran headlong into unresolvable complexities of nature. Still others, as errors of logic that should not have occurred, blow my already extended ego when I discover them. But I reserve a special place in perverse affection for a small class of precious ironies—errors that pass nature through a filter of expectation and reach a particular conclusion only because nature really works in precisely the opposite way. This, I know, sounds both peculiar and unlikely, but bear with me for the premier example of life's little joke—as displayed in conventional iconography (and interpretation) for the most famous case study of all, the evolution of the horse.

In his original 1874 article, Marsh recognized the three trends that define our traditional view of old dobbin's genealogy: increase in size, decrease in the number of toes (with the hoof of modern horses made from a single digit, surrounded by two vestigial splints as remnants of side toes),
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and increase in the height and complexity of grinding teeth. (I am not treating the adaptive significance of these changes here, but wish to record the conventional explanation for the major environmental impetus behind trends in locomotion and dentition: a shift from browsing on lush lowland vegetation to grazing of newly evolved grasses upon drier plains. Tough grasses with less food value require considerably more dental effort.)

Marsh's famous chart, drawn for Huxley, depicts these trends as an ascending series—a ladder of uninterrupted progress toward one toe and tall, corrugated teeth (by scaling all his specimens to the same size, Marsh does not show the third "classical" trend toward increasing bulk).

We are all familiar with this traditional picture—the parade of horses from little eohippus (properly called Hyracotherium), with four toes in front and three behind, to Man o' War. (Hyracotherium is always described as "fox terrier" in size. Such traditions disturb and captivate me. I know nothing about fox terriers but have dutifully copied this description. I wonder who said it first, and why this simile has become so canonical. I also wonder what the textbook tradition of endless and thoughtless copying has done to retard the spread of original ideas.)

In displays at our Harvard Museum, and in the fine institution that sponsors this magazine, the evolution of horses looks like a line of school children all pointed in one direction and arrayed in what my primary-school drill instructors called "size place" (also stratigraphic order in this case). The most familiar of all illustrations, first drawn early in the century for the American Museum of Natural History's pamphlet on the evolution of horses, by W.D. Matthew, but reproduced hundreds of times since then, shows it all: size, toes, and teeth arranged in a row by order of appearance in the fossil record. To cite just one example of this figure's influence, George W. Hunter reproduced Matthew's chart as the primary illustration of evolution in his high-school textbook of 1914, A Civic Biology. John Scopes assigned this book to his classes in Tennessee and was convicted for teaching its chapters on evolution, as William Jennings Bryan issued his last hurrah: "No more repulsive doctrine was ever proclaimed by man...may heaven defend the youth of our land from [these] impious babblings."

But what is so wrong with these evolutionary ladders? Surely we can trace an unbroken continuity from Hyracotherium to modern horses. Yes, but continuity comes in many more potential modes than the lock step of the ladder. Evolutionary genealogies are copiously branching bushes—and the history of horses is more lush and labyrinthine than most. To be sure, Hyracotherium is the base of the trunk (as now known), and Equus is the surviving twig. We can, therefore, draw a pathway of connection from a common beginning to a lone result. But the lineage of modern horses is a twisted and tortuous excursion from one branch to another, a path more devious than the road marked by Ariadne's thread from the Minotaur at the center to the edge of our culture's most famous labyrinth. Most importantly, the path proceeds not by continuous transformation but by lateral stepping (with geological suddenness when punctuated equilibriums apply, as in this lineage, at least as read by yours truly, who must confess his bias as coauthor of the theory).

Each lateral step to a new species follows one path among several alternatives. Each extended lineage is a set of decisions at branching points—only one among...
hundreds of potential routes through the labyrinth of the bush. There is no central direction, no preferred exit to this maze—just a series of indirect pathways to every twig that ever graced the periphery of the bush.

As an example of distortions imposed by converting tortuous bushes into directed ladders, consider the men associated with the two classical iconographies reproduced here. When Huxley made his formal capitulation to Marsh’s interpretation in print (1880), he extended the ladder of horses as a metaphor for all vertebrates. Speaking of modern reptiles and teleost fishes, Huxley wrote (Proceedings of the Zoological Society of London, 1880, p. 661): “They appear to me to be off the main line of evolution—to represent, as it were, side tracks starting from certain points of that line.” But teleosts (modern bony fishes) are an enormously successful group. They stock the world’s oceans, lakes, and rivers and maintain nearly 100 times as many species as primates (and more than all mammals combined). How can we call them “off the main line” just because we can trace our own pathway back to a common ancestry with theirs more than 300 million years ago?

W.D. Matthew slipped into an equally biased assessment of value because his designation of one pathway as a ladder forced an interpretation of all others as diversions. Matthew (Quarterly Review of Biology, 1926, p. 164) designated his ladder as the “direct line of succession,” but acknowledged that “there are also a number of side branches, more or less closely related.” Three pages later, Matthew adds the opprobrium of near indecency to his previous charge of mere lateliness, as he describes (p. 167) “a number of side branches leading up in a similar manner to aberrant specialized Equidae now extinct.” But in what way arc extinct lineages more specialized than a modern horse or in any respect more peculiar? Their historical death is the only possible rationale for a designation of aberrancy, but more than 99 percent of all species that ever lived are extinct—and disappearance cannot be the biological equivalent of a scarlet letter. We might as well cast modern horses aberrant because, much to Montezuma’s later sorrow, they became extinct in the land of their birth.

Yet we have recognized the bushiness of horse evolution from the very beginning. How else did Marsh forestall Huxley, but by convincing him that his European “genealogy” of horses was only a stratigraphic sequence of discontinuous stages, falsely linking several side
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branches that had disappeared without issue?

As an example of businesness, and of the value of appropriate metaphors in general, consider the finest book on the evolution of horses that has ever been written for popular audiences—G.G. Simpson's Horses (Oxford University Press, 1951). Simpson redrew the genealogy of horses as a modest bush with no preferred main line. He also criticized the conceptual lock imposed by the bias of the ladder when he noted that modern one-toed horses are a side branch and extinct three-toed creatures the main line (if any center can be designated at all).

As nearly as there is a straight line in horse evolution, it culminated and ended with these animals [the three-toed anchitheres], which, like their ancestors, were multiple-toed browsers. From this point of view, it is the line leading to modern horses that was the side branch, even though it outlasted the straighter line of horse evolution (p. 130).

Yet Simpson, who held a lifelong commitment to the predominant role of evolution by transformational change within populations rather than by accumulation across numerous events of discrete, branching speciation, could not entirely let go of biases imposed by the metaphor of the ladder. In one revealing passage, he accepts businesness, but bemoans the complexities thus introduced, as though they clouded evolution's essence of transformational change:

Miohippus...intergraded with several different descendant groups. It is sad that this introduces possible confusion into the story, but there is not much point in criticizing nature for something that happened some millions of years ago. It would also be foolish to try to ignore the complications,
which did occur and which are a very important part of the record.
But these “complications” are not a veil upon the essence of lineal descent; they are the primary stuff of evolution itself.

Moreover, Simpson restricted his business as much as possible and retained linearity wherever he could avoid an inference of branching. In particular, he proposes the specific and testable hypothesis (see his illustration) that the early part of the record—the sequence of *Hyracotherium*—*Orohippus*—*Epitihippus*—*Mesohippus*—*Miohippus*—*Hypohippus*—tells a story of linear descent, only later interrupted by copious branching among three-toed browsers: “The line from *Eohippus* to *Hypohippus*, for example, exemplifies a fairly continuous phyletic evolution” (p. 217). Simpson especially emphasizes the supposedly gradual and continuous transformation from *Mesohippus* to *Miohippus* near the top of this sequence:

The more progressive horses of the middle Oligocene and all the horses of the late Oligocene are placed by convention in a separate genus, *Miohippus*. In fact *Mesohippus* and *Miohippus* intergrade so perfectly and the differences between them are so slight and variable that even experts find it difficult, at times nearly impossible, to distinguish them clearly.

The enormous expansion of collections since Simpson proposed this hypothesis has permitted its test by vertebrate palentologists Don Prothero and Neil Shubin. Their results falsify Simpson’s gradual and linear sequence for the early stages of horse evolution and introduce extensive business into this last stronghold of the ladder.

Prothero and Shubin have made four major discoveries in the crucial segment of history that Simpson designated as the strongest case for a gradualistic sequence of lineal transformation—the transition from *Mesohippus* to *Miohippus*.

1. Previous experts were so convinced about the imperceptibly gradual transition between these two genera that they declared any search for distinguishing characters as vain and arbitrarily drew the division between *Mesohippus* and *Miohippus* at a stratigraphic boundary. But far richer material available to Prothero and Shubin has permitted the identification of characters that cleanly distinguish the two genera. (Teeth are the hardest part of a vertebrate skeleton and the fossil record of mammals often contains little else. A technical course in the evolution of mammals is largely an exercise in the identification of teeth, and an old professional quip holds that mammalian evolution is the interbreeding of two sets of

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There is no evidence of long-term changes within these well-defined species [of Mesohippus and Miohippus] through time. Instead, they are strikingly static through millions of years. Such stasis is apparent in most Neogene [later] horses as well, and in Hyracotherium. This is contrary to the widely-held myth about horse species as gradually-varying parts of a continuum, with no real distinctions between species. Throughout the history of horses, the species are well-marked and static over millions of years. At high resolution, the gradualistic picture of horse evolution becomes a complex bush of overlapping, closely related species.

Horse evolution now pervades the entire phylogeny of horses.

We can appreciate this fundamental shift in iconography and meaning, but where is the "precious irony" that I promised? What is "life's little joke" of my title? Simply this. The model of the ladder is much more than merely wrong. It never could provide the promised illustration of evolution progressive and triumphant—
for it could only be applied to unsuccessful lineages.

Bushes represent the proper topology of evolution. Ladders are false abstractions, made by running a steamroller over a labyrinthine pathway that hops from branch to branch through a phylogenetic bush. We cannot force the successful bushes of evolution into a ladder because we may follow a thousand pathways through them, and we cannot find a criterion for preferring one over another. Who ever heard of the evolutionary trend of rodents or of bats or of antelopes? Yet these are the greatest success stories in the history of mammals. Our proudest cases do not become our classic illustrations because we can draw no ladder of progress through a vigorous bush with hundreds of surviving twigs.

But consider the poor horses. Theirs was once a luxuriant bush, yet they barely survive today. Only one twig (the genus Equus, with horses, zebras, and asses) now carries all the heritage of a group that once dominated the history of hoofed mammals—and with fragility at that, for Equus died in the land of its birth and had to be salvaged from a stock that had migrated elsewhere. (In a larger sense, horses form one of three dwindling lines—tapirs and rhinos are the others—that now represent all the diversity of the formerly dominant order Perissodactyla, or odd-toed ungulates, among hoofed mammals. This mighty group once included the giant titanotheres, the clawed chalicotheres, and Baluchitheriwm, the largest land mammal that ever lived. It now hangs on as a remnant in a world increasingly dominated by the Artiodactyla, or even-toed ungulates—cows, deer, antelope, camels, hippos, giraffes, pigs, and their relatives.)

This is life's little joke. By imposing the model of the ladder upon the reality of bushes, we have guaranteed that our classical examples of evolutionary progress can only apply to unsuccessful lineages on the very brink of extermination—for we can linearize a bush only if it maintains but one surviving twig that we can falsely place at the summit of a ladder. I need hardly remind everybody that at least one other mammalian lineage, preeminent among all in our attention and concern, shares with horses the sorry state of reduction from a formerly luxuriant bush to a single surviving twig—the very property of extreme tenuousness that permits us to build a ladder reaching only to the heart of our own folly and hubris.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.
A Civilization’s Remains

John R. Alden

What visitor to Peru could ignore the spectacular remains of the Inca Empire? Yet the magnificent stonework in the city of Cuzco, the spooky grandeur of Machu Picchu, and the incredible tale of the Spanish conquest represent only the latest chapter of Peru’s cultural legacy. The Incas were preceded by several empires, a double handful of puissant warring states, a revolutionary pan-Andean religious cult, and a multitude of local incipient civilizations. These complex societies evolved from a diverse collection of food-producing economies that in turn developed out of a late Pleistocene tradition of hunting and gathering. Peruvian prehistory, in short, recapitulates the epic story of human cultural development—the evolution of civilization.

This recognition is hardly newsworthy. But because archaeologists have been slow in working out the details of Andean prehistory, it is worth noting that during the last two decades, the Peruvian version of human evolutionary progress has become considerably clearer. Ceramic chronologies have been refined, settlement systems delineated, and the economic and political dimensions of pre-Incan cultures have begun receiving the attention they deserve. Peruvian Prehistory reviews the specifics of this archeological progress.

In the book’s ten chronologically arranged chapters, a collection of specialists examine “recent research results and their ramifications.” The contributions vary widely in their breadth and geographical coverage, but all assume that the reader is familiar with Andean geography and the basic details of Peruvian prehistory. This is in no way an introductory text. The book was designed as a state-of-the-art review for a professional audience, and it achieves this end reasonably well.

Peru’s prehistoric record begins about 12,000 years ago in the high rolling grasslands of the Andean puna. Yet even this simple generalization, the author of the book’s first chapter admits, is controversial. Other archeologists argue for a much earlier initial occupation, and the absence of sites in other ecological zones may reflect nothing more than “a lack of good facilities and agreeable conditions for archaeological field work.”

Whenever people first arrived in Peru, by 8000 B.C. they had occupied both the Andean highlands (chapter 1) and the Pacific coast (chapter 2). Relatively sedentary populations inhabited the narrow coastal valleys (where both terrestrial and marine resources were utilized) and the central puna (where groups of twenty to fifty people lived by hunting deer and llama, alpaca, vicuna, and guanaco), while the residents of the highland valleys moved from zone to zone to exploit plants and animals as they became seasonally available. Domesticated beans and peppers appear as early as 8500 B.C. in the highland valley site of Guitarrero Cave, and domesticated maize, squash, and tubers are all present by 3000 B.C.

While the earliest domestication was a highland phenomenon, the first settled villages appeared on the coast. Although the process of this development remains unclear, early sedentary life in Peru does not seem to have depended on food production. In fact, as the book’s third chapter relates, large sites with mound architecture and signs of incipient social differentiation are known from the fourth millennium B.C.—before the introduction of ceramics and even before coastal peoples depended on agriculture for subsistence.

Early in the second millennium B.C., during the initial ceramic period, the importance of cultivated crops increased. At the same time, a system of complementary connections between shoreline fishing villages and inland agricultural centers developed in the larger coastal valleys. Within a matter of centuries, the small ceremonial precincts of the late preceramic expanded into impressive...
complexes of pyramids and plazas. "Leveling alone [at one site on the central coast] required movement of over two million cubic meters of material," and several valleys supported sites covering almost half a square mile. Developments that took nearly 4,000 years in the Middle East took less than half that time in Peru.

The book's second section, "The Florence of Complex Society," begins with the appearance of Chavin sculpture, pottery, textiles, and architecture about 900 B.C. This event, the emergence of the first pan-Andean artistic style, marks "a decisive change in central Andean prehistory." Chavin is a rather small site in a remote valley on the Andes' eastern flank, certainly less impressive than the cities of the coast. But because objects sharing the style and iconography of Chavin's stone sculpture have been found across much of central and northern Peru, it is clear that this site played an important role in a cultural phenomenon that cut across earlier social, political, and ethnic boundaries—a phenomenon that pan-Andean archeologists call a horizon.

In one of this book's best chapters, Richard Burger argues that the Chavin horizon represents the spread of a religious ideology. Comparing Chavin with the later Pachacamac cult, an ethnographically known religious/ceremonial network centered on a site just south of Lima, Burger points out that even though the preeminence of the Chavin style has been exaggerated, its spread seems to mirror the adoption of a new ideology by Peru's more advanced societies. This change, he speculates, may have been occasioned by an environmental crisis affecting the Peruvian coast. Such ideas are not new, but Burger does an excellent job of defending them.

The early intermediate period, 200 B.C. to A.D. 600, is examined in chapter 5. Like the initial ceramic, the early intermediate was a time of cultural regionalism. "The great coastal architectural complexes which were associated with the Chavin cult...were all gradually abandoned."

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They were replaced, however, by the even more impressive centers of the Moche, Lima, and Nazca cultures—a trio of imperialistic multivalley conquest states. These societies managed complex irrigation networks, built the largest adobe pyramids in ancient Peru, and produced wonderfully expressive ceramics, textiles, and metalwork. Although the coast still has too many unexcavated sites, inadequately surveyed valleys, and chronological sequences based on pottery from looted cemeteries, the fascinating complexities of the early intermediate are gradually being resolved.

During the next period, the middle horizon, the Andean highlands assume center stage. The author of this chapter argues that the era's two most prominent sites, Huari and Tiwanaku (Tiahuanaco in an earlier orthography), seem to represent two distinct patterns of organization. Tiwanaku, on the southern margin of Lake Titicaca, is described as the source of a horizon style like the earlier Chavin. Huari, near modern Ayacucho, is interpreted as the center of a centralized, secular state prefiguring the Inca empire in both administrative structure (with roads and way stations tying Huari to a series of scattered provincial capitals) and economic organization (with the state supported by a tax or tribute in labor from subject peoples). Both analogies are somewhat forced, but they do offer a clear direction for future research.

The book's seventh chapter is devoted to the late intermediate (A.D. 1100-1476). During this era the Chimú state, which controlled most of the north coast, was the most powerful political unit in Peru. The Chimú capital, Chan Chan, covered about two square miles, and the nine great walled compounds at the site appear to have served as royal residence, administrative center, and burial compound for nine successive Chimú rulers. Neighboring valleys each had their own Chimú administrative center, and the large and complex irrigation systems that the Chimú built offer evidence of the engineering skill and vast amounts of labor that this state was able to command.

The authors of this chapter then examine the origins of the Inca Empire. Ethnohistoric accounts collected by the Spanish reveal, they note, that the Inca civilization arose from a late intermediate context of endemic conflict. The Cuzco Valley seems to have been politically united throughout the era, and after many years of "intensive and protracted warfare with a variety of neighboring polities," it emerged as the dominant highland power. By the end of the late intermediate, the people of Cuzco had conquered most of Peru.

Unfortunately, the book's treatment of the Inca Empire is unsatisfying. The two contributions on the Inca review strategies for combining archeological, documentary, and ethnographic research and analyze some very specific problems but never describe Inca history, society, or political and economic organization. It is almost as if a chapter was missing. We get tantalizing glimpses of the empire that "controlled the largest territory of any New World state," but those who do not already know a great deal about the Inca will find little to help them here.

Peruvian Prehistory ends with a chapter titled "A View from the Tropical Forest." This contribution describes the diversity of the Amazonian environment and emphasizes the long, if sparse, record of contacts and commerce between this region and the Andean highlands. It also makes the point that "particularly with respect to the development of agriculture, the tropical forest cultures made important contributions to the beginnings of Peruvian civilization." Still, the eastern jungle was only marginally important to Peru's highland societies during most of the last two thousand years.

In summation, this book has several major flaws. Because it has been several years since the contributions were completed, the book does not offer an up-to-the-minute report on the state of Peruvian archaeology. There are gaps in its coverage, the most obvious being a cursory treatment of plant and animal domestication and the failure to systematically examine the Inca Empire. The book's ten chapters are not tied together with an introductory or concluding essay, the authors presume too much prior knowledge of their readers, and the writing is often larded with unnecessary professional jargon.

On the positive side, what is old hat in the corridors of museums and universities is often quite new to the world at large. The book's contributors all describe specific sites and artifacts and use these data to reconstruct patterns of adaptation, sociopolitical organization, and cultural change. Each chapter has a good map and the book's bibliography is excellent. Peruvian Prehistory is clearly directed toward an audience of specialists. But for readers who know the basics, it offers a valuable overview of recent advances in the field of Andean archaeology.

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Because rain and snowmelt cannot sink into the permafrost, countless lakes and streams dot the desert-dry tundra.
Life upon the Permafrost

The Arctic is briefly green in spring, thanks to an endless winter that’s just below the surface

Text and photographs by Fred Bruemmer

Early in the nineteenth century, Fyodor Shergin, a merchant of Yakutsk in northeastern Siberia, fed up with melting snow and ice for water or hauling it from the Lena River, decided to have a well dug. But the ground was frozen nearly rock hard, winter and summer. His workers built fires and slowly melted and hacked their way into the icebound earth. Shergin, who was wealthy and persistent, sank his well for ten years and then, having reached a depth of 380 feet, gave up. The frozen ground had defeated him.

In 1844, the famous Baltic-German scientist Alexander Th. von Middendorff visited Yakutsk, saw Shergin’s well, realized its importance, and wrote the first scientific account of permafrost, the stratum of frozen ground that shapes most of the north and underlies about a quarter of the earth’s land surface. Shergin’s effort had been heroic but futile. The permafrost layer is 700 feet thick beneath Yakutsk. But his well is now a national monument, and Yakutsk, appropriately enough, is the world’s most important center for permafrost studies, carried out at the romantically named Eternal Frost Institute.

Permafrost had, of course, been noted by other arctic explorers, although the word itself was not coined until 1945, when Simon W. Muller described it in a U.S. military publication. Dionysus Settle, chronicler of Martin Frobisher’s 1577 expedition to Baffin Island, observed that there “the earth ... even in the very Summer time is frozen, and so combineth the stones together, that scarcely instruments with great force can unknit them.” James Isham of the Hudson’s Bay Company, stationed on the bleak west coast of Hudson Bay, even had a shrewd notion of how permafrost was formed and wrote in 1743: “The shortness of the summer’s is not Sufficient to thaw the Ice the severity of winter occasion’s therefore it gathers more and more Every year, for which Reason the frost is never out of the ground, in these parts, for in Dig’ing three or four foot dowe ... in the mids’t of the summer you shall find ... Ice and above six or Eight foot Downe it’s all hard Ice.” But only recently has the extent and importance of permafrost been realized.
Permafrost forms where annual freezing exceeds annual thaw. The more intense and prolonged the cold, the thicker the permafrost. The town of Thompson in northern Manitoba has a mean annual air temperature of 24°F, and the permafrost there is 50 feet thick. In Barrow, Alaska, the average temperature is 10°F, and the permafrost is 1,300 feet thick. In Verkhoyansk, Siberia, the temperature has dropped to a record low of −96°F, and in the same region, the permafrost layer in one place is 4,800 feet thick. Creeping ever deeper into the earth during hundreds of thousands of years, the upper earth cold is eventually defeated by the heat from the earth's hot core.

The extent and depth of permafrost changes with the earth's climate. The Norsemen settled western Greenland about A.D. 1000, during a climatic optimum when the temperature was 3.6 to 7 degrees warmer than it is now and permafrost lay deep within the ground. Three centuries later the Little Ice Age began, the temperature dropped by 5.5 to 12.5 degrees, the permafrost level rose, the Vikings' graves became progressively shallower, and their marginal agriculture failed. When the explorer John Davis landed on the west Greenland coast in the summer of 1586, the air was alive with the songs of "larks and linnets," but there were no humans. Climate had vanquished the Vikings.

All plant, animal, and human life upon one-quarter of the earth is profoundly influenced by permafrost. A hard, cold, unyielding layer just below the surface, it underlies all of Greenland, much of northern Scandinavia, half of the Soviet Union, 80 percent of Alaska, and nearly half of Canada. When you fly above this immense region in early summer much of it is verdant, lush and aglitter with water. Birches and larches, the predominant trees of Siberia's boreal forest, stretch toward the horizon. Alaska's North Slope is a deep green, lake-dotted plain. A maze of hundreds of thousands of rivers and lakes (perhaps millions, for no one has yet counted or named them all) and infinite tundra meadows cover the central arctic region of Canada, twice the size of France, known as the Barren Grounds. Greenland was named a thousand years ago by Eric the Red for its deep green valleys cut by rushing brooks and rills; yet much of this waterlogged land receives less precipitation than the Sahara.

That is the paradox of the Arctic: it is a sodden, water-seamed land with a desert-dry climate. The circumpolar tundra receives an average annual precipitation of eight inches, less than the Mojave Desert, yet it is home to about 900 species of
vascular plants. Some of Siberia's taiga and tundra regions east of the Yenisey River receive only six inches of precipitation per year; Ellesmere Island, where herds of thousands of busily nibbling arctic hares have been seen, receives only about one and a half inches of precipitation; and Peary Land in northernmost Greenland, twice the size of Maine, is among the places on earth that receive the least precipitation—less than one inch per year—yet 100 species of vascular plants grow there in sufficient profusion to provide fodder for musk ox herds. Most of this precipitation falls as snow. Capt. Thomas James, who wintered in 1632 at what was later named James Bay, wrote that the snow was “as dry as Dust and as small as Sand and would drive like Dust with the Wind.”

The reason for this seeming impossibility, watery land with an arid climate, is permafrost. The cement-hard layer holds the north's rare and precious moisture near the surface. Summer's scant rain and the meltwater of winter's thin snow cannot seep into the soil. Instead, they collect in lakes and tarns, fill the rivers that meander across the vast tundra plains, and soak the thin top layer of soil that thaws in summer, keeping vital moisture within reach of plant roots. Without permafrost, wrote the Canadian botanist A.E. Porsild, “most of the arctic zone would be a lifeless desert.”

From the air much of the far north looks as if it had been formed by a creator obsessed with geometry. Many lakes are round. Square miles of land are covered with a network of contiguous stone circles. On the tundra, polygons (mostly tetragons) formed by ice wedges stretch to the horizon, and earth-covered ice cones, called pingos, rise from some moist tundra plains. This surrealistically geometric landscape has been shaped by permafrost and by the persistent, titanic power of thawing and freezing.

In spring and summer, the top layer of earth thaws to a depth of a dozen or more feet near the southern limit of permafrost and from a few inches to several feet in the far north. This top stratum is known as the active layer, an apt term. Its thickness controls, in part, the limit of northern tree growth. Pines, with their long taproots, need at least eight feet of summer-thawed ground; birches, white spruces, and balsam poplar manage with four; and the shallow-rooted, amazingly hardy black spruces survive where permafrost is within eighteen inches of the surface in midsummer. Where the active layer is thinner, only prostrate dwarf willow and dwarf birch creep across the ground.

Rain and meltwater soak the earth and, on hillsides, seep downward along the impermeable permafrost layer. In valleys and on the plains this water may erupt, sometimes as ice sheets called naled or aufeis, or it forms ice lenses and ice domes within the ground, so that the surface rises, buckles, and heaves, and the trees upon it tilt crazily in all directions. Scientists call this the drunken forest.

On treeless tundra slopes, the water-saturated soil slowly slips and slides over the icy, stone-hard permafrost base even on hills with a gradient of only three or four degrees, sometimes producing terraces of crescentic solifluction lobes. The creeping, soggy soil tears roots, covers plants, and can bury the burrows of lemings and voles. Yet these moving hillsides are rarely barren. Specialized plant communities, adapted to soil creep, make their home upon this shifting ground.

Average yearly precipitation totals only eight inches on the tundra, left, but large areas of the region are lush and soggy. Forests of shallow-rooted black spruce, below, can survive where the permafrost is never more than eighteen inches from the surface.
In spring and fall, on warm days and cold nights the moisture-filled active layer thaws and expands, freezes and contracts. Earth and stones caught in this thaw-freeze sequence, prevented from moving downward by the unyielding permafrost, are pushed to the surface and arranged in patterns by the shifting, sifting soil. Clay and silt erupt into closely spaced blisters called mud boils. On the wet, deceptively smooth-looking tundra meadows, these frost heaves form foot-high hummocks covered by specialized vegetation, mostly grasses and sedges that insulate and protect them. These wobbly, tousle-headed tussocks make walking across the tundra a slow, exhausting, ankle-wrenching experience. By means of a process not yet fully understood, the stones that are squeezed to the surface are often arranged in neat circles, one to six feet in diameter, with the biggest stones on the periphery and smaller stones inward. The centers of these stone circles are usually clay or silt; in early summer, they are waterlogged, gooey and tacky as taffy.

Summer's moisture-swollen active layer freezes hard in early winter, and both the active layer and the permafrost beneath may contract and crack. The meltwater that trickled into the frost fissures in summer turns to ice and expands ever so slightly. These nascent ice wedges, growing at an average rate of less than one millimeter a year, enlarge the fissures, and each summer more meltwater seeps in. Decades pass, centuries, millennia, and hundreds of millions of these ice wedges grow, like icy carrots, deeper and deeper into the ground. Old ice wedges are three to fifteen feet wide at the surface and reach ten to thirty feet into the ground. Some, in Siberia, measure thirty feet at the surface and penetrate one hundred and fifty feet into the earth. Most are 1,000 to 5,000 years old, though some, according to geographer Troy L. Péwé, may be 32,000 years old. These ice wedges divide and segment the earth, and their surfaces, meeting usually at right angles, form the polygons, ten to one hundred feet in diameter, that give immense regions of the Arctic their strangely geometric appearance.

Earth-covered ice hills grow on some tundra plains, the largest concentration, about 1,500, on the Tuktoyaktuk peninsula in Canada's western Arctic. These are the pingos, a word derived from the Inuktitut (Eskimo) pinguqjaluit (the “thing that thrusts upward”) and first used in the south by Porsild in a paper written in 1938.

There is no permafrost beneath the large and old lakes and rivers. According to J. Ross Mackay of the University of British Columbia, Canada's foremost expert on pingos and permafrost, most pingos form when a tundra lake is abruptly drained. The surrounding permafrost moves inward upon the column of unfrozen, water-saturated earth that was beneath the lake, the water is pressed inward and upward and finally erupts as an ice pimple upon the tundra. Mackay received permission to drain an arctic lake and create all conditions necessary to develop a pingo. When I asked him how long it would take, he smiled and said, "Oh, about a thousand years!"

Pingos do grow very slowly. Ibyuk, the largest pingo on the Tuktoyaktuk peninsula, 3,000 feet around its base, 157 feet high, its vast core of pure ice covered by an insulating overburden of earth 45 feet thick, is a pingo in its prime, about 1,000
to 1,500 years old. Only one pingo is named for its “rapid” growth. The Inuit call it Pingorsarajuk, “the poor thing that is getting to be a pingo,” or Aliksuktuk, “the one that is growing.” It was sketched by the explorer John Richardson in 1848, seen by Porsild in 1932, and studied by Mackay from 1972 to 1979. Basing his estimate on the fastest present pingo growth (about thirty-five centimeters per year), Mackay believes Aliksuktuk commenced growth probably before 1750, and the name indicating growth is probably at least 200 years old. Now, alas, Aliksuktuk’s growth has ended, and it is slowly shrinking.

Six thousand years ago another pingo, Kuparuk, on Alaska’s North Slope near the Beaufort Sea, was in its prime. Small bands of Northern Archaic people camped upon the pingo because it was the highest spot on the tundra and stood near a major caribou migration route. From its elevation they could spot the animals miles away. Millennia passed, the people vanished, and the pingo aged and shrank. When John E. Lobell of the University of Alaska excavated the ancient hunting camp in 1983, the pingo was less than twelve feet high. Today Kuparuk has disappeared, but the caribou, guided by ancient instincts, still migrate past the spot where it once stood.

Permafrost preserves permanently; it is the deepfreeze of the north. In Siberia, fishing cooperatives keep their catch, often hundreds of tons, in huge storage rooms within the permafrost. On Little Diomede Island, in the Bering Strait between Alaska and Siberia, vast amounts of walrus meat from the spring hunt are stored in ancient "meat holes" dug far into the permafrost. Whalers on Herschel Island in the Beaufort Sea, headquarters of nineteenth-century whaling in the western Arctic, blasted and hacked ice cellars into the ground to store provisions brought from San Francisco, Hawaii, and the Polynesian Islands and caribou, fish, and musk ox meat obtained in the Arctic from the Inuit. Two of the great cellars, now a century old, are still used. Trappers occasionally store char and seal in them as winter provisions.

In 1845, the veteran arctic explorer Sir John Franklin led an expedition of two ships and 129 officers and men into the Canadian Arctic in search of the North-west Passage. All perished, three of the crew during the first winter spent at Beechey Island at the southwest tip of Devon Island. One was twenty-year-old chief petty officer John Torrington, who had caught pneumonia. His mates laboriously hacked out a five-foot-deep grave and buried him in a felt-lined coffin. One
hundred and thirty-eight years later, in August of 1984, Owen Beattie, professor of anthropology at the University of Alberta, opened the grave and the coffin. There, unchanged by time, lay Torrington, his frozen body showing "no signs of decay and only slight dehydration."

Among the strangest of the hundreds of men who searched for the missing Franklin expedition was Charles Francis Hall, a Cincinnati printer and businessman who, at the age of thirty-seven, felt a messianic calling to find Franklin, left family, home, and business, headed north on a whaler, and during the next years became one of the best and most daring of arctic explorers. In 1871 he headed the United States North Polar Expedition. With typical luck and verve he pushed his ship, the *Polaris*, through ice-choked seas to the very top of Greenland and planned to spend the winter there in a bight he named Thank God Harbor. The crew was hostile and afraid. This was too far north for most of them. Hall, ignoring their fear and anger, made short sledding expeditions. He returned from one and, in the darkness and cold, drank a cup of black coffee, complained of its bitterness, and shortly after had a violent seizure. He rallied, lived for two weeks, died, and was buried in a two-foot-deep grave, dressed in his blue naval uniform and wrapped in the American flag. Ninety-seven years later Chauncey Loomis, associate professor of English at Dartmouth College, exhumed the body, which looked "abstract, [like] an icon, or a Rouault portrait." Loomis and his associates sent tissue samples to Toronto's Centre of Forensic Sciences, which reported its tests had revealed "an intake of considerable amounts of arsenic by C.F. Hall in the last two weeks of his life."

Entire mammoths and hundreds of thousands of their giant tusks have been preserved in permafrost. Antony J. Sutcliffe, curator of Pleistocene mammals at the British Museum (Natural History) writes that "it has been estimated that 550,000 tonnes of mammoth tusks still lie buried... along the 1000 km coast between the rivers Jana and Kolyma." Mammoth ivory was traded from Siberia to China more than 2000 years ago. It came, according to ancient Chinese records, from an animal called *yin shu*, "the giant mole," which lived within the earth and perished when it came to the surface. As in so many legends, there was some truth in this one. Mammoths were found from time to time in Siberia; they protruded from the permafrost ground and were invariably dead. (Catherine the Great had high hopes that a live mammoth would be found and corresponded with Voltaire on the subject.) Most, no
The polygon-shaped land formations that characterize the tundra, left, are formed by slow-growing ice wedges that divide and segment the earth. An ice wedge, below, penetrates the ground in the northern Yukon. Beginning as small amounts of meltwater that trickle into narrow fissures and then freeze, such wedges typically reach ten to thirty feet into the ground.

doubt, slipped on a river bank thousands of years ago, were engulfed by summer’s silt and mire, cooled quickly, and were sealed and preserved by permafrost.

The most famous adult mammoth to emerge from its ancient entombment was found in 1900 on the banks of the Berezovka River in northeastern Siberia. By the time scientists, led by Otto F. Herz of the Imperial Academy of Sciences, reached the place in September 1901, wolves had eaten part of the body and trunk of the animal. The Berezovka mammoth had been buried in permafrost for about 40,000 years, but reported Herz, “the flesh from under the shoulder, which is fibrous and marbled with fat, is dark red in color and looks as fresh as well-frozen beef....” The Berezovka mammoth’s stomach contained thirty-three pounds of food; that of another mammoth found in the same region showed it had been brows-
Pingos, ice-core hills with earthen mantles, form when permafrost exerts pressure on moisture in the layer above. Ibyuk, below, is the largest such hill on Tuktoyaktuk peninsula, a pingo-studded land near the Beaufort Sea in the western Arctic. Melted, a pingo, right, forms a circular lake, surrounded by the earth that once covered it.

(1958–79) to build and cost $103 million. The extra time and cost were largely the result of problems caused by permafrost. To provide insulation, the roadbed is six to eight feet thick. One construction company tried to save money by using “sub-standard ice-rich soils” as fill, and in the spring, “large sections of the newly constructed road simply melted away.”

A warmed building erected on permafrost will gradually thaw the ground and sink into it. Many old buildings in Alaska and Siberia have a list and it is almost invariably the kitchen end of the house, its warmest place, that has settled farthest into the permafrost. Perhaps the earliest attempt to solve this problem of building upon permafrost was undertaken on the Labrador coast by German Moravian missionaries. In 1832 they brought a large church, prefabricated in Germany, to their mission in Hebron, sunk four massive oak pillars deep into the ground, and suspended the entire building from these pillars, leaving a four-foot-high cold-air space between the floor and the ground.

In Siberia today, great high-rise buildings are constructed upon permafrost in a similar manner. Holes are steam-thawed into the ground, reinforced concrete piles are jackhammered into them to a depth of at least thirty feet, and upon these piles, which remain forever frozen into the permafrost, the building is constructed. In the Canadian north, huge augers drill holes into the permafrost and wooden piles are used. Single houses are often built upon thick, duct-ventilated pads of insulating gravel.

Vital but vulnerable, permafrost shapes the north, where the frozen earth is quick to hurt and slow to heal. When plant cover is destroyed, plant regeneration is slow. Uninsulated, the soil thaws deeply in summer, resulting in extensive lateral erosion and long-lasting damage. Initially, explorers and industrial developers, oblivious to permafrost and thermokarst alike, wounded and scarred the land.

New regulations now limit such damage. But even in a short span much harm has been done. As botanist Ira Wiggins was already pointing out twenty-five years ago, “the activities of white men during the past fifteen years have done more to change the face of the arctic tundra than has been done by the Eskimo inhabitants during their entire history.” Indeed, cart tracks left on Melville Island in the Canadian Arctic in 1819 by the British naval expedition under William Edward Parry are still visible today. And tractor tracks made now in the far north, will be visible a thousand years hence.
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Life, the Great Chemistry Experiment

by Sandra Postel
life—all life on earth—is a chemical formulation. The earliest life forms, often described as "simple," were complex groupings of chemicals. During the first stage of life more than four billion years ago, they acquired the wondrous ability to replicate themselves. How many millions of failed chemistry experiments must have occurred before life discovered that process?

Life took another giant step two billion years ago when green plants mastered the chemistry of converting sunlight and chemicals into complex molecules. One spillover of this process was surplus oxygen, released into the atmosphere during photosynthesis. It was the "worst atmospheric pollution incident that this planet has known," said British scientist James E. Lovelock, because oxygen was deadly to many of the organisms alive at that time.

Life’s mastery of chemistry advanced when air-breathing fish and amphibians evolved less than 400 million years ago, and again when warm-blooded mammals first appeared some 200 million years ago.

If this chronology is collapsed into a twenty-four-hour drama, humans stepped onto the stage only a few minutes ago, mastered fire two seconds ago, and grew to dominate all living things with our industrialized civilization and five billion people in a fraction of a second.

Humans turned to chemistry for entertainment—and power. The fireworks of the ancient Chinese and the "Greek fire" used by Hellenic navies were related in chemistry, but many centuries of experiments and thought passed before the "powder monk," Berthold Schwarz, adapted gunpowder for a firearm in the fourteenth century. That medieval monks, like sorcerers, would dabble in chemistry should not surprise us. Monks and sorcerers were searching for power, whether for good or evil. Unlike witches, who dealt with the supernatural, sorcerers sought for power in the natural, or real, world, and the roots of modern laboratory science can be traced to those wizards of the Middle Ages.

The ancient fairy tale of the sorcerer's apprentice is one example of our long fascination with the power of the sorcerer. And the tale, with its moral about the dangers of using powers we do not understand, has remained popular as we have sped into the industrial and atomic ages.

As we continue our headlong rush into what might best be termed the Age of Chemistry, we should take great care not to act as thoughtless apprentices, but rather as wizards of white magic who learn, question, and delve with extreme care into the tremendous powers of chemistry to do good for all humankind. Because we have the gift—albeit limited—of understanding, we also have the responsibility to avoid creating a disaster for all life on earth. If we fail, we players of the last few seconds in the great drama will most certainly be swept away with the rest of life.—The Editor

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Power plants, furnaces, factories, and cars have released 185 billion tons of carbon into the air since 1860.
ll humankind has a stake in the life-and-death game of agriculture. The rules of the game are governed by the growth patterns of crops and fairly predictable regimens of warmth and rain. For centuries, farmers have marched to their fertile fields, played the game with great skill, and most often won.

Changes in longstanding rules to which farmers have carefully adapted threaten not only their livelihoods but, ultimately, food security for the earth's hungry populations. We see hints of these effects during severe droughts, most dramatically in Africa in recent years and, to a lesser degree, in the southeastern United States last summer. Further shifts in agricultural conditions worldwide could generate unprecedented pressures on global food supplies.

Within the next fifty years, the earth's climate may change more than it has since agriculture began some 10,000 years ago. Human activities have caused a buildup in the atmosphere of chemical compounds that are known as "greenhouse gases." These gases let the sun's radiation pass through, but trap the longer-wavelength radiation emitted from the earth, which otherwise would escape into space. The anticipated result is a global warming and a worldwide shift in temperature and rainfall patterns. Crops in key food-producing regions will become vulnerable to heat waves, drought, and the loss of water for irrigation.

Scientists have long suspected that carbon dioxide (CO₂) plays a central role in regulating the earth's temperature. Since 1860, the combustion of fossil fuels (coal, oil, and natural gas), in power plants, home furnaces, factories, and automobiles, has released some 185 billion tons of carbon into the atmosphere. In addition, the clearing and burning of forests for cropland and pasture has contributed more than 100 billion tons. Since the early 1800s, the level of CO₂ has increased about 30 percent, and is still rising.

Recently, scientists have found new gases among the greenhouse gang of culprits. Methane and nitrous oxide (laughing gas) have also been increasing in the atmosphere as emissions from human activities have added to those from natural sources. And a family of synthetic chlorine compounds, used in such diverse consumer products as aerosol sprays, refrigerators, and air conditioners, could be second only to carbon dioxide in contributing to the greenhouse effect. Many scientists believe that, collectively, the climate-altering potentials of greenhouse gases other than CO₂ are now about as important as that of CO₂ alone.

The earth's climate will change gradually as the concentrations of greenhouse gases increase. Indeed, evidence exists that the warming has already begun. But climate modelers typically focus their predictions on what will happen from the equivalent of a doubling of carbon dioxide over preindustrial levels, which, taking into account all the greenhouse gases, could occur as early as the year 2030.

Most models agree that temperatures will rise everywhere, though by greater amounts in the temperate and polar regions than in the tropics. Since a warmer atmosphere can hold more moisture, average precipitation worldwide is expected to increase by 7 to 11 percent. In many regions, however, this additional rainfall would be offset by higher rates of evaporation, causing soil moisture—the natural water supply for crops—to decrease.

Recent model results indicate that large grain-producing regions of North America, the Soviet Union, and possibly, China could dry out during summertime. More than half of the world's cereal exports come from North America, and the United States alone accounts for more than two-thirds of total exports of corn. A drier average growing season, along with more frequent and severe heat waves and droughts, could lead to substantial crop losses in these major breadbaskets.

As a rule of thumb, for example, corn yields in the United States drop 10 percent for each day the crop is under severe stress during its silking and tasseling stage. Five days of severe temperature or moisture stress during this critical period would cut yields in half. With the anticipated climate change, such stressful conditions probably would occur frequently in the U.S. cornbelt.

While some regions suffer, prospects for expanding production could improve in others. Warmer and wetter conditions might increase rice production in India and much of Southeast Asia. The picture remains unclear for Africa. But reconstructions of the so-called Altithermal period some 4,500 to 8,000 years ago, when summertime temperatures were higher than at present, suggest that northern and eastern Africa could get more rainfall. If so, average flows of the Niger, Senegal, Volta, and Blue Nile rivers would increase, permitting an expansion of irrigation.

In northern latitudes, higher temperatures and milder winters might open vast tracts of land to cultivation. Agricultural production in Canada, northern Europe, and the Soviet Union might expand northward.

Unfortunately, shifting crop production to areas benefiting from climate change would not only be costly but would also have to overcome some serious constraints. Thin, nutrient-poor soils cover much of northern Minnesota, Wisconsin, and Michigan, so a northward shift of the U.S. cornbelt in response to higher temperatures would result in a substantial drop in yield. Poor soils would also inhibit successful northward agricultural migrations in Canada, Scandinavia, and the Soviet Union.

Centuries would be needed for more productive soils to form. While the present desert regions of North Africa were savannas suited for grazing during the Altithermal period, these lands also would require a long time to regain their former fertility.

Low-lying agricultural areas face the added threat of a substantial rise in sea level. Since water expands when heated, oceans will rise with the increase in global temperature. Warmer temperatures will also melt mountain glaciers and parts of polar ice sheets, transferring water from the land to the sea. By the middle of the next century, sea levels could rise as much as three feet, increasing risks of flooding in agricultural lowlands—where much of the world's rice is grown. Of particular concern are the heavily populated, fertile delta regions of the Ganges River in Bangladesh, the Indus in Pakistan, and the Chang Jiang (Yangtze) in China.

The productivity of major food crops will respond not only
to changes in climate but directly to the higher concentration of CO₂ in the atmosphere. Carbon dioxide is a basic ingredient for photosynthesis, the process by which green plants transform solar energy into the chemical energy of carbohydrates. Experiments suggest that as long as water, nutrients, and other factors are not limited, every 1 percent rise in the CO₂ concentration may increase photosynthesis by 0.5 percent.

Adapting to climatic change will exact heavy costs from governments and farmers. The expensive irrigation systems supplying water to the 670 million acres of irrigated cropland worldwide were built for present climatic regimes. These irrigated lands account for only 18 percent of total cropland, yet they yield a third of the global harvest. Irrigated agriculture thus plays a disproportionately large role in meeting the world’s food needs. Shifts in rainfall patterns could make existing irrigation systems—including reservoirs, canals, pumps, and wells—unnecessary in some regions, insufficient in others. Moreover, seasonal reductions in water supplies because of climatic change could seriously constrain irrigated agriculture, especially where competition for scarce water is already increasing.

A look at one key food-producing region—the western United States—highlights how costly climatic change could be. Some climate models suggest that much of this area could experience a reduction in rainfall, along with the rise in temperature, which would diminish the water supply. Assuming a 10 percent decrease in precipitation and a 3.5°F increase in temperature, supplies in each of seven western river basins would be reduced some 40 to 76 percent. Such reductions would create severe imbalances in regional water budgets. With no climatic change, only in the Lower Colorado region would water consumption exceed supply by the end of the century. With the assumed climatic change, however, consumption in the year 2000 would exceed the renewable supply in four regions, with local shortages probably occurring in the other three river basins.

Since agriculture is by far the biggest consumer of water, balancing regional water budgets would likely require that irrigation cease on a substantial share of cropland. This is happening now in portions of the Lower Colorado, where consumption already exceeds the renewable supply. Correcting the large imbalances resulting from such an altered climate could require that as many as 11.4 million acres be taken out of irrigation in these seven western U.S. regions—roughly one-third of the area currently irrigated.

A reduction of that magnitude would have high costs, measured either by the capital investments in obsolete dams, canals, and irrigation systems or by the replacement value of that irrigation infrastructure. Investment needs for expanding irrigation vary widely, but assuming expenses of $600 to $2,000 per acre, replacement costs could range from $7 billion to $23 billion in the United States alone. Worldwide, maintaining food security under the altered climate could require new irrigation systems with a global price tag of $200 billion.

The need for new drainage systems, flood control structures, cropping patterns, and crop varieties would greatly magnify the costs of adapting to a changed climate. According to some ballpark estimates, the annual cost of a greenhouse gas-induced warming of 4.5°F could amount to 3 percent of the world’s gross economic output. Much of this expense would result from the loss of capital assets in agriculture. Poorer countries would have the most difficulty adapting, and as food production typically generates a relatively large share of their incomes, their people would suffer most.

Moreover, as climate expert William W. Kellogg points out, the need to adapt to climatic change will arise “against a backdrop of increased world population, increased demand for energy, and depletion in many places of soil, forests, and other natural resources.” The disruptions created by a changing climate may thus bring new pockets of famine, losses of income, and the need for huge capital investments, which many countries will find difficult to afford.

Some change in the world’s climate is already inevitable. Yet since carbon dioxide is the key variable in the climate equation, the magnitude of climatic change—and the pace at which it unfolds—will depend greatly on society’s future use of coal, oil, and natural gas. Especially with the recent drop in oil prices, restraining carbon emissions will require investments in energy efficiency and alternative energy sources beyond what the market alone would induce. It will also demand a virtual cap on carbon emissions from industrial countries to allow for needed growth in energy use in the Third World.

Preserving forests and planting trees can also help minimize the threat of climatic change. The clearing and burning of tropical forests adds perhaps 20 percent to the amount of carbon released to the atmosphere each year from the burning of fossil fuels. Trees also remove carbon dioxide from the air during photosynthesis. Increasing global forest cover would thus help stabilize atmospheric CO₂ levels.

Averting a major change in climate is possible, but requires immediate action. No nation has yet taken steps explicitly geared toward limiting emissions of CO₂. Cooperation among governments is essential, since carbon emissions anywhere contribute to climatic change everywhere. But meaningful reductions could begin with concerted national measures by the world’s three largest users of coal—China, the Soviet Union, and the United States.
nation's 18.2 million acres of woodlands were damaged, including two-thirds of the fabled Black Forest in the southwestern state of Baden Württemberg.

Spurred by West Germany's alarming discovery, other European nations assessed the health of their own forests. A sobering picture emerged.

Trees covering nearly 48 million acres in Europe—an area the size of Austria and East Germany combined (14 percent of Europe's total forested area)—now show signs of injury linked to air pollution or acid rain. The key symptoms for the conifers, the hardest hit, parallel those found in West Germany: yellowing of needles, casting off of older needles, and damage to the fine roots through which trees take up nutrients. In eight countries—Austria, Czechoslovakia, Finland, Luxembourg, the Netherlands, Poland, Switzerland, and West Germany—one-quarter to half the forested area is damaged.

National estimates often mask serious damage in specific regions. Total damage in Sweden is placed at about 4 percent, but an estimated 20 percent of the forested area in the south is affected. In 1984, foresters in France surveyed portions of the French Jura and Alsace-Lorraine, adjacent to West Germany's Black Forest, and found that more than a third of the trees were injured, at least 10 percent of them severely. In some heavily polluted regions of Eastern Europe, numerous trees are now in the last stages of decline. In Poland, for example, dead and dying trees cover 1 million acres, and trees with lesser damage occupy an additional 4.6 million acres.

The alpine regions of Austria, France, Italy, Switzerland, and West Germany exhibit the worst damage. Swiss officials worry about the increased risk of landslides and avalanches as dying trees are removed from forested hillsides. Already some villagers have been told to evacuate.

North Americans must travel to mountaintops in the eastern United States to see the kind of massive tree disease and death spreading throughout Europe. In the high-elevation forests, most red spruce trees are undergoing serious dieback—a progressive thinning from the outer tree crown inward. More subtle signs of ill health come from the discovery that pine trees in a broad region of the Southeast grew 20 to 30 percent less between 1972 and 1982 than between 1961 and 1972. In a November 1985 report, U.S. Forest Service analysts stated that the net annual growth of softwood timber in the Southeast "has peaked and turned downward after a long upward trend."

Although less well documented, declines in growth appear to have occurred throughout the Appalachians, extending north into New England. In written testimony presented to the U.S. Senate in February 1984, soil scientist Arthur H. Johnson noted that similar growth reductions preceded the "alarming incidences" of forest damage in Europe.

Hundreds of scientists in the affected countries continue to search for the cause of this unprecedented forest decline. Collectively, they offer a bewildering array of hypotheses, attesting to the difficulty of unraveling a mystery within a complex natural system. Most agree, however, that air pollutants—probably combined with natural factors, such as insects, cold, or drought—are a principal cause. Explanations focus on acid rain, sulfur dioxide, nitrogen compounds, heavy metals, and ozone, which singly or in combination cause damage through the foliage and forest soils.

Changes in soils may be irreversible for the near future. A severely damaged forest in Eastern Europe shows the kinds of soil alterations that can take place. Large portions of the Erzgebirge, a mountain range northwest of Prague, Czecho-
slovakia, are now a wasteland. Near the industrial city of Most, where power plants burn high-sulfur coal, sulfur dioxide concentrations average much higher than in most other industrial areas, and thirteen times higher than in a seemingly undamaged rural forest about 100 miles to the southeast. Peak concentrations register several times higher than the average. The numerous dead and dying trees in this industrial region may thus be succumbing to the classic smoke injury known to occur near large sources of uncontrolled pollution.

Chemical measurements of runoff water from the Erzgebirge suggest that acidification has profoundly altered the soil's ability to support a forest. Czech geochemist Tomas Paces found that losses of the nutrients magnesium and calcium from the damaged forest were several times greater than from the undamaged rural forest. Runoff of aluminum, which normally remains bound up in soil minerals, was thirty-two times greater from the damaged forest. With the loss of calcium and other elements that can buffer incoming acidity, aluminum mobilizes to serve as the buffering agent. In soluble forms, this metal can be toxic to trees. Finally, outputs of nitrate exceeded those from the undamaged forest by a factor of twenty. Paces believes this reflects the damaged forest's inability to properly recycle nitrogen—a loss of basic ecosystem function.

Forests in the industrial regions of Eastern Europe have received extremely heavy pollutant loads during the last few decades. Few forests outside these regions have been drastically damaged. But the possibility of more widespread destruction from chemical stress may increase with time. Ecologist C.S. Holling of the University of British Columbia points out that natural systems may absorb stress for long periods so that change occurs very slowly. Eventually, however, systems may reach a stress point, and as "a jump event becomes increasingly likely and ultimately inevitable," forest ecosystems could collapse.

Substantial economic losses have already resulted from the existing level of pollution stress on forests. The Czechoslovakian Academy of Sciences estimates the cost of acid pollution at $1.5 billion annually, with forest damage accounting for much of the total. In West Germany, researchers at the Technical University of Berlin forecast that German forest industries will suffer direct losses averaging $1 billion annually through the year 2060. Healthy forests, in addition to supplying timber, protect the quality of streams and groundwater supplies, control soil erosion, and provide recreation. Adding in projected losses of these functions, the Berlin researchers estimate that the total cost of forest damage in West Germany over the next several decades will average $2.4 billion per year.

In Switzerland, forest damage threatens the tourist industry that underpins the economy of some Alpine cantons. In North America, sugar maple harvesters lament a drop in maple syrup production and visible deterioration of the sugar maple trees. With weather conditions or other natural factors unable to explain the sugar maple decline, acid rain and air pollution have emerged as probable causes.

In the United States, field and laboratory experiments, combined with the findings of reduced tree growth, strongly suggest that ozone is reducing the productivity of some commercial forest species. Ozone results when certain nitrogen and hydrocarbon pollutants, emitted largely by automobiles, mix in the presence of sunlight. In many rural areas of Europe and North America, summer ozone concentrations now measure two to three times higher than natural background levels.

Researchers at Cornell University subjected four tree species—white pine, hybrid poplar, sugar maple, and red oak—to a range of ozone concentrations typically found in the United States. In all four species, net photosynthesis, a measure of a tree's growth, decreased proportionately with increases in ozone. So even with no outward sign of damage, trees covering large regions are very likely losing vigor and growing slower. Growth reductions of even 1 to 2 percent per year amount to a large loss of timber over a tree's lifetime.

Chronic stress from a variety of chemical pollutants now places a substantial share of the industrial world's forests at risk. In just one year, forest damage in West Germany jumped from 34 percent to 50 percent. The damage increased only slightly during 1985 and 1986, perhaps because of weather conditions beneficial to the trees. Forest damage in all of Europe is now 14 percent, and growing. No one knows how many of the injured trees will eventually die or if and when forest damage will rapidly worsen. Whether the unexplained decline in growth of eastern United States forests portends a similar decline also remains unknown.

With many uncertainties and a variety of pollutants under suspicion, any effective action to protect forests has proved difficult. Most efforts so far have focused on single pollutants or technologies to control pollutants from specific sources. Some twenty-one nations are now committed to reducing their sulfur dioxide emissions by at least 30 percent within a decade. Austria, Sweden, and Switzerland recently enacted pollution control standards for automobiles roughly equal to those in the United States. New cars will likely employ catalytic converters to curb the nitrogen and hydrocarbon compounds that contribute to the formation of acid rain and ozone.

The oil price increases of the seventies were a largely unheralded boon for the environment. Higher prices led consumers and industries to use energy more efficiently, which in turn lowered the output of carbon, sulfur, and other fossil fuel pollutants. Without West Germany's 8 percent decline in total energy consumption between 1979 and 1984, air pollution damage to the nation's forests probably would be worse.

Despite improvements made during the last decade, enormous potential remains for increasing energy efficiency in the world economy. The existing world automobile fleet, for example, travels an average of eighteen miles per gallon of fuel. Test vehicles now under study can achieve three to five times greater fuel economy, reducing pollutant emissions commensurately. Setting progressively stricter standards could help achieve this technical potential far faster than will market incentives alone.

Similarly, great gains could be made by setting efficiency standards for common household electrical appliances. U.S. legislation that seems likely to become law in 1987 would require major appliances to be 15 to 25 percent more energy efficient by 1990 than they were in 1985. This measure alone would eliminate the need to build 20 to 25 large power plants, thereby restraining emissions of carbon dioxide, sulfur dioxide, and nitrogen oxides.
Forest health is inescapably linked to energy use. Any strategy that offers hope of saving the industrial world’s forests must include rapid introduction of pollution control, concerted boosts in energy efficiency, and shifts from fossil fuels to less-polluting energy sources. Meanwhile, with each passing year of continued pollution stress, the cost of lost forest productivity mounts, as does the risk of forest decline and death.

The first case of environmental cancer turned up more than two centuries ago. In 1775, epidemiologist Percival Pott found high rates of scrotal cancer among British chimney sweeps and related the cause to their unusually high exposure to soot, a byproduct of combustion.

Since then, the health hazards of environmental pollutants have spread widely to the general population. The same fossil fuel pollutants that damage forests also harm people. In the United States alone, they may cause as many as 50,000 premature deaths each year, mostly through effects on the respiratory system.

Metals, including lead, cadmium, and mercury, have become a growing cause for concern. Released into the atmosphere through the combustion of fossil fuels, incineration, and other high-temperature processes, metals return to earth in concentrations 100 to 10,000 times greater than natural levels. If introduced into the body in large enough quantities, they can cause varying toxic effects, including cancer and damage to the liver, kidneys, and central nervous system.

More recently, the proliferation of synthetic chemicals applied to croplands, dispersed into the air, and disposed as waste on land has added new dimensions to environmental health risks. Some 70,000 chemicals are at present in everyday use, with between 500 and 1,000 new ones added to the list each year. Estimates of the share of cancer deaths they cause vary, but the most widely accepted range from 1 percent to as much as 10 percent. Because of the long lag time—often twenty to forty years—between exposure to a cancer-causing chemical and the appearance of the disease, the number of cancers induced by synthetic substances could increase markedly over the coming decades.

One family of synthetic chemicals, the chlorofluorocarbons (CFCs), pose some of the most far-reaching health risks because of their capacity to alter the chemistry of the atmosphere. In the early seventies, four decades after CFC production began, scientists began warning that these compounds could destroy the life-protecting layer of ozone in the upper atmosphere.

Ozone, a chemical that forms irritating urban smog in the lower atmosphere, performs a vital function in the upper atmosphere. It absorbs ultraviolet radiation from the sun, which if allowed to reach the earth would have many harmful effects, such as inducing skin cancer and damaging crops. Once aloft, the CFCs migrate to the upper atmosphere where the sun’s intense rays break them down, releasing atoms of chlorine. This chlorine in turn drives a series of reactions that destroy ozone. Largely as a result of worldwide CFC emissions, stratospheric concentrations of chlorine are now more than twice natural levels.

Virtually all CFCs produced are eventually released to the atmosphere, so trends in production largely determine future effects on the ozone layer. Production of CFC-11 and CFC-12, the most worrisome members of the CFC family, rose steadily from the early thirties to the early seventies as demand grew for their use in aerosol sprays, air conditioners, refrigerators, and insulating foam products. Production dropped for several years after the United States and several other industrial countries banned or restricted aerosol uses of CFCs. Yet since 1982, worldwide production has again turned upward.

A recent assessment by the U.S. Environmental Protection Agency, though preliminary, warns that if current trends continue, an additional 40 million cases of skin cancer—800,000 of them leading to death—could strike U.S. residents over the next eighty-eight years. Increased exposure to ultraviolet radiation would also likely impair human immune systems, making people more vulnerable to disease. More people would develop cataracts. Because greater amounts of radiation could increase the formation of smog, respiratory problems and other pollution-related health effects could also increase.

Concern about the pace and predictability of ozone depletion has heightened recently with the discovery of a “hole” in the ozone layer over Antarctica. There, ozone levels drop by about 40 percent each September and October, shortly after sunlight reappears following the continent’s cold, dark winter. This finding took scientists by surprise, and they cannot yet explain why it occurs. Whether it portends a more-rapid-than-expected depletion of the ozone layer globally is a looming and urgent question.
International negotiations regarding CFCs are in progress but so far have not produced concrete results. A cost-effective first step would be a worldwide ban on using CFCs in aerosol products, which account for roughly one-third of annual CFC production globally. Such a ban actually proved beneficial to the U.S. economy, with available substitutes saving consumers an estimated $165 million in 1983 alone.

But even stronger action is needed to reduce the risks of ozone depletion. U.S. negotiators have proposed freezing global CFC emissions over the near-term, and then gradually phasing them out. This proposal would not only protect human health, but could ultimately preserve the habitability of the earth.—Sandra Postel

ur longstanding struggle to improve the human condition may founder as we enter uncharted territory. Our efforts to feed and enrich the lives of all humans have brought about global chemical changes, some of which may be irreversible. A frustrating paradox is emerging. The same efforts we employ to improve living standards are themselves beginning to threaten the health of the global economy. Everyday activities such as driving automobiles, producing food, and generating electricity are adversely affecting the earth's capacity to support continuously expanding human numbers.

A human population of 5 billion, expanding at 82 million per year, has combined with the dramatic power of industrial technologies to expand the scope of human-induced environmental change. We have inadvertently set in motion ecological experiments that involve the whole earth, and as yet we do not have the means to monitor the results.

A sustainable society satisfies its needs without diminishing the prospects of the next generation. By many measures, contemporary society fails to meet this criterion. Questions of ecological sustainability are arising on every continent. The scale of human activities has begun to threaten the habitability of the earth itself. Nothing short of fundamental adjustments in population and energy policies will stave off the host of costly changes now unfolding.

The ozone depletion and pollution-induced forest damage described in the preceding pages are relatively recent discoveries. Yet the activities believed to have brought about these threats—the release of chlorofluorocarbons and fossil fuel pollutants—have been under way for decades. Taken by surprise, industrial societies may trap themselves into costly tasks of planetary maintenance—perhaps seeding clouds in attempts to trigger rainfall where it has diminished with climatic change or seeking means of protection from increased exposure to ultraviolet radiation or liming vast areas of land sterilized by acidification. While perhaps giving brief local relief, these efforts will be like applying band aids to a profoundly sick patient.

Because environmental systems can reach thresholds beyond which change occurs rapidly and unpredictably, we need early warning systems that would alert society in time to avert disaster. Despite impressive progress, the scientific groundwork has yet to be laid for monitoring the earth's life-support systems. Meanwhile, the pace of change quickens.

We have crossed many of nature's thresholds in a short period of time. No one knows how the affected natural systems will respond, much less how changes in natural systems will in turn affect economic and political systems. We can be reasonably certain that deforestation will disrupt hydrologic cycles and that ozone depletion will induce more skin cancer. But beyond these first-order effects, scientists can provide little detail.

Any system pushed out of equilibrium behaves in unpredictable ways. Small external pressures may be sufficient to cause dramatic changes. Stresses may become self-reinforcing, rapidly increasing the system's instability.

The environmental problems of the chemical age stretch beyond the authority of existing political and social institutions. Matters of the global environment now warrant the kind of high-level attention that the global economy receives. World leaders historically have cooperated to preserve economic stability, even to the point of completely overhauling the international monetary system at the 1944 conference in Bretton Woods. They periodically hold summit meetings on international economic problems. Policymakers carefully track economic indicators to determine when adjustments—national or international—are required. Similar efforts are needed for the global environment, including the delineation and tracking of environmental indicators, along with mechanisms for making prompt adjustments when the environment is threatened.

Technological and demographic changes are leading us into the twenty-first century with political institutions inherited from the nineteenth. The need to comprehend our responsibility in time to exercise it successfully presses upon us. The values that guide the management of technology in modern societies have not been clearly articulated, and the need for cooperation is not yet widely recognized in a world where diplomacy remains tied to anachronistic definitions of national sovereignty. That we know so little about the consequences of our activities is humbling. That we have brought so much responsibility upon ourselves is sobering.

A sustainable future calls upon us to simultaneously arrest the carbon dioxide buildup, protect the ozone layer, restore forests, stop population growth, boost energy efficiency, and develop renewable energy sources. No generation has ever faced such a complex set of issues requiring immediate attention. Preceding generations have always been concerned about the future, but we are the first to be faced with decisions that will determine whether the earth our children will inherit will be habitable.—Lester R. Brown

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The expeditions, discoveries, and scientists behind the greatest natural history collection ever assembled—at the American Museum of Natural History.

Preston, former columnist for *Natural History* magazine, tells the fascinating stories of the explorers who journeyed to the farthest ends of the earth for the Museum. He writes about remarkable discoveries they made—everything from priceless gems and huge dinosaurs to totem poles and ancient jades.

*Dinosaurs in the Attic* chronicles such Museum explorers as Barnum Brown, the man who collected more dinosaurs than any person living or dead; Carl Akeley, who sacrificed his life collecting for the African Hall; Robert E. Peary, who discovered a "mountain of iron" in Greenland, which turned out to be the world's largest meteorite; and Roy Chapman Andrews, who penetrated the unmapped expanses of Outer Mongolia and discovered the vast fossil fields of the Gobi Desert. Preston writes about the complex motives which compelled these men and women to risk their reputations and their lives in pursuit of science.

The book also takes the reader on an armchair tour of the labs, storerooms, vaults, and attics of the Museum and the remarkable "hidden" collections they contain—the mumified Copper Man, the tusk vault, the great dinosaur bone storeroom, the gem vault, the carnivorous beetles, and much more. A wonderful book for anyone interested in exploration, discovery, and the history of science.

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"Anyone interested in natural history must obtain this book."—Charles R. Crumly, Harvard University
Arctic Seas That Never Freeze

When ice locks up most of the water in the far north, bears, birds, and seals head for aquatic oases known as polynyas

by Maxwell J. Dunbar

In the vast white expanse of the frozen Arctic, birds and mammals find green plants and abundant prey in oases of open water. Some of these are only narrow, temporary, ice-free flaws between the edges of the land and the packed sea ice. But areas known as polynyas can be the size of inland seas and remain open even when the winter night and ice close in on the rest of the Arctic.

Since 1936, when as an undergraduate I spent a summer studying the plankton in these ice-free zones, I have been fascinated with the open waters of the north, where seabirds and seals feed on the krill and other small crustaceans brought to the surface on upwelling currents. When the air is thirty-five degrees below zero, polynya waters, which are just at the freezing point, steam.

Open water is such a lure for wildlife in the Arctic that except for a single colony of black guillemots, David Netteship of the Bedford Institute of Oceanography has found no major seabird colonies in the Canadian Arctic away from polynyas and other ice edges. Narwhals and other whales seeking food in open waters in early winter are sometimes caught in temporary ice-free holes and then drown or are hunted down. (In 1985 the Soviet icebreaker Moskva broke through some fifteen miles of ice off northeastern Siberia to reach about 3,000 trapped beluga whales. The shy whales would not follow their rescuers to safety, and the crew tried to lead them with music. Pop and martial music failed, but Wagner struck a responsive chord, and the whales followed the ship to the strains of Tristan and Isolde.)

Humans, too, depend on polynyas. Peter Schledermann, an anthropologist at the University of Victoria, has pointed out that native people who survived by hunting lived by these open waters. The Polar Eskimos of Cape York in Greenland, for instance, long depended for their winter walrus hunting on the Smith Sound polynya. (The American explorer Elisha Kent Kane was so impressed by this expanse of open water that he believed he had discovered an open Arctic Ocean.) In the eighteenth century, Dutch, British, and American whalers hunting right whales followed their prey into the great polynya of Smith Sound, at the northern end of Baffin Bay, and Lancaster Sound. The polynya of Smith Sound, known by whalers as the North Water, covers up to 33,000 square miles.

Polynyas may vary considerably in size from year to year, but their distinguishing feature is that they recur each year in the same place and at the same time. Any surface ice that forms on them is forced downstream by strong currents or downwind before prevailing winds. Thus, polynyas are extremely efficient ice factories, producing, by one estimate, four times as much ice a year as nearby areas where the sea is frozen solid.

Navigators, whalers, and people indigenous to the Arctic have long known that life is abundant along the ice edge. On the Canadian research vessel Calanus, I often approached and entered this spectacular area, known to biologists as the marginal ice zone, and the magic never let me down. Birds, seals, and whales are all drawn here, and if the early navigators had been equipped with plankton nets, they would have discovered a corresponding richness in what would then have been called lower life. For many years scientists suspected that the biological richness of this habitat was caused by the upwelling of deeper, warmer water rising to the surface as winds push colder surface water away from the ice edge. In 1979, a Norwegian expedition finally showed this to be so.

Physical oceanographers then speculated that the North Water polynya in Smith Sound was caused by upwelling in Baffin Bay. But two expeditions in 1928, one Danish and one American, had found no evidence of this, although deeper, warmer water certainly exists. These were both summer expeditions, however, so it is still possible that some upwelling takes place in winter. I believe prevailing northerly winds over the Greenland coast blow the ice away and cause upwelling. But the hypothesis has not been verified, since no research vessels have ever sailed the arctic polynyas in winter.

Research in antarctic polynyas indicates that upwelling occurs by haline convection. In this process, which may well occur in the Arctic, sea water freezes, and salt is concentrated in brine pockets. The brine leaches out of these pockets and forms a layer beneath the ice. This heavier, saltier water sinks, and less saline water rises from below.

Phosphates, nitrates, and silicates rise to the surface with the upwelling water.

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Ice floes at the edge of an arctic polynya. Strong winds may keep polynya waters from freezing solid, while upwelling currents bring nutrients to the surface. In and among the ice floes, algae and other floating plant life form the base of the arctic food web.

Photographs by Fred Bruemmer

When these plant nutrients, formed in deeper water by the chemical breakdown of dead organic matter, reach the sunlight, the scene is set for the great outburst of microscopic plant life in the spring.

The key roles in the ice-edge ecosystem are played by three actors: ice algae, crustaceans that graze on the algae, and two species of polar (or arctic) cod. The thick growth of green-brown ice algae, found in the lowest few centimeters of the sea ice, was first noted in the middle of the nineteenth century, but only in the past twenty-five years has it been studied extensively. The algae within the ice may make up as much as one-quarter of the algal growth of the central Arctic Ocean.

Ice algae begin to grow in February and March—many weeks before the bloom of free-floating microscopic plant life called phytoplankton—and grow for some six weeks or until the ice stops thickening. Soon after the algae form, the ice teems with voracious shrimplike amphipods that
While the arctic ice cover is varied and changes with the season, polynyas remain open all year. The map below shows the major polynyas and ice conditions in winter. Open water is vital to the survival of many arctic animals, from polar bears to seabirds. Thick-billed murres (see page 54) and other seabirds often establish colonies near polynya waters, where fish and crustaceans are available before the spring thaw comes to the rest of the Arctic. Polynya waters remain at or near the freezing point, but with air temperatures often 30 degrees or more below zero, the waters steam, right.

Joe LeMonnier

![Map of Arctic Polynyas]  
Legend:  
- **Continuous ice cover**  
- **Consolidated pack ice in motion**  
- **Unconsolidated pack ice in motion**  
- **Thick-billed murre colony (50,000 or more pairs)**  
- **Murre feeding area**

feed on the underside of the ice as if it were an upside-down sea floor. A diver can see them invading every small cavity in search of plant food. These crustaceans are consumed, in turn, by the little polar cod, whose jutting lower jaw is adapted to feeding on the underside of the ice.

With the coming of spring the algae in the ice may break off and begin to grow at the surface of the now nutrient-rich waters. Sunlight, after months of arctic night, incites the sudden resurgence of waterborne plant life. Zooplankton begin to feed, and fishes, birds, and mammals follow. A similar cycle occurs, a half-year and a world apart, in the Antarctic, where other species have developed similar adaptations to living on the ice edge. Arctic and antarctic cod, although from different families, are similar in shape, and both have a high resistance to freezing.

Plankton communities, which provide food for fish, develop first along the edges of the ice and polynyas. Consequently, Ross's gulls and black guillemots nest near and feed at polynyas during the winter in the high Arctic. But for most of the birds, polynyas are resting and feeding stations, used when they return northward in springtime to establish breeding colonies.

Murres (see story on page 54) and kitiwakes are known to fly as much as 120 miles from their breeding colonies to the ice edge and back. They, along with black guillemots, feed largely on small, free-swimming crustaceans and arctic cod. Dovekies and fulmars, which typically feed out on open waters, eat the larger zooplankton, mainly at night when the organisms are closer to the surface.

Polynyas are also critical to the survival of many marine mammals. For young ringed seals, polynyas may provide safe wintering areas away from territorial adults, which scratch out and maintain breathing holes in the fast ice. Many walruses and bearded seals spend the winter in polynyas. In March–April 1979, aerial surveys over the North Water recorded about 700 walruses and 37 bearded seals.

Ian Stirling of the Canadian Wildlife Service believes that the concentration of polar bears around polynyas is related to the presence and numbers of young ringed seals, which may be easy prey on the unstable ice. Polar bears also eat kelp, and where polynya waters are shallow, kelp fronds grow from beneath the ice and up into seal breathing holes. In some areas, the bears, says Stirling, feed on these plants all winter.

During the spring, white whales, narwhals, and bowheads migrate north from their overwintering area in Davis Strait, 600 miles south of Smith Sound. The whales travel along the shoreline polynyas of eastern Baffin Bay to feed in the North Water, then turn south and penetrate the first cracks and open waters in Lancaster Sound, where about a third of the white whales and 85 percent of the narwhals that inhabit North American waters
spend their summers, retreating from the high Arctic waters as winter approaches.

On rare occasions, polynyas and the open edges along some shorelines freeze over completely—with dire results for wildlife. Stirling reports that during severe ice conditions in the Beaufort Sea in the winter of 1973-74 the numbers of ringed and bearded seals dropped by about 50 percent and reproductive success by 90 percent. When the polynya at the eastern end of Lancaster Sound remained frozen in the spring of 1978, seabirds had a disastrous breeding season.

Polynyas support a relatively simple ecosystem consisting of ice edge, open water, algae, krill, and cod. The loss of any one of these can quickly bring about the loss of the others. Plans under way to develop the Arctic’s gas, oil, and mineral resources would bring more traffic through Lancaster Sound and the North Water polynyas. Such plans should be undertaken with the greatest care.
Seabird Citadels of the Arctic

Why do millions of thick-billed murres
breed only in large, noisy colonies?

by Tony Gaston

Within the vast stillness of the Canadian Arctic, seabird colonies are teeming pockets of life. As a biologist with the Canadian Wildlife Service, I have spent the last ten summers in the Arctic investigating the biology of thick-billed murres, a species of seabird whose vast populations are among the largest in the avian world. My studies were aimed at assessing the likely impact on the birds of the huge oil and gas developments that are casting a threatening shadow over arctic marine environments.

Up close, their colonies assault the senses: tens of thousands of murres shoulder one another in rows along the cliffs; an unlovely aroma wafts up from the sea; above all, there is no respite from the noise if one camps within earshot. Every avian arrival warrants a comment from a neighbor—a grunt of surprise, an enthusiastic greeting, or a scream of disapproval. With round-the-clock daylight in summer, the colony never sleeps.

The birds establish these immense colonies in areas that best enable them to meet their two basic needs: feeding and breeding. For six or seven months of the year, many of the seas and straits that dissect Canada’s Arctic archipelago are gripped by ice. The few birds that remain over winter, such as some black guillemots, are confined to small areas of open water, called polynyas, where strong tidal currents prevent freezing. (See story, page 50) When the ice begins to break up, generally in May, seabirds pour northward from wintering grounds in the Atlantic to take advantage of the newly exposed waters and the good feeding provided by fresh stocks of fish and crustaceans. In Canada’s eastern Arctic, three and a half million murres are joined by a million and a half northern fulmars and a quarter of a million black-legged kittiwakes. Across Baffin Bay, in the Thule district of Greenland, ten to twenty million doveis form the Northern Hemisphere’s largest assemblage of seabirds.

To breed, thick-billed murres need cliff ledges on which to lay their single pear-shaped egg. As yet, no bird has developed a seaworthy floating nest: at one time or another, every seabird must come ashore to lay its egg on solid ground. Once on land, however, seabirds and their nests are vulnerable to foxes, minks, cats, rats, and even mice. To reduce the risk of predation, seabirds breeding outside the Arctic have adopted two basic strategies: either nesting on islands that host no land predators or using precipes inaccessible to all but winged predators. Many seabirds that nest on small islands, such as stormy petrels, take the added precaution of visiting their breeding site only at night to avoid encountering diurnal predators, such as falcons or large gulls.

In the Arctic, where winter ice cover provides a convenient bridge to offshore islands, arctic foxes are capable of reaching any island, however remote. Moreover, twenty-four-hour daylight during the breeding season means that there is no night and thus no chance of nocturnal visits to the colony. Not surprisingly, therefore, most arctic seabirds, including murres, fulmars, and kittiwakes, breed on cliffs, choosing the highest and steepest they can find.

Seabirds are found throughout the world’s oceans, and huge colonies are not confined to the north. In the Canadian Arctic, however, small colonies are virtually nonexistent. Nearly one and a half million breeding pairs of thick-billed murres cram into just ten colonies, the smallest containing more than ten thousand pairs. By contrast, the west coast of Greenland, south of Baffin Bay (at about the same latitude as the Canadian Arctic but with a more temperate climate), supports many smaller colonies. This was true even before overhunting brought about recent population declines. Other smaller aggregations, mixed in with the similar common murre, are found in Newfoundland and Labrador and in the Gulf of Saint Lawrence, where conditions are also less severe than those prevailing in the Canadian Arctic. Early in my investigations, I was intrigued by the strange lack of small murre colonies in my study area. I eventually arrived at an explanation for their absence that I think holds the key to

During the short arctic summer, thick-billed murres crowd onto narrow breeding sites on cliff ledges.
David Hieser
many important aspects of the species' ecology and also has implications for their conservation.

Thick-billed murres feed mainly on fish, such as arctic cod, sculpin, capelin, and sand eel, and on large zooplankton, in particular, mysids and the shrimplike amphipods. They dive to depths of 300 feet, staying underwater for one to two minutes at a stretch. Early in the season they feed at the edge of landfast ice, sometimes in polynyas. Once the solid ice has fragmented, they seek open water, often among floating ice pans (flat expanses of drifting sea ice, not to be confused with icebergs, which calve from glaciers).

Many birds travel long distances from their colonies, flying up to two hours one way, in search of food. On high cliff colonies, like the ones at Prince Leopold Island in Barrow Strait or the Minarets on eastern Baffin Island (see map, page 52), you can sit a thousand feet or more above the sea and watch birds constantly arrive and depart. Those leaving the breeding ledges usually first fly down to the sea to bathe and preen a little, then leave for the feeding grounds. At any given moment, there may be thousands of murres on the water close to the colony, and every few seconds one takes flight and heads out.

The departures are independent, but as they move away from the colony, individual birds begin to converge, forming small groups that, in turn, merge into flocks of twenty to a hundred by the time they have traveled a few miles. Scanning with binoculars or a telescope reveals thin streams of these outgoing flocks following one another at intervals of half a minute or so. They continue in straight lines to the horizon, where the tiny specks dissolve into the shimmer rising from drifting sea ice—rivers of birds flowing toward their feeding grounds.

Inbound flocks are generally larger. Like departing groups, they fly low over the water until they come within a couple of miles of their destination but then begin to climb and fragment as each bird makes a beeline to its own nesting ledge.

If birds return to the colony only when they have been successful in obtaining food, then their flight lines should provide

an excellent clue to the whereabouts of good feeding areas. From a human vantage point on the cliff top, the heading of incoming flocks is easy to see, but can the outgoing birds see it? And if they can, do they make use of the information?

Two observations encourage me to think that they do. The outgoing flocks of murres form long lines, or V formations, as do geese. They fly low, practically touching the water. Intermittently, the leading bird gains a few feet of altitude, presumably to take a look around. Frequently, it changes course immediately afterward, with the rest of the flock following. The change in altitude is too insignificant to enhance the visibility of nearby coasts, which rise many hundreds of feet above the sea. But it must greatly improve the bird's ability to spot incoming flocks flying close to the waves, particularly when, as is often the case, fog limits visibility to a few hundred yards.

The second observation involves birds arriving on the cliffs to feed their chicks. One member of each pair is always
Many murres settle for a mere foothold in the standing room only conditions on the ledges, left. To cover its solitary egg, a murre must sometimes press up against the vertical cliff wall, and a change of incubation duty calls for painstaking maneuvers. Stark, inaccessible terrain is preferred for nesting. The rugged Minarets of Baffin Island, below, pose a formidable obstacle for even the most resourceful land predators.

Steve Smith

present at the site—often mere inches of rock ledge—to protect the chick. If there is a change of brooding duty, the bird that has been tending the chick normally flies down to the water. However, an arriving bird that departs immediately after depositing some nutritious morsel, without relieving its mate, usually flies directly away from the colony, losing altitude gradually. It makes no attempt to join outgoing flocks. Such a bird has just come from the feeding area and thus knows exactly where to go. It has no incentive to join the others on the main highway.

There is strong circumstantial evidence here that murres watch what other murres do to find out where to go for food. As suggested by biologists P. Ward and A. Zahari in the mid-1970s, the colony appears to be acting as an information center. This is hardly surprising, given the huge numbers of birds commuting from a single spot. For centuries sailors have made use of seabird flight lines to help them find land. The birds themselves could hardly ignore such an obvious and vital clue. But is this food-finding behavior a consequence of colonial life or a cause? Obtaining up-to-date information about the position of feeding areas is essential for murres in the Arctic. Breakup of the winter pack is unpredictable, and huge areas of drifting ice intermittently obstruct the surrounding sea throughout the July and August breeding season. Wind and currents can dramatically shift the ice cover within a day or two, denying the birds access to some feeding areas, while creating others in completely different directions from the colony. These unpredictable conditions apply over most of northern Hudson Bay, Hudson Strait, northern Davis Strait, and the Northwest Passage—some hundreds of thousands of square miles.

With possible feeding areas as much as sixty miles from the colony, heading the wrong way could be very expensive for a murre, in terms of time and energy. This creates very strong selection pressure for using every available scrap of information: birds adept at finding food within a reasonable time span will rear healthier offspring and rear them faster than less efficient murres.

In eastern Canada during the breeding season, small colonies of murres are present only outside the zone of drifting pack ice. If cues taken from other birds on the location of feeding areas are vital in areas of heavy pack, then the absence of small colonies in such areas may be attributable to a lack of constant and reliable data. Birds in small colonies simply cannot find enough food to maintain their young as good feeding sites disappear.

If the unpredictable shift of feeding areas, caused by quick changes in ice cover, sets a lower limit to the size of arctic murre colonies, what fixes the upper limit? Assuming that information concerning the whereabouts of food increases with colony size, we might expect colonies to go on expanding indefinitely. That they do not suggests that colonial breeding entails penalties as well as profits.

All the murres hunt for exactly the same food. As the colony grows, the increasing population will deplete food supplies in nearby waters, so that birds must travel farther and farther afield to satisfy their needs. When flight time limits the frequency with which murres can feed their chicks, the young grow at a slower rate. I have observed this effect in practice. At Coats Island, in northern Hudson Bay, the chicks in a colony of 25,000 pairs regularly reach eight and a half ounces before they depart at three to four weeks of age. By contrast, at Digges Sound, 300 miles away, where 300,000 pairs breed, the chicks average only five and a half ounces at departure. Eventually, for the very largest murre colonies, the declining availability of food must be reflected in lower survival rates of the chicks, and the size of the colony stabilizes.

At the peak of the last Pleistocene glaciation, about 18,000 years ago, all the waters of the eastern Canadian Arctic were icebound. The present cycle of seasonal ice breakup was probably established no more than 10,000 years ago. If conditions were the same then as they are today, how did the arctic murre colonies develop in the first place?

The sudden simultaneous arrival and nesting of thousands of birds seems inconceivable. Seabird colonies are not founded in that way. Rather, they begin with a few individuals and grow by accretion. We can never be certain how the present colonies originated, but during a warm period about 6,000 years ago, the climate in the Canadian Arctic was less severe than at present and perhaps similar to that found
today along the west coast of Greenland. Under such benign conditions, small colonies may have been founded. Those that reached a critical size were later able to withstand climatic deterioration.

Such a scenario is not merely of academic interest. If the arctic colonies could be established only in a more temperate climate, then these great avian citadels must be regarded, a little like arctic flowers on a mountain in the temperate zone, as relics from an earlier age. If lost, they could not be regenerated without a change in climate.

Under natural conditions, few catastrophes could destroy a colony of hundreds of thousands of seabirds. Human ingenuity, however, has found a way. Plans are afoot to transport oil, in specially strengthened tankers, from offshore fields in the Beaufort Sea to refineries on the east coast of North America via the Northwest Passage. A major spill from such a tanker, occurring during the murres' breeding season, might kill enough birds to plunge the colony below the threshold of viability.

The general picture that emerges from consideration of the arctic murre colonies is of two forces working in opposition. On the one hand, increasing colony size improves the ability of colony members to locate current feeding areas, minimizing the risk of a wasted journey. On the other hand, the increased number of birds lowers the average density of food around the colony, forcing birds to travel farther and farther for a payoff.

Feeding-site information seems to be critical in areas of intermittent ice, so that colonies of fewer than 10,000 pairs cannot persist indefinitely. Above this threshold, colonies vary in size, but at a certain point, which seems to be between a quarter and a half million pairs in Canada, local depletion of food stocks sets a limit to successful reproduction.

If these ideas are correct, we can make two different predictions about what might happen to an arctic murre colony that suffers catastrophic mortality from an oil spill. If numbers do not drop below the threshold of about 10,000 pairs, we might expect a rapid recovery, aided by the relaxation of competition for local food supplies. If numbers fall well below the threshold, however, we might expect the opposite effect: poor reproduction causing an accelerated decline until the colony disappears, forever. Predictions that can be tested are grist for the mill of science, but this is one hypothesis that I shall be glad to see remain unproved.
Alum Cove, Arkansas

by Robert H. Mohlenbrock

My first visit to Alum Cove, a rocky ravine in Arkansas’s Ozark National Forest, was prompted in 1977 by a telephone call from Paul Redfern, a botanist from Southwest Missouri State University. Paul told me he had just found French’s shooting star, a rare and delicate wildflower, growing beneath a sandstone overhang at Alum Cove. Paul knew I would be interested in his discovery, since until then, this plant had only been found at a few places in southern Illinois. In fact, French’s shooting star, originally discovered in 1871, was the only flowering plant that grew on my home turf and nowhere else in the world. Despite the possibility of losing an exclusive claim, I was excited that this little plant might be living in the wild about 250 miles from its nearest colonies in Illinois.

I rushed to Alum Cove, where I verified that the plant Paul Redfern had discovered was indeed French’s shooting star. At the same time, I was introduced to a beautiful natural area with significant vegetation communities. The geological setting is that of a rocky basin carved into a massive sandstone escarpment that includes several arches, overhangs, and a natural bridge whose forty-foot span rises more than thirty feet above a usually dry, rocky stream bed. John David McFarland III, an Arkansas geologist, describes the Alum Cove rocks as crossbedded quartz sandstones sandwiched between layers of shale. He attributes the formation of the stone bridge and other features to the erosion of the sandstone: ground and surface water gradually remove iron oxide, the cementing material that holds the grains of sand together, allowing wind and gravity to do their work.

In the lush ravine bottom, the dominant trees are the American beech, with its broad crown, unlobed leaves, and smooth, light gray bark; and the sweet gum, with its pointed crown, roughened, dark bark, and five-lobed, star-shaped leaves. Umbrella magnolia, with two-foot-long leaves in pendulous clusters, adds an Appalachian element. The trees in the ravine cast dense shade over a sparse shrub layer and a thick carpet of spring wildflowers. Sure to catch the eye is the rattlesnake plantain orchid—not because of its flowers, which are tiny and white, but because of its dark green leaves patterned with bright white veins. Stranger yet are beechdrops, six-inch-tall plants that look more like twigs stuck in the ground because they have no leaves and contain no chlorophyll. They get their entire nutrient supply from the roots of beech trees, to which they attach themselves with long, underground runners. Despite their unusual appearance, these “twigs” bear tiny purple flowers in September and October and are therefore flowering plants.

Upland from the ravine bottom, the predominant trees are oaks—red, white, black, and scarlet. Joining them is mockernut hickory, whose large nuts resemble (mock) those of the very tasty shagbark hickory but house disappointingly little food material. The trees in this slope community are spaced farther apart than those in the ravine bottom, permitting more sunlight to penetrate and an overall drier habitat. Drier and even more open conditions prevail on the ridgetops above Alum Cove. Oaks still dominate, but black gum becomes an important tree species. Here and there, shortleaf pine makes an appearance.

The ravine, slope, and ridgetop communities at Alum Cove are typical of the surrounding Boston Mountains, but the sandstone overhangs provide niches where plants with special ecological requirements may develop. Such microhabitats are the spawning grounds for new species and undoubtedly gave French’s shooting star its beginning.

The plant was discovered by George Hazen French, the second biologist ever to join the faculty of Southern Illinois University. On the fresh spring morning of May 6, 1871, French bicycled to a sandstone ravine about ten miles south of Carbondale, entering a densely shaded forest dominated by sugar maple and white oak. He followed along the base of a sixty-foot-high, east-facing sandstone bluff, which was undercut here and there by erosion to form overhangs. Under one of these over-
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hangs, sheltered from the sun's rays, French discovered his shooting star.

French was undoubtedly excited by his find, because he knew that the common shooting star, the only other shooting star in southern Illinois, was a plant that grew out in the open in rather dry woods or even prairies. The plants under the overhang were a little smaller than the common shooting star, and the leaves, instead of tapering gradually to the base, were cut abruptly into a distinct leaf stalk. But French was puzzled because he could find absolutely no difference between the flowers of this plant and the flowers of the shooting stars out in the open.

Botanists who classify plants generally follow an unwritten rule that differences in flower structure may constitute a valid reason for naming a new species, but differences in leaf shape generally do not, since leaves tend to be influenced more by local environmental conditions. When French sent some of his specimens to George Vasey, the national botanist in Washington, D.C., Vasey acknowledged that what French had found was different all right, but not different enough to make it a new species. Vasey considered the plant to be a variation of the common shooting star, describing it as Dodecatheon meadia var. frenchii.

In 1932, however, when botanist Per Axel Rydberg ran across French's specimens of shooting star in the dried plant collection at the New York Botanical Garden, he reopened the controversy. He decided it should be recognized as a species and accordingly changed the Latin name to Dodecatheon frenchii.

After John Voigt and I joined the botany faculty at Southern Illinois University in the 1950s, we became interested in French's shooting star and visited the many sites in southern Illinois where the plant had been found since its initial discovery. Our interest was piqued further when a respected botanist in Wisconsin, who had never seen French's shooting star in the wild, suggested that it was neither a good species nor even a good variety, but that its peculiarities could be attributed to its adverse, shaded environment. He proposed that if French's shooting star were to be transplanted to an open habitat, it would eventually assume the characteristic leaves of the common shooting star, and vice versa.

To test this theory, John Voigt devised a transplant experiment, which we carried out. We moved a few French's shooting star plants to the ridge above a sandstone overhang and took some common shooting stars from the ridge and relocated them back under the overhang. Although the experiment was repeated several times, the common shooting star never survived beneath the overhang. The French's shooting star plants on the ridge survive to this day, thirty years later, and still have their telltale stalked leaves.

Meanwhile, Ladislao Olah joined the botany faculty at Southern Illinois University in 1962 as a cell biologist, and he too became interested in the shooting star problem. In examining the chromosomes of the two kinds of plants, Olah discovered that French's shooting star had twice as many chromosomes (forty-four) as the common shooting star. This genetic evidence weighs heavily on the side of those who consider French's shooting star to be a distinct species.

Following the unexpected discovery of French's shooting star at Alum Cove in northwestern Arkansas, this species has been found under a single overhanging bluff in southern Indiana, at one setting in southeastern Missouri, and at a few places in central and eastern Kentucky. Despite identification of these new localities, French's shooting star is still considered rare enough to be a candidate for the Federal Endangered Species list being prepared by the United States Fish and Wildlife Service. Its widespread but sporadic occurrence remains a mystery for biologists to unravel.

"This Land" highlights the biological phenomena of the 154 U.S. national forests. Robert H. Mohlenbrock is Distinguished Professor of Botany at Southern Illinois University at Carbondale.
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THE GLENLIVET: JUST SLIGHTLY OUT OF REACH.
Sea Cow Family Reunion

A paleontologist finds the missing link in the lineage of a fantastic marine mammal

by Daryl P. Domning

The evolutionary history of the Sirenia, the order of plant-eating marine mammals that includes the manatee and dugong, has intrigued me since my high-school days nearly twenty-five years ago. While still an undergraduate, I dedicated my research career to understanding their extensive but fragmentary fossil record. I also learned in those days of another kind of sirenian—popularly known as Steller’s sea cow—that became extinct more than two centuries ago. This animal was even stranger than its odd living relatives, the manatees and dugongs, and its strange story matched its peculiar characteristics.

Early in November of 1741, the Russian brig Saint Peter was searching her way along the bleak chain of islands now known as the Aleutians, her demoralized and scurry-ridden crew hoping to regain their base at Petropavlovsk before the onset of the fast-approaching winter storms. They had been the first Europeans to set foot in Alaska, but little else had gone right with Vitus Bering’s second voyage of exploration of the seas between Asia and North America, and now the captain commander himself lay in his cabin near death. The crew’s hopes of quick relief were abruptly ended when they were shipwrecked on an unknown and uninhabited island in this northern sea that, along with the island, was later to be named Bering after their dead leader.

The island was devoid of humans but not of life—fortunately for the crew who would have to endure the bitter winter before building an escape vessel from the wreckage of their ship. When the survivors reached safety in Kamchatka the next summer, the ship’s naturalist, Georg Wilhelm Steller, reported, among other notable discoveries, that Bering Island was surrounded by herds of huge sea cows feeding on kelps in the shallow water. From his past reading, Steller recognized the animals as sireniens. But he also realized they were no ordinary sea cows.

These animals lived in the frigid water of subarctic latitudes, whereas the manatees of which he had read lived in tropical waters. In addition, these arctic sea cows reached lengths of twenty-five feet, nearly twice the size of the tropical sea cows. They had a thick, rough, barklike epidermis and were completely toothless, having only the horn pads at the front of their jaws that all sireniens use to mash their food. They were unique among vertebrates above the level of lobe-finned fishes in having no finger bones in their short, clawlike flippers. Perhaps strangest of all, and unlike any other marine vertebrate, they seldom or never submerged themselves completely but habitually floated with their backs out of the water.

Fortunately for Steller and his shipwrecked companions, but unfortunately for the animals, these sea cows were very good to eat. Only some 2,000 sea cows existed in the vicinity of Bering Island in 1741, and within twenty-seven years Russian fur hunters had eaten them to extinction. As a result, later scientists knew Steller’s sea cow only from descriptions by Steller and a handful of other explorers and from incomplete skeletons dug from the beaches of Bering Island in the nineteenth century.

All this I knew by the time I began my graduate work in paleontology at the University of California at Berkeley in 1968. I also knew that, despite the rather extensive fossil record of the sirenian family Dugongidae, to which Steller’s sea cow belongs, there were no known fossils connecting the bizarre animal of Bering Island, Hydrodamalis gigas, with other members of the family.

At the time, paleontologists thought that Hydrodamalis was probably derived from Miocene Atlantic sea cows belonging or related to the genus Metaxyther-
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The latter had also apparently once lived in the North Pacific; a fragmentary specimen had been reported in 1925 from late Miocene rocks (about ten to twelve million years old) in southern California's Santa Barbara County and named *Metaxytherium jordani*. Nevertheless, according to the late paleontologist George Gaylord Simpson, neither that form nor any other species of the family Dugongidae showed "a definite foreshadowing of the specializations of *Hydromanalis*," by which he meant their enormous size, strange flippers, and lack of teeth.

This view began to change in the 1960s as a result of discoveries in California of several better-preserved late Miocene specimens of *M. jordani*. These specimens differed so greatly from any of the Atlantic and Mediterranean fossil sirenians bearing the name *Metaxytherium* that I put this species in a new genus, *Dusisiren* ("siren of the west").

The new specimens of *Dusisiren jordani* showed close ties to Steller's sea cow. In the latter, the edge of the bone at the rear of the skull was greatly enlarged and roughened for the attachment of powerful neck muscles. Alone among fossil sea cows, *Dusisiren* showed a similar though lesser development of this area, as well as other important resemblances in the functional design of the neck region. Furthermore, the cheek teeth of individuals varied considerably in size. This would be expected if teeth were no longer essential to the animals' survival. An immediate ancestor of the toothless Steller's sea cow probably would have had smaller teeth. But this was not enough to demonstrate a direct ancestor–descendant relationship with Steller's sea cow. For a form to have been a direct ancestor it had to have existed prior to the descendant and to have lived in an area accessible to an area occupied by the descendant. In addition, if the ancestor's structure differs greatly from the descendant's, then forms intermediate in structure and dates of existence must be found in order to show the course of evolution. Finally, the case for direct descent is greatly strengthened if changes in form can be explained as functional adaptations to changes in ancient environments.

In the case of the North Pacific sea cows, several of these criteria had been met. Of all known sirenians *Dusisiren jordani* was by far the closest relative and best structural ancestor for *Hydromanalis*; it lived on the coasts of the North Pacific, and it antedated Steller's sea cow.

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**Simplified Sirenian Family Tree**

- **Hydromanalis gigas** (Steller’s Sea Cow)
  - Teeth absent in juveniles and adults; finger bones lost

- **Hydromanalis cuestae**
  - (Avila Beach, Laguna Niguel, and San Diego, California)
  - Teeth absent in adults; finger bones probably lost; body size much larger

- **Dusisiren dewana**
  - (Great Yamagata Sea Cow, Japan)
  - Teeth and finger bones reduced in size; wrist bones significantly altered

- **Dusisiren jordani**
  - (Santa Barbara County, California)
  - Body size larger; teeth lost; snout less downturned

- **Dioplotherium allisoni**
  - (Baja California and Southern California)

- **Metaxytherium**
  - (U.S. East Coast and Peru)

- **SIRENIANS (Sea Cows)**

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by some ten million years. But actual links between them were still missing.

This situation changed suddenly when I learned of a skull of late Miocene or Pliocene age that the Natural History Museum of Los Angeles County had salvaged in 1966 from a construction site at Laguna Niguel, south of Los Angeles. Its well-preserved palate showed no trace of tooth sockets. Here was the first known Hydrodamalis from Tertiary rocks, but it was of unprecedented size. Although the whole posterior portion of the skull had been destroyed by the earthmover, the part that remained was longer than any complete Steller’s sea cow skull known, and it must have belonged to an animal well over thirty feet long. This paleontological find was puzzling. If it represented an ancestor of the Recent Steller’s sea cow, did that not indicate that the descendants of Dusisiren must have first doubled in length and then gotten smaller?

Closer consideration showed that this conclusion did not necessarily follow. Virtually all the remains of Steller’s sea cows in the world’s museums came from Bering Island. And Steller had written that the Bering Sea winter was hard, even on the sea cows; so hard that by spring their ribs had begun to show through their thick hides. Evidently, the Bering Island habitat was not optimal but marginal and might have resulted in stunted growth in this subarctic population, while more fortunate animals in southern California might have attained their full potential size.

More importantly, this Miocene-Pliocene sea cow, perhaps three to seven million years old, proved to be intermediate between Dusisiren and Steller’s sea cow in the details of its anatomy. In its lack of teeth, it agreed with the latter, but the portion of its upper jawbone that had once held developing teeth was not as atrophied as in Steller’s sea cow, and there were details of the snout, cheekbone, and frontal bone that clearly recalled the Miocene Dusisiren.

Not long after the discovery of the Laguna Niguel skull, the widening of a sea-side road at Avila Beach, near San Luis Obispo, California, unearthed the skeleton of a large marine mammal. Thought at first to be that of a whale, on further examination the skeleton was recognized as that of a toothless sirenian. Eventually a colleague called this specimen to my attention, and a quick trip to San Luis Obispo confirmed what I had hoped for—the skeleton was another Pliocene Hydrodamalis, but much more complete than the one found at Laguna Niguel. And it provided striking evidence of its descent. Again, the toothless palate and other features were unmistakably like those of Steller’s sea cow, but the braincase (missing from the Laguna Niguel specimen) was almost identical to that of Dusisiren. Throughout the skeleton there was a nearly equal mixture of morphological characteristics seen in the Miocene and the Recent Bering Island forms, vividly exemplifying the phenomenon of “mosaic evolution”—the occurrence of primitive and advanced characteristics in the same species. This presumably results from stronger selection for change in some organs than in others. I named this intermediate Pliocene form Hydrodamalis cuestae in honor of the faculty and students of Cuesta College, near San Luis Obispo, who excavated it.

In time, other isolated bones of Dusisiren and Hydrodamalis from California and Baja California were collected or identified in museum collections, filling in more details of the evolutionary picture. These included a partial skull of H. cuestae from San Diego even larger than the one from Laguna Niguel. Paleontologist Tom Deméré at the San Diego Natural History Museum invited me to join

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him in studying this and other specimens. Another interesting item was a large rib, clearly of *Hydrodamalis*, that had been found in Japan and brought to my attention. Of late Pliocene age, it was the first record of fossil sirenians in the northwest Pacific. The available fossils seemed to indicate that the ancestors of Steller’s sea cow had evolved in the eastern Pacific and dispersed to Asia around the northern rim of the ocean after the animals developed a tolerance for cold climates.

Light was also thrown on the earlier end of the lineage between *Dusisiren* and Steller’s sea cow. Christian de Muizon, a researcher at the Muséum National d’Histoire Naturelle in Paris, excavating in early and middle Miocene rocks of Peru, discovered remains of a sea cow belonging to a species of *Metaxytherium* known from beds of similar age on the east coast of the United States. In Miocene times, before the creation of the Central American land bridge, the same species of sirenian clearly lived along the eastern coast of the United States south of what is now New Jersey, in the Caribbean, and in the eastern Pacific; and those members of this species that spread north to California probably gave rise to *Dusisiren*.

So far a coherent picture had taken shape: a neat sequence of skeletal stages stretched from the early Miocene *Metaxytherium* found in Peru through the late Miocene *Dusisiren jordani* and the Miocene-Pliocene *Hydrodamalis lineatae* found in California to the Recent Steller’s sea cow from Bering Island. Yet an important link was still missing from this chain. *D. jordani* was a fully normal sea cow, meaning it had functional teeth and a paddle-like flipper containing finger bones. The Avila Beach species, however, already stood (or floated) firmly in the camp of Steller’s sea cow, lacking teeth as an adult and apparently having a hook-like forelimb. Almost no fossil evidence bridged the gap between these two very different kinds of animal. In a 1977 journal article, I went out on a limb and speculated about the structure of the still undiscovered intermediate form. I referred to it as *Dusisiren* Species D, and predicted that it would have teeth like its ancestor *D. jordani*, but would have a forelimb like that of Steller’s sea cow and would be found in eight-or nine-million-year-old rocks of the North Pacific region.

That was a risky hypothesis in several respects. It took the fossil record at face value, assuming that Steller’s sea cow had not branched off from *Dusisiren* at some time much earlier in the Miocene epoch, before ten or twelve million years ago. It assumed, instead, that the lineage of Steller’s sea cow had not branched at all, but consisted of a simple temporal sequence of species, one evolving into the next, over nearly twenty million years. That was the simplest explanation of the available data—but evolution does not always take the simplest route.

Very soon, however, this explanation was strikingly confirmed. The summer of 1978 was a dry one in northern Japan, and the Mogami River, north of Tokyo, was reduced to a fraction of its normal volume as it flowed through the countryside of Yamagata Prefecture. Two schoolboys exploring the exposed riverbed were surprised to see a series of large ribs and vertebrae protruding from the rocks. In the following weeks, an excavating team led by Shizuo Takahashi of the Yamagata Prefectural Museum uncovered most of a skeleton, including skull and forelimbs, of a late Miocene sirenian. Consulted about this skeleton, I was able to determine from photographs and some of the animal’s teeth that it was an advanced form of *Dusisiren* and almost certainly, judging from its forelimb, was *Dusisiren* Species D, the creature whose existence I had pre-
dicted. The discovery caused a minor sensation in the Japanese press, which christened the beast Yamagata Dai Kaigu — the Great Yamagata Sea Cow.

Through the generosity of the Yamagata Prefectural Museum I was able to travel to Japan in the summer of 1982 and study the skeleton at firsthand. By then its preparation was well advanced and showed that it was as perfect an intermediate between Dusisiren jordani and the species found at Avila Beach as the latter had been between Dusisiren and Steller's sea cow. Its skull was relatively primitive and contained a full set of teeth, but they were smaller and simpler than those of D. jordani. Its well-preserved forelimb, however, was pure Steller's sea cow: the abbreviated clawlike hand skeleton, with its vestigial finger bones, seemed grotesquely out of proportion to the powerful upper parts of the limb. The wrist bones were ingeniously modified to lock together in mutual support when the animal used its flippers to pull itself along the rocky sea floor. For the first time, an actual specimen substantiated Steller's sometimes-doubted observations — and incidentally fulfilled my own predictions nicely.

Dated by means of microscopic diatoms fossilized in nearby rocks, the Yamagata sea cow turned out to be between 9 and 10.4 million years old, exactly intermediate between D. jordani and H. cuestae in age as well as morphology. Paleontologist Tsunemasi Saito, Takahashi, and I named it Dusisiren dewana, after Dewa, the ancient name of the Yamagata district. The final and most dramatic missing link in the evolution of Steller's sea cow had been found.

The establishment of an evolutionary line of descent, however, is not the ultimate goal of the paleontologist; the really interesting questions only begin to arise at that point. Why does one kind of animal evolve into another? What forces of natural selection could account for the changes observed? These problems require paleontologists to look beyond the lineage in question and examine the biological and physical context of its evolution.

The family branch to which Steller's sea cow belonged had once, in mid-Miocene times, shared the coast of California with another sea cow, Dioplotherium allisoni. That sea cow differed from Dusisiren in having large tusks and a strongly downturned snout deflected some 70° from the palatal plane, resembling that of the living dugong of the Indo-Pacific seas. Evidently it was, like the dugong, a bottom feeder, specializing on sea grasses growing close to the ocean floor. Dusisiren (and later, Hydrodamalis), in

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contrast, had snout deflections of 45° or less. Steller had made it clear that Hydrodamalis had not fed on sea grasses (which are abundant only in the tropics) but on kelps, the large brown and red algae that flourish in cold North Pacific waters. The relatively soft and nonfibrous texture of these algae was believed to explain why Hydrodamalis could do without teeth. Marine plants in general have a very incomplete fossil record, but by good luck large kelps were known to have existed in California as far back as the middle Miocene. Therefore I was able to conjecture that while Diploterotherium probably ate small, bottom-hugging sea grasses, Dusisiren must have exploited the large algae of its time, which grew up toward the surface and did not require a sharply deflected snout for comfortable cropping. However, since Dusisiren still retained teeth, it presumably included some of the fibrous sea grasses in its diet. Its descendant Hydrodamalis specialized still further on kelp eating and eventually no longer had a need for teeth.

Did this scenario make any sense in the context of North Pacific geological history? Two facts dominated the paleoecological picture: After the middle Miocene, the climate began to cool, a trend that lowered the temperature of coastal waters and culminated in the Pleistocene ice ages; and in the late Miocene and Pliocene, the California Coast Ranges and other mountains were uplifted, draining the previous coastal inlets. The result was to change the Pacific coastline of North America from a series of broad embayments and protected basins to the exposed, rugged shore seen today. This was all that was needed to assemble the remaining pieces of the sirenian puzzle.

Most sea grasses grow best in warm, sheltered waters, in contrast to kelps, which prefer cold, high-energy environments. The cooling and draining of coastal embayments would have eliminated any tropical sea grasses from the northeastern Pacific, accounting for the disappearance of Diploterotherium by the end of the Miocene. The very same trends would have been beneficial to the large marine algae, explaining both the survival of Dusisiren and the dietary specialization of its descendants.

To feed on kelps, however, the sea cows had to spend more time in cold, turbulent waters off exposed, rocky shores. Increased body size and thicker skin and blubber helped conserve heat; but the blubber and various corollaries of increase in size, such as reduced proportion of body weight represented by the skeleton, led to greater buoyancy. This was not a disad-
vantage because much of the kelp biomass lay at or near the surface. There were also additional benefits: floating with the back out of the water reduced conductive heat loss, provided exposure to radiant warmth from the sun, permitted entry into shallower water for foraging and for escape from such potential predators as sharks and killer whales, allowed seabirds to remove parasites from the skin (as Steller had witnessed), and possibly reduced wave drag when swimming. Evidently there was no lack of selective pressure for either voluntary or obligatory floating.

On the other hand, the new environment had its dangers. To maintain steering control while feeding among treacherous waves and tides, the sea cows must have had to keep swimming slowly into the current, much like ships riding out a storm. Indeed, Lieutenant Waxell, Captain Bering's second-in-command and a veteran seaman, noticed that *Hydrodamalis* behaved in exactly this way. Increased flexibility of the neck, which skeletal features seemed to suggest and which Steller affirmed, would have been useful for reaching to the sides to crop plants while the body maintained its orientation to the waves and currents. In shoal waters, clawlike forelimbs like those of the Yamagata sea cow must have been ideal for pushing away from rocks, pulling forward against wave surges, and detaching plants. And when all else failed, the barklike hide protected against scrapes.

These and other adaptations to the cooling Pacific allowed the descendants of *Dusisiren jordani* to spread as far north and west as Japan and to flourish until the coming of humans in the Pleistocene. Floating conspicuously in shallow water, the large, tasty mammals had no defense against this new predator. In the absence of any other apparent cause for its extinction, *Hydrodamalis'* survival only in the vicinity of two islands that had never before been reached by humans clearly points to us as the culprits. In view of all the Pleistocene megafauna that shared the same fate, and probably through the same agency, we are lucky that Steller and his shipmates recorded for posterity the few shreds of knowledge about this unbelievable animal that they did. And how fortunate that so many of its ancestors' bones—among which the Great Yamagata Sea Cow is surely the most important—have been preserved.

Daryl P. Domning is a paleontologist and associate professor in the Department of Anatomy at Howard University in Washington, D.C.
Clusters' First Stand

by Thomas D. Nicholson

Most of the bright planets are clustered too close to the sun in the morning to make for easy viewing. Mercury, Venus, and Jupiter rise before the sun but too far south; only Venus rises early enough and is bright enough to be seen at dawn. Watch for it, especially at the end of the month when the moon is near. Saturn, also a morning star near Antares in Scorpius, is up from midnight until dawn.

Mars is our only evening star, still moving slowly east through the stars of Taurus, where it can be found after dark drifting between two well-known star clusters, the Pleiades and the Hyades. Both clusters are prominent features of Taurus and easily visible to the unaided eye; both also offer attractive telescopic views.

Visually, the Pleiades is a tightly packed group of dim stars, appearing like a patch of cloudy light in a hazy sky or one bathed in bright moonlight. But in clear, dark skies it is readily seen to be composed of individual stars, six in the form of a tiny "dipper" (not the Little Dipper). The brightest one (third magnitude) is Alcyone; the others are fourth magnitude. Some persons can see a seventh star, the fifth-magnitude Merope, sometimes considered to be a test of eyesight. The popular name for the group, the Seven Sisters, includes Merope. Ordinary binoculars show dozens of stars, and astronomical photographs reveal hundreds.

The Hyades is a V-shaped group of a dozen or so stars bright enough to be seen without a telescope. The bright red star Aldebaran (not a member of the cluster) is at the top of the V's left side. The cluster forms the imaginary face of Taurus, the Bull, and Aldebaran marks its right eye. Over a hundred cluster stars are telescopically visible.

The Pleiades and the Hyades are the two brightest examples of open star clusters, loose organizations of stars (from several dozen to several hundred) moving together through space on parallel paths that gradually separate with time. About 1,000 such clusters are known in our galaxy, the Milky Way. They range in size from about ten to forty light-years across (the solar system is about half a light-year across). The Hyades cluster is about 130 light-years distant from the earth; the Pleiades cluster about 400. Both are named for the daughters of Atlas.

Events in the calendar below are given in local time unless otherwise indicated.

April 1: Mars and the crescent moon decorate the sunset sky. The moon is easily visible until well after dark; Mars, still barely in the range of first magnitude, is not visible until the sky darkens. You will see Aldebaran first, to the moon's left, then Mars will show up between the two. If it isn't clear tonight, look again tomorrow. Mars will be below the moon, Aldebaran to its left, and the three form a triangle.

April 3: The star near the crescent moon is Alnath, at the tip of the Bull's right horn. Another star (Zeta Tauri), below Alnath and about half as bright, marks the end of the left horn. The V below both, with reddish Aldebaran, is Taurus's face.

April 4-6: The moon slides over from Taurus to Gemini in the early evening of the 4th. Apogee moon (farthest from the earth) and first quarter occur on the 6th. On the night of the 6th, the moon comes into line with Pollux and Castor, passing exceptionally close to the former as it goes by. The moon is then very nearly at its greatest northerly latitude (distance north of the ecliptic). Since Gemini is also the most northerly constellation of the zodiac, the moon will be very high when it crosses the meridian (the north–south line in the sky) on these nights.

April 8-10: Moving into Leo on the night of the 8th, the moon passes by Regulus on the afternoon of the 9th, drifting away from the star during the night. By the 10th it is above Regulus.

April 11: Virgo is home to the autumnal equinox, where the sun crosses the equator on the first day of autumn. But we can't see the autumnal equinox then because it is in the sky in daylight. In the spring, however, it is well up in the evening, right above where the moon is shortly after dark tonight.

April 13: Full moon is at 9:31 p.m., EST. just before it moves slowly and majestically toward the star Spica, so close that it occults the star over the North Atlantic and western Europe. At the same time, the moon will be in the pentumbra of the earth's shadow, causing a penumbral lunar eclipse. Think of it as a partial solar eclipse as seen from the moon.

April 14-17: The moon is now a morning object, in the sense that it rises after sundown and remains in the sky past daybreak. It moves into Libra late on the 14th and out again early on the 16th. On the 17th it is in Scorpius, where it has a date with the bright reddish star Antares at about 2:00 a.m., EST, when it crosses in front of the star and obscures it from the southern latitudes. Both the moon and the star are well above our horizon at the time, but the moon is just a bit too far north for the occultation to be seen at our location. We will see a very close conjunction.

April 17-18: Moonrise is at about 11:00 p.m., and after midnight Saturn and the moon will climb the eastern sky together, the moon lagging slightly behind the planet. Perigee moon (nearest the earth) occurs at about noon, EST, on the 18th, in Sagittarius, where it will be seen after it rises at about midnight.

April 19: Mercury and Jupiter are in conjunction in Pisces at approximately 7:00 a.m., EST, but the two planets are not far enough to the sun's right to be visible in the morning.

April 20: The moon reaches last-quarter phase at 5:15 p.m., EST, just as it slips over into the constellation Capricornus. It rises after midnight and remains visible past dawn.

April 21: Mars finally moves past Aldebaran at about 7:00 a.m., EST, and appears to its east on subsequent mornings.

April 22-23: The not particularly dis-
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April 27: New moon is at 8:34 P.M., EST, in Aries.

April 30: Given a clear western horizon, the slender young crescent moon could be visible at dusk, again close to Mars.

The spring Sky Map shows the sky for April, May, and June from latitude 40° north at the hours given below. To use the map, hold it vertically in front of you with south (S) at the bottom and match the lower half of the map with the stars you see when you face south. As you face other directions, roll the map to bring the corresponding compass direction to the bottom of the map. The stars move continuously westward during the night. By morning (before dawn), stars on the western half of the map will have set, those on the eastern half will have moved into the west, and new stars (those of the summer evenings) will have risen in the east. The map represents the sky at about 2:00 A.M. on April 1; 1:00 A.M. on April 15; midnight on April 30; 11:00 P.M. on May 15; 10:00 P.M. on May 31; 9:00 P.M. on June 15; and 8:00 P.M. on June 30. Add one hour for daylight time. The map can be used for an hour or more before and after the times given.
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That Greasy Kid Stuff

The potato chips we all grew up eating are undergoing a change for the better

by Raymond Sokolov

When I was a boy long ago in Detroit, my favorite "meal" was a large bag of potato chips. Brands meant nothing to me. I liked them all equally well. The very idea that an industrial food product par excellence could vary in quality from brand to brand or bag to bag had never occurred to me. This was Detroit, the Vatican of the assembly line of interchangeable parts. And the potato chip fitted in perfectly with this vision of uniformity.

I was never challenged in this "automotive" concept of the potato chip. Indeed, the only claim of brand superiority that I ever heard until quite recently (the only claim, that is, which could not instantly be dismissed as the obligatory boast of an ad) came from a dried-up old man who for a time courted the aged but foxy aunt of one of my own aunts.

When this gaffer came a-wooing, he brought plain brown cartons of potato chips. He was a minor executive at a minor local chip company, and one of his perks was access to chips deemed too large for sale to the general public. I forget if these giant disks were withheld because they were too fragile for bagging or because they would confuse people and destroy the illusion that all chips were identical. It may even have been that management liked them so well they kept them for their own delectation. This is what we were led to believe by my aunt's aunt's beau—not directly, but by implication.

The trouble with the suitor's megachips was that they had nothing to recommend them except their size. If anything, they tasted less delicious than the normal kind. This experience soured me on potato chip connoisseurship for a long time. As an adult, I was reinforced in this special form of Philistinism by an authoritative-sounding newspaper article that asserted that most potato chips were sold rancid but that consumers were accustomed to the rancid taste and rejected fresh chips. Since I adored commercial chips and found they all tasted alike, I assumed I was one of the millions with degraded palates who preferred rancid chips. So be it, I told myself.

Lately, however, I have been changing my mind. The steady state of the potato chip industry is now a thing of the past. Over recent months, I have found commercial potato chips that are obviously superior to the chips we all grew up with. They are available in regular markets all over the country under several brand names. But the product is essentially the same: a crispier, slightly thicker, slightly greasier chip, tasting powerfully of the spud it was made from.

You might call it the nouvelle chip although, like the nouvelle cuisine, it is really not new at all but a return to an old idea, renamed and repackaged. The key word here is Hawaiian. Most of the nouvelle chips refer to Hawaii on the bag. Others identify themselves as hand cooked or kettle cooked. If you haven't noticed them yet, you probably haven't been paying attention to the potato chip racks in your supermarket. This sets you apart from most Americans.

Potato chips are the epitome of mass-market fast-food. Open the bag and pop them in. Americans buy nearly $3 billion worth a year. So potato chips account for nearly half the salty snacks sold in the United States. And a single company, Frito-Lay, dominates the industry.

You would not suppose, would you, that the General Motors of potato chips would take serious notice of the emergence of the nouvelle chip. Well, the chip game is not at all, it turns out, like the car business.
GM might have ignored Japan for years and years, but Frito-Lay twice tried unsuccessfully to buy the Maui Potato Chips Factory, according to the owners, the Kobayashi family, whose Kitch’n Cook’d Chips started the *nouvelle* chip revolution. Mark Kobayashi, the grandson of the firm’s founder, says he constantly turns down offers from big American and Japanese companies. He is too proud to sell a Maui cottage industry that has inspired imitators from California to Cape Cod.

It all started when Kobayashi’s grandparents were interned on the mainland with other American Japanese during World War II. Somehow they learned a recipe for cooking potato chips and recreated it thirty years ago on Maui. Without perhaps realizing it, the Kobayashis invented the *nouvelle* chip now appearing in your neighborhood, manufactured by mainland companies with infinitely greater capital and the ambition to sell their chips in every mall and pop stand in the land. What the Kobayashis really did was preserve the most traditional recipe for chips and make them as they were originally made at the hour of their creation in the 1870s.

It took roughly 250 years for the potato to make its way from Peru to Spain and thence to be naturalized and universally adopted as a popular food. French fries did not reach England until roughly 1870, according to C. Anne Wilson, the British food historian. They really were French in origin, a commercial food from the start, produced by street vendors in Paris in quarter-moon shapes and called *pommes Pont-Neuf*. Since the potato did not “arrive” in France as a staple food until the early 1800s, it seems probable that French fries did not exist until somewhat later. At any rate, authorities agree that they were French and reached England about 1870. This matters to the history of the potato chip, because the chip is a special case of the French fry itself. The earliest recipe I know for potato chips comes from Mary F. Henderson’s *Practical Cooking and Dinner Going*, published in New York in 1878. (I learned this in Susan Williams’s remarkable survey *Savory Suppers and Fashionable Feasts, Dining in Victorian America*, Pantheon, 1985.)

Henderson calls her chips Saratoga potatoes. This lends support to the anecdote repeated in *The American Heritage Cookbook* that potato chips were invented by accident at a fashionable resort in Saratoga Springs, New York, in the nineteenth century. The resort was Moon’s Lake House, and the chef was George Crum. A patron kept sending back French fries, complaining that they were too thick. The irate Crum sliced some potatoes paper thin, fried them, and sent them out to a rapturous reception. This mixture of legend and fact does seem to fit into a logical scenario. The French fry reaches England around 1870. A recipe for potato chips appears in an American book in 1878. All authorities agree that Victorian chips were Saratoga chips. So it does seem probable that the French fry crossed the ocean in the early seventies and was further refined by Crum or some other Saratogan soon after.

Or it may be that the deep-fried potato reached England and America separately from France. The English-speaking world does divide sharply in its fried potato vocabulary. “Chips” over there are French fries. But English potato chips, in the American sense, are always called crisps, except in one situation: when they are handmade (one wants to say when they are produced in the Hawaiian style).
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and served with game (see recipe). This exception supports the idea of a separate invention of the potato chip in England. Someone like Chef Crum must have sliced potatoes thin, but this chef decided to serve them with game. Instead of viewing his invention as a special new thing, he saw it as a kind of French fry (chip). Instead of becoming a popular food in England, the game chip was limited to the aristocratic table during hunting season. Later, when the American chip arrived, it couldn’t be called chip; so a new term was created: crisp.

Note well, that there is no confusion in England between the two kinds of potato chips. Over here we are rediscovering this difference and, in a sense, rediscovering our roots. The best evidence justifies our thinking of the potato chip as a regional dish of upstate New York invented in Saratoga around 1875. Today’s Hawaiian chips constitute a return to the original conditions of hand cookery during the Victorian dawn of the chip. Those innocent prisoners of war, the Kobayashis, must have encountered one of the last practitioners of a method made virtually obsolete by industrial machines. The modern, mass-produced chip is a triumph of cost-effectiveness: Potatoes are cut thinner than anyone could cut them with a kitchen knife, then fried for a minute or so.

But how exactly do they improve on this in a factory designed to duplicate a small kitchen? To find out, I accepted the invitation that the Cape Cod Company makes to all its customers to visit the firm’s one and only factory in Hyannis, Massachussets, on Cape Cod. Following the street map on a Cape Cod potato chip bag, I found the imposing but not gigantic building tucked away in the sandy hinterland of Hyannis. To the naive eye, the glassed-in production facility looked big and mechanized, with belts and degreasing centrifuges. There is an impressive amount of hand inspection, but I assure you the peeling and slicing of the potatoes is done by machine. The interesting part is the cooking itself. The famous open kettles are vats of cottonseed oil into which what looks like a bushel of sliced potatoes are dumped. Presumably those potatoes are sliced a tad thicker than the standard competition’s potatoes. The oil does definitely appear to be at the moderate end of the deep-frying temperature scale. I would guess it is approximately 355°, the point at which cooking oil begins to smoke lightly. This is precisely the temperature at which home cooks have traditionally cooked potatoes. The appearance of the first wisps of smoke are almost as reliable an indication of temperature as is the boiling point of water.
At the Hyannis factory, shortly after the potatoes hit the oil, a dramatic cloud of steam rises from the kettle. The potatoes are giving off their water. Even though they have been chosen for low water content, the potatoes are still composed mostly of H2O. To keep them from sticking together during cooking, a man stirs the vat systematically with a rake. After almost ten minutes (eight and a half minutes is said to be average), the batch is golden brown and finished. As far as I could tell, the potatoes are not soaked after slicing, which is what standard recipes recommend to prevent oxidation and the resulting discoloration. Instead, they are dumped right in the oil.

"That's the big flavor difference," says another Kobayashi clone, Bob Campbell of Clark, South Dakota. "And the higher quality oil." He returned from a trip to Hawaii just over a year ago and decided to try his hand at Hawaiian potato chips made from the potatoes he grows on his own farm, which was formerly a supplier for Frito-Lay. He calls his product Dakota Style Chips.

His and all the other Hawaiian chips popping up around the country tend to cost a bit more than mainstream, non-Hawaiians. They are certainly fattening. But they are prepared without additives or preservatives. Some are available salt free. All of them taste like the potatoes they started out as. And some of them are appealingly dark.

This is the Kobayashi mark of distinction. The late Dewey Kobayashi reportedly spent fifteen years searching for the ideal chipping potato. He settled on Burbank russets, from the Tule Lake area of northern California. Russets contain more sugar, which turns chips brown. Most manufacturers want a light gold chip and avoid russets. You don't have to go to Hawaii to try Hawaiian chips. A very big company is producing them nationally. And in Hyannis, Anheuser-Busch, through its subsidiary company Eagle Snacks, produces its own Hawaiian chips. The Cape Cod Company has been a division of Eagle Snacks since 1985. Will corporate greed destroy the Hawaiian chip renaissance? Should you care? Are Hawaiian-style Saratoga chips better? You decide. There is no end to connoisseurship.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

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**Roast Pheasant with Game Chips and Bread Sauce**

(Slightly adapted from *The Farmhouse Kitchen*, by Mary Norwak, Penguin)

- 1 large pheasant
- 5 tablespoons butter
- 4 strips bacon
- 4 medium potatoes
- Oil for deep frying
- 1 medium onion, peeled
- 4 cloves
- 1 cup milk
- Pinch of mace
- 6 peppercorns
- 1 1/2 cups dry bread crumbs
- 2 tablespoons heavy cream
- Salt
- Pepper

1. Preheat oven to 350°.
2. Spread a plump young pheasant with butter and put some butter inside the bird. Leave a tablespoon of butter for the sauce.
3. Cover the bird with bacon strips and roast for 45 minutes. Meanwhile, prepare the game chips and bread sauce.
4. Heat 3 inches of oil to 395° in a 3- to 4-quart saucepan. If you do not have a deep-frying thermometer, heat the oil until it begins to smoke. While the oil is heating, peel the potatoes, cut wafer thin with a mandolin, a slaw cutter, an appropriate blade on a food processor, or the large blade on a metal grater. Soak in ice water.
5. Before the oil is sufficiently hot to use, you should still have time to stick the onion with the cloves and put it in a saucepan with the milk, mace, and peppercorns. Bring to the boil and then remove from heat. Let stand for 30 minutes.
6. Drain and dry the potato slices. Carefully lower a cupful of them into the hot oil. The best way to do this is with a wire basket designed for the job. If you don't have one, use a skimmer to add and remove batches of chips. Stir the chips while they cook to prevent sticking together. When they are richly brown, drain over the pan and then spread on paper towels. Continue until all the slices are cooked. Cooking time will depend on the thickness of the slices, the heat of the oil, and the relative quantities of oil and potato. Four minutes is a reasonable amount of time per batch, but you may find that if you use very thin slices only a few minutes at a time, you could be ready to drain them after a minute. Sprinkle chips with salt.
7. Strain the milk, discard the onion. In another pan, add the bread crumbs to the milk and heat until it resumes the boil, stirring gently. Stir in remaining tablespoon of butter and the cream. Season to taste with salt and pepper. Serve separately in a sauceboat to accompany finished bird.

Yield: 4 servings
At the American Museum

Latin America Month
April is Latin America Month in the Leonhardt People Center at the American Museum of Natural History. Each weekend will celebrate the cultural achievements of Latin American countries. Programs will feature Mexican folktales, Andean dances, modern Brazilian carnival, Afro-Brazilian religious dances, South American Highland music, chamber music, spinning and weaving, and Huichol arts (a sacred and ceremonial art form related to shamanism). *The Legend of the Golden Coffee Bean*, the story of a homeless Indian girl in search of wealth and happiness who finds that true fulfillment is found through love and sharing, will be presented Monday, April 20, at 1:00 and 3:00 p.m. in the Kaufmann Theater. These programs are free to the public, and seating is on a first-come, first-served basis. For a complete schedule of events call (212) 769-5315.

The Chaco Phenomenon
In the late 1000s, the Hyde Exploring Expedition (named after Frederick Hyde, a trustee of the Museum) recovered cylindrical pots; stone figures of birds, frogs, and tadpoles; wooden flutes; and many turquoise beads and pendants from New Mexico’s Chaco Canyon. The exhibition of these artifacts has been extended through August 2, 1987.

At the Planetarium
Actor Burt Lancaster narrates *The Seven Wonders of the Universe*, a Sky Show that journeys through time and space in search of celestial canyons, alien landscapes, and other galactic marvels. For information call (212) 769-5920.

Members’ Programs
An evening of traditional Javanese music and dance presented by the New York Indonesian Consulate Gamelan (music ensemble) can be enjoyed by members on Thursday, April 23, at 8:00 p.m. in the Main Auditorium. The typical gamelan consists of gonglike instruments, such as metallophones, as well as bamboo flutes and a two-string fiddle. This performance will also feature several dances, including *Panji-Bugis*, the story of a pirate prince; and *Golek Ayun-Ayun*, a female-style court dance of Yogyakarta. Tickets are $7 for members and $10 for nonmembers.

In a slide presentation on Tuesday, April 7, at 7:30 p.m. in the Main Auditorium, ornithologist Brian Harrington will explain the migratory patterns of shorebirds, including those that fly up to 18,000 miles with only brief pit stops. Tickets are free for members and $4 for nonmembers.

On Sunday, April 12, at 11:30 a.m. and 1:30 p.m. in the Kaufmann Theater, naturalist Darrel Schooling will discuss how plants and animals may have arrived at and evolved in the isolated Galápagos archipelago. The morning program is geared toward families with 7- to 10-year-olds, the afternoon program is for adults. This program is free and open only to members. Tickets are required.

For further information on members’ programs call (212) 769-5600.

Free Programs
Middle Eastern and North African dances will be performed by the Cabash Dance Experience, Sunday, April 5, at 2:00 and 4:00 p.m. in the Kaufmann Theater.

*American Heritage: Music and Dance*
Members of the Vanaver Caravan will perform step dances from Quebec, Appalachia, and Louisiana on Saturday, April 18, at 2:00 p.m. in the Kaufmann Theater. *The Dream Comes First*
Natural healing, as expressed in a blend of traditional and contemporary Native American culture, is the focus of this slide-lecture demonstration on Saturday, April 25, at 2:00 p.m. in the Kaufmann Theater.

*The Many Colors of Kathak Dance*
Kathak dance was born and nurtured in the temples of North India and later flourished in the courts of Muslim rulers. The Gangani Kathak Dance Company will perform Sunday, April 26, at 2:00 p.m. in the Kaufmann Theater.

*Natural History Film Series*
These film programs from the acclaimed international film and television festival Wildscreen ’86, will feature some of the newest works by wildlife film makers. From the arctic polar bear to the African elephant, films will portray wildlife conservation and scientific study. Screenings are Sunday, April 4, at 11:00 a.m. and 4:00 p.m. in the Kaufmann Theater.

For further information on these free programs call (212) 769-4215.
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The scene was not so much an abduction as an elopement. The wingless female thynnine wasp had been calling chemically from her “balcony” of flowers. Eager to mate, she used pheromones to flag down one of the many available suitors cruising the area. According to entomologist John Alcock of Arizona State University, “the male that makes first contact almost always wins the female, picking her up and carrying her off in copula in a nuptial flight.” In this Australian species, *Megalothy unus klugii*, the pair first alight momentarily on a nearby stalk to couple in peace and then, still bonded, resume their aerial maneuvers for up to several hours, the female coiled under her partner’s streamlined abdomen.

An indispensable part of the mating ritual is the nectar feast. Touching down on flowers, the male sips nectar. Every three or four minutes, he offers a droplet to the female, who uncoils and partakes. The common term for the male’s action is regurgitation, but Alcock describes it as a mouth-to-mouth nuptial gift. By nourishing the female, the male is making an investment in the reproductive capability of the mother of his offspring. When the pair finish mating, the female is literally dropped, sometimes in the vicinity of her original perch. Earthbound once again, she will burrow into the ground and lay one egg on each beetle larva she finds. When the egg hatches into a grub, it will eat the larva. And when ready to remate, the female will emerge, climb a stem, and board another flight.—J.R.

Photographs by B.A. Wells and A.G. Wells
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While teaching and doing research in Chile in 1976, Tom D. Dillehay (page 8) and his students discovered the wetland archeological site of Monte Verde. Despite its considerable antiquity, the site was distinguished by excellently preserved wood, seeds, and other organic remains. Because its artifacts are a valuable aid in understanding the peopling of the New World, Dillehay has analyzed the site extensively. He is currently conducting ethnarcheological research on a ceremonial site in the life of the Mapuche Indians, who live in the region where Monte Verde was discovered, and investigating early food-producing societies in northern Peru. Dillehay is an associate professor of anthropology and the director of the Kentucky Anthropological Research Facility at the University of Kentucky in Lexington. Further details about Monte Verde are contained in "The Cultural Relationships of Monte Verde: A Late Pleistocene Settlement Site in the Sub-Antarctic Forest of South-central Chile" and in "The Implications of the Lithic Assemblage from Monte Verde for Early Man Studies" in New Evidence for the Pleistocene Peopling of the Americas, edited by Alan Lyle Bryan (Orono: Center for the Study of Early Man, 1986).

Montreal-based naturalist Fred Bruemmer (page 30) has been studying and taking photographs of the Arctic for "what seems like forever." Previous articles in Natural History have ranged through many disciplines, covering Greenland Eskimos, the birds of Prince Leopold Island, beluga whales of the high Arctic, and the polar bears of Cape Churchill, Canada. In his circumpolar travels to Siberia, Alaska, Lapland, and Spitsbergen, Bruemmer has also taken thousands of pictures of permafrost phenomena. His meetings with scientists who were studying permafrost fueled his interest in the subject, and this month's article is the result. For further study of permafrost, Bruemmer recommends The Periglacial Environment, by H.L. French (London: Longman Group, Ltd., 1976), and Geomorphic Processes in Polar Deserts, by Troy L. Péwé (Tucson: University of America Press, 1974). His latest book, Arctic Animals, was published in Canada by McClenann and Stewart and will be issued by NorthWord in the United States this fall.
Studying the Arctic and skiing have been long-time pursuits of Maxwell J. Dunbar (page 50). Now, at seventy-two, he says he skis a little less than he used to, but his enthusiasm for studying the northern ice is unflagging. Professor emeritus at McGill University’s Institute of Oceanography in Montreal, Dunbar is continuing to study polynyas and polar marine ecosystems, projects he began in western Greenland in 1935 as an undergraduate at Oxford University. From 1941 to 1946 Dunbar served as Canadian Consul in Greenland, getting in some fieldwork in the fjords as well. He used his knowledge of northern waters to design a vessel for the Fisheries Research Board of Canada where he served as a director from 1947 to 1955. For further reading, Dunbar recommends Polynyas in the Canadian Arctic, edited by I. Stirling and H. Cleator, a collection of essays published in 1981 by the Canadian Wildlife Service (Ottawa: Occasional Paper No. 45), and The Arctic Ocean, edited by L. Rey (London: Macmillan Press, Ltd., 1982).

Veteran wildlife photographers Bert and Babs Wells (page 84) find a wealth of subject matter in the vastness of Western Australia, where they work as a team. They found the wasps featured in this month’s “Natural Moment” in dry, shrubby swampland north of Perth. When they spotted a female wasp in a “soliciting” posture atop a stem, they rigged up their camera and flash, retreated to a remote control trigger, and waited. Within a split second of the male wasp’s arrival, he had the female airborne, and the Wellses had their pictures. They used a Nikon F2 with motor drive, a 105-mm lens, and two small high-speed strobes (flash duration 1/10,000 of a second). Bert, who has earned many international photography awards, and Babs, a field ornithologist, most recently collaborated on a photographic study of the northwest corner of Australia, The Wild Pilbara. They are currently working on a book about Australia’s honey possum.

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“The extraordinary concentration of thick-billed murres into a small number of very large colonies struck me while working as a wildlife consultant in the Canadian Arctic in the 1970s. I have continued to work on thick-billed murres ever since,” says Tony Gaston (page 54). He has spent the past ten summers studying these seabirds at their bastions on the cliffs of high Arctic islands. A native Englishman, Gaston earned his doctorate in zoology at Oxford University. In addition to his work in the far north, he did three years of fieldwork in the tropical thorn forests of India and spent two years in the western Himalayas. He has also undertaken expeditions to Turkey and the central Sahara. Gaston plans to return to India in the future to investigate the ecology of hawks and eagles in tropical rain forests and to encourage wildlife conservation there. He is the coauthor, with David Nettleship, of The Thick-Billed Murres of Prince Leopold Island (Ottawa: Canadian Wildlife Service Monograph Series Number 6, 1981). More information on seabirds, including murres, can be found in Seabirds of the World, with photos by Eric Hoskins and text by Ronald M. Lockley (New York: Facts on File, 1984), and Franklin Russell’s The Sea Has Wings, with photos by Les Line (New York: E.P. Dutton, 1973).

“More than twenty-five years ago, having visited most of the national parks of the United States and found them increasingly congested,” reports botanist Robert H. Mohlenbrock (page 60), “I started taking working vacations with my family in the 154 national forests of our country. Many of the natural features that draw people to the parks are available in the forests but are not well publicized.” After years of exploration, Mohlenbrock is helping others enjoy the forests through his Field Guide to U.S. National Forests (New York: Congdon and Weed, 1984) and his column for Natural History, “This Land,” the thirtieth installment of which appears in this issue. Born in southern Illinois, Mohlenbrock, who has done extensive research on Illinois plant life, is the author of the ten-volume Illustrated Flora of Illinois. His other publications include Where Have All the Wildflowers Gone (New York: Macmillan, 1983), a book about endangered plant species of the United States. He is currently working on field guides for the wildflowers of North America. Mohlenbrock’s concern for the preservation of natural areas and rare plant species led, in 1985, to the International Union for the Conservation of Nature appointing him as Chairman of the North American Plant Specialists for the Species Survival Commission. On the faculty of Southern Illinois University at Carbondale since 1957, Mohlenbrock has been a Distinguished Professor since 1985.
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Cover: Children and other young mammals develop muscles and coordination while playing. In the South Pacific, four-year-old Tania Christian swings from a tree on Pitcairn Island, where the rebellious sailors landed and settled after their famous mutiny on the Bounty. Photograph by Melinda Berge | Photographers Aspen. Story on page 54.
The Cicadas Are Coming, the Cicadas Are Coming

Nineteen eighty-seven will be another big year for the seventeen-year cicada. According to evolutionary biologist Chris Simon of the University of Hawai'i (who wrote for us on the periodical cicada in May 1979), this year's mass emergence began in Georgia in late April and will begin in Indiana and New York in mid-May. The numbers should be overwhelming in the Baltimore and Washington, D.C., areas.

Periodical cicadas have thirteen- or seventeen-year life cycles, and scientists group all of those that emerge contiguously and synchronously in numbered "broods" (year classes). Each brood was once thought to have evolved independently after the last glacial maximum 18,000 years ago, but Simon's recent research on biochemical variation of enzyme proteins among broods demonstrates that all periodical cicadas stem from three major groups—eastern seventeen-year broods, western seventeen-year broods, and centrally located thirteen-year broods.

All of the members of brood 10, having passed through five nymphal stages since they went underground in 1970, will emerge from the ground within a one- or two-week period, when trees will resound with the singing of the males. After mating, the females will lay their eggs in slits they have made in tree branches. Adults will die within four to six weeks of their emergence. And the nymphs that hatch from the eggs will drop down from the branches and burrow into the earth, starting another cycle.

Turtle Tracks

Kemp's ridleys (see Natural History, November 1986) are the world's rarest and most secretive sea turtles. Born on a single beach in Mexico, the turtles make tracks into the Gulf of Mexico and then vanish, except for occasional sightings on coastal feeding grounds or rare strandings. Anne Meylan (an associate in herpetology at the American Museum of Natural History) witnessed such a stranding in December 1985, when cold-stunned, nearly dead Kemp's ridleys began washing up on the icy New York shore of Long Island Sound. By the end of the winter, Meylan and members of the Long Island-based Okeanos Ocean Research Foundation had recovered some fifty turtles, but only a few could be warmed and revived.

After a search through the records of ridley strandings and sightings along the East Coast from Florida to Cape Cod, Meylan suggested that Long Island Sound may be a regular stop on the yet uncharted migration route of these rare turtles: from the gulf through the Straits of Florida, north with the Gulf Stream, perhaps as far as Cape Cod (with time spent feeding in Long Island Sound), then
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out into the swirling currents of the Sargasso Sea before a return trip to the gulf breeding grounds.

But without more reports of ridleys in Long Island Sound, the stranded turtles might have just been considered victims of weather and currents. Meylan now reports that the turtles “are definitely out there again.” Last summer, fishermen using traps and nets in Long Island Sound came up with seven live ridleys. And during the past winter, twenty-seven more Kemp’s ridleys were found stranded on the beaches of the sound.

With growing interest in the fate of these turtles, state and federal agencies are supporting new efforts to study and preserve them. Shrimp nets, one of the major killers of Kemp’s ridleys, may soon be less lethal. A device has been developed that allows turtles to escape from the nets after accidental capture and will soon be required in inshore waters off the east coast of Florida and in the gulf, where ridleys are abundant.

Fertile Ferret?

On March 1, 1987, a team from the Wyoming Game and Fish Department...
caught the last known black-footed ferret living in the wild. A large male, about four years old, it was first spotted last summer but eluded capture throughout the fall and winter. After a full week’s watch at a burrow the animal had been seen to enter, ferret trackers caught and moved it to a breeding center near Laramie. Wildlife experts suspect that there may be a few more wild ferrets left in Wyoming, but diligent tracking has turned up little evidence this winter.

The latest capture brings the number of captive ferrets to eighteen. The eleven females, able to mate as yearlings, are all capable of breeding. Four of the seven captive males are of breeding age, but one is thought to be infertile.

The March 1 capture came not a day too soon. Ferret breeding season peaks in February but extends into March. According to Harold Harju of the Wyoming Game and Fish Department, the newest captive will be quarantined briefly as a safeguard against the “remote” chance it has distemper. Then, the staff at the Sybille Research Center near Laramie will attempt to breed him with one of their females.

The fortunes of the endangered animal (see Natural History, February 1986) have seesawed in recent years. In 1981, when most wildlife experts had concluded that the ferret was extinct, a breeding group was discovered near Meeteetse, Wyoming. In 1984, researchers counted 128 ferrets. A subsequent die-off of prairie dogs (the ferrets’ main prey) from sylvatic plague and an outbreak of canine distemper among the ferrets caused both the captive and wild populations to plummet. Hope for the species’ survival now centers on captive breeding.

If their numbers recover sufficiently, black-footed ferrets will be reintroduced into the wild. The two prime requirements, according to Louise Richardson of Biota, a wildlife consulting firm, are plenty of prairie dogs (as prey) and plenty of open space. Each population may need up to fifty individuals to be viable. Richardson estimates that each ferret may need a 100-acre home range and that a female with a litter to feed may require as much as 400 acres in which to roam and hunt. Harju notes that efforts are now under way in Montana and Colorado, as well as Wyoming, to evaluate possible “transplantation” sites. The long-term plan, says Harju, is to reintroduce and then to split the ferret populations until four or five separate populations thrive in the wild. In the meantime, the large, vigorous male taken on March 1 may help save his species.

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Death by Natural Causes

Did human hunters extinguish the legendary Ice Age animals of North America?

by Donald K. Grayson

“A railroad through the Pleistocene” was what Teddy Roosevelt called the train that took him through the African savanna in 1910. Modern Africa, he wrote, provides a glimpse of what other parts of the world were like before the last Ice Age ended, some 10,000 years ago. His comparison was apt: the relative scarcity of large mammals that today distinguishes North America from Africa is of recent origin. At the end of the Pleistocene, some thirty-five mammal genera became extinct in North America, either vanishing altogether (twenty-seven genera) or ceasing to exist on that continent while continuing to exist elsewhere (eight genera). (The genus is a more reliable unit of analysis than the species, which can be difficult to define paleontologically. At the species level, the list of extinct mammals is much longer.)

Mammoth, mastodon, and saber-toothed cat are the most widely known of the extinct species, but many others were just as spectacular. Modern sloths are tree dwellers in Central and South America—fat ones may weigh twenty pounds. In the Shasta ground sloth, the giant beaver was most abundant in the Great Lakes area but lived as far north as Alaska and as far south as Florida. The southeastern states were also home to two genera of capybaras. Now confined to Central and South America, capybaras are the largest living rodents, adults reaching weights of more than one hundred pounds (imagine a long-legged guinea pig the size of a Newfoundland dog, and you will not be far off). One of the extinct North American capybaras was nearly half again this size. Horses were abundant in North America until they disappeared about 11,000 years ago (they were reintroduced by Europeans during early historic times). The tapir lived as far west as California and as far north as Pennsylvania. Two genera of pecaries became extinct, three of camels, three of four-pronged antelope (the horns of modern antelope have two prongs), and three genera of animals closely related to the musk ox. The musk ox itself ranged into the northern United States.

There were large carnivores as well, including the cheetah and the lion, the latter bigger than, but belonging to the same species as, its modern African counterpart. The most powerful North American Ice Age predator was the giant short-faced bear, highly carnivorous and a third larger than today’s Alaskan brown bear, itself the world’s largest living land carnivore. A smaller but closely related extinct bear was primarily herbivorous; the genus lives on in the mountains of South America as the spectacled bear.

All in all, the North American mammal fauna at the end of the Pleistocene constituted a diverse set of often very large land animals. Why all these mammals became extinct and why the extinctions apparently occurred at about the same time are questions that have exercised scientists for nearly two centuries.

There is broad agreement that these extinctions occurred between 12,000 and 10,000 years ago and that they may, in fact, fall more precisely about 11,000 years ago. As archeologist David Meltzer and paleontologist Jim Mead have recently shown, there are no trustworthy radiocarbon dates for the extinct mammals that are more recent than 10,000 years ago. And when detailed attempts have been made to date materials from just before the time of extinction, those dates routinely run down to, but not much more recently than, 11,000 years ago. For instance, dozens of dates show that both the Shasta ground sloth and Harrington’s mountain goat abandoned caves in the Grand Canyon by or soon after 11,000 years ago.

Accepting that all the extinctions took place at about the same time requires a leap of faith, however. Reliable dates that fall between 12,000 and 10,000 years ago exist for only seven of the thirty-five genera, and attempts to document that the others survived this late have proved surprisingly fruitless. While they may all have been extinct by 10,000 or 11,000 years ago, at least some of the animals may have succumbed thousands of years earlier. If so, the nature of the problem to be solved changes considerably.

Scientists have explored two possible causes of North American extinctions at the end of the Pleistocene: climatic change and predation by human hunters. Climate-based explanations arose as soon as the existence of the extinct mammals was first recognized, about 1800. Accounts that depended at least in part on human predation were also suggested, but remained purely speculative until it was acknowledged that people had coexisted with the now-extinct mammals. For the Old World, that turning point came in 1859, when excavations at Brixham cave

This is the seventh in a series of articles exploring archeological sites and other lines of evidence that bear on the peopling of the New World.

North America during the Pleistocene, however, there were four genera of huge, ground-dwelling sloths. The largest of these, Rusconi’s ground sloth, found primarily in the southeast, reached a length of eighteen feet—the size of a giraffe—and probably weighed three tons. The smallest, the Shasta ground sloth, lived mainly in the western part of the continent and weighed about three hundred pounds—the same as a healthy modern black bear.

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in England made scientists receptive to the stratigraphic evidence that amateur archeologist Boucher de Perthes had accumulated in France. The idea that people had played a major role in the extinctions immediately became very popular, although the Ice Age antiquity of human hunting in the New World was not conclusively demonstrated until about sixty years ago.

The human predation explanation for North America really came into its own in 1967, when ecologist Paul Martin of the University of Arizona formulated his hypothesis of “Pleistocene overkill” (see, for example, his article in Natural History, December 1967). Martin observed that the North American extinctions appear to have occurred rather abruptly about 11,000 years ago; that the mammals that became extinct were primarily large herbivores whose adult body weight exceeded one hundred pounds; that most of the extinct vertebrates that were not large herbivores may well have been ecologically dependent on those herbivores; and that, unlike earlier episodes of mass extinction during the previous 65 million years, this one was not accompanied by comparable losses among small mammals, amphibians, reptiles, and invertebrates.

There was, Martin argued, something odd about this wave of extinctions, and to explain it, he focused on a tantalizing correlation. Archeologists had shown that from about 11,500 to 11,000 years ago, many parts of North America were occupied by people who at least occasionally killed large, now-extinct mammals. Many believe that these people (generally called Clovis, after a site near Clovis, New Mexico) were the first to penetrate far into North America. Their distinctive artifacts, notably their fluted spear or dart points, have been found associated with the remains of mammoth, mastodon, horse, tapir, and camel.

Martin speculated that these big-game hunters had entered the New World across the Bering land bridge but had been kept out of the heart of North America by the massive ice sheets that covered Canada during much of the late Pleistocene. Toward the very end of the Ice Age, he argued, these people moved south through an ice-free corridor that opened just east of the Canadian Rockies, emerging south of glacial ice about 11,500 years ago. Here they found themselves in a vast expanse of territory devoid of people but abundant in big-game mammals that were unadapted to human predators. The hunters took rapid advantage of this food source, quickly attained high rates of population growth, and spread southward explosively. In their wake, they left extinct populations and, ultimately, extinct genera of mammals.

Martin’s work not only presented the first precise explanation of the extinctions but also divided the scientific world. You were either for or against overkill, and the perceived need to take a stand on this issue led scientists to favor either human predation or environment as the best explanation, although these were certainly not mutually exclusive.

At first, during the late 1960s and 1970s, the scientists who found overkill unconvincing had nothing equally concrete with which to replace it. Their arguments depended almost entirely on the extinctions having occurred at the same time as a major episode of climatic change, the end of the Ice Age. Perhaps inevitably, they concentrated on finding ways in which to show the overkill model wrong, scrutinizing virtually every statement in the overkill account that appeared testable. In the most crucial instances, they found overkill wanting.

For example, one of the earliest responses to the overkill hypothesis was drawn from the archeological record. If people had hunted the herbivores to extinction, critics argued, then the sites that documented that hunting should exist. But a survey of the late Pleistocene North American archeological record showed that such documentation was limited to only a few genera. Where, opponents of overkill asked, are the associations of humans with capybaras, giant beavers, ground sloths, or the extinct antelope?

This seemed to be such a strong criticism that Martin responded to it soon after it appeared. He had in the meantime concluded that the overkill in North America had been an extremely rapid affair, which he likened to a “blitzkrieg.” There were so few associations, he countered, because overkill happened so quickly, diminishing the chances that the archeological results would be preserved. The wonder was not that there were so few kill sites, but that there were any at all.

I might point out that we lack kill sites for precisely those animals for which we have a generally poor late Ice Age fossil record to begin with. Thus, the lack of kill sites may be telling us as much about the paleontological record as about human predation on the animals involved. But my
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point here is not to argue about kill sites but to note the argumentative interplay in which opponents of overkill used the lack of kill sites to disprove overkill, in response to which supporters of overkill simply removed North American kill sites as a test. "Scarcity of evidence," Martin has said, "is a requirement of the blitzkrieg model."

Tellingly, in other parts of the world the presence of kill sites has been used as strong confirmation of overkill. The New Zealand archeological record, for instance, contains great numbers of sites with the remains of moas, large flightless birds that became extinct after the arrival of people there some 1,000 years ago. Martin has used these kill sites to support a human role in the extinctions. Thus, either scarcity of evidence or abundant evidence can be used to support the overkill position.

The same process has happened time and again during the past two decades: the tests that opponents of overkill thought were so salient were met with adjustments to the overkill hypothesis that removed them as tests. A second example can be drawn from a very different area. In 1977, I pointed out that the heavy losses of mammalian genera at the end of the Pleistocene had been accompanied by heavy losses among birds. Of all genera of mammals that became extinct in North America during the entire Pleistocene (1.6 million to 10,000 years ago), nearly half disappeared at the epoch's end. Similarly, all bird genera that became extinct in North America during the Pleistocene, 45 percent (ten genera) were lost at the end of it. Of these birds, only one seemed likely to have depended on large mammals for its existence. This was Merriam's teratorn, a huge vulture with a twelve-foot wingspan, related to the modern California condor. The other nine genera included a stork, a shelduck, a blackbird, several vultures much smaller than the teratorn, and three genera of eagelike birds. Because I doubted these birds could have been dependent in any important way on the large mammals that vanished, I concluded that overkill could not account for the losses.

At the time, Paul Martin and I agreed that the details of the adaptations of these birds were simply not available to us. But in 1984, Martin, with paleontologist Dave Steadman, took a very different approach. By analogy with the living cownbirds (which eat insects off the backs of cattle or stirred up by them), the extinct blackbird became a "mastodon bird," fully dependent on the large mammals that became extinct. The extinct stork became dependent on the carrion of those mammals, even though modern storks of the same genus survive (outside North America) primarily on such things as frogs and lo-custs. The extinct Grinnell's eagle became a pure scavenger, even though the modern crested eagle of South America, which belongs to the same genus, does not scaven-ge. Similar arguments were advanced for nearly every genus of bird that went extinct at the end of the Ice Age. Possibly they were dependent on those mammals, but not only do we not know this, we have little hope of finding out. What I had considered a test of the overkill hypothesis had been skillfully eliminated.

In saying this, I do not mean to be overly critical of those on the overkill side, for they had no precise climate-based account to compare, favorably or unfavorably, with their own. But the result of the debate may have been to make overkill virtually immune to challenge. One can almost now say that the extinctions might as well have occurred that way, since it is no longer clear that anything could prove otherwise.

As this debate continued, those who felt that climate was the cause of the extinctions were busy attempting to build explanations as detailed and perceptive as that built by Martin. Recently, a more adequate series of climatic accounts has finally emerged. All take note that at the end of the Pleistocene some North American mammals retained their geographic ranges unaltered, the distribution of others changed drastically, while still others became extinct. Those whose ranges changed were primarily small, while those that became extinct were primarily large. The yellow-cheeked vole, for example, today found in Alaska and northwestern Canada, was living in Tennessee at the end of the Pleistocene.

That small animals changed distribution while large ones went extinct is a predictable result of climatic change. It is a fact of life, and of earth history, that smaller mammals exhibit lower rates of extinction than larger ones. There are many reasons why this may be the case, but one is that larger animals have greater food and space requirements than smaller ones, thus making them more vulnerable in the face of altered environments. The bigger an animal is, the fewer of them there are in a given territory; this alone tends to render large mammals more prone to extinction than small ones.

Faunal change at the end of the Pleisto-ocene formed a continuum. Those who suspect that climate was the ultimate cause of the extinctions argue that only climatic change can explain this continuum and that overkill makes sense only if one part
of that continuum—the extinction of the large animals—is examined in isolation.

Recent attempts to build climatic explanations of the extinctions tend to focus on changes in seasonal temperature distributions at the end of the Pleistocene as the cause. Paleontologists Russell Graham and Ernest Lundelius, for instance, observe that many late Pleistocene paleontological sites include species of plants and animals whose ranges do not currently overlap. To give but one example, when the yellow-cheeked vole lived in the southeastern United States at the end of the Pleistocene, it shared its habitat with the eastern pack rat. Today these two species are separated by a gap of 1,200 miles: eastern pack rats ranging no farther northwest than the central Plains states; yellow-cheeked voles ranging no farther southeast than central Alberta.

Graham and Lundelius argue that the former coexistence of such species can be explained only if late Pleistocene winters were not as cold as they subsequently became (thus allowing the southern species to range farther north) and summers were not as warm (thus allowing the northern species to range farther south). They stress that many late Pleistocene plant communities were also rich in species, compared with the more homogeneous plant communities we see around us today. The end of the Pleistocene, they conclude, saw the loss of equable climates in many parts of North America, the establishment of more homogeneous plant communities and of the modern ranges of such small mammals as the yellow-cheeked vole, and the extinction of many large mammals that were unable to adapt to these new environmental conditions.

This account seems to offer many opportunities for testing. For example, Lundelius has now shown that one of the prime observations in North America—that small-mammal range readjustments occurred at the same time as large-mammal extinctions—seems also to hold for Australia, where mammalian extinction toward the end of the Pleistocene was also massive (and which Martin contends was also caused by human predation).

As the validity of these new climatic accounts is probed, scientists will learn much more about the nature of North America at the end of the Pleistocene. Whether or not this increased knowledge will resolve the debate over the cause of the extinctions is an entirely different matter. This is especially true if—as seems entirely possible—it was some combination of human activities and climatic change that caused the extinctions of all these animals.
Grand Mesa, Colorado

by Robert H. Mohlenbrock

The mountain that rises abruptly 6,000 feet above the Colorado and Gunnison river valleys, twenty-five miles east of Grand Junction, Colorado, looks as if its top has been sheared off by some giant machete. Contained within the Grand Mesa National Forest, this is Grand Mesa, perhaps the largest flat-topped mountain in the country. Not that the 250-square-mile summit is completely flat; it just lacks any skyward-pointing peaks. There are crevices and canyons, particularly around the periphery, and a narrow ridge runs along much of the mesa’s length. In addition, more than 300 lakes pock the surface.

The summit of Grand Mesa, which averages 10,500 feet above sea level, supports large, open meadows punctuated by patches of Engelmann spruce. Rocky outcrops harbor fleshy-leaved succulents known as stonecrops and rosecrowns. Because the winter snowpack prevails for many months, meadow wildflowers do not begin to bloom until at least late May. Jacob’s ladder, larkspur, and columbine abound. Marsh marigolds grow in continuous colonies in wet seepage areas.

Below the spruce zone, and extending down to about 8,000 feet, aspens grow, often propagated in dense stands by their extensive root systems. Coralroot orchid and monkshood are two of the showier wildflowers that grow beneath these trees. On the mountain slopes below the aspens is a zone of scrubby vegetation dominated by the low-growing Gambel’s oak. More open areas in this zone support the bushy growth of mountain mahogany and sagebrush. Here and there are isolated patches of lupines, beardtongues, and a sunflower-like plant known as mule’s-ears.

From a distance Grand Mesa can be seen to consist of a series of nearly horizontal rock layers of various thickness. One hundred thirty million years ago, before these layers were formed, a great sea covered the region. As this sea receded westward, it left behind mud and the shells of countless clams. Eventually these deposits became consolidated into a 5,000-foot layer of gray-black shale, which forms the foundation of Grand Mesa.

One hundred million years ago, as
Grand Mesa, Colorado

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Mountains began to form to the west of Grand Mesa, streams deposited vast quantities of sand, silt, and clay on the shale. These materials eventually became a 2,000- to 3,000-foot layer of gray-brown sandstone, interlaced with coal seams that were formed from ancient decomposed vegetable matter. (Numerous coal mines operate near Grand Mesa today.) Streams poured more sandy sediments into the area, forming the next stratum, more than 2,000 feet thick in some places, of red sandstone and mudstone. Subsequently the land's surface sagged near Grand Mesa. Water filled this huge depression, forming the prehistoric Green River Lake. Sand, silt, and mud combined with the skeletons of fishes, clams, snails, and microorganisms on the lake bottom to form another 2,000-foot-thick layer of gray and brown sandstone and gray to brown to black beds of oil shale.

Thirty-five million years ago, with renewed warping of the land surface in the Rocky Mountain region, basins deepened and volcanoes formed. The Grand Mesa and surrounding areas were uplifted a few thousand feet. Then massive amounts of molten rock pushed up as domes into the overlying rocky layers. One of these domes, immediately to the southeast of what is now Grand Mesa, is now the West Elk Mountains. About 10 million years ago, cracks developed near the east end of Grand Mesa. According to geologist Robert G. Young, some lava reached the surface, where it flowed westward down an old stream valley before cooling to form a sheet of basalt. Eventually, as a result of eight or nine different lava flows, the entire surface of Grand Mesa was covered by a cap of lava up to 500 feet thick. Since that time, the sides of the old valley have been entirely removed by erosion, while the broad valley bottom, protected by the lava, has become the mountaintop.

But nature was not finished. During the Wisconsinan glaciation, which began about 100,000 years ago, a massive ice sheet several hundred feet thick covered most of the top of Grand Mesa. Deposits left behind as this ice melted can be found along the northern and western edges of the mesa. After westerly winds piled up sand and red dust over the top of the mesa, building up a soil layer, a second ice sheet sent tongues of ice down precipitous slopes, adding more deposits. During the past 5,000 years, permanent streams have gradually carved deeply into much of the softer layers, but the protective lava cap has eroded very little, enabling the mountain to retain its tabletop character.

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Empire of the Apes

Discoveries of more fossil apes make life’s little joke even funnier

by Stephen Jay Gould

After a fifth phone call delayed the beginning of this essay, I began to long for the blessed solitude of Shelley’s Venice.

And then, the town is silent—one may write
Or read in gondolas by day or night, Having the little brazen lamp alight,
Unseen, uninterrupted.

Yet most of Julian and Maddalo does not extol rest and learning but recounts the tale of a man driven mad by unrequited love. Still, the learned Count Maddalo can discern value in the “maniac’s” suffering, for pain has driven him to poetry:

“Most wretched men
Are cradled into poetry by wrong,
They learn in suffering what they teach in song.”

While I would not equate the wrong of heartache with the wrong of simple error, I can appreciate the salutary side of any honest intellectual fault—for nothing illumines a good argument quite as well as the primary mistake that it corrects.

In all of evolutionary biology, I find no error more starkly instructive, or more frequently repeated, than a line of stunning misreason about apes and humans. I have been confronted by this argument in a dozen guises, from the taunts of fundamentalists to the plaints of the honorably puzzled. Consider this letter from April 1981: “If evolution is true, and we did come from apes, then why are there still apes living. It seems if we evolved from them they should not be here.”

If we evolved from apes, why are apes still around? I label this error instructive because it falls into the class of stark either-or: if you accept a false notion of evolution, the statement is a deep puzzle; once you correct this fallacy, the statement is evident nonsense (in the literal sense of unintelligible, not the pejorative sense of foolish).

The argument is nonsense because its unstated premise is false. If ancestors are groups of creatures that are bodily transformed, each and every one, into descendants, then human existence would preclude the survival of apes. But, plainly, we mean no such thing in designating groups as ancestors—lest no reptiles remain because birds and mammals evolved or no fishes survive because amphibians once crawled out upon the land.

Ladders and bushes, the wrong and right metaphors respectively for the topology of evolution, resolve the persistent nonpuzzle of why representatives of ancestral groups (apes, for example) can survive alongside their descendants (humans, for example). Since evolution is a copiously branching bush, the emergence of humans from apes only means that one branch within the bush of apes split off and eventually produced a twig called Homo sapiens, while other branches of the same bush evolved along their own dichotomizing pathways to yield the other descendants that share most recent common ancestry with us—gibbons, orangutans, chimps, and gorillas, collectively called apes. (These modern apes are, by genealogy, no closer to us than we are to the common ancestor that initiated the ape—monkey split more than 20 million years ago, but human hubris demands separation—so our vernacular saddles all modern twigs but us with the ancestral name ape.)

The proper metaphor of the bush also helps us to understand why the search for a “missing link” between advanced ape and incipient human—that musty but persistent hope and chimera of popular writing—is so meaningless. A continuous chain may lack a crucial connection, but a branching bush bears no single link at a crucial threshold between no and yes. Rather, each branching point successively restricts the range of closest relatives—the ancestors of all apes separate from monkeys, then gibbon lineages from ancestors of other great apes and humans, then forebears of the orangutan from the chimp–gorilla–human complex, finally precursors of chimps from the ancestors of humans. No branch point can have special status as the missing link—and all represent lateral relationships of diversification, not vertical sequences of transformation.

An even more powerful argument on behalf of the bush arises from the reanalysis of classical ladders in our textbooks, particularly the evolution of modern horses from little eocippus and the “ascent of man” from “the apes.” I argued last month that a precious irony—life’s little joke—pervades these warhorses of the ladder: the “best” examples must be based upon highly unsuccessful lineages, bushes so pruned of diversity that they survive as single twigs.

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related survivors, and we can draw no rising ladder for the evolution of antelopes, rodents, or bats—although these are the three great success stories of mammalian evolution. But if only one twig survives, we apply a conceptual steamroller and linearize its labyrinthine path of lateral branching back to the main stem of its depleted bush. Horses, rhinos, and tapirs are not glorious culminations of ascending series within the Perissodactyla (odd-toed hoofed mammals) but three little twigs, barely hanging on, the remanants of a bush that once dominated the diversity of large mammalian herbivores. Similarly, we can specify a ladder of human ascent only because the bush of apes has dwindled to a few surviving twigs, all clearly distinct. If the bush of apes were vigorous and maintained a hundred branchlets evenly spaced at an expanding periphery, we would have many cousins and no chain of unique ancestors. Our vaunted ladder of progress is really the record of declining diversity in an unsuccessful lineage that then happened upon a quirky invention called consciousness.

This argument against human arrogance can be grasped well enough as an abstraction but becomes impressive only with its primary documentation—the record of vigorous diversity among apes in former times of greater success. The theme of previous vigor has also just received a boost from a new discovery—one that I had the great good fortune to witness last year.

The cercopithecoid, or Old World, monkeys are the closest relatives of the ape–human bush. Robert Jastrow, in his recent, popular book, *The Enchanted Loom: Mind in the Universe*, contrasts the evolutionary fate of these two sister groups:

The monkey did not change very much from the time of its appearance, 30 million years ago, to the present day. His story was complete. But the evolution of the ape continued. He grew large and heavy, and descended from the trees.

This statement, so preciously wrong, so perfectly arse-backward, shows just how far astray the metaphor of the ladder can lead. There is no such creature, not even as a useful abstraction, as *the monkey or the ape*. Evolution’s themes are diversity and branching. Most apes (gibbons and orangutans, and chimps and gorillas a good part of the time) are still living in trees. Old World monkeys have not stagnated; they represent the greatest success story among primates, a bush in vigorous radiation and including among its varied products baboons, colobins, rhesus and proboscis monkeys.

In fact, precisely opposite to Jastrow’s claim, apes have been continuously losing and cercopithecoids gaining by the proper criteria of diversity and expansion of the bush. Let us go back to the early Miocene of Africa, some 20 million years ago, soon after the ape–monkey split, and trace the fate of these two sister groups. First of all, we would not find these Miocene ancestors as different from each other as their descendants are today—limbs of a bush usually diverge. Early Miocene apes were quite monkeylike in their modes of life. Compared with monkey forebears, early apes tended to be larger, more tree bound, more narrowly tied to fruit eating, and less likely to cope with a strongly seasonal or open environment.

Second—and the crucial point for this essay—apes were more common in two important senses during the early Miocene: more common than cercopithecoids monkeys at this early stage in their mutual evolution; and absolutely more diverse (just in Africa) than apes are today (all over the world). Taxonomic estimates vary, and this column cannot treat such a highly technical and contentious literature, but early Miocene African apes have been placed in some three to five genera and perhaps twice as many species.

The African middle Miocene already records fewer species, although apes now appear for the first time in the fossil records of Europe and Asia. Old World monkeys meanwhile begin an acceleration that extends to our own time. Apes continue to decline and hang on in restricted habitats—yielding isolated groups of gibbons and orangutans in Asia, and chimps, gorillas, and the descendants of a small African group called australopithecines. If the resident zoologist of Galaxy X had visited the earth 5 million years ago while making his inventory of inhabited planets in the universe, he would surely have corrected his earlier report that apes showed more promise than Old World monkeys and noted that monkeys had overcome an original disadvantage to gain domination among primates. (He will confirm this statement after his visit next year—but also add a footnote that one species from the ape bush has enjoyed an unusual and unexpected flowering, thus demanding closer monitoring.)

We do not know why apes have declined and monkeys prevailed. We have no evidence for “superiority” of monkeys; that is, for direct struggles of Darwinian competition between apes and monkeys in the same habitat, with ape extinction and cercopithecoid prevalence as a result (alas, no chest pounding à la King Kong). Perhaps a greater flexibility in diet and

*Supervisor Kamoya Kimeu gathers fossils at West Turkana site*
environmental tolerance allowed monkeys to gain the edge, without any direct competition, in a world of changing climate and fewer stable habitats of trees and fruit. According to this interpretation, those few apes that could adapt to a more open, ground-living existence, had to develop some decidedly odd features, not in any way "prefigured" by their initial design—the knuckle walking of chimps and gorillas, and the upright gait of australopithecines and you know who.

This striking reversal of Jastrow's homily, and of all standard biases of the ladder, rests most forcefully upon the comparison of initial Miocene success with later restriction of the bush of apes. But how great was this first flowering, and how severe, therefore, the later pruning? Unfortunately, this most crucial of all empirical questions encounters the cardinal problem of our woefully imperfect fossil record. We know the extent of later pruning; it is not likely that any living species of ape remains undiscovered on our well-explored earth. But what was the true diversity of early Miocene apes? Did they live only in Africa? What fraction of the African fauna has been preserved? What have we collected and identified of the material that has been preserved?

If our current collections contain most of what actually lived, then the pruning has been notable but modest. But suppose that we have only 10 percent or even only half of the true diversity, then the story of decline and restriction among apes is far more pronounced. How can we know how much we have?

One rough indication—about the best we can do at this early stage of knowledge about Miocene primates in Africa—comes from the composition of new collections. Suppose that every time we find new early Miocene apes in Africa, they belong to species already in our collection. After several repetitions (particularly if our collections span a good range of geographies and environments), we might conclude that we have probably sampled a substantial amount of the true bush. But suppose that new sites yield new species most of the time—and that we can mark no real decline in the number of novelties. Then we might conclude that we have sampled only a small part of a much more copious bush—and that the story of decline and shortfall in the empire of apes has been more profound than we realized. Quite an effective antidote to the bias of the ladder and its attendant invitation to human arrogance!

In other words, we are seeking, as my colleague David Pilbeam, our leading student of fossil apes, said to me, "an asymptote" in the discovery of new apes. An asymptote is a limiting value approached by one variable of a curve as the other variable increases toward infinity. When further collecting of fossils only yields more specimens of the same species, we have probably reached the asymptote in recoverable kinds of apes. We also reach asymptotes fairly quickly in training cats or cajoling children and should learn to recognize both the subtle point of diminishing returns and the actual asymptote not much further down the line.

An exciting discovery about the history of Miocene apes has recently furnished our best evidence that we have not yet come near the asymptote of the early bush of apes. This discovery provides the strongest possible evidence for an even greater intensity of life’s little joke in our own evolution. The bush was bushier, the later decline in diversity more profound. We do not yet know the true extent of the initial success of apery.

In January 1986, I spent a week with Richard Leaky at his field camp on early Miocene sediments near the western shore of Lake Turkana in Africa’s Great Rift.
Valley. Little vegetation obscures the geology of this arid region, and naked sediments stretch for miles, their eroding fossils littering the surface.

The data on genetic differences between chimps and humans suggest that our twig on the bush of apes last shared a common ancestor with chimps some 5 to 8 million years ago; in other words, the human lineage has been entirely on its own only for this short stretch of geological time. The oldest human fossils are less than 4 million years old, and we do not know which branch on the copious bush of apes budded off the twig that led to our lineage. (In fact, except for the link of Asian *Sivapithecus* to the modern orangutan, we cannot trace any fossil ape to any living species. Palentologists have abandoned the once popular notion that *Ramapithecus* might be a source of human ancestry.) Thus, sediments between 4 and 10 million years in age are potential guardians of the Holy Grail of human evolution—the period when our lineage began its separate end run to later domination, and a time for which no fossil evidence exists at all.

Richard Leakey almost surely has many square miles of good sediment from this crucial time in his field area at West Turkana. But he is not yet searching these beds. He is concentrating his efforts on older rocks of the early Miocene (15 to 20 million years ago) when the bush of apes had its great initial flowering in Africa. He is working before the time of maximal intrigue for several reasons. In part, he may be saving the best for later, perfecting his techniques and “feel” for the region before zeroing in on the potential prize. He also has the fine intuition and horse sense of any good historian—it may be best to begin at the beginning and work forward. But, most importantly, he has a professional’s understanding that problems of maximal public acclaim are not always the issues of greatest scientific importance.

The public may yearn, above all, to know the status of our common ancestor with chimpanzees, but Richard Leakey recognizes that the early Miocene is also a time of mystery, promise, and conceptual importance. Mystery because we know so little about the actual diversity of apes at this time of their greatest success. Promise because he has sediments that can deliver many of the missing goods. Conceptual importance because we have as much to learn from documenting the base of our ancestral bush as in searching for the little branchlet that led directly to us later on. The early Miocene is a good place to explore.

The ground of West Turkana glistens with crystals of quartz and calcite. The local Turkana children, passing time during long hours of tending goats under the relentless sun, collect geodes into piles and smash them to reveal the crystals inside. We are looking for duller fragments of bone.

There are no great secrets to success, no unusual basis for “Leakey’s luck,” beyond hard work and experience. In some areas, fossil-bearing strata are rare and must be traced through geological complexities of folding and faulting to assure that fieldworkers search only in profitable places. But here, the entire sequence is fair game (although some strata, as always, are richer than others), and all exposures of rock must be scrutinized. The key to success becomes patience and a trained workforce.

Leakey maintains a staff of trained Kenyan observers. He selects them from among employees of his museum in Nairobi and then provides a long course in practical mammalian osteology (study of bones)—until they can distinguish the major groups of mammals by scraps of bone. The main ingredient of Leakey’s luck is unleashing these people in the right place.

Kamoya Kimeu supervises this exploration. He has found more important fossils than any one else now alive. One night in camp, he told me his story. As a boy, he tended goats, sheep, and cattle for his father. He attended school for six years and then went to work for a farmer. His employer urged him to return to school and study to become a veterinary paramedic. Kamoya then walked for several days back to Nairobi, where his uncle told him that Louis Leakey, Richard’s father, was recruiting people to “dig bones.” His mother gave him only cautious approval, telling him to quit and come home if the task involved (as he then suspected) digging up graves. But when he saw so many bones from so many kinds of creatures, he knew that nature had strewn these burial grounds. The sediments of West Turkana are, if anything, even more profuse.

When I arrived on January 16, Kamoya’s team had just found a new and remarkably well-preserved ape skull (in a profession that usually works with fragments, mostly teeth, a skull more than half complete, and with a fully preserved dentition, is cause for rejoicing). The next day, we studied and mapped the geological context and then brought the specimen back to camp. I wrote in my field book: “everyone is very excited because they have just found the finest Miocene ape skull known from Africa. It is quite new—with a long face, inflated nasal region, incisors worn flat with a diastema [gap] a finger wide to the massive canine—almost like a beaver among apes.”

Research is a collectivity, and we all have our special skills. Kamoya’s workers are the world’s greatest spotters; Richard also has a hawk’s eye, the intuition of a geologist who has lived with his land, and the organizational skills of a Washington kingpin; his wife, Meave, has an uncanny spatial sense and can beat any jigsaw champ in putting fossil fragments together; yours truly, I fear, is good for one thing only—seeing snails.

All field naturalists know and respect the phenomenon of “search image”—the best proof that observation is an interaction of mind and nature, not a fully objective and reproducible mapping of outside upon inside, done in the same way by all careful and competent people. In short, you see what you are trained to view—and observation of different sorts of objects often requires a conscious shift of focus, not a total and indiscriminate expansion in the hopes of seeing everything. The world is too crowded with wonders for simultaneous perception of all; we learn our fruitful selectivities.

I couldn’t see bone fragments worth a damn—and Richard had to direct my gaze before I could even distinguish the skull from surrounding lumps of sediment. But could I ever see snails, the subject of my own field research—and no one else had ever found a single snail at that site. So I rest content with my minuscule contribution, made in character, to the collective effort. At the top right of page 143 in the November 13, 1986, issue of *Nature*—the article that describes the new skull—a few snails are included in the faunal list of the site, some added by my search image. (I also found, I believe, the first snails at the important South African hominid site of Makapansgat two years ago—where I also couldn’t see a bone. I think I am destined to be known in the circle of hominid exploration as “he who only sees the twisted one.”)

The traditions of nature writing demand that this personal narrative now continue at some length, with overwritten paens to the wonder of this discovery, set in glowing clichés about the stark and fragile (two good adjectives) beauty of the countryside. But I insist. First of all, it isn’t my style; it also doesn’t match anything that actually happens in the field. People have varied reactions to such good fortune. Some may jump up and down, fall upon their knees to praise God, or wax eloquent about the new line wrested from nature’s complex book. Most people 1
know, certainly including Richard, Kamoya, and myself as outsider, do not have personalities that match these romantic stereotypes. The conversation may flow more happily at dinner; some kind of glow must form within. But you still have to make sure that the trucks have gas, that the water jugs are full—and you do have to get up at dawn the next day because it's too hot to work in the afternoon. My favorite kind of excitement is quiet satisfaction.

Richard and Kamoya's team found a second, smaller ape skull that field season at West Turkana. Both are new genera, not merely variants on familiar themes of the ape's bush. Richard and Meave Leakey published two papers in the November 13, 1986, issue of *Nature* describing these new forms as *Afropithecus* (the one I witnessed) and *Turkanapithecus*. In the most interesting line of the *Afropithecus* paper, they write: "*Afropithecus* displays characters typical of a variety of Miocene hominoids combined in a single taxon." In other words, this new genus represents a unique combination of features known to vary among early apes—as if we might shuffle the known variations into many more plausible combinations as yet undiscovered. The bottom line after all this exegesis is simplicity itself: we are not at, perhaps not even near, the asymptote for true diversity of apes at their flourishing beginning. If one field season in uncharted lands could yield two new genera, how many remain undiscovered yet in the hundreds of square miles still open for exploration? Apes were bushier than we had ever imagined during their early days; human evolution seems even more twiggy, more contingent on the fortunes of history (not enjoined like the successive rungs of a ladder), less ordained, and more fragile. Our vaunted march to progress, the standard iconography of our evolution, is just one more expression of life's little joke.

I have consciously permitted a professional's bias to permeate this essay so far. I have been equating "success" with numbers of branches on the bush—for paleontologists tend to view large-scale evolution as the differential birth and death of species, and we slip too easily into an equation of success with exuberance of branching. But, of course, we must also consider the quality of twigs, not merely their number. *Homo sapiens* is one small twig, holding with just a few others all the heritage of a group once far more diverse in branches. Yet our twig, for better or for worse, has developed the most extraordinary new quality in all the history of multicellular life since the Cambrian explosion. We have invented consciousness with all its sequels from Hamlet to Hiroshima. Life's little joke shows us our fragility, our smallness on the proper metaphor of the bush; but we have turned the joke upon itself with the power of one evolutionary invention.

The prophet Micah caught both sides of this tension with great understanding when he wrote that fragility and size of origin imply little about ultimate effect: "But thou, Bethlehem Ephrathah, though thou be little among the thousands of Judah, yet out of thee shall he come forth unto me that is to be ruler in Israel" (Micah 5:2). If we could merge the two themes, and if rulers could learn humility and respect from our common origins as fragile twigs on the bush of life, then we might break the equation between ability and right to dominate and might even fulfill that most famous of Biblical prophecies, which is, after all, about the proper nurturing of trees and bushes—and they shall beat their swords into plowshares, and their spears into pruning hooks."

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.
One of 17 steps involved in producing the new edition from Audubon's original plates for The Birds of America.
The first opportunity to acquire prints direct from John James Audubon's own plates since 1838.

In the Ornithology Department of the American Museum of Natural History, there is one room which is only open by special arrangement. It is called the Audubon Hall.

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To mark Audubon's bicentennial, the Museum has decided to issue a new edition of six prints struck from these original double-elephant sized plates, last used in the early 19th century.

The first new edition since the 1830s.

The six prints in the new edition are: The Wild Turkey, Male; the Female Turkey and Young; the Snowy Owl; the Mallard Duck; the Canada Goose; and the Great White Heron.

Five years ago, the Museum began looking for a firm which retained the old 19th century skills of copper plate printing and coloring.

After a long search a firm was selected, Alecto Historical Editions of London.

An edition which is closer to Audubon's intentions.

What may surprise many who appreciate Audubon's work is that the artist, although delighted with the superb quality of the original engravings, was terribly disappointed with the coloring of many of the prints.

Indeed in one of Audubon's letters, he writes to his printer Robert Havell;

"These recent proofs are no more like my drawings than a chimney sweep is to your beautiful wife."

The Museum and Alecto therefore went back to Audubon's original watercolors, notes, letters and even bird specimens to produce this edition.

The results have not only surpassed our expectations but have also met with outstanding recognition among curators, art historians and Audubon experts.

The well known British naturalist David Attenborough wrote; "These new impressions of the 150-year-old plates could well be judged to be a finer representation of Audubon's intentions than any produced during the artist's lifetime."

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A very limited edition.

Because of the extremely high value of the original plates and the possibility of stress to them, the Museum is limiting the edition to just 125 sets worldwide.

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Already most of the edition has been claimed, the majority of the sets going to important collections in North America including the Library of Congress, the Boston Public Library, the McIlhenny Collection and the National Library of Canada.

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The prints will be available for private viewing in major cities throughout the country during the next three months.

The plates will be coming back to the Museum where they will remain untouched for at least 50 years.
Fatherhood in Frogdom

In the rain forest of Puerto Rico, males take over in the clutch

by Daniel S. Townsend

"Co-co-qui-qui-qui-qui." A barrage of high-pitched, staccato notes issued from a rolled palm frond on the rain forest floor. Inside the roll, by the light of my headlamp, I could see two male frogs, facing each other about two inches apart. The frog that was calling was the apparent defender of a clutch of large, pearl white eggs behind him; the other frog was an intruder. The intruding male lunged forward and dived under his opponent, driving him back toward the eggs. The two frogs wrestled for a few seconds, then were quiet. During the next ten minutes, the first frog gave more calls and both frogs struggled several times. Then, with a sudden convulsive thrust, the second frog got past the vociferous male and snapped up several of the twenty or more eggs in the clutch. Hardly pausing to swallow, he cannibalized another three eggs. Meanwhile, the calling frog scurried back past the eggs and, after the egg-eating episode, delivered several lunging bites to the cannibal, driving him back from the clutch. As the frogs faced each other again, several more episodes of calling, wrestling, and biting ensued. Twice more the intruder reached and cannibalized part of the clutch. Finally, in wrestling him back yet again, the frog that was calling turned the intruder around and forced him away from the palm frond with a series of bites.

I had just witnessed one of a dozen nest defense contests that I would see during my study of male parental care by the terrestrial frog—Eleutherodactylus coqui—known to Puerto Ricans as el coqui. The aggressive defense of eggs turned out to be one of the most important components of male parental care among these rain forest denizens of Puerto Rico's Sierra de Luquillo.

Parental care is the norm in birds and mammals whose warm-blooded, rapidly growing offspring depend on their parents for survival. In fishes, parental care appears to be primarily a defensive response to aquatic predators of eggs and young. But most anurans—tailless amphibians, such as frogs and toads—have a fundamental logistic problem in caring for their offspring. As their taxonomic designation (amphi, "both," bios, "life") indicates, eggs and larvae typically live in
one world—the aquatic—and adults in another—the terrestrial. Nonetheless, parents care for their young in about 10 percent of anuran amphibian species (about 3,500 species are currently recognized). Most frogs that exercise parental care live in the tropics, where several groups have evolved ways of reproducing that are partly or completely nonaquatic, thereby removing a major obstacle to close association of adults and offspring.

Some anuran groups took a giant step away from standing water when they evolved direct development: instead of laying their eggs in water where, after a period of embryonic development, they hatch into tadpoles, direct developers pass through the tadpole stage within the egg. What hatches is a miniature replica of the adult, ready to start life as a four-footed animal. *Eleutherodactylus* is one genus that has taken this mode of development to an extreme; many tadpole features, gills, for example, and certain mouthparts, are either greatly modified or lost altogether. Other, novel modifications have appeared, such as a tiny two-pronged egg tooth in *E. coqui*, which appears at the tip of the embryo's upper jaw late in development. With this tooth, the miniature frog (about the size of the word "frog" on this page) rips open the egg capsule and hatches.

Although only a fraction of all species exhibit parental care, frogs and toads display a marvelous diversity of parental behaviors, including egg guarding, egg transport, tadpole attendance, tadpole transport, and live-bearing. Dart-poison frogs (of the family Dendrobatidae) of Central America, for example, attend terrestrial eggs, then carry the hatched tadpoles on their backs to streams or tiny pools of water that collect in air plants. (The designation "dart-poison" comes from the practice of Central and South American Indians who extract a poison from the skins of adult frogs in this family to coat the tips of their darts.) Females of some species of these dart-poison frogs regularly visit the air plants that contain their tadpoles and deposit nonfertile eggs as food. Another group, the marsupial frogs, are so called because, as the female lays her eggs, they are pushed up into special sacs, or pouches, on her back by the hind legs of the clasping male. There, special epidermal tissue grows around the eggs to protect and possibly nourish them as they develop.

One of the most bizarre forms of parental care occurs in the Australian frog *Rheobatrachus silus* (see "This View of Life," July 1985). After the eggs are laid, the female swallows them, gastric activity ceases, and several weeks later froglets are born by propulsive vomiting. But by far the most common form of parental care in frogs is that of egg guarding, the type exhibited by *E. coqui*.

In the summer of 1979, I began my study of *E. coqui*. Some of the questions I set out to answer were: Was parental care practiced only by males? How loyal were coqui parents to their eggs? And what reward, if any, did a frog reap from its parental effort?

*Eleutherodactylus coqui* is a small brown frog native only to Puerto Rico. It is the most widespread of the island’s sixteen native species of that genus. High population densities of the coqui are found in the low- to mid-elevation rain forest that cloaks the windward slopes of the Sierra de Luquillo. As with most species in this large Neotropical genus, *E. coqui* is completely terrestrial and nocturnal. By day, the frogs retreat into protected nooks and crannies in the rain forest, such as curled dead leaves, rolled leafstalks of dead palm fronds, cracks and holes in tree trunks, and cavities under rocks and roots. At dusk, they emerge from their daytime retreats: females and preadults climb up into the vegetation and begin foraging for insects, spiders, and other invertebrates;
The coqui is one of only two species of egg-laying frogs that fertilize their eggs internally. In the mating clasp, left, the female—typically 25 percent larger than the male—remains beneath her mate with her hind legs locked over his. The posture is probably correlated with internal fertilization. Below: A male coqui calls from a leaf of a Piper shrub.

Both photographs by Daniel Townsend

males adopt positions at elevated calling sites and begin their nocturnal cacophony, often calling well into the early morning hours.

As with most anurans, advertisement calling is exclusively a male activity that serves both to attract mates and to announce a male’s territorial stake. Coqui males call from perches up to several yards above the ground. The advertisement call consists of two notes: the first is a pure tone that lasts about a tenth of a second; the second note, which starts at a higher frequency and rises in pitch, sounds like the first part of a wolf whistle. The coqui’s name is truly onomatopoetic, and thousands of tiny throats proclaim it nightly in the rain forest.

On warm, wet nights during Puerto Rico’s rainy season, from March through October, the rain forest rings with an almost deafening chorus of coquies. The principal desired outcome of a male’s acoustic efforts is courtship that leads to mating. A typical courtship begins during early to midevening, when an egg-bearing female approaches and touches a calling male, whereupon the male leads the female away from the call site. As he approaches a prospective nest site, the male’s calls become progressively softer. Once inside the nest, the male assumes a position on the female’s back reminiscent of the mating position of pond frogs in temperate waters. But unlike its aquatic-breeding counterpart, a male coqui does not clasp the female with his forelegs nor does the pair mate immediately. Instead, they remain in the nest for the rest of the night; eggs are not laid until after dawn the next morning. In the interim, the female ovulates; that is, the eggs pass out of her ovary and into the oviducts. Then, still in the predawn hours, she initiates a reverse hind leg clasp, in which she places her hind legs on top of the male’s, even though she remains beneath him. This clasp, which has never been reported in any other anuran, brings the urogenital openings of the male and female close together. The clasp is therefore probably associated with the most unexpected event that occurs during the hours before egg laying, namely, internal fertilization.

The only other egg-laying frog known to have internal fertilization (a few live-bearing species must necessarily practice it) is the unique *Ascaphus truei* of the northwestern United States, whose males have a short tail that acts as an intromittent organ. Coqui males, however, seem to lack any specialized anatomy for transferring sperm. In *A. truei*, internal fertilization appears to be an adaptation to breeding in fast-flowing mountain streams. Internal fertilization in *E. coqui* may well represent adaptation to the opposite condition, the lack of water. The deposition of eggs in the dry terrestrial environment may present difficulties in effective fertilization of the egg mass. If, in some coqui ancestor, sperm were introduced into the female prior to egg laying (oviposition), the increase in effective fertilization could have had a large selective advantage. Once internal fertilization evolved, the possibility for retention of the fertilized eggs by the female existed, and live-bearing was possible. It is not so surprising then to find that one of the other *Eleutherodactylus* species of Puerto Rico, *E. jasperi*, is a live-bearer.

Parental care in *E. coqui* begins immediately after oviposition. As the female lays her eggs (the average clutch contains twenty-eight eggs, although clutch size correlates with female body size), she moves out from under the male. When egg laying is finished, the female ends up in front of the male, and he huddles on the new eggs. As this picture suggests, only male coquies guard the eggs. In more than 600 clutches, I never found a female in attendance. Females, in fact, are aggressively forced out of the nest cavity by the male within hours of egg laying. Apparently, once the clutch has been laid, the male regards the female as just another nest intruder: aggressive calls and even biting attacks are used to chase her from the nest at dusk. This is not the most romantic of farewells.

Once banished from the nest, the female returns to her home territory, which can be fifty feet from the nest site. She has nothing more to do with her last batch of eggs and goes back to feeding and soon begins to put yolk into the eggs of her next clutch. Females can produce a new clutch every eight to ten weeks during the wet season and may lay up to six clutches a year. In contrast to females, which may move many yards to mate, the male parent often uses his regular daytime retreat as a nest, and it is usually within six feet of his normal calling site.

This observation raised a serious question: Was an attendant male really caring
for the eggs or simply using a normal retreat that coincidentally contained a clutch (albeit one he had fathered)? Hourly checks of hundreds of nests revealed that attendant males spend a great deal of time with their eggs, about 98 percent of the daylight hours and 75 percent of the night. Daytime presence in a nest is not necessarily remarkable, since coquies typically stay in retreats during the day anyway. But the high nocturnal fidelity of parental males is markedly different from the behavior of nonparental adults. Nighttime surveys of the known retreats of nonparental adults revealed that they are present only 12 percent of the time. Clearly, parental males do change their behavior after obtaining a clutch. Moreover, they maintain a high level of nocturnal attendance throughout the seventeen- to twenty-six-day period when the eggs are developing.

Another indication that attending males make a real commitment to their eggs is that most parental males stop calling for the entire period of parental care, whereas nonparental males call on most nights. I did not hear any males give advertisement calls from inside a nest, and even during the 25 percent of the night that parental males were not in their nests, they seldom called. Most of their time outside their nests was spent feeding or rehydrating (amphibians do not drink water, they rehydrate by sitting in wet places and absorbing water through their permeable skin by osmosis). By ceasing to call, a male is giving up any chance of remating. Thus, once they obtain a clutch, males dramatically alter their behavior to concentrate on parenting.

While spending so much time at their nests, male coquies are not idle: they brood the eggs (that is, they cover the eggs with their body as birds do) and defend them against other coquies that may be intent on cannibalizing them. Most of the time is spent brooding. Brooding does not, of course, serve the incubatory function that it does in birds. Like most amphibians and reptiles, E. coqui cannot generate the internal heat to raise its body temperature above the ambient level. Yet male coquies are in physical contact with their eggs about 85 percent of the time they are in their nests. And parents seem to change their brooding posture according to the weather. During dry periods, males press themselves tightly against the eggs, arranging their legs so as to cover the maximum surface area of the clutch.

Brooding has less to do with heat than with moisture. Ted Taigen, a physiological ecologist at the University of Connecticut, found that throughout most of the period of development, the eggs of E. coqui have a lower water content than the blood of brooding males. When a male sits on his eggs, water moves by osmosis from his blood directly across his abdominal surface into the eggs. If he needs to rehydrate, he leaves, but soon returns to his eggs, ready once again to supply them with moisture. Taigen also found that,
short of death from dehydration, eggs that developed with subnormal water levels produced smaller hatchlings.

Nest defense is the more active investment of the male coquí in his offspring. While he might only have to defend his eggs a few times during his period of parental care, the price of failing to do so is great. An undefended nest can be cleared of eggs by a single coquí intruder in fifteen minutes. Parental males have several means of defending their nests. The aggressive co-co-qui-qui-qui call is a variation of the advertisement call. It begins with a low first note, followed by a rapid series of shorter notes that rise in pitch. Individual aggressive calls may contain up to thirty-seven notes and go on for four and a half seconds. As an intruder enters and moves deeper into a nest, the male's calls became louder and longer. And yet, in the dozen or so contests that I witnessed, intruders were not daunted by the aggressive call alone.

Every nest encounter that I saw escalated into hand-to-hand combat once the intruder moved too far into the nest. Most wrestling consists of parental males clasping and pushing intruders back. Sometimes the parental male just braces his legs against the side of the nest cavity and holds the intruder, preventing him from going farther. The most effective weapon is biting, and males do not shrink from any threat. A coquí will bite almost any object introduced into its nest—a stick, pen, or finger. While parental males often make lunging bites, the ultimate tactic is to bite and hold on. In one contest, a parental male held an intruder's head in its mouth for twenty-two minutes. The intruder was sufficiently dissuaded and left the nest without consuming any eggs. While intruders may sustain skin lacerations from a parental male's attack, they do not retaliate. Their sole objective, apparently, is to reach and eat the eggs.

What reward do males receive for their parental effort? By leaving parental males with their clutches in some nests and removing parental males from others, I found that 77 percent of guarded clutches hatched, compared with 23 percent of orphaned ones. More interesting were the reasons that clutches failed to hatch. The major cause of egg mortality was desiccation. With normal care, eggs virtually never died from desiccation. But when males were removed, about 45 percent of the clutches succumbed to dehydration. The second major cause of clutch failure was cannibalism. About 14 percent of clutches were devastated by cannibalism even when males were guarding them.

When males were removed, however, cannibalism accounted for 32 percent of clutch failures. Egg predation by invertebrates, such as large crickets and maggots from fly eggs laid on coquí eggs, was a negligible cause of mortality.

Male coquíes garner a large benefit in increased hatching success by virtue of their parental care, but how large a price do they pay? One possible cost is in terms of energy and another is reproductive. The cost in energy results from feeding less on their usual diet of insects, a consequence of spending time in a nest site where food is not as plentiful as elsewhere. Using a technique that causes frogs to regurgitate their stomach contents without being injured, I found that the frequency of empty stomachs was about five times higher in brooding males than in males advertising for mates. Analysis of abdominal fat bodies, a major energy storage site in anurans, revealed that those of brooding males were, on average, smaller than those of calling males. Yet not all parental males were suffering significant energy losses. In fact, the fat bodies of one parent were almost three times larger than those of any other male. Furthermore, some calling males had completely depleted fat bodies. Overall, then, parental care does not carry a heavy energy cost, certainly not a debilitating one.

The reproductive cost of parental care originates from the same source as the energy cost; that is, long-term fidelity to the nest. As mentioned above, most parental males do not call. Do these males thereby sacrifice potential matings to protect their eggs? There was no way to test the question directly. Nonetheless, by knowing how many females mated in a particular area of forest and how many males were calling (and hence competing for those females) in the same area, I could estimate the ratio of egg-bearing females to advertising males. The ratio yields the probability that any given calling male could obtain a mate on any particular night.

Based on the estimate of a nightly mating probability, a parental male that does not call definitely pays a mating price. In other words, females are likely to be mat-
In the rain forest, the nocturnal coqui is more often heard than seen, but as unofficial symbol of the Commonwealth, it is a ubiquitous commercial image.

Ray Pfortner, Peter Arnold, Inc.

EL COQUI NIGHT CLUB

Peter Arnold, Peter Arnold, Inc.

ing in the vicinity of the parental male while he is home watching the kids. I calculated that over an egg-development period of twenty days, a parental male might sacrifice, on average, somewhat less than one additional mating.

This finding raised a critical question: Do the benefits outweigh the costs? A mathematical model that combines the costs and benefits of parental care showed that they do. Males that care for their eggs from egg laying to hatching, and spurn advertising for additional mates, produce more offspring than any other combination of care and abandonment. In fact, the benefits of parental care are such that males would probably provide care even if mating costs were much greater.

With all that we now know about how and why male coquis care for their eggs, another question begs asking: Why don’t females take care of their eggs? The question is not trivial. In the rain forests of Jamaica, Central America, and South America there are Eleutherodactylus species in which females do guard the eggs. Why have males of E. coqui (and at least four other Puerto Rican species) taken over the chores while males of other species practice sex with no strings attached? The answers, when we find them, will undoubtedly raise new questions.
Painting the American Frontier

Artists found inexhaustible fuel for the imagination in the West

by Peter H. Hassick

It is unreasonable to expect that any great interest will be excited abroad in the fruits either of the pen or pencil here, except so far as the subjects are novel, or the execution superlatively great. Tales of frontier and Indian life...the adventures of the hunter and the emigrant—correct pictures of what is truly remarkable in our scenery, awaken instant attention in Europe. If our artists or authors, therefore, wish to earn trophies abroad, let them seize upon themes essentially American.

Henry Tuckerman, Book of the Artists, 1867

After 1800, the United States started to evolve into a truly continental nation, with the states controlling a tremendous western domain in common. And beginning with the War of 1812, fought largely to gain control of the Mississippi Valley, Westerners began to have a political voice. The West was also the locus of the Indian and of America’s greatest asset (in the minds of many artists and writers), the wilderness. Moreover, the egalitarian West and its Daniel Boones seemed to embody the nation’s democratic mood. The time was ripe for new visual interpretations of the region—art that reflected the individual, the anecdotal, and the egalitarian.

Combined with these forces was a growing belief in racial uniqueness, a concept that had a double edge for the Indian. On the one hand, it gave credence to the belief that Indians were savage by nature rather than by circumstance. On the other hand, as savagery was overtaken by civilization, the Indian would disappear. He was thus to be valued and memorialized as the natural man, a vanishing counterpoint to the evils of civilization.

In these postures, the Indian began to fill the chapters and canvases of America’s arts and to prevail in the American popular mind.

In 1828 James Fenimore Cooper had complained openly about the lack of materials for a writer on American subjects. Writers were limited by what Cooper termed the “baldness” of American life compared to that of Europe: “There are no annals for the historian; no follies (beyond the most vulgar and commonplace) for the satirist; no manners for the dramatist; no obscure fictions for the writers of romance; no gross and hearty offenses against decorum for the moralist; nor any of the rich artificial auxiliaries of poetry.” Fortunately, writers found solace and inspiration in America’s wilderness landscape and lore. There was much promise in the burgeoning West, and American audiences were eager to read of adventures and exploits on the frontier. There was much with which to identify—the suggestion of paradise beyond known borders, the manifestations of physical growth and maturity for Jacksonian America, and the lure of exotic characters like the Indian and the mountain man. The West was a cornucopia for the imagination.

By 1830 American literature had begun to advance notions of national identification with Western themes. Writers in search of American sources of inspiration had raised frontier figures to the level of national heroes. Popular perceptions of the West and its people afforded exceptionally appealing avenues for literary exploration.

This store of literary sources became even more abundant as writers began to look beyond the Mississippi River over the expanses of the Great Plains. Here were literary themes ready even for the painter’s canvas, as a reviewer of Washington Irving’s Tour of the Prairies (1834) recounted:

The Death Struggle, Charles Deas (1845)
Sheiburne Museum, Shelburne, Vermont

From American Frontier Life: Early Western Painting and Prints, © Cross River Press, Ltd. Published 1987 by Abbeville Press. Reprinted with permission of the publisher.
The Jolly Flatboatmen in Port, George Caleb Bingham (1857)
The St. Louis Art Museum, St. Louis, Missouri
The boundless prairies stretch out illimitably to the fancy, as the eye scans his descriptions. The athletic figures of the riflemen, the gaily arrayed Indians, the heavy buffalo and the graceful deer, pass in strong relief and startling contrast before us. We are stirred by the bustle of the camp at dawn, and soothed by its quiet, or delighted with its picturesque aspect under the shadow of night. . . . Our hearts thrill at the vivid representations of a primitive and excursive existence; we involuntarily yearn, as we read, for the genial activity and the perfect exposure to the influences of nature in all her free magnificence. . . .

Such Edenic subjects were, according to the same enthusiastic reviewer, "susceptible of immediate transfer to the canvas of the painter."

As the pages of American literature filled with essays on frontier life, so, too, did the canvases of artists. Much of what unfolded on the frontier could


be considered sources for epic historical paintings, works that focused on such ideals as pioneering or Manifest Destiny or progress through civilization and found their fullest pictorial expression in Daniel Boone’s conquest of the wilderness or the press of wagon trains over the crest of the Rockies.

But much about the frontier was not epic. There were many recorded factual incidents, not representative of any universal truth or mythology, that were nonetheless worthy of the painter’s effort. The buffalo hunt, the capture of wild horses, the camp cook lost on the prairie, and the Indian Medicine Dance are representative subjects. Everyday, otherwise unrecorded occurrences thus inspired what is known as genre treatment—realistic depictions of ordinary events from everyday life. A rest on the prairie, voyagers in a canoe, Indians playing cards, or a trapper’s wedding provided exemplary themes. It is in the areas of documentary or “eyewitness” accounts
of specific incidents that some of the most appealing works of the period are found.

These works are known collectively as exotic genre because the locale or the artist’s environment was far beyond the reach of the ordinary observer. Exotic was also a favorite word in the nineteenth century, loaded with emotional and psychological suggestion. Like the word sublime, the term exotic connoted picturesqueness. The relatively sophisticated eastern and, to some degree, European audiences had a healthy appetite for “primitivist nostalgia.” The frontier satisfied a vital urge for vicarious exploration of a sublime and exotic world. The exotic genre paintings exemplify a fundamentally narrative tradition, in the sense that the common artistic mission was to tell a story.

Men of letters had settled on Daniel Boone as the quintessential national hero of the westward movement. Boone, in turn, was the popular precursor of the pioneer, the flatboatman, the woodsman, explorer, and mountain man. Whether plying the uncertain waters of western rivers or trapping beaver in the shadow of the Rocky Mountains, these frontiersmen became emblematic of republican ideals and the emerging democratic man.

The artists who explored the pictorial dimensions of the frontier revealed this extraordinary otherworld, saturated with the sounds and sensations, the colors and rhythms of an untrammeled wilderness and unspoiled nature.

Peter H. Hassrick is the director of the Buffalo Bill Historical Center.

The Lost Greenhorn, Alfred Jacob Miller (n.d.)
Buffalo Bill Historical Center, Cody, Wyoming
Ballplay of the Sioux on the St. Peters River in Winter, Seth Eastman (1848)
Amon Carter Museum, Fort Worth, Texas
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As religious hymns fill the air, a column of costumed marchers parades through the village, past the festively decorated houses that line the narrow streets. Flags and pennants, crosses, and images of Christ are carried high as horsemen lead a medieval-looking procession that seems out of place in modern Chile. Beyond the village the column winds through dusty rural roads. Suddenly, the lead horsemen burst into a rhythmic gallop, shout out challenges in all directions, and brandishing thongs or wooden swords, pull ahead of the procession. Just as suddenly they cease and resume their solemn pace until the next outburst. Correr a Cristo, the tradition of “running Christ against the bandits,” is still alive in Chile. In the face of government decrees banning public meetings except for patriotic rallies and religious festivities, the correr, which had both secular and religious origins in the early nineteenth century, continues to express both piety and belligerence.

Chile separated from the Spanish Empire in 1821 and consolidated as a sovereign state more quickly than any other Latin American country. The struggle for independence was a hard one for the young republic, and the animosities engendered within the Chilean colonial society flared up repeatedly in the form of disobedience and, on several occasions, outright insurgencies against the central government. Royalist infiltrators frequently sowed discontent among rural populations and organized bands of outlaws to harass government troops; thus, while the new rulers could enforce respect in the cities and towns, the countryside remained beyond the powers of the republican militia.

Although most guerrilla strongholds had been neutralized by the early 1840s, bandits continued to terrorize the countryside just outside the growing Chilean cities. This sequel to disobedience and armed challenge lasted throughout most of the nineteenth century. Neira the Bandit established his domain in the hills south of Santiago, and from there rampaged unprotected rural roads and plundered farming communities. The picturesque village of Alhué, not far from the capital, is said
On the Sunday after Easter, the road to Colina is crowded with horsemen and marchers celebrating domingo de Cuasimodo. With banners and crosses, they escort the local priest (in the coach at center) along the country roads to bless the old and the infirm.
Ranchers and farmers plan a year or more in advance to "run in Cuasimodo." Families decorate carriages, left, and ride on floats, below, in processions that begin early in the morning and end in a celebratory mass at sundown.

...to have been a bandit haven. Farther south, in the prosperous areas along the banks of the Maule River, the outlaw Pincheira brothers were so firmly installed that government troops did not even dare venture into the territory. The audacity of the bandits in ambushing the militia made them legends, their exploits immortalized in tales and ballads.

The Catholic church, which had bowed to the republican authorities and sought protection by means of patronage agreements, was not spared by the outlaws. Gold chalices, offertory monies, and liturgical implements were coveted booty. Robbers fashioned colorful crossbelts, saddle covers, and plastrons from stolen priests' vestments. Banditry grew to such proportions that, in the middle of the nineteenth century, concerned priests, terrorized peasants, and government officials decided to take drastic measures to foil the assaults on isolated churches and protect rural clergymen during their periodic visits to parishes. A guard of armed Chilean horsemen known as huasos took it upon themselves to escort the priests and their acolytes, and very soon, what started out as a protective measure became a religious tradition and a horsemen's pageant.

The introit of the Mass on the first Sunday after Easter—Low Sunday—begins with the Latin words Quasi modo geniti infantes (In this way we are born as babies) to remind the faithful of Christ's resurrection the previous Sunday. Thus, Low Sunday is known among Spanish-speaking Catholics as domingo de Cuasimodo and was the day chosen by the huasos to demonstrate their allegiance to the church and willingness to protect their priests. Originally, huasos dressed in festive garb, mounted their most vigorous horses, and rode wildly through the country roads ahead of the procession. The lead rider carried an image of Christ or a large crucifix, and his companions challenged the bandits to come out of their dens and submit to Christ's precepts and the laws of the state. Some horsemen hoisted national flags and local banners to let it be understood that for the time being, the rural roads were under the control of devout and patriotic Chileans.

In the course of the years, the festivity lost some of its original gaiety. With rural roads cleared of bandits, huasos began to take this opportunity to display their most elegant outfits. Chile has few religious festivities for which the rural population, and most particularly the huasos, can get all dressed up. The celebrations of Corpus Christi, which were popular in the past (although they lacked the attraction of...
galloping horsemen), have lost their original luster and solemnity and have been reduced to a simple procession around cathedrals or main churches. The festival of The Lady of Carmel, the patron lady of Chile, is an occasion for religious schools, representatives of the armed forces, sports clubs, and pilgrims to demonstrate their reverence for their patron lady and has nothing of the meaning and color of domingo de Cuasimodo.

The llaneros, mounted herdsmen of the Venezuelan llanos; the gauchos, rugged cowboys of the Argentine pampas and southern Brazilian grasslands; and the huasos are the most famous horsemen of South America. Their roots go back to the Spanish conquistadors, who originated in Andalusia and adopted many riding traditions and a love for horses from the Moors. The wild riding habits of the huasos also show the influence of the Araucanian Indians of southern Chile, who, after trading or stealing horses from the Spaniards, became skillful riders themselves. Over the course of more than three centuries of war between Spaniards and Indians, the relationship between man and horse became a matter of survival. The horse in Chile was not only a work animal but also a means of transportation and warfare. The military tradition is evident in the horse’s harness and in the modern huaso’s attire.

The basic outfit resembles that of the Andalusian riders. A short jacket, which ends a few inches above the waist and gives an impression of leanness to the upper body, is covered by a manta, a short cloak of red, black, green, and white. The tight-fitting black trousers, held by a wide, colorfully fringed waistband, are overlaid by a leather sheath, a stylized version of what were once chaps. Boots are high-heeled and spurs are held by a silver filagree spurtrap and a heel band with a large rowel, which among the richer huasos, is cast in silver. This large spur was used in the past not only on the horse but also on an enemy, mounted or on foot. The wide-brimmed cloth hat has a relatively low, flat-topped crown. During the summer months a straw hat of similar shape is preferred.

The saddle is derived from the Spanish war saddle: a sturdy wooden frame covered with brocaded velvet, with a solid pommel at the front for protection, and at the back, a high, almost vertical cantle, which keeps the rider secure. When the horses are used in cattle roundups or rodeos, the saddle has a high horn for holding a rope. A short skirt, usually made of colorful, woven wool, is placed between the saddle and the animal’s back. Hanging from the sides of the saddle are the stirrups, which in this case are not made of flat leather straps but of braided cowhide. The lower end of the stirrup has developed into one of the most elaborate elements of a huaso saddle: a carved wooden cup, which was designed by Jesuit craftsmen, is decorated with baroque motifs not
In the town of Quilicura, the celebrants' costumes and decorations are elaborate and traditional, but the mode of transportation is more modern, with some participants riding bicycles instead of horses.

found in other equestrian traditions. For a huaso, spectacular stirrup cups and silver spurs are status symbols.

Another element of the harness in which huasos try to outshine one another is the two-part bridle, consisting of a headstall and a bit. The headstall is of fine leather strips delicately woven into one band that goes across the horse's brow and another that holds the bit. Silver encrustations on the bit are another manifestation of the horseman's social status.

This elaborate harness and the special huaso outfit are a display of affluence not otherwise seen among rural dwellers. Early in the Cuasimodo tradition, the escorting was done by wealthy landowners and their stewards: they were the only people allowed to keep arms and maintain good mounts and the only ones who could afford such costly outfits. The common campesino (rural laborer) was no more than a bystander or a follower on foot.

In time, however, some alterations were made in the way the escorts dressed, and participation in the procession was extended to the less affluent. The original hat has been replaced by a white kerchief tied at the back of the head. Around the shoulders and covering the colorful manta, the huasos wear a white surplice, similar to that worn by an acolyte, emphasizing the religious purpose of their escorting mission. The horses of the procession leaders are dressed in attractive caparisons, mimicking the capelike coverings on the mounts of tournament knights in the Middle Ages. The accompanying huasos need not be rich, only willing to put their savings into the Cuasimodo equipment, which is worn but once a year. Often the commitment to be a member of the escorting group is made for life at a young age, and the outfit is donated by a rich patron, usually a powerful landowner. Moreover, rural towns that hold famed Cuasimodo processions have instituted formal groups to organize and run these festivities, the members of which are referred to as cuasimodistas. Money for the clothes, comparisons, flowers, and colored ribbons is raised among the members of these fraternities through raffles and dances.

Priests and acolytes and their liturgical implements are transported in old-fashioned coaches decorated with flowers, palm leaves, and streamers. As the procession proceeds through villages and hamlets, the sick and elderly are brought to the doors or windows of the adorned houses to receive Holy Communion and a blessing from the priest. Formerly, the priest's coach was the only vehicle in the column of riders, but now other horsedrawn coaches and carts are part of the procession. These are also beautifully decorated and carry not only men—as in past times—but also women and children who make vows on behalf of the health or well-being of a family member.

Today, only in remote areas of the country, where horses continue to be the most effective means of transportation, is the procession conducted entirely on horseback and are the early traditions pre-
Wealthy landowners who once made up the main body of Cuasimodo riders now exhibit their equestrian skills and expensive riding outfits in the rodeo arena. The Champion of Chile Rodeo in Rancagua, a three-day festival of food, crafts, and sports events, is carried live on radio. Spectators often dress as well as the four huasos below. Right: A rider demonstrates his skill at running, stopping, and turning his mount.

served in their original character. In the rural areas surrounding the larger cities and, more particularly, in the vast basin of Santiago, modernization has put its stamp on the nature of the processions. Vegetable growers and proprietors of small parcels of land have replaced landowner horsemen. Since bicycles and motorcycles have become the preferred and most expeditious means of transportation, some processions have been virtually transformed into bicycle parades. A good number of individuals also express their religiosity by jogging alongside the riders and cyclists. Cuasimodo is slowly developing into a votive festivity—one of the many that exist in central Chile—a way to find comfort amidst the hardships of daily life and the generalized feelings of uneasiness that pervade social interaction in the country.

In fact, religious festivities have been on the upsurge in the country during recent years and are attracting high levels of mass participation, probably because they have become the Chileans' most practical opportunity for outdoor communal celebrations. Beyond being religious gatherings and expressions of loyalty to the church, they are opportunities to meet in public and demonstrate social cohesion. There has been an unexpected revival of religious processions honoring certain patron saints: in the semiarid Norte Chico region of Chile, before the onset of the winter rains, Saint Isidore, the patron of the peasants, is implored to send a good rainy season and a bountiful summer harvest; not far from Valparaiso, the votive processions for the Lady of Lo Vazquez are back in fashion; and more people are participating in popular masses during the festivities of Saint Sebastian, in Yumbel.

Another reason for the revival of religious celebrations involving mass participation is that during the past fourteen years of military rule—in itself an anomaly for a people with deeply entrenched democratic ideals and unaccustomed to obeying imposed rules—the hierarchy of the church, with just a few exceptions, and most priests have sided with those oppressed by the present regime. The strong defense of the poor adopted by the church has increased its ascendance and respect among the populace. This has meant serious confrontations between the military rulers and the representatives of the church. Thus, the proliferation of national flags and other symbols of patriotism in processions like Cuasimodo is not to be mistaken for a profession of loyalty to those who govern; rather, it is an expression of belief in the principles that created a democratic Chile.
Why the Deer and the Antelope

Whether at home on the range or high up in the mountains, young ungulates give their all to get into shape

by John A. Byers

In the classic Norwegian novel Kristin Lavransdatter, the heroine anxiously awaits the quickening of her first child. Author Sigrid Undset made the moment Kristin first feels the child move the center of a dramatic scene, but her description of the sensation itself is simple: "Deep down within her she felt as though a fish moved its tail." Undset surely intended that sentence to be purely descriptive, but it is also lyric biology, reminding us of the evolutionary continuity between the fetal kicks of humans and the fishy movements of our most distant vertebrate ancestors.

Embryonic movements are not confined to humans; they are common, if not universal, in vertebrates and also occur in invertebrates. In the species in which embryonic movements have been studied, they are described, in scientific jargon, as neurally generated, spontaneous, and patterned. In other words, embryos "decide" to move in predictable, nonrandom ways. In some respects, these apparently purposeless movements resemble the bucking of a colt. Could it be said that embryos are playing?

Like play, embryonic movements are outwardly wasteful, expending energy that presumably could be put to better use in growth or husbanded to augment later reproduction. Assuming, however, that natural selection acts to curtail needless energy expenditure, we must conclude that both play and embryonic motility are beneficial. But how? What can a fetus accomplish by wiggling around in the womb? The answer may be that it is getting into shape. The neuromuscular system probably needs to work in order to develop properly, a message familiar to all of us in this exercise-crazed time: weight lifting makes muscles larger and stronger, while disuse makes them shrink; aerobic training enables muscles to work longer, while sedentary habits have the reverse effect. Repeated attempts to ride a bicycle generally result in success as the motor commands issued by the brain change with experience. Such plasticity is most pronounced when the nervous system and muscles are being assembled and connected to each other. Thus, I propose that embryonic movements evolved to pro-
Play

With awe-inspiring leaps and turns, young chamois prepare for the ups and downs of life in Europe's mountains. The camera has caught the kid at right suspended above the ground in the midst of an aerial twist. Between bouts of play, kids often stand stock still as if dazed.

Gunter Ziesler
mote optimal development of the neuromuscular system. Because development continues past birth, play is, to my mind, simply an evolutionarily more recent consequence of the way in which these systems develop.

Young animals at play seem bent on a high standard of physical self-improvement. They often tear around as if possessed, obviously spending energy and sometimes taking big risks. Consider a typical play bout in the pronghorn, a plains-dwelling ungulate still abundant in the high deserts of the American West. At the National Bison Range in Montana, where I conduct my study of the pronghorn, fawns, usually twins, are born in late May to early June, and for the first two to three weeks of life, they and their mothers spend much of their time hiding from predators. Fawns may lie motionless for several hours, while their mother remains some distance away, giving no clue that her vulnerable young are nearby. When she returns, the young suckle and then usually play briefly until the mother signals the need to find a new hiding place. Play begins as early as two days of age and increases in intensity and duration, reaching a peak at twenty-one to thirty days, when most mothers have brought their fawns out of hiding to join a group of other mothers and fawns. At this stage, fawns play mostly at dawn and dusk (a pattern typical of most ungulates), normally just after suckling. Because mothers in the same social group tend to nurse their young synchronously, several fawns may be ready to play at the same time.

After suckling, fawns stand for a few moments as if dazed. Then they begin to fidget: holding their heads high, they repeatedly twitch them back and to the side or lower and shake them from side to side, as if to dislodge a fly from their ear. Next
Growing up on the grassy plains of North America requires speed more than agility. For the pronghorn fawn below and the juvenile elk at left, running is the best form of playful exercise. The animals may sprint as fast as they can for a minute or so and then switch to a new gait, in which all four feet simultaneously leave and then touch the ground. Pronghorn fawns at play also sometimes flare their white rump patches, the species’ alarm signal.

Tom and Pat Leeson

comes a flurry of vigorous actions found only in play, in which some locomotor act, such as jumping or leaping, is performed simultaneously or sequentially with a rotation of a body part or the whole body about its resting axis. One sequence, taken from my data on a twenty-five-day-old fawn and written in the sort of shorthand essential to recording fast, complicated movements, went as follows: “Down-up (forelegs slightly spread apart, head and neck rapidly brought down between the forelegs, then as rapidly brought upright), down-up, headshake, heel kick (both hind legs kicked back and to one side, rotating the torso), heel kick, down-up, heel kick, headshake, headshake, heel kick, heel kick, half leap (leap upward using only the forelegs, head and neck stretched upward, hind legs remain on the ground), half leap, heel kick, side jump (jump sideways, all feet simultaneously leave and retouch the ground), headshake, down-up, rear turn (rear onto hind legs, then pirouette and fall forward, now facing in a new direction), down-up, headshake, heel kick, down-up.”

Such a sequence usually takes less than ten seconds to complete, and a casual observer would not see the chain of distinct acts I have described. Rather, the fawn simply looks as though it would like to jump out of its skin and is moving as rapidly and wildly as possible in its attempts to do so. I have observed visitors to the Bison Range burst out laughing when watching fawns perform this way. Typically, a fawn performs several sequences in a few minutes. Between sequences, it may attempt to suckle again, but its head briefly with another fawn, or run a few steps; mostly, however, fawns simply stand, looking expectant, as though they don’t quite understand what’s happening to them.

Eventually, the bouts of jumping, leaping, and twisting are followed by periods of real running. A fawn begins by running within or close to its social group, weaving its way among the other animals and often feigning butts at them in passing. Now and then, it spins around and takes off abruptly in a different direction. Next, the little animal picks up speed and begins to run in loops, away from and back to the group, in a path resembling a comet’s orbit. Fast turns and other rotational movements are discarded as the fawn stretches its neck forward, lays its ears back, and lengthens its stride, now sprinting as fast as it can. Bison Range visitors are likely to gasp when a fawn goes full throttle. At about twenty-five days of age, a pronghorn will run for an average of seventy-six seconds, although it may keep going for nearly five minutes. Toward the end of a running bout, fawns usually switch to a new gait, called stotting—a series of springy, forward leaps in which all four feet simultaneously leave and then land on the ground. The arcs away from the group become shorter, and finally, the fawn stops at the group and stands, panting heavily, its mouth open and its little black tongue hanging out.

Pronghorn play is essentially a rehearsal of high-speed running, a crucial ability in this plains-adapted species, which, unable to hide from them, must
outrun predators. (Actually, pronghorn are much faster than any of their extant predators and do not need their blinding speed. In the Pliocene and Pleistocene, however, pronghorn had to contend with the North American cheetah and a long-legged hyena, Chasmaporthetes, which probably exerted the selection pressure for the running ability we see today.) The physiological and anatomical effects of such intense exercise are many and include influences upon the development of muscle mass, muscle biochemistry, muscle capillary density, bone size and shape, and heart size and pumping ability. Play probably also influences the development of synapses in many areas of the brain.

Running flat out across the grassy plains may be the best kind of exercise for a pronghorn fawn, but what about the many ungulates that spend their lives negotiating rocky cliffs? Siberian ibex, for example, naturally inhabit the high mountains of central Asia. Ibex are goats, members of the genus Capra, which comprises six species, including the domestic goat. The playfulness of goats, and especially their tendency to perform twisting leaps, is legendary: the Latin root from which Capra is derived also gives us caper, or capriole, "a playful leap." Goats are sure-footed, agile climbers: some forage in trees, and in the wild, all escape predators by dashing up into steep, rocky terrain. Wild goats, and especially ibex, spend a good part of each day on and around cliffs. An ibex can walk nonchalantly up a slope that a human normally would attempt only with climbing equipment and can ascend completely vertical surfaces by leaping from one tiny outcrop to another.

Unable to travel to Asia, I watched ibex kids for two summers in one of the world's great zoological parks, the Brookfield Zoo, just outside Chicago. At Brookfield, the ibex herd inhabits a naturalistic rocky "island"—known as Ibex Island—which has cliffs and steep slopes, as well as many flat areas, and a dry, flat-bottomed moat. Both flat and sloped areas are available to kids, and the island is large enough to allow high-speed running.

Like pronghorn and other ungulates, the ibex I observed at Brookfield were most playful at dawn and dusk, which in the summer were about 4:30 to 7:00 A.M. and 7:30 to 9:30 P.M. The zoo was a wonderful place at those hours: calm and peaceful, either before or following the day's onslaught of visitors; silent, except for the dawn chorus of siamangs and other gibbons or the evening duet of peacocks and wolves (only in a zoo would one discover that wolf howling makes peacocks crow). Play usually began socially: kids butted gently head to head, reared on their hind legs before falling forward to butt at a partner, neck wrestled while standing shoulder to shoulder, and mounted one another. Sometimes, a solitary kid might begin play with a series of movements similar to those performed by pronghorn fawns. In both cases, this play was followed by fast running, but unlike pronghorn, ibex kids continued to jump, leap, twist, and turn as they ran. Also the kids showed a striking preference for playing on the slopes; if they were on flat surfaces when they started to play, they soon ran onto slopes and remained there for the rest of the bout.

Some of the acrobatics I was privileged to witness were truly hair-raising, surely some of the most spectacular movements.
animals ever perform. Many a kid would dash uphill toward a sharp ridge, soar into space as it cleared the ridgetop, and then, in midair, while falling toward a steep downhill slope, violently thrust its hind legs back, up, and to one side, rotating its whole torso ninety degrees or more to one side. A still photograph of the kid at this moment would show it lying on its side, suspended six feet above a steep slope. As darkness fell on some evenings, the kids continued to play until I could only hear the sounds of their hoofs on rock or occasionally see a dark form hurtling through the air.

The dangers of such play are real. During the first summer of my study, I saw kids take bad falls three times, and I saw many other minor falls and near misses. Throughout the summer, usually at least one of the fourteen kids on Ibex Island was limping because of a slip or a fall that had occurred in play. In the wild, kids playing on cliffs may even risk death. I think natural selection has maintained this risky form of play in ibex because, on average, the costs are outweighed by the benefits that follow from learning to move skillfully on steep terrain. Natural selection apparently has acted on ibex mothers to “think” so, too: I observed many instances in which females performed leaps, neck twists, and heel kicks, thereby encouraging their own or closely related kids to play. Kids found it hard to resist such antics and usually began to play. Females only acted this way when their own or related kids stood lazily while other kids were playing.

I recently surveyed the scientific literature and found reasonable descriptions of play for fifty-seven species, representing all the ungulate families. Young of all these species run in play, and many also engage in jumps, headshakes, and fast turns—just the sort of high-speed movements used by adults attempting to evade predators. Many ungulate young even give species-specific alarm signals in play: pronghorn fawns flare their white rump patches, and ibex kids give the alarm whistle.

Besides flight from predators, ungulates at play also mimic intraspecific fighting. Here, the form of play is more family specific. Hippopotamus young, for example, spend a lot of time mock biting and grappling mouth to mouth, while ibex kids butt heads and neck wrestle. In ibex, young males participate far more in this kind of play than do young females. Males also play mostly with other males and tend
Ears back, tail wagging, legs kicking, a wildebeest calf frolics alongside two more sober adults, below. Grown ungulates seldom engage in such antics, although mothers have been known to indulge in a few leaps and kicks to encourage their young to play. Elk, right, and other ungulate young also play socially. Here, two calves, their fur still covered with spots, practice the sparring that will stand the males, at least, in good stead during rutting season in the years to come.

Tom Mangelsen

John Dominis, Wheeler Pictures

to prefer partners of equal or slightly larger size. Ibex probably are highly polygynous, so fighting skill, which often determines access to mates, is more important to males than to females. Once again, the details implicate motor training.

Until recently, my work has concentrated on ungulates. Others have recorded playful behavior in many birds and in hundreds of mammal species—lions, wolves, bears, primates, mice, seals, and porcupines. But not all vertebrates play. Reptiles, amphibians, and fish—the ectothermic, or "coldblooded," vertebrates—are a decidedly unplayful lot. The reason is not immediately obvious, for they, too, show embryonic movement—and thus might have reason to play. Furthermore, physiologists have demonstrated that fish and frogs, at least, also respond to exercise by adaptive changes in muscle size and biochemistry. Thus they might be able to benefit from playing.

Why then don't they play? Because it seems their metabolic rates are just too low. Metabolic rate, measured by how fast an organism uses oxygen to burn glucose, sets the ability of an organism to engage in sustained activity and sets the rate at which it can recover from exercise. Recall the pronghorn fawns, panting heavily with their tongues hanging out; they were repaying the oxygen debts they accumulated while sprinting. What would happen if we were able to try to make a salamander imitate a pronghorn play bout? First, because of its low metabolic rate, it would not even come close to running for an equivalent time or distance; it would collapse first. Second, it would repay its oxygen debt very slowly; the pronghorn fawns stop panting after a few minutes, but the salamander would be incapacitated for hours. Third, the salamander would have spent an enormous percentage of its daily energy budget (about 40 percent; the pronghorn fawns spend about a tenth of this).

The potential advantages of play thus apparently existed in vertebrates long before the birds and mammals evolved. The cost of play was too high for the ectotherms, however, and it was only when the birds and mammals appeared on the scene and perfected endothermy (warmbloodedness) that the cost was reduced enough to make playing worthwhile. This makes me wonder if the dinosaurs, which may have been endothermic, might have been playful and if living mammals with low metabolic rates—the insectivores and the marsupials—play much. Unable to investigate the first possibility, I am currently working on the second.
A Guide to the Field Guides

In May, a naturalist’s fancy may turn to thoughts of woodland walks. But selecting the right field guide to take along can be difficult, given the number of handbooks available. To simplify the problem, Natural History has asked three experts to list their recommendations in the areas of birds, mammals, trees, and wildflowers.

Birds

by Pete Dunne


Description: 4¼ by 7½ inches, 16 oz., paperback. Birds are organized by families and nominally arranged in the order established by the American Ornithologists Union (AOU), standard checklists, and most other field guides. The book covers those species that might be expected to occur east of the 100th meridian: from the Atlantic Coast to the Great Plains; from the Arctic to the Gulf of Mexico. A companion book covering western birds is currently being revised.

Distinguishing Features: Concise and well-conceived text—illustrations on opposite page—discusses key field marks, similar species, voice, range, and habitat. This arrangement facilitates quick reference in the field. Large and detailed range maps (color coded to depict geographical and seasonal distribution) are grouped as an appendix. The illustrations are excellent and somewhat stylized to depict how the birds usually appear under field conditions. Tiny arrows draw attention to key field marks.

Comments: Unquestionably the best book for the beginning birder who lives within the book’s geographical scope. Its structure and focus are linked to the fundamentals of field identification—a discipline that every birder must learn and use in the field. The principal concern is distinguishing one species from another—the feather-splitting subtleties that separate subspecies and distinguish regional forms are mercifully minimized. This is also the only field guide in which the author and artist are one. The harmony that exists between text and depiction facilitates comprehension and retention.

One small criticism might be leveled at the book. The range maps are isolated from the text. It is annoying but a fair trade-off, given the excellence and excellence of the maps.


Description: 4½ by 7½ inches, 12 oz., paperback. This is arguably the best all-around field guide for North American birding. As handy and field worthy as Peterson’s, this guide has the added appeal of covering the entire North American continent north of Mexico. The organization is comparable to that of Peterson’s Guide. Water birds occupy the first half of the book; land birds claim the balance. The common and scientific names are in accord with the most recent AOU updating. The recent revision (1983) incorporated range changes and added a number of Eurasian strays, as well as several more useful comparison plates.

Distinguishing Features: The layout and design are a utilitarian masterpiece. Information for all species is presented in one linear sweep across the page. Range maps appear with the text. Descriptions are terse, clean, accurate. Arthur Singer’s illustrations are excellent—very lifelike depictions, stylistically bound by a single artist’s brush. Sonograms, graphic depictions of bird songs, are included for many species.

Comments: This is the guide for birders whose fundamental skills have firm and who now want to expand their horizons. The guide’s most compelling attribute is its clean, utilitarian accuracy. Its authors intended to convey key information quickly and to facilitate quick reference. This revised edition is not as aesthetically balanced as the original edition. To cut time or costs, some illustrations have been jury-rigged, and new species have been crowded onto existing plates. Reproductions in initial printings of this edition tended to be faint or lacking in definition. The problem seems to have been corrected in recent runs.


Description: 5 by 8 inches, 1 lb., 6 oz., paperback. The state-of-the-art field guide. Although larger than the Peterson and Robbins guides, it fits into standard belt pouches, field jacket pockets, and for many, between a belt and the small of the back. The guide covers all of North America’s birds. Species are arranged in the accepted manner—water birds first, land birds follow. Range maps, text, and painted illustrations are presented in a linear sweep across adjoining pages.

Distinguishing Features: Detailed and sophisticated, this guide is the crucible of sixty years of field identification skills. It contains much-needed descriptions of rare transients from Eurasia and the Neotropics. Descriptions and illustrations attend to subtle plumage differences relating to subspecies, age, sex, and for some
Well, the Glenlivet Scotch whisky does cost around $20.00. Which some say is a small price to pay for a Scotch which has been made in the same unique way since 1747. A 12-year-old single malt Scotch with a smoothness and unique character that is unsurpassed to this day. All of which could explain why people are so strangely possessive about The Glenlivet. Which is a pity. You might just have to buy a bottle of your own.

groups, molt and feather wear. The book is
the product of a number of skilled experts
and artists—a field guide according to a
committee. An endeavor such as this
might have produced a hodgepodge, but it
didn't. The text moves with crisp uniform-
ity and terse descriptions. The illustra-
tions are more of a mixed bag: some
groups approach perfection; others have
been criticized not so much for inaccuracy
as for style.
Comments: The book purports to be defini-
tive: all encompassing yet field worthy;
detailed but readable. This may be the last
field guide to birds to accomplish this. The
trend in field identification is toward both
looking close (at definitive details) and
looking from afar (making identifications
on the basis of subjective hints and clues).
Both of these disciplines require specialty
guides, so birding has grown past the point
at which knowledge may be housed in one
book—at least any book that you might
care to lug around the field.

The Audubon Society Master Guide to
Birding, edited by John Farrand, Jr.,
Alfred A. Knopf, Inc., 3 Vols., $13.95
each, 447, 398, and 399 pp., respectively.

Description: 5¾ by 8¾ inches each, total
weight, 4 lbs., 5 oz., paperback. The sum
total of bird identification knowledge and
skills is now measured in volumes. Figur-
ing into this encyclopedic effort are thirty-
eight authors, twelve artists, and a veri-
table portfolio of photographers. Species
are organized in accordance with the
AOU classification system. Detailed and
generally excellent descriptions are com-
bined with one (and usually several) pho-
tographs or illustrations (or both).

Distinguishing Features: The Master
Guide's most compelling attribute is the
sheer volume of information it contains.
This includes good, hard-hitting field
marks and the subjective minutiae of
plumage differences, as well as useful and
informative descriptions of behavior and
habitats. Small reproductions of photos or
illustrations, inset as sidebars, use arrows
to draw attention to field marks.

Comments: This is not a book for begin-
ers—nor is it really a "field handbook."
A field guide presupposes portability and
quick reference to key information—
ever of which is a key attribute of the
Master Guide. But as a reference text, it is
invaluable. It is the source you will turn to
when you return from a day's birding with
an identification as yet unresolved. The
books do not lack for problems. Species
descriptions vary in terms of length, style,
depth, and focus. Illustrations were
clearly substituted when photos were un-
available, and the photos vary widely in
terms of usefulness and quality. Consis-
tency, on the whole, is lacking, and the
book suffers for it. However, the wealth of
information offered by an absolutely stel-
lar case of authors is humming.

The Audubon Society Field Guide to
North American Birds, Eastern Re-
region, by John Bull and John Farrand, Jr.
Western Region, by Miklos D.F. Ud-
vardy. Alfred A. Knopf, Inc., $13.50 each;
784 and 852 pp., respectively.

Description: 4 by 7½ inches, 1 lb., 4 oz.
(Eastern), 1 lb., 4½ oz. (Western), plastic
covered. The two books of this set (which
together cover North American birds
found both east and west of the 100th
meridian) fit neatly in back pockets and
on counter tops in proximity to the window
feeder. Text and species descriptions are
grouped separately. Black-and-white range
maps appear with the text. Photos are used
in place of illustrations. Birds are not
ordered by family (as in other guides
discussed) but are grouped by color or
shape.

Distinguishing Features: The grouping of
birds by color or shape, meant to simplify
search-and-identify efforts for beginning
birders, doesn't work. In fact, it is confus-
ing. Males and females of the same spe-
cies are often separated; dissimilar species
occupy the same page. Birds difficult to
categorize are wedged into unlikely cate-
gories. The separation of text and illustra-
tions rates a 9.5 on the 10-point frustra-
tion index scale. The book might have worked
better if illustrations were used instead of
photos. To simplify bird identification,
variables were eliminated. Most of the
photos show adult male birds in breeding
plumage. Females are shown when they
differ significantly from males; immature
plumages get short shrift. This works until
you discover a bird not portrayed in the
book—which you will.

Comments: Despite the guide's shortcom-
ings, the text is wonderful. The descrip-
tions are well conceived, accurate, and
very, very readable. Best of all, each spe-
cies account contains a lively, interesting,
informative, and often anecdotal para-
graph that touches upon habitat, nomen-
cature, behavior, and identification.

Related Species: Birding is a field that
boasts a plenitude of field guides—for
specific geographical regions, for specific
groups of birds, for finding birds, and for
birds already found. Here are some exam-
pies: Robert S. Ridgely's A Guide to the
Birds of Panama (Princeton University
Press, $38.50) is a fine example of a new
guide dealing with up-and-coming
birding mecca. Peter Harrison's Seabirds,
$29.95, and the recently published Shore-
birds, by Peter Hayman et al., $35.00
(both from Houghton Mifflin Company),
are fine examples of detailed and focused
specialty guides. For finding birds, any of
the birder's guides written by James A.
Lane—a Birder's Guide to the Rio
Grande Valley, Southern California,
North Dakota, Florida, etc. (L and P
Press, PO. Box 21604, Denver, Colorado,
$7.00 each) are exemplary. And, finally,
a simple but stunning two-volume begin-
ers guide, the Audubon Society's Familiar
Birds of North America, Eastern and
Western Regions (Alfred A. Knopf, Inc.,
$4.95 each), a coffee-table book in mini-
ature; the Everyday's guide to birds.

Pete Dunne is the director of natural his-
tory information for the New Jersey Au-
dubon Society.

Mammals
by Roger B. Swain

A Field Guide to the Mammals of
America North of Mexico, by William
H. Burt and Richard P. Grossenbecker.
Peterson Field Guide Series, Houghton
Mifflin Company, $11.95; 289 pp.

Description: 4½ by 7⅛ inches, 11 oz.,
paperback. This well-known pocket guide
covers all 380 species of native mam-
imals—including whales, dolphins, and
porpoises—found north of Mexico,
although the range maps extend as far
south as the Tropic of Cancer.

Distinguishing Features: Color drawings
of animals are grouped on two dozen
plates in the center of the book with the
Peterson field identification system of
arrows and italics for differentiating similar
species. Descriptions, arranged in taxo-
monic order, briefly detail the species' 
habitat, habits, young, and economic sta-
tus (whether the animal is considered ben-
eficial or valuable for fur or meat). This
book also contains black-and-white photo-
graphs of skulls of 101 species and dental
formulas for land mammals. References
to additional reading are grouped by state.

Comments: This portable, lightweight
book is the easiest field guide to flip
through and identify an animal, but the
species' descriptions are less informative
than in the Audubon Society Field Guide.

The Audubon Society Field Guide to
North American Mammals, by John O.
Whitaker, Jr. Alfred A. Knopf, Inc.,
$13.50; 743 pp.

Description: 4½ by 7¼ inches, 11 oz., paperback. Covers tracks, droppings, and other signs of mammals in both North and Central America (including such tropical species as the tapir). Also describes tracks of some birds, reptiles, amphibians, and insects and other invertebrates.

Distinguishing Features: Black-and-white line drawings of footprints, track patterns, scats, marks on twigs and branches fill nearly every page. These are interspersed with detailed advice about recognizing and interpreting even the smallest trace of an animal’s passage.

Comments: Signs of animals are much more common than the animals themselves. Based almost entirely on the author’s own lifetime experience, this anecdotal and authoritative account is the next best thing to having Olaus Murie himself along as guide.


Description: 5 by 8½ inches, 8½ oz., paperback. A guide to the mammals, birds, and reptiles that can be found along roadsides, streets, and highways.

Distingising Features: The first half of this book consists of color photographs in which animals with similar silhouettes are grouped together. The subsequent descriptions, printed on thinner paper stock, are in taxonomic order. Range maps are smaller than in the Peterson volume, but additional range charts (by state and province) for the smaller mammals are included in an appendix. No references.

Comments: This book contains the most comprehensive descriptions—including behavior, ecology, and history—of any pocket-sized field guide to mammals.

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Distinguishing Features: This book is not merely a guide to animals that have lost their lives, but to ones that have lost their third dimension. Silhouettes illustrate the forms that various road-killed animals come to assume.

Comments: Although written with humor, this is a serious introduction to the consequences of improved human transportation on other vertebrates. The bodies, flattened by passing vehicles, are more than a curiosity. As presented here, they become a rich laboratory for investigations of animal ecology and behavior.


Description: 4 by 6 inches, 4 oz., paperback. A diminutive, breast-pocket field guide covering 218 species, including cetaceans.

Distinguishing Features: Color illustrations throughout picture animals in their natural habitats. Short descriptive text aimed at young readers and multicolored range maps accompany each entry. This is the only one of these field guides that discusses mammalian evolution.

Comments: Since its first publication in 1955, this tiny book has done more than any other to introduce young people to mammalogy. Although it can be used as a field guide, most young naturalists treasure it as a dream book, a private catalog of animals they hope to see.

Similar Species: A FIELD GUIDE TO THE WHALES, PORPOISES, AND SEALS OF THE GULF OF MEXICO AND EASTERN CANADA, by Stephen K. Katona, Valerie Rough, and David T. Richardson (Charles Scribner's Sons, $22.95; 255 pp.), is an account of the twenty-two whale and six seal species found in the region, abundantly illustrated with black-and-white photographs and line drawings, with emphasis on interpreting what can be seen when observing from shore or boat. The large format (11 1/4 by 8 5/8 inches) MAMMALS OF THE AMERICAN NORTH, by Adrian Forsyth (Camden House, Ontario, $29.95; 315 pp.), is a lavishly illustrated guide to the 180 species of mammals, including marine species found in Canada (many of whose ranges extend farther south and are so mapped). The welcome emphasis here is on viewing animals with a scientist's perspective, and the author repeatedly digresses to explain why a particular species is important to current decrees in ecology, evolution, or behavior—a new development in field guides, and one that promises to be highly successful.

Trees
by Roger B. Swain


Description: 4 by 7 1/2 inches, 16 oz. (Eastern), 14 oz. (Western), plastic covered. The boundary separating these two volumes runs from southwestern Texas north to the arctic tree line along the eastern edge of the Rocky Mountains. The eastern guide describes 364 species and the western guide 314 species. Included are not only native species but also some naturalized and cultivated introductions. Absent are nearly 100 native tropical species confined to southern Florida and some subtropical species found along the Mexican border.

Distinguishing Features: The first half of each volume consists of color photographs, divided into four general categories—leaves, flowers, fruits and cones, and autumn leaves. Within each category, the photographs are further grouped by similarities in appearance. The second half of the book, printed on thinner stock, contains species descriptions arranged in taxonomic order. Most are accompanied by range maps and silhouettes of mature specimens. No bibliography.

Comments: The best pair of field guides for thumb-through identification of trees.


Description: 4 1/2 by 7 1/4 inches, 13 oz., paperback. Guide to the identification of the 646 species of native trees, shrubs, and vines and those introduced species that have naturalized, from Newfoundland south to North Carolina and Tennessee and west to the Dakotas and Kansas.

Distinguishing Features: Book is divided into five sections by leaf shape and arrangement. Section keys lead to plates of back-and-white and green diagrams illustrating leaf, twig, and bud characteristics that distinguish species. The arrangement of species descriptions is artificial, although botanical relationships can be found in the appendix, along with keys to plants in winter and glossy terms. No range maps. No bibliography.

Comments: This by-the-numbers approach may seem old-fashioned and time-consuming, but it works. The book's range, however, is limited.


Description: 4 1/2 by 7 1/2 inches, 10 oz., paperback. Covers nearly 600 native and introduced tree species growing north of Mexico.

Distinguishing Features: Species descriptions are arranged by botanical family, and each is accompanied by a range map and color illustrations of one or more parts of the tree. Bibliography.

Comments: Covers many of the subtropical and tropical species missing in the Audubon and Peterson field guides. Range maps are the most prominent of any tree guide and are an important tool for identification.


Description: 7 1/2 by 4 3/4 inches, 6 oz., paperback. Covers 191 species of plants, mostly in cultivation.

Distinguishing Features: This guide is divided into five sections—trees, shrubs, climbers/vines, waterside plants, and miscellaneous. Within each section, plants are listed alphabetically by their genus. Each entry gives the common name, plant family, place of origin, description, season of bloom, and a one-quarter to one-third page color photograph of a representative specimen.

Comments: An essential book for the temperate-zone traveler headed for warmer climates. With it, one can quickly identify most of the conspicuous specimens encountered in gardens, parks, or even tropical conservatories.

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Wildflowers by Richard LeBlond


Description: 8 by 5 inches, 1 lb., 5 oz., hardcover. Newcomb's is slightly larger than paperback guides but worth it in terms of accuracy and quality of field experience. It has a limited range (northeastern United States and adjacent Canada), but its coverage is comprehensive (1,375 wildflowers, vines, and shrubs). Species order is determined by an introductory verbal key, with individual descriptions facing hand-drawn illustrations.

Distinguishing Features: Identifications are made by means of a verbal key based on flower structure and leaf arrangement and outline. There are detailed illustrations, mostly black and white.

Comments: This guide offers excellent introductory material to identification characteristics. The key is easy to learn and user-friendly ("wrong turns" are often anticipated and corrected). Identification accuracy is excellent. With experience, the guide can often be used with plants in bud or fruit.


Description: 7½ by 4½ inches, 17 oz., paperback. This guide is one of four that together cover most of the United States (although not the Southeast). Species are grouped by color and by structure within the color groups. Descriptions face hand-drawn illustrations.

Distinguishing Features: Comprehensive coverage is provided, with nearly twice as many species illustrated and described as in the Audubon guide. There are detailed illustrations, mostly in black and white but some in color. Description length has been sacrificed to include more species.

Comments: The sections on flower structure within color groups are wordy and numerous. This, combined with busy illustrations (sometimes ten or more species to the page), can make identification tedious. However, the drawings are excellent and do have the advantage of showing stem and leaf detail often missing in photos. The accuracy of identifications made with this guide is good.


Description: 7½ by 4 inches, 21 oz. (Eastern), 17 oz. (Western), plastic covered. The cover and color plates are of durable material, but the text pages are thin and fragile. Color photo illustrations fill the first half of this guide, species descriptions fill the second half. The illustrations are grouped by color, then by flower structure within the larger color groups.

Distinguishing Features: The color groupings, clarity and size of photos, and the visual aids for flower structure facilitate field identification. There are many related (but not illustrated) species described in the text.

Comments: The beautiful photos alone are worth the price of the books. The color keys provide either a quick identification (if you are lucky) or a long haul for the thumb. The 'books' detailed species de-

Description: 7 1/2 by 4 1/2 inches, 13 oz., paperback. Covers the entire United States. Species are arranged systematically by family relationships. Descriptions face colored, hand-drawn illustrations.

Distinguishing Features: This is a compact and relatively comprehensive guide (1,552 species). The illustrations are somewhat lacking in detail and color accuracy, but they do show leaf and stem structure. Descriptions are brief and the illustrations crowded to allow room for more species.

Comments: The systematic arrangement groups related plants. However, structural and color characteristics usually vary widely within and among plant families, so one must thumb randomly through the book for each identification. But if you’re going on a cross-country trip and can take only one wildflower guide, this is it.

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The Greeks Had a Word for It

by Thomas D. Nicholson

Certainly words have a fascination all their own. Take syzygy for instance. For one thing it has no ordinary vowels, although it has vowel sounds (pronounced siz-eh-jee, with the accent on the first syllable). For another, that word can make news even when the event it describes isn't happening, and a lot of people seem to like the word, whether or not they know what it means.

Syzygy comes from the Greek syzygia (the Greeks had sense enough to put two vowels in it), or "to join with." Except for an obscure usage in Greek and Latin prosody (the metrical structure of poetry), the word is used only in astronomy. It refers to what we usually call a conjunction or an opposition, where two objects in the solar system are in line with the earth.

As this month's "Celestial Events" illustrates, such occurrences are common: the moon is in line with the sun and with each of the planets about twice a month; the planets are in line with the sun about twice a year and with one another less frequently. Most of the events are reported in this column, but we don't usually call them syzygys because that is not sufficiently specific. To say "there is a syzygy today" wouldn't be very helpful. We could say "the moon is in syzygy," but with what—a planet or the sun? And even if we were to say "the moon is in syzygy with the sun," that would not indicate whether the moon is new or full. So we don't use the word very often.

But early this past January, everyone was blaming syzygy for coastal flooding and heavy rains in eastern North America. No one could deny that high tides produced a lot of flooding. But syzygy, "a rare alignment of the Sun, Moon and Earth that increases gravitational pull," as the New York Times described it, had little or nothing to do with the flooding. It had even less effect on increasing gravitational pull, and it isn't at all rare.

Syzygy does affect tides (they "spring" when the moon is new or full, hence new-and full-moon tides are called spring tides) and so did a number of other celestial events occurring at about that time: perigee moon (when it is nearest the earth) on December 30; the earth's perihelion (when it is nearest the sun) on January 4; and the high declination of the sun and moon. Natural History published a good review of how these and other factors affect the tides in its June/July 1959 issue.

Blame for the coastal flooding that plagued eastern North America January 2-3 belongs to the storm surge associated with the intense rain and snow that swept up the eastern seaboard. Easterly winds drove ocean waters toward the coast, raising the high-tide level above the flooding stage. The high tide contributed to the flooding, but the culprit was the storm. It certainly was not the syzygy, which took place three days before the flood.

Our editor sent me the clipping quoted above from Florida (he's a loyal reader of the Times even when he is down south in the winter researching nature's wonders), along with the comment that he was sorry we didn't mention syzygy in the magazine because its impact in Florida was very great for a celestial event. I did report the new moon of December 30 (a real syzygy) and the perigee that came within a few hours of it, predicting that exceptionally high tides would occur on the following day (they usually lag by about half a day along the East Coast). I hope the editor will forgive me for not "calling" that storm. After all, my deadline (which I occasionally even manage to meet) is two months before the magazine is available on the newsstands.

Events in the calendar below are given in local time unless otherwise indicated.

May 1: The first glimpse of the new crescent moon is at sundown tonight. Located near Taurus's eastern border, it is joined after dark by Mars and Aldebaran, aligned below it but visible only to those with a clear view of the western horizon.

May 3: Tonight's moon is higher, brighter, and fuller. The two stars close by are Pollux and Castor in Gemini. Apogee moon (farthest from the earth) is at 9:00 P.M., EST.

May 4-6: Venus and Jupiter are companions in the east at dawn. Both are bright enough to be seen in the morning twilight, but they will be very low, requiring an exceptionally clear and unobstructed eastern horizon for good viewing. Jupiter gets better during the month because as the sun moves eastward through the stars it separates from the planet, and Jupiter rises earlier each night. But Venus, racing east faster than the sun and catching up with it, is slowly leaving the morning sky. The Eta Aquarid meteor shower will reach its maximum at about 8:00 P.M., EST, on the 4th. The meteors can be seen on any of these dates after midnight. They are often bright but not very numerous (about twenty per hour).

May 5: First-quarter moon is at 9:26 P.M., EST, about when it is leaving Cancer to enter Leo. The bright star rising to its left after sunset is the Lion's Regulus.

May 7: The Big Dipper is highest in the sky during the early evening at this time of year. The two "pointer" stars at the end of the Dipper's bowl are guides to the North Star (Polaris) and, in the opposite direction, to the Lion. Tonight they also point almost exactly to the moon. Leo is just above the moon, between it and the Big Dipper. The Lion's head (outlined by a circular group of stars that form a reverse question mark with bright Regulus at the dot) is to the right; the hindquarters and tail (marked by a triangle of stars), to the left. Mercury is in superior conjunction (passing behind the sun) and enters the evening sky today.

May 9-11: The waning moon is in Virgo, skipping past its bright star Spica from the 10th to the 11th. The occultation of Spica at about 6:00 A.M., EST, on the 11th is visible over areas adjacent to the Pacific Ocean.

May 13: The moon becomes full in the middle of Libra, at 7:50 A.M., EST, but moves into Scorpius by nightfall.

May 14: The star near the moon tonight is Antares. We missed the occultation of the star, which took place at about noon, EST, but it was visible from southern and southeastern Asia.

May 15: Perigee moon is in Sagittarius
at about the tip of the teapot’s spout tonight. Saturn is rising with the moon.

May 16: The waning moon has moved left to the teapot’s handle. Both Sagittarius and Saturn rise above it tonight.

May 18–19: Moonrise on the 18th is at about midnight in Capricornus. The moon then moves into Aquarius late on the 19th and reaches last-quarter phase at 11:02 P.M., EST.

May 22: Mercury is moving into a good evening elongation during the rest of May and early June, and it is brighter now than it will be in June. Reaching its most northerly distance away from the ecliptic (the sun’s annual path on the celestial sphere) and being near the summer solstice (the point where the ecliptic is farthest north) combine to keep Mercury up high and late after sunset.

May 23–24: Our last view of the morning crescent moon before its next syzygy is near Venus and Jupiter in the eastern sky at dawn. Jupiter is nearest the moon on the 23rd; Venus is below it. The moon is between the two planets on the 24th.

May 27: The new moon syzygy (as distinguished from the syzygy that occurs with the full moon) is at 10:13 A.M., EST, giving us a shot at seeing the new crescent moon before the end of the month.

May 29: If the evening crescent moon is visible tonight, try looking at it with binoculars. You should enjoy a good view of the craters along the terminator (the line dividing the illuminated and the dark parts of the lunar disk) cast into sharp relief by the rising sun. Put the moon in the top of the binocular field, and see if you can find Mercury near the bottom of the field. Mars is also nearby to the left of Mercury, but much dimmer and redder.

May 31: The moon is a slender crescent in Cancer, below Gemini’s Pollux and Castor, which it passed earlier this month. Apogee moon, also the second one of the month, is at about 1:00 P.M., EST.

Editor’s Note: The Sky Map in the April issue shows the evening constellations and stars for this month and gives the dates and times for use.

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Deconstructing Dinner

The nouvelle cuisine looks at Escoffier through the wrong end of the telescope

by Raymond Sokolov

On a recent visit to New Haven, Connecticut, I spent some time in a small church meditating about deconstruction. Have no fear. The episode was brief and did not recur. I was early for a friend’s wedding and had a few moments of repose during which I reflected with some amusement on the contrast between the exceedingly old-fashioned appearance of Yale and its recent conversion to the modish vanguard of French thought. Yale is the American capital of deconstruction, a method of literary criticism difficult to perform and more difficult to explain (as readers of a recent article on the subject in the New York Times Magazine have reason to know).

I propose to give only a practical and nonliterary demonstration of the method, leaving it to the learned gentlemen and gentlewomen of the Yale English Department to expound the central dogma of deconstruction and its intricacies as a tool for peeling away the artifices of authors and unmasking the meanings for which their tropes and symbols are cleverly misleading signposts. So there I was in the Yale chapel, flanked by wife and colleagues, bathed, you might say, in the sauce of nuptial bliss, and still my mind turned momentarily from the happy scene to a riveting idea that amounts to a deconstruction of the nouvelle cuisine.

As should be clear to anyone who has eaten in any ambitious new restaurant or chili parlor in the past decade, the once-revolutionary school of cooking that emerged in France about 1970 has now become orthodoxy around the world. But the question can still be asked: What is the nouvelle cuisine? You know it when you see it, but it is notoriously difficult to define. It is not diet food, even though its reigning genius, Michel Guérard, wrote a best seller for dieters. It is also not simpler or lighter than classic haute cuisine, not in any fundamental sense at any rate. It does depart from the past, seeking novel combinations, novel ingredients, novel presentations. And in its early days, this movement of young chefs brought with it a whiff of revolution, Oedipal and technical. The rise of Japan in the world also influenced the look of nouvelle cuisine. But none of these elements by itself defined nouvelle cuisine nor were any of them indispensable to it.

Almost all of the original claims made about and for the cuisine now look more like public relations than theory. But everyone who has experienced the thing itself knows that it can be recognized on sight. It is a style. But it is a sly style, one whose true nature has barely ever been discussed by its practitioners. They are not shy, but the language they use is almost an ideal text for deconstruction, because it is so purely metaphorical. I am using language here in a broad sense to include chef’s words—their menu language and their recipes—as well as their dishes. The world of nouvelle cuisine, as I am about to show, is a forest of symbols and allusions, which the knowledgeable diner can “read” and decode much as a literary deconstruction might decode the figurative code of a poem.

Classic cuisine was also a code, literally, which included the language of menus and cookbooks. Dishes were identified with terms such as Montmorency and Paloise, words that in ordinary speech re-
fer to people and places, but which in the
two of the traditional haute cuisine
denoted, respectively, a roast duck sauced
with cherries and a béarnaise sauce made
with mint instead of tarragon. In most
cases, these chef’s terms were a pure code
without even a tangential connection to
their name’s everyday referent. Espagnole sauce was in no way Spanish. The
old culinary language simply gave names
to dishes that honored people and places
and rarely gave the uninitiated any direct
information about the dish they were go-
ing to get. A thorough deconstruction
of this code would undoubtedly reveal sym-
bo]c patterns of high interest (even
though the historic documentation would
necessarily be spotty), but for the moment
we must limit ourselves to noticing that the
nouvelle cuisine chefs were all trained
in a system of cookery that they had
learned to describe in a special code. They
all knew exactly what garnishes and sauce
got with sole à la normande. The fish,
poached in fish and mushroom stock, was
surrounded by poached mussels and shrimp
with a line of four poached oysters and
four fluted mushroom caps alternating
down its center. All of this was coated
with sauce normande, an elaborate con-
cocction of fish stock, mushroom and mus-
sel cooking liquids, egg yolks and cream,
and then additionally garnished with six
truffle slices and six croutons cut in loz-
enges alternating around the perimeter of
the sole. Four gudgeons, the freshwater
fish Gobio gobio, fried at the last minute
and themselves decorated with manchongs
(paper sleeves!) were arranged on the
platter with four medium “trussed” cray-
fish. All the elements were compulsory;
not until 1912, did Escoffier finally concede in a parenthesis that the truffles were optional.

The names of haute cuisine dishes were primarily useful as shorthand devices. They not only dressed up a menu; they performed a real service for people who did not want to take time to rattle off the four canonical garnishes associated with rôtie de veau Maubeuge. Haute cuisine lingo saved everyone the bother we now endure from waiters who do not benefit from a convenient code and have to tell you that tonight’s special is moose haunch with wild rice balls, broiled shiitake mushrooms, and a partridge in a pear mouse. Wouldn’t it be easier if that particular collection of foods were always identified as moose Mamaroneck? It would be simple, but the culinary world we live in is an unsettled place. You can almost count on not getting moose with the same accompanying side dishes on another night. But in the world set down in Escoffier’s Guide Culinaire they did repeat garnish combinations. Over the 150 years that stretched from the time of Carême in the early nineteenth century until the dawn of nouvelle cuisine, French chefs refined a closed system of dishes whose basic unit was a serving platter filled with a main food item, say a roast, tricked out with its prescribed garnishes. Nouvelle cuisine not only subverted the old culinary code, it also abandoned platter service and substituted for it an equally intricate method of service based on individual plates arranged in the kitchen.

These are the truly revolutionary features of nouvelle cuisine. They are an attack on the structure and the meaning of the old style of dining. The attack was masked in many ways. Perhaps it would be closer to the mark to say nouvelle cuisine was marketed as the cuisine of slim modern people, of people who valued fresh food or food presented with streamlined simplicity and provocative ingredients. All those elements were present, but they fronted for the real revolution, which transformed the old code by using it as material for a most elaborate system of culinary parody, punning, and metaphor. The nouvelle cuisine looks at Escoffier through the wrong end of the telescope. It puts ironic quotation marks around Carême and sets the old code in italics so that the old words now all mean something else, are metaphors for new ideas for which no names previously existed.

“Nouvelle cuisine” itself is a kind of metaphor. It does not actually mean a “new cuisine.” When the adjective precedes the noun in French, it takes on a figurative sense. So nouvelle cuisine is new in a figurative—and problematic—sense, like New York or New Orleans (Nouvelle Orlean). Just as these cities of the New World (nouveau monde, not monde nouveau) are reflections of York and Orlean, not re-creations of them, so the nouvelle cuisine refers back to classic French haute cuisine, neither as a copy nor a radical reform. It is, instead, a parody or perhaps a pun based on the old culinary code of Carême and Escoffier.

In the dawn of what we may, with appropriate irony, call the new era, gastronomic pilgrims trekked to dismal Roanne near Lyons to eat chez Troisgros, where they were served the great prix fixe menu of the postwar period: a deceptively dull-looking black-gray thrush pâté with juniper berries, scallops of salmon in sorrel sauce, Charolais beef in an intense but transparently clear brown sauce, and a tray of many, many desserts.

I ate this meal in 1969, long before the term nouvelle cuisine had been coined by the French food journalists Henri Gault and Christian Millau. But the experience already embodied the key elements of the mature movement. The salmon dish, especially (see recipe), was a sign of things to come. The sauce was pulled together quickly, without flour thickening, from a highly reduced fish stock, crème fraîche, and sorrel. The taste was extraordinary, as was that of the salmon, almost Japanese in its near rappiness. And what might be called the design of the dish emphasized lightness with its unnaturally thin pieces of fish.

These were the things that caught my eye in 1969 in that poky little dining room across from the Roanne rail station. But the most important feature of the dish was the name on the menu. If the salmon had been cooked until it flaked, and if the sauce had been thick and conventional, this dish would still have been a symbol of revolt, because it justified its witty name: escaïlnopas de saumon. The Troisgros brothers were serving salmon scallion. They had transferred (metaphorized) a classic food idea onto a surprising and provocative new ingredient. The sharp-eyed diner would notice that the chef had cut the salmon into thin flat slices of scallops and then had pounded them thinner, just as he would have pounded veal scallops. Except that he would have pounded the veal to make it tender as well as attractively thin. Pounding salmon will change its texture in a minor way, but the main gain is conceptual. The thin salmon pieces are mock scallops. They are delicious, but they are also wity. They turn the old world on its head. But it is important to remember that salmon-as-veal is not just a
Salmon Scallops with Sorrel Sauce

(Slightly adapted from The Nouvelle Cuisine of Jean and Pierre Troisgros, translated by Roberta Wolfe Smoler, William Morrow and Co., 1978)

2–2½ pounds heads and bones from any fresh, white-fleshed (non-oily) fish
1 onion, thinly sliced
Bouquet garni (sprigs of thyme and parsley and a bay leaf, tied together)
2 pounds fresh salmon
4 ounces fresh sorrel leaves, about 1 quart tightly packed
¼ cup dry white wine
3 tablespoons dry vermouth
2 shallots, chopped
1 ½ cups crème fraîche
3 tablespoons butter
½ lemon
Kosher salt
Freshly ground pepper, preferably white
1–2 tablespoons oil

1. To make a fish stock: Rinse the fish heads and bones thoroughly. Then place in a heavy saucepan with the onion. Cook 10 minutes over low heat, covered. Stir frequently. Add cold water to cover and the bouquet garni. Bring slowly to the boil, skimming surface until no scum remains. Lower heat and simmer 25 minutes. Strain through a fine sieve lined with cheesecloth and reserve.

2. Choose a piece of salmon from the thickest part of the fish. Bone into two fillets. Discard skin and use tweezers to pull out tiny bones hiding in the center of the flesh.

3. Cut fillets in half lengthwise. Start by laying each fillet flat on a board. Hold steady with the flat of one hand and run a thin, sharp knife, with blade turned parallel to the fillet, through the fish to create two thin scallops (the model here is veal scallopine) from each fillet.

4. Lay the scallops between two sheets of lightly oiled wax paper and pound gently with the side of a cleaver or a wooden mallet. Don’t overdo this.

5. Remove the stems from the sorrel and strip out the central vein from the leaves, working from bottom to top. Wash and tear larger leaves into 2 or 3 pieces.

6. For the sauce, combine fish stock, wine, vermouth, and shallots in a large heavy saucepan and reduce over high heat until bright and syrupy and boiled down almost to a glaze. Then add crème fraîche and boil until slightly thickened. Add sorrel and stir for 25 seconds with a wooden spoon. Then stir in the butter cut in small pieces. Complete with a few drops of lemon juice, salt, and pepper. Remove from heat and distribute in the centers of 4 large heated plates. Proceed immediately to cooking the salmon scallops.

7. Warm a skillet large enough to hold all 4 scallops. Coat the bottom with oil.

8. Salt and pepper the scallops on their less presentable sides and then place them in the skillet, seasoned side up.

9. Cook 25 seconds, then turn over carefully and cook on the second side for 15 seconds. Remove to paper toweling. Pat off any excess oil. Then place the scallops, seasoned side down, in the sauce. Sprinkle lightly with salt. Serve immediately.

Yield: 4 servings

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

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Members' Programs

Matteo and his EthnoAmerican Dance Theater trace the evolution of castanets from their origin as an ancient Egyptian weapon to their role as a musical instrument, on Thursday, May 21, at 7:30 p.m. in the Main Auditorium. The repertoire includes an eighteenth-century costume dance featuring small ivory castanets, a gypsy wedding dance of northern India, and a Haydn minuet performed with finger cymbals. Tickets are $5 for members and $8 for nonmembers.

Celestial Rhythms, Thursday, May 7, at 7:00 and 9:00 p.m., in the Planetarium Sky Theater. Part of the members' concert series at the Hayden Planetarium, this show combines laser visuals and special effects with popular musical selections, including Pachelbel's "Canon in D," the "Top Gun" theme, and Madonna's "True Blue." The music will be performed by Jonn Serrie and Mark Petersen. Tickets are $9 for members and $12 for nonmembers.

Space Age Music, Saturday, May 9, at 11:15 A.M. in the Planetarium Sky The-
ator. In this family program musicians will demonstrate new, high-tech musical equipment and perform a variety of popular music. Tickets are $4 for members and $6 for nonmembers. For further information on members' programs call (212) 769-5600.

Free Programs

Storyteller

Leslie Marmon Silko reads from her book, Storyteller, a collection of tales and poems from the Southwest Pueblo people, on Friday, May 1, at 7:00 p.m. in the Linder Theater. Ms. Silko's stories are traditional and based on the experiences of her own family, but include the larger social realities of hunger, poverty, and injustice.

Earth-Women-Creators-Warriors-Shamans

This theater piece of creation myths and legends of the Southwest Indians will be performed for families by Viva and Hortensia Colorado and Gloria Miguel, with music by Louise Mofsie, on Saturday, May 2, at 2:00 p.m. in the Linder Theater. Seating is on a first-come, first-served basis. For further information call (212) 769-5305.

From Traditional African Dance to Breakdance

Mama Lu Parks's Traditional Jazz Dancers, a company that has appeared at the Village Gate and the Brooklyn Academy of Music's "Dance Black America Festival," will perform Wednesday, May 27, at 7:30 p.m.in the Main Auditorium. Ms. Parks has conducted master classes for Mikhail Baryshnikov and Twyla Tharp. This presentation is part of a lecture/performance series on the history of African and African-American dance. For information call (212) 769-5315.

At the Planetarium

"The Secret of the Cardboard Rocket," a new program for children ages 6 to 9, will be given Saturday, May 16, at noon in the Hayden Planetarium. The adventure begins when two young children build a cardboard rocket in their backyard and blast off one night for a tour of the planets with a magical friend. After landing on the moon, Venus, and Mars, the children fly through Jupiter's lightning storms and Saturn's rings. For further information call (212) 769-5919.

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Dinner companions were not always so easy to come by. When the United States, Russia, Japan, and England signed a treaty in 1911 calling for conservation of the sea otter, barely a thousand survived. The Alaskan Department of Fish and Game now estimates there are some 150,000 otters in that state’s waters. Adult females average forty-five pounds, males from forty-five to ninety pounds. Each consumes about 20 percent of its body weight in echinoderm, crustacean, and mollusk meat a day. A challenging diet, what with beating sea urchins, wrestling crabs, and cracking mussels, but otters seem to take it all lying down. Bon appétit.—B.D.S.

Photograph by
Tom Walker
When he's not trapping live deer mice in his kitchen, Donald K. Grayson (page 8) ponders the disappearance of many North American animals at the end of the last Ice Age, a topic that has interested him ever since, as a first-year graduate student, he read Pleistocene Extinctions: The Search for a Cause, edited by Paul S. Martin and Herbert E. Wright (New Haven: Yale University Press, 1976). Now a professor of anthropology at the University of Washington and a curator of environmental archeology at the university's Thomas Burke Memorial, Washington State Museum, Grayson is concerned with the environmental and archeological history of deserts. His projects include research on North American desert mammals, on the archeology of the Great Basin and other western deserts, and on Paul Tournel, who in 1828 was among the first to find and accept associations between human artifacts and bones of extinct mammals. For additional reading, Grayson says the reference book is Quaternary Extinctions: A Prehistoric Revolution, a volume of thirty-eight papers, edited by Paul S. Martin and Richard G. Klein (Tucson: University of Arizona Press, 1984). Antony J. Sutcliffe's On the Track of Ice Age Mammals, (Cambridge: Harvard University Press, 1985) is an enjoyable introduction to Pleistocene mammals oriented to the British Isles, while Pleistocene Mammals of North America, by Bjorn Kurten and Elaine Anderson (New York: Columbia University Press, 1980), describes North American fauna.
As a graduate student in the late 1970s, studying the behavioral ecology of salamanders, biologist Daniel S. Townsend (page 28) “became aware of and intrigued by the reproductive behavior and sexual strategies of another major group of amphibians—frogs and toads.” Realizing that “the greatest diversity of anuran reproductive behavior occurred in the tropics,” he seized the opportunity to study a Puerto Rican frog that exhibited male parental care. His affair with the reproductive ecology, behavior, and life history of tropical anurans goes on. Currently, as a National Science Foundation Postdoctoral Fellow at the University of Florida, Townsend is studying the behavior and ecology of eight frog species that live on the steep, forested slopes of Jamaica’s Blue Mountains, where some species practice female rather than male parental care. An excellent view of the diversity of anuran reproduction is presented in “The Many Ways To Beget a Frog,” by Martha L. Crump (Natural History, January 1977). Townsend also recommends Biology of Amphibians, by William Duellman (New York: McGraw-Hill, Inc., 1986), as “the most authoritative book on amphibian biology, behavior, and evolution currently available,” and Animal Social Behavior, by J.F. Wittenberger (Boston: Duxbury Press, 1981).
In 1973, on the very first day of his very first class in animal behavior, John A. Byers (page 54) was surprised to learn how little was known about play in animals. His interest in the topic grew until, in the summer of 1976, he began observing Siberian ibex at Chicago’s Brookfield Zoo. Witnessing the ibexes’ amazing twists and turns in midair, Byers was hooked. Now associate professor of zoology at the University of Idaho, Byers has just finished a sabbatical year surveying marsupials in Australia. He reports that “watching marsupial babies is great fun, but they don’t play much.” Back in the States, Byers plans to resume his long-term study of pronghorn at the National Bison Range in Montana, where he is looking at—among other things—how early experience influences subsequent events in an animal’s life, including mating success. Two rich sources of information about play are Robert Fagen’s Animal Play Behavior (New York: Oxford University Press, 1981) and Play in Animals and Humans, edited by Peter K. Smith (Oxford: Basil Blackwell Publisher Ltd., 1984). In December 1971, Natural History published a special supplement on play. Readers can learn more about other aspects of Byers’s research by turning to an earlier Natural History article, “Peaceable Peccaries” (June 1981).

“I would give you a picture of myself but I’m always on the other side of the camera and mostly working alone,” says photojournalist Tom Walker (page 80), who is now at work on his second book about Alaskan wildlife. His first, published this month by the Graphic Arts Center, Portland, Oregon, is composed of photographs taken since he came to Alaska in 1967 to tag moose for the Alaska Department of Fish and Game. Walker is also the author of Living in the Alaskan Bush: A Guide to Log House Building. While compiling his portfolio, he taught photography at the Community College in Fairbanks. The otter photograph in this month’s “Natural Moment” was taken on an early spring morning when the weather in Resurrection Bay was uncommonly clear. Walker used Kodachrome 64 in a Nikon FE with a 300-mm lens.

Cesar N. Caviedes (page 44) is an international scholar. Born in Valparaiso, Chile, he is now a citizen of Canada but resides in Florida, where he is a professor of geography at the University of Florida at Gainesville. Fluent in French, Spanish, German, Italian, Portuguese, and English, he has studied in Germany and Italy and taught in Chile, Venezuela, and Canada. Writing about huasos was a diversion from his studies of El Niño and its effects on the people of the South Pacific. He will continue these studies later this year in Tahiti, Samoa, and the Cook Islands, and at the same time pursue his hobby, which is writing on the westward migrations of the Polynesians. For further reading he recommends Chile: A Country Study, by Andrea T. Merrill (Washington, D.C.: Union of America Press, 1982), and The Horsemen’s International Book, by Jean Froissart and Lily Froissart (London: St. Paul, 1980).
Nuclear electricity gives America the power to make critical economic decisions.

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The growth of nuclear energy

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Cover: Alert for trouble from any direction, two meerkats stand in the morning
sun of Africa's Kalahari Desert. Photograph by Alain Degré. Story on page 34.
The Legacy of Tortuguero

When zoologist Archie Carr came to Tortuguero Bay, Costa Rica, in 1953, it was one of the last places in the Caribbean where sea turtles nested undisturbed. If Carr is not there this year to see the turtles struggle up the sands of Tortuguero to bury their eggs (he is now ill and working at his home in Gainesville, Florida), someone Carr-inspired and Carr-trained surely will be. Fishermen, turtle hunters, and biologists call, wire, and write Carr from seaside villages in the Caribbean, ships at sea, and field stations in the Gulf of Mexico. They report from the nesting beaches of Ascension Island (a place Carr once called "a crumb of land in the open ocean between South America and Africa," difficult for sailors to locate, yet the turtles unfailingly find it after a 1,200-mile journey from the coast of Brazil). They report from the Azores where they find sea turtles that were born on beaches in Mexico. "Just write 'Archie Carr, Florida,'" says one biologist, "and it will get to him."

Grand Cayman Island fishermen had told Carr that the same turtles they captured off the Mosquito Banks of Nicaragua carried the 300 miles back to Grand Cayman to keep in turtle crawls would turn up again on the Mosquito Banks after storms dumped them back into the sea. The fishermen knew they were the same turtles because they recognized the initials they had carved into the animals' plastrons. Carr figured he would find out as much, and more, about sea turtle migrations by tagging turtles and recording their recapture. He tagged thousands and offered five dollars for each one returned. This was three times the going rate that fishermen got for each one sold. "If my name goes down in the canons of zoology it will be as the instigator of the five dollar turtle-tag reward," Carr wrote. "Never," he added, "was so little spent to learn so much."

In 1967, his network of sea turtle informants still in its infancy, Carr wrote in Natural History (August–September; October) that he was ready to take a guess at where turtle hatchlings go after they scuttle down the nesting beaches and into the sea. Based on circumstantial evidence, Carr’s hunch was that for the first two to four years of their lives, hatchlings travel the open seas on raftlike mats of sargassum. A fine enough hypothesis as far as it went (and backed up over the years by reports of rafting hatchlings), but rafts of sargassum are Atlantic phenomena, so the question of what young sea turtles do for shelter and food when they travel in other oceans was still unanswered.

Larry Ogren, a one-time Carr student and now a biologist with the National Marine Fisheries Service, says Carr posited dozens of possible explanations and then with an agile logic, tested them: discarding some; evolving others. "He didn’t have a flotilla of vessels for work on the high seas. He relied on fishermen, watermen, and the Caribbean turtle captains. He would go up to a shack and hunker down with one of the natives, talk to him in the local dialect, and then go off and lecture in Spanish to students at the University of Costa Rica." (Carr’s son, Archie, a director at the New York Zoological Society, recalls that when his father’s collection of stories, The Windward Road, was published in an unauthorized version in the Soviet Union, the Russian preface said Professor Carr was “obviously a man of the people.”)

After twenty years of verifying and cataloging rumors, sightings, and tag returns, Carr had what he felt was prima facie evidence. He writes: "Then one day I looked out of a little airplane and saw the whole surface of the sea banded with narrow weedlines, spaced across the water with unaccountable regularity.... If you tell a physical oceanographer about that, and can persuade him or her to speak..."
While most people tolerate the status quo, some make their own alterations.

Here's to rare character.
English and to tell you why, and how regularly, convergent downwelling occurs in the surface water, and how this assembles flotsam in lanes and bands, you will learn that the process is common. . . .

"In a river you see this in miniature wherever the current washes around a snag or over a submerged boulder and makes a swirl on the downstream side. A gang of gyrrid beetles will probably be there, picking up stuff that collects along the edges of the swirl; and a baited hook cast into the curve of the little rip is likely to be taken by a fish. At the downstream end of a bar where the separated current comes together, or in the roil of water over a sunken boulder, it is the same." It also occurs when the river meets the sea.

Sailors call them driftlines. Fishermen have long known that tuna and swordfish can be found beneath them, seabirds above, all feeding on the small fish that gather at the current edges and the tiny shellfish that encrust the flotsam—everything from plankton to pieces of ships, logs, seaweed, and hatching turtles. Anything that floats will be drawn to the edges of currents and eddies where they form a vital, floating feeding ground.

Carr says now that after hatching turtles leave the breeding beaches, they paddle out into ocean currents where they find safe niches for themselves in these current fronts—plenty of food and a measure of protection as they traverse the oceans on its greater and lesser gyres before coming in to live in coastal waters. (Female turtles don't return to nest until they are from fifteen to fifty years old.)

Photographs taken from the space shuttle show current fronts in every ocean. "I could kick myself in the butt for not realizing sooner that if these currents gather all this other stuff they will gather food and turtles."

They will also gather tar, oil, plastic, and toxins. Carr expresses concern that we are underestimating the hazards of ocean pollution by assuming that it is dispersed evenly throughout the sea. The evidence—turtles and seabirds with plastic pellets and oil in their stomachs, for instance—shows that pollution comes together with the plants and animals at these productive current edges, whose importance goes beyond sea turtles. According to Carr, the current edges are a wholly unexplored ecosystem.

"He never loses sight of the big picture," says David Ehrenfeld, now a professor of biology at Rutgers University, who as a student of Carr's, spent some time in Tortuguerro placing eyeshades on sea turtles to see if they could still find their way to the ocean (in most cases they could).

Medfly Replay

The Mediterranean fruit fly, commonly called the medfly, invaded California in 1980 and again in 1982, causing consternation among commercial fruit growers state-wide. (The insect came from the Mediterranean and is thought to have been transplanted unknowingly by humans, hundreds or perhaps thousands of years ago, to Hawaii, Mexico, and parts of Central America.) As recorded in Natural History (May 1982), the favorite foods of the medfly (Ceratitis capitata, one of about 4,000 species of the family Tephritidae) are soft-skinned fruits such as peaches and apricots. Within some thirty days, ten to twenty flies can create substantial damage in an orchard.

In 1980 and 1982, a campaign was mounted to eradicate the pest. The insecticide malathion, mixed with a protein bait, was sprayed from the air over the Los Angeles and San Jose areas in 1980. The same spray was dispersed from ground rigs during the second infestation in 1982. No medflies have been caught in northern California since 1982 and only four flies have been found since then in southern California, two in the Los Angeles area, one in Santa Barbara, and one in San Diego. Most of the medflies were originally found in private backyards, and only a single commercial orchard in the state was penetrated—an apricot orchard in Welsey, about fifty miles southeast of San Jose.

Robert V. Dowell of the California Department of Food and Agriculture says the program was "completely successful." Although the state is currently considered free of medflies, it is not necessarily safe for all time because people arriving from out of state often bring in fruit containing medfly maggots and pupae, and there are instances of maggot-infested fruit shipped to California from Hawaii, where the medfly is widespread. The nuisance yellowish white maggots turn a fruit's flesh into a viscous brown mass.

Not unexpectedly, environmentalists objected to the spraying program, fearing a possible malathion link to cancer or birth defects. But so far, no instances of birth defects directly related to the spray have been recorded (and it is probably too early to have any verdict on cancer). Nevertheless, to avoid future disputes the state is using other means to protect itself. One is triangular traps, eight inches long and four inches wide, containing a dental wick with a sticky lure that attracts and imprisons the flies. Each trap can hold several hundred flies. Five traps per square mile have been set out in urban areas and about two per farming area for a total of more than 30,000.

Another forward-looking program is one to sterilize male medfly pupae. The pupae are held until they mature, and the sterile males are then shipped to wherever they may be needed. When wild female medflies mate with sterile males, they lay eggs that don't hatch. Funded in 1981 by the state of California, a laboratory in Hawaii is producing sterile males.

Meantime, the medfly has appeared in Florida. Five were found in flytraps in local gardens in the Hialeah area in March of this year. Authorities in the Florida Department of Agriculture say that if five were found, doubtless many more are present. Since the medfly reproduces rapidly, even a small population can pose a threat to Florida's $2.5 billion fruit industry.

This is not the first appearance of medflies in Florida. The insect was found in the Orlando area in 1929-30 and in the environs of Miami in 1956. Seven more infestations have occurred since then, the most recent in 1985.

Like California, Florida is combating the fruit fly with malathion, baited traps, and millions of sterile males. But the problem can probably never be completely eliminated because, as in California, most fruit flies are brought into the state in maggot-infested fruit carried by travelers and in boxes of infested fruit shipped from out of state in un inspected first-class mail. As Harold Denmark, chief entomologist of the Florida Department of Agriculture, says, "Humans are the culprits."
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Points of Order

Excavations in Venezuela and Colombia put the Ice Age hunters of North America in a new perspective

by Alan L. Bryan

In 1969–70, my wife (archeologist Ruth Gruhn) and I drove a Land-Rover from New York to Patagonia and then back to Brazil, to visit all known early archeological sites in Central and South America. We were particularly eager to examine discoveries at the base of the Paraguaná Peninsula in northwestern Venezuela. Today the area is a semidesert thorn forest, probably not very different from what it was like toward the end of the Pleistocene, the Ice Age that drew to a close about 10,000 years ago. José M. Cruxent took us to his excavations at Taima-taima and Muaco, two sites where he had unearthed stone spearheads and a few other stone artifacts associated with mastodon bones. Cruxent was sure that several mastodons had been killed by hunters at these sites, but at Muaco materials of different ages had been mixed together by upwelling water from a large spring head. There was no evidence that water had similarly disturbed the Taima-taima materials, although seepage had kept the older deposits wet.

The spearheads were long, narrow, and flaked on both faces. Cruxent called them El Jobo points after a site about sixty miles southwest, where he had collected many examples from the surface. The nearly cylindrical El Jobo points had evidently been made to fit into socketed shafts, like the wooden and bone spearpoints that some present-day hunters still use in Amazonia, farther south. At Taima-taima, the radiocarbon dates on material from the layer that yielded the mastodon bones and the points indicated that they had been deposited together about 13,000 years ago, more than a millennium before the earliest dated mammoth kill in North America.

For a half century most North American archeologists have maintained that the original American colonists were specialized big-game hunters who advanced across Siberia and Alaska and thrust deep into the heart of North America. On the western High Plains between Wyoming and the Texas panhandle, as well as in environmentally similar southeastern Arizona, archeologists have discovered more than a dozen sites where mammoths and giant bison were killed with distinctive “fluted” spearheads. These biafactorially flaked spearheads, which have carefully thinned bases shaped to fit onto a split stick shaft, are known as Clovis points, from a site near Clovis in eastern New Mexico. The kills they are found with are consistently radiocarbon dated between 11,500 and 11,000 years ago.

By 11,000 years ago the mammoths were gone, but people continued to hunt giant bison for another millennium with more delicately flaked Folsom fluted points. The genus *Bison* did not become extinct, but gradually evolved into the smaller modern species that was hunted by Plains Indians using a sequence of projectile point styles and many innovative techniques, including the stampeding of bison over cliffs. By about 1880, a combination of overhunting and fencing had nearly wiped out the animals.

The evidence from Taima-taima challenged the accepted interpretation of Clovis artifacts. After we returned from our tour of important South American sites, I summarized my findings for the journal *Quaternary Research*, taking the view that different kinds of biafactorially flaked projectile points had been perfected independently by hunting cultures in widely separated parts of the southern continent between 13,000 and 11,000 years ago. I argued that these developments had been stimulated not by Clovis technology but by the responses of early inhabitants to regional environmental opportunities. Not unexpectedly, my interpretations, published in 1973, were criticized by North American archeologists, who maintained that the evidence from sites dated earlier than 11,000 years ago must be flawed.

In 1976, on our way to explore for early cave occupations in Brazil, my wife and I arranged to stop over in Venezuela to discuss the reaction to my article with Cruxent. But Cruxent had decided that action was more important than words. Much to our surprise, he had arranged a digging crew for us at Taima-taima, as well as a separate crew who arrived each morning to pump out the overnight accumulation of seepage. We spent the next six weeks digging all day, and in the evening, we flopped into hammocks after a creole dinner in a nearby village. The dig was exhausting but highly successful because we found most of the skeleton of a juvenile mastodon with the central section of an El Jobo stone point lying in the pubic cavity. Cut marks on the inside of some ribs suggested that the hunters had crawled inside the partly dismembered animal to remove favored internal organs. A humerus with cut marks showed us that steaks were removed from the foreleg, perhaps with a jasper flake found nearby. The skull and another limb bone were missing, they probably had been dragged away. The hunters apparently used large leg bones from an adult mastodon as a chopping block, while they butchered portions of
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the juvenile mastodon; these bones were covered with crisscrossing cut marks.

Near the skeleton there was a concentration of vegetable matter preserved by the constantly wet conditions. This compact mass included small twigs sheared by the mastodon’s cusped teeth. Apparently these were the stomach contents of the slain beast: they later yielded several radiocarbon dates, consistent with the previous ones, that placed the kill at no later than 13,000 years ago.

We were careful to record the stratigraphy at the site in detail, as it showed that the bones and artifacts had not intruded from later occupations. We distinguished four primary strata separated by intervals of eroded but unbroken soil surfaces. Mastodon remains and artifacts were present only in the lowest layer: there was no evidence that humans had used the site again after the mastodons had disappeared from the area. Horses and glyptodonts (giant armadillo-like beasts) lived and died on the next oldest land surface, which probably existed about 12,000 years ago. Organic material from a swamp deposit still higher in the geological section yielded several radiocarbon dates of about 10,000 years ago, but no mammoth remains or artifacts were found in this black clay. The upper layer, consisting of colluvium—material washed down from nearby slopes—was similarly barren. In other words, neither the El Jobo artifacts nor the mastodon bones could have come from a higher level in the site.

Our work at Taima-taima in 1976 not only confirmed Cruxent’s earlier conclusions but also suggested that human predation may have contributed to local extinction of the mastodons. Because of its early date, the field evidence from Taima-taima refutes the specific hypothesis that the Clovis hunters were the earliest Americans. But the mastodon kill could be used to support the broader assumption that all early Americans were specialized hunters of large mammals, such as mastodons, mammoths, and bison. An alternative theory, however, is that the earliest Americans were general foragers who hunted animals of all sizes whenever they had the opportunity. In South America, the search for the earliest sites logically turns to Colombia, through which groups would have had to move to get to Venezuela or anywhere else on the continent.

The first South Americans probably followed a coastal route, but so far the oldest-known sites in Colombia are in the interior. During our Land-Rover tour in 1970, my wife and I had traveled to the high Sabana de Bogotá in central Colombia to visit the El Abra rock-shelters, which had been excavated by Gonzalo Correal of the Universidad Nacional de Colombia and Wesley Hurt of Indiana University. Analysis of pollen has shown that Andean forests spread down onto the Sabana de Bogotá during a warm interval near the end of the Pleistocene, between 13,000 and 11,000 years ago. The climate then became dry and cold again for a millennium, until warmer conditions finally were established.

The El Abra rock-shelters were first occupied during the warm interval, soon after 13,000 years ago, about the same time that the El Jobo hunters were killing mastodons at Taima-taima. There is no evidence, however, that the inhabitants of the rock-shelters ever made bifacially flaked stone projectile points of any kind. Instead there are many small, unifacially retouched tools made from stone cores and flakes. These include scrapers, perforators, and implements resembling speckles. The only bifacially thinned artifact that has been found is a point fragment from an 11,000-year-old occupation of Tequendama Rock-shelter. This anomaly was evidently an item traded from elsewhere. The Abriense industry, named after the El Abra site, continued with gradual changes in the percentages of different types of artifacts until the introduction of pottery, about 5,000 years ago. The advent of pounding and grinding tools about 8,500 years ago signals an increased emphasis on plant foods.

During late Ice Age times, the Abriense occupants of Tequendama Rock-shelter, southwest of El Abra, hunted deer and other small mammals, probably with perishable projectile points of wood (tropical forest people in Amazonia still use wooden and bone points). They were more interested in useful edges for scraping, whitling, and cutting than in carefully shaping stone projectile points for penetration of thick hides. The lack of any associated large mammal remains in these Colombian Pleistocene rock-shelters was nevertheless recognized as a problem by Correal, who has been looking for early sites for nearly twenty years. Correal knew that Pleistocene large-mammal remains had been recovered from several open localities on the Sabana de Bogotá; he reasoned that local people would not have ignored this abundant resource.

To close the apparent gap in the archaeological record, Correal decided to follow up an early report of mastodon remains found in an old lake bed near Tibitó, not...
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far from El Abra. He did not know exactly where the mastodon bones had been found, but he guessed that if prehistoric people had anything to do with the bones, they would have concentrated their activities around a large boulder that offered a high and dry place to work in the middle of what was then a swampy flat. To his elation, a test pit at the base of the 12-by-18-foot boulder yielded broken bones and tusks of mastodons, horses, and especially deer, many of them burned and cut, along with simple Abriense tools and flakes. Additional excavations in 1980 around the periphery of the boulder also yielded the remains of small mammals, including cavies, rabbits, and armadillos. A radiocarbon date of about 11,740 years ago supported the conclusion that the site was inhabited by the same people who occupied the El Abra rock-shelters.

Tibitó was not a kill site, like Taimataíma, or a specialized butchering site: the people who used it were not interested primarily in mastodons or other large mammals but in many different kinds of animals and plants. It seems to have been a campsite to which a group of hunters and gatherers repeatedly brought the products of their efforts. Careful examination of the edges and surfaces of some of the broken mammal bones at Tibitó shows they were used as scrapers and cutting blocks in processing plant and animal remains for food and other purposes.

There is no evidence that these early people of highland Colombia were specialized big-game hunters. Rather, they seem to have been very successful foragers who hunted mainly deer and collected a variety of locally available raw materials, including useful bones, tusks, and teeth of mastodons. These large animals may or may not have been killed by hunters from their group.

Although sites on the high, cold Sabana de Bogotá and the hot, semidesert coast of northwestern Venezuela only 650 miles northeast were occupied at about the same time, the economy and the technology of the late Pleistocene occupants of these two areas were significantly different. The Colombian findings suggest that there were general foragers in the New World before the appearance of specialized big-game hunting or the manufacture of bifacially flaked spearheads. The earliest groups probably used their hunting spears with wood, bone, or unifacially flaked stone points. Large animals may more often have been taken in traps, including nets, and surrounds.

In South America, most projectile point styles were limited in distribution. This is particularly true of El Jobo points, which
so far have been identified only in northwestern Venezuela. My conclusion is that the Clovis complex similarly originated as an indigenous adaptation to regional conditions, when foraging bands began to emphasize the hunting of seasonally abundant migratory mammals. This became possible as they learned where herds would be at certain times of the year. These animals included caribou in the Great Lakes region and mammoth and bison on the Great Plains. Some of these innovative hunters started to flake bifacial projectile points, and the idea of fluting some of these points spread widely because the points proved effective.

Fluted points similar to Clovis have been found throughout the continental United States (including central Alaska), southern Canada east of the Rocky Mountains, and as far south as Costa Rica. Fluted points with constricted waists have been found farther south, but the only radiocarbon-dated context (9,000 years ago) is at El Inga, near Quito, Ecuador. These El Inga points apparently reflect a southern influence: waisted "fishtail" points without flutes were developed by horse and guanaco hunters about 11,000 years ago in southern Patagonia; the manufacture of these fishtail points then spread northward through the pampas and up the Andes to southwestern South America and Central America, where the concept of fluting was applied to them as an effective way to thin the base for hafting onto a split stick shaft.

Most archeologists have assumed that all makers of flute points were specialized big-game hunters. However, Clovis kill sites have been found only on the High Plains and adjacent, environmentally similar areas of North America. As with the later Eskimo adaptation in the high Arctic, innovation of a specialized technology for hunting large mammals was a prerequisite for survival on the prehistoric High Plains. This specialized economy persisted as long as the bison survived.

The unusual situation on the High Plains cannot be extrapolated to other regions having more diverse resources. While an economic specialization of hunting mastodons developed locally on the arid northwest coast of Venezuela, on the Sabana de Bogotá, where there was a greater diversity of edible plants and mammals, including deer as well as mastodons, the original, flexible foraging economy remained the most effective way to make a living. There the Abriense tradition persisted for many millennia after the extinction of the mastodons apparently resulted in the abandonment of the specialized El Jobo adaptation.

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Bushes All the Way Down

We are all products of a recent African twig

by Stephen Jay Gould

An old English rhyme captures, quaintly but succinctly, a central truth of nature's dilemma:

Pale Ebeneezer thought it wrong to fight
Puffing Bill who killed him thought it right.

Or, in American translation, "There ain't room enough here for the both of us."

The tale of Ebeneezer and Bill epitomizes a rule of thumb in ecological and evolutionary theory called the principle of "competitive exclusion." This doctrine holds that if two coexisting species are "too close" in their ecologies and mode of life, they cannot both persist in the same area. We cannot imagine that both will pursue their common modes of life with an absolutely equal efficiency; one must perform at least ever so slightly better, and this species will, in course of time, eventually supplant the other (so long as space and resources are limited, as they always are in our finite world).

Yet, manifestly, species of similar form and relationship do often coexist in stability. In these cases, biologists argue that the domain of ecological difference is large enough to permit joint survival. (The principle can become meaningless if we use the fact of coexistence as a priori evidence for sufficient difference, and evolutionists have often so erred. But if we search for such cases of coexistence in order to test the principle by a subsequent study of ecological disparity, then competitive exclusion may have scientific value.)

In any case, the principle of competitive exclusion became the centerpiece of an explicit hypothesis about human evolution that enjoyed a great vogue in the 1960s and 1970s but has now been disproved—the "single species hypothesis," the last bastion for the metaphor of the ladder in studies of human evolution.

In the classic statement of the single species hypothesis ("Competitive Exclusion Among Lower Pleistocene Hominids: The Single Species Hypothesis," Man, vol. 6, 1971, pp. 601-14), M.H. Wolpoff quoted Ernst Mayr, our greatest living evolutionary theorist, on the interpretation of competitive exclusion:

The logical consequence of competition is that the potential coexistence of two ecologically similar species allows three alternatives: (1) the two species are sufficiently similar in their needs and abilities to fulfill these needs so that one of the two species becomes extinct, either (a) because it is "competitively inferior" or has a smaller capacity to increase or (b) because it has an initial numerical disadvantage; (2) there is a sufficiently large zone of ecological nonoverlap (area of reduced or absent competition) to permit the two species to coexist indefinitely.

The single species hypothesis held that no two human species ever coexisted and that our evolution has progressed as a series of successive stages on a single pathway leading to modern Homo sapiens. Wolpoff and his colleague C.L. Brace applied their single species hypothesis particularly to the record of early human evolution in Africa—arguing that the two classic lineages of australopithecines, the so-called graciles and robusts, must belong to a single species, with pronounced geographic and sexual variation previously misinterpreted as evidence for multiple lineages.

But why did Wolpoff and Brace hold so strongly to this view of competitive exclusion, especially since the principle permits coexistence of two species if their domain of ecological overlap is small enough? The single species hypothesis rested upon the specific argument that the uniqueness of human life styles precluded such small overlap between coexisting species. Wolpoff identified culture as the reason for necessary competition to the point of exclusion. Other animals can become narrow specialists on a particular type of food or within a limited space in a rich environment. Such specializations can minimize competition with relatives committed to different foods and spaces—and permit close evolutionary cousins to dwell together in stability.

But culture defines human uniqueness, and culture is, by definition, expansive. We become learning animals and develop ways to exploit more kinds of foods and places. Our evolution must proceed toward greater generality—that is, toward the domain of overlap, where competitive exclusion must operate if two human species inhabit the same area. Even though australopithecine culture scarcely rivaled our own, Wolpoff deemed it rich enough to build an ecological niche so broad that only one hominid species could inhabit Africa at any time. Wolpoff wrote:

Culture acts to multiply, rather than to restrict, the number of usable environmental resources. Because of this hominid adaptive characteristic implemented by culture it is unlikely that different hominid species could have been maintained. . . . Competition would most likely cause each hominid species to develop the ability to utilize a wider range of resources and thus increase the amount of competition. One surely must succeed at the expense of the other.

As an extension of the single species hypothesis, Wolpoff and Brace sought to interpret other supposed cases of apparent interaction between two differing peoples as evolutionary sequences of direct transformation—in particular, Neanderthal evolving into modern humans, rather than Neanderthal interacting with, and replaced by, a discrete group of invaders (Cro-Magnons of modern type), as dramatized in the popular novels of Jean Auel. (If Brace is right, then Ayla's struggle is fiction in more ways than one.)

In fact, Brace often derided hypotheses of interaction and replacement, labeling all such ideas as "hominid catastrophism"—a reversion to the old preevolutionary habits of special pleading: to avoid an interpretation of direct evolutionary transformation, we suppose that a
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new species migrates in from elsewhere and wipes the "primitives" out.

If the single species hypothesis be valid, then Brace's ridicule is justified—for no other species can exist to form the phalanx of an invasion, and all temporal sequences should be interpreted as cases of evolutionary transformation. But if the single species hypothesis is wrong, and if human evolution follows nature's conventional topology of the bush (rather than our culturally bound hope for a ladder of progress), then "hominid catastrophism" should be an anticipated consequence of evolution, not a term of reproach. If splitting and twigginess are primary themes of human evolution, then different species may exist to meet and interact.

As the single species hypothesis had set its roots in a claim about our long African prehistory (from our split with the chimpanzee lineage some five to eight million years ago to the exodus of Homo erectus from Africa about a million years ago), so too did it fall in Africa. By 1976, the hypothesis had already faded, since most paleontologists had concluded that gracile and robust australopithecines represented separate lineages, not males and females of a single species. In that year Richard Leakey and Alan Walker described two hominids from the same geological formation (about 1.5 million years old) so different in appearance that no one could dispute their separate status ("Australopithecus, Homo erectus, and the Single Species Hypothesis," Nature, vol. 261, pp. 572-74). Fortunately (for clarity in conclusion, but not for the single species hypothesis), these two skulls displayed extremes of gracile and robust tendencies—thus accentuating differences to the point of resolution.

One skull represents the so-called hyperrobust form Australopithecus boisei, a small-brained creature with a protruding face and massive brow ridges. The other, quite modern in appearance, has been placed in Homo erectus, the species supposedly ancestral to modern humans. Thus, much of human prehistory in Africa included at least two coexisting lineages—our own and the surviving robust australopithecines. (Richard Leakey sees even more bushiness in our African story, for he argues that three hominid species coexisted just before this time—H. habilis, presumed ancestor of H. erectus; the robust lineage; and surviving populations of the gracile lineage, A. afarensis. As with the apes of last month's column, our knowledge may not be near the asymptote of hominin bushiness.) So Africa has fallen to bushiness, but how far can we extend this favored metaphor? Surely, at some point we must reach a twig that grows straight out without further branching to modern Homo sapiens. Where is the teeny ladder of this ultimate twig?

About a million years ago, after our long and exclusively African prehistory, some populations of H. erectus migrated out of Africa (while others stayed) to colonize parts of Europe and Asia. (As Java man and Peking man, we knew about these Asian H. erectus even before we had discovered their australopithecine forebears in Africa.) Some paleontologists have identified H. erectus as a bottom rung of the ultimate ladder, arguing that this ancestral species transformed itself, in toto and in various places, into modern humans (H. erectus and H. sapiens) become, in this interpretation, grades of structural improvement within a single evolving lineage, not proper species by the usual criterion of branching). Carleton Coon advanced the extreme form of this argument when he claimed, in his popular book The Origin of Races (1962), that five separate groups of H. erectus had independently evolved in parallel, in Africa, Europe, and Asia, to H. sapiens.

The alternative viewpoint, following the metaphor of the bush, still interprets H. erectus as our ancestral species but seeks a later and local point of origin for modern humans. After all, H. erectus thrived on three continents. Why insist that all its populations moved upward and onward to our current glory? Why not argue that H. sapiens, like most species, branched from one of these populations and then spread out, eventually to displace H. erectus populations (or their descendants) in other parts of the world—a classic case of "hominid catastrophism" as a legitimate pattern of evolution?

The hints have been with us for a decade, but strong evidence has just emerged for a radical version of bushiness to this bitter end. To summarize the conclusions baldly (the evidence follows in a moment): all modern humans are products of a very recent twig that lived exclusively in Africa until 90,000 to 180,000 years ago. We therefore branched from H. erectus in Africa, the center of origin for all hominid species discovered so far. Modern H. sapiens migrated from Africa to the rest of the world (reaching Europe and Asia quickly, Australia some 40,000 years ago, and the Americas some 10,000 to 20,000 years ago). All modern humans are a product of this split and migration; the previous emigration of H. erectus to Asia left no descendants. (Lest this seem improbable or complex, consider the story of horses, told in this forum two months ago in the first column of this trilogy. Remember that T.H. Huxley mistakenly concocted a European ladder of horses from four separate lineages that migrated sequentially to Europe, where each became extinct without issue.) Fossil hominids older than this date of splitting for H. sapiens in Africa—including the Asian H. erectus and probably the famous Neanderthals of Europe—are separate lineages on the hominin bush and played no role in our ancestry. For African H. sapiens—the forebears of us all—as for Judah the Maccabee:

See the conquering hero comes! Sound the trumpet, beat the drums! (although we have no evidence for martial replacement by African invaders; the indigenous people of Europe and Asia may have disappeared earlier or for other reasons).

The hints are in stone and bone. Sophisticated blade tools appeared in Africa nearly 100,000 years ago, long before they replaced simpler flake tools in Europe or Asia. Concomitantly, the oldest modern humans have been found in African sediments some 100,000 to 140,000 years old. Moreover, some paleontologists are now arguing that the Asian populations of H. erectus developed a suite of anatomical specializations absent both from modern humans and from African fossils usually called H. erectus. If this tentative claim is affirmed, then Asian H. erectus would be debarrd from the ancestry of modern humans, while African forms remain admissible. (I leave for another time the interesting implication for taxonomic re-alignment—that African populations now placed in H. erectus may require redesignation as a separate species. The name Homo erectus must, by rules of nomenclature, remain with the Asian forms that first received this label.)

The firmer evidence lies in molecules, for we all carry genetic traces of our ancestry. During the past decade, molecular evolutionists have recognized the power of mitochondrial DNA for unraveling the histories of recently evolved groups. Mitochondria are the energy factories of all complex (eukaryotic) cells. They presumably originated, more than a billion years ago, as entire cells of primitive (prokaryotic) type that began living as symbionts within the ancestors of eukaryotic cells. As a heritage of their independent origin, mitochondria have their own DNA—arranged as a short, circular molecule. Mitochondrial DNA has two favorable features for the reconstruction of evolutionary histories. First, it evolves about ten times faster, on average, than nuclear DNA—thus permitting sufficient resolu-
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tion for such recent and rapid events as the origin and spread of modern humans. Second, compared with nuclear DNA, its pattern of inheritance is simple and direct. Since the business end of a sperm is all nucleus, mitochondrial DNA is strictly maternally inherited. We can therefore trace lineal paths of descent, rather than the complex cross-fertilizing of nuclear lines of descent that may come from either parent. Moreover, the entire mitochondrial genome is inherited as a unit. Prokaryotic cells (like modern bacteria and the precursors of mitochondria) do not have paired chromosomes; DNA is arranged instead as a single continuous molecule. When chromosomes pair, as in all nuclear DNA of eukaryotic cells, exchanges occur between the two members in each generation. Nuclear chromosomes are, therefore, continually fractured and reconstituted. But the mitochondrial genome is a stable entity, passed intact from mother to offspring and altered only by mutation. It is therefore an ideal tracer for genealogical histories.

Rebecca L. Cann, Mark Stoneking, and Allan C. Wilson have just published our most extensive data on variation in human mitochondrial DNA (“Mitochondrial DNA and Human Evolution,” Nature, January 1987, pp. 31–36). They studied 147 people drawn from five geographic populations (Africans, Asians, Caucasians, aboriginal Australians, and New Guineans) and succeeded in surveying about 9 percent of the entire mitochondrial genome of 16,569 base pairs.

Cann and her colleagues found 133 variants among the 147 subjects (most people are unique, but very little different from many others). As the next (and crucial) step, they arranged these 133 mitochondrial types into an evolutionary tree. We now encounter an important property of such molecular information: the data themselves are abundant and “hard”; but interpretations rest upon assumptions that, although reasonable and proper, must be stated and evaluated. In principle, a vast number of evolutionary trees may be constructed from 133 variants. How shall we decide which to prefer?

In such cases, we generally invoke the assumption of parsimony—that is, we build the evolutionary tree that requires the minimal number of mutational changes to link the 133 variants. (This procedure matches our intuitions: confronted with mouse, rat, and human, we would assume a closer tie between mouse and rat rather than the unparsimonious solution that mouse evolved to human and human back to rat—for this second, unparsimonious tree would require a much longer pathway of linkages, namely, a double run both up and down the long rodent-to-human road, rather than a single excursion, as in the first solution. But parsimony is a procedural assumption that might be wrong in any particular case, not an a priori truth of nature.) In the mitochondrial example, we may worry less about the parsimony assumption because conclusions are, in the profession’s jargon, so “robust”—that is, a large family of most parsimonious and nearly parsimonious alternative trees all yield the same basic solution.

The minimal length tree for 147 humans has a simple and striking topology. It includes two major branches joining at the base. One contains only Africans, the second includes other Africans plus everybody else. Cann and colleagues compared this most parsimonious tree with several alternatives. The conceptually opposite tree for example—one that links each of the five geographic groups to an independent root and corresponds to Coon’s old theory about separate origins from different stocks of H. erectus—would require fifty-one more mutations to make all the linkages.

These data provide two strong reasons for viewing Africa as the unique source of modern humans: first, of course, the form of the tree itself, with its African root; second, the greater mitochondrial diversity maintained by peoples of African descent. The older a group, the longer the time available for generating diversity. Cann found as much variation within the African populations as between Africans and any other geographic group.

The tree’s form tells us “where,” but not “when.” Since mitochondrial trees say nothing about the anatomy of our common African ancestor, we need subsidiary information from paleontology—and this requires knowledge of timing. If the two great branches of the mitochondrial tree joined in Africa more than a million years ago, then our most recent common ancestor would presumably have looked like H. erectus. If the joining occurred much later, then our common roots are much more shallow—and we all probably branched from a subset of a population that had already become H. sapiens.

To derive such an estimate of timing, we must make an additional assumption, more tenuous than the previous statement about parsimony. We assume that mitochondrial DNA changes by mutation at a constant average rate over considerable stretches of time. Such an assumption is not required by evolutionary theory, and alternative ideas of greatly variable rates (due to differing intensities of natural se-
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lecan) can easily be defended. The justifications for this assumption are primarily twofold: first, the presupposition of constancy, though initially derived by many evolutionary theorists, has worked in many cases where we can check a molecular tree against known dates of branching from the fossil record. Second, the tree derived under this assumption is also robust: large departures from constancy would be required to change its form or its timings substantially. In any case, the figures reached under the principle of constancy must be viewed as ballpark numbers tied to their assumptions, not as established facts.

Many studies of diverse animal groups yield the same estimate of 2 to 4 percent change in mitochondrial DNA per million years. Combining this figure with measured distances among the 147 people, we derive a time scale for diversification and spread of modern humans. This exercise suggests a conclusion surprising to many (though not to me and other devotees of the bush) and stunning in its implications about human unity: despite our external differences of skin color, hair form, and size, all modern humans have a remarkably recent, or "shallow," common ancestry, occurring well after our anatomical transformation to H. sapiens in Africa.

The assumption of constancy at 2 to 4 percent suggests that the common ancestor for all existing human mitochondrial DNAs lived in Africa between 140,000 and 290,000 years ago. This branch then split into the two main limbs of Cam's tree, and members of the second limb left Africa later—only 90,000 to 180,000 years ago. All non-African racial diversity arose within this geological millisecond, and the underlying unity of all humans is, as I have argued before (November 1984), a "contingent fact of history," not a hope of liberal ideology.

If these dates are right, we must also accept the conclusion that older inhabitants of Europe and Asia died out without contributing anything to our genetic heritage. European Neanderthals, for example, predate this time of migration from Africa. If the invading Cro-Magnons had hybridized with Neanderthals or if Neanderthals had simply evolved to humans of modern form, all hypotheses have been popular, then the mitochondrial tree would not have its unique and shallow African root—for older mitochondrial DNA would not have been found in European populations. Of course, a greater sample of humans might yield different mitochondrial variants of greater distinction, but the data as now known suggest no such heterogeneity in human ancestry.

Before leaving this subject, I must correct one striking misinterpretation that has begun to fuel popular accounts of this discovery. Noting that all human mitochondrial DNA can be traced to a single African type, some have dubbed this conclusion the "Eve hypothesis" and have actually claimed an implication that we all owe our ancestry to a single female who lived about a quarter of a million years ago. The data do mean that all modern humans may contain, in their genealogical ancestry, one African female (or a few with the same mitochondrial type), but such a perfectly orthodox, almost necessary conclusion says little about the size of our ancestral population at this time of origin. To say that we all include one woman in our ancestry is not to claim that only a single woman existed at that time—though this is the ludicrous misinterpretation that has spawned some lurid press accounts. After all, the ancestral human population may always have included, say, 50,000 people during the time of its African origin, but all modern humans may still trace a mitochondrial genealogy to just one female among these 50,000.

In fact, such a pattern of boom and bust for everyone else is not at all surprising but an expected and predicted result in our tough and random world, exposing each and every one of us to the continuous slings and arrows of outrageous fortune. Most genealogical processes work this way. Consider human family lines, for example. If we started with a population of twenty family names, with twenty people per name, and maintained the population at constant size for many generations under uncertain conditions of human life (disease, conquest, infertility), most names would eventually die out and we would all be Smiths or Goldsteins (if we didn't confound the process by adopting new names as the old lines expired). Yet this later uniformity would permit no conclusion that a certain Ms. Goldstein had lived alone in Eden way back when—for the population had always numbered 400.

This principle rests upon a well-established mathematics beyond the scope of this column and its author. Its conclusions are firm, though surprising to those (most of us, alas) who do not understand the nature and power of random processes. For example, in a purely random system even for a large population beginning with 15,000 unrelated females, we can calculate a 50 percent probability that, 18,000 generations later, all members of the population would be descendants of but one female among these 15,000.

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

Selections from the lost journals of a celebrated literary naturalist

by Loren Eiseley

From Part II (1947–1966)

Item: Ideas for Harper's
An essay on old animals, e.g., Henny & the turtle. Connect with the vanishing of such things from our streams and earth. Our aged have increased in numbers, but the magnificent ancients of the earth have vanished. Once in a long-forgotten glade I came on such a giant, the nostalgic thrill of the monster. Hippo at the Bronx.

Monsters are Memories
Human beings get old in a dreamy fashion—the reptiles keep growing like trees, becoming more and more ancient and formidable. The great gars swimming up the stream.

Lament for Monsters
Is the reptile unique by its constant growth?

***

The blizzards by the Pole are not a likely place to search for the secrets of life. Only this, I think, can explain the amazing indifference that the public of two generations has shown toward the contents of one of the sledges drawn painfully southward over the Antarctic ice barrier by a trio of starving men. Captain Scott and that immortal company who perished with him are well known to science. Nevertheless,
in the chronicles of their passing, in the records of those who found them huddled in their last bivouac, a line at best is devoted to that single sledge. They dragged it with their dying breath, yet its contents, by the curious whims that sometimes afflict the final reports of ill-fated expeditions, have been little mentioned since. Its significance is therefore uncertain, but this we know, it was not gold. It was a sledload of fossils. There are men, I think, who would have understood this effort had it been made on other continents.

***

Few laymen realize that every bone that one holds in one's hands is a fallen kingdom, a veritable ruined world, a unique object that will never return through time.

***

Last evening the largest house centipede I have ever seen died peacefully on our bathroom rug.
It is a strange thing to record the death of a centipede with the reluctance with which one speaks of the death of a pet sheep dog, but at the last I think I may have been a little confused on the whole subject. Toward the end this centipede was very tired; and like two aging animals who have come into a belated understanding with each other, we achieved a mutual tolerance if not respect. He had ceased to run with that flowing, lightninglike menace that is part of the horror of centipedes to man; and I, in my turn, ceased to drive him away from the woolly bathroom rug on which his final desires had centered. It took me a little while to realize that he wished to spend his remaining days there, but after I understood, I am proud that he came to no harm at my hands and that he died there so peacefully that it took me a while to realize that he was gone.

***

A few days ago, I observed, after a night's rain, cicadas (the seventeen-year form?) emerging from their larval cases around the tree near the Wynnewood station. The grubs coming to the surface were creeping toward the nearest tree. Those I observed were creeping in the proper direction to reach it. Was this chance or do they have a way of sensing or seeing the tree? The grubs were a yellowish, earth-stained brown, the emerging adults white with red eyes.
I was greatly impressed with the number that failed to achieve their passage into the world of light. Some failed to wriggle free from their old garb and died only partly out of the grub form. Some worked clear, but their wings failed to develop properly; others crept painfully about with stiff legs or other defects, which seemed largely due to hormonal failures or low viability. The wastage is tremendous, even leaving aside the birds that attack the emergents in their helpless stages. Nevertheless, the wood, next day, was full of the successful. They appeared, in contrast to the Middle Western two-year variety, very sluggish and unwilling fliers. They were easy to pick up and seemed to prefer to cling rather than fly. The color is dark, the red eyes remaining.
A high wind on the day of emergence caused much damage to wings still soft and forming, as well as hurling many to the ground. This event certainly added to the casualties. I noticed an attacking spar-
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row striking the wings from one individual, and I found other wings in pairs with the body gone, mute testimony to the attack of birds. Later I saw an ant carrying away the wings.

***

February 14, 1954

A long abandonment of this record, but I shall now try to get back into the spirit of it. The thought struck me yesterday that one queer thing about mammals is that they have never developed footless land forms. Weasels and certain of their relatives are sinuous and long bodied, but none of them have actually paralleled the snake in adaptation. Perhaps the latter requires belly plates to be successful, since whales have certainly lost the hind limbs. It is interesting to speculate on the amount of correlation involved in (1) loss of legs and (2) correlated (?) development of locomotion by plates which requires muscular adjustments, etc.

A good essay could also be written on animals living in holes, etc., and the dangers of going out into the world.

***

September 1, 1955

It occurs to me that there is a very clear analogy between the way in which an apartment house (or another building for that matter) acquires its biota and the way an oceanic island acquires its plant and animal population. An apartment house newly built (a recent volcanic island upthrust from the waves) is destitute at first of a fauna. If it is remote from neighborhoods where such a fauna may be acquired (islands far at sea), it may be destitute of insects, silverfish, etc., for a longer period. As time runs on, however, the chance of immigrants arriving intensifies. A pair of roaches may arrive in a box (floating timber), and soon the house is populated so extensively that even professional exterminators can only keep the population reduced. [How close] the apartment house may lie to other, older ones or to neighborhood groceries, as in, say, New York, will play a part in the time involved before population is acquired. Now, to give this a figurative evolutionary twist, we might imagine each house more self-contained than it actually is and lasting over more than one geological period. Let us say that in one house roaches have grown adjusted to a given poison, in another they have developed clever adaptations for evading the traps set for them by people, or perhaps other insects have been introduced to combat them. Say spiders.

All of this would mean a series of self-contained apartment (island) worlds in which intense but quite different forms of selection were going on. In the end, after the passage of some millions of years, the once similar biotas might be quite different. The heating system (climate) in the different apartments might also be hot, cool, humid, dry, etc. Eggs, larvae, etc., will thus be struggling against quite different natural environments.

I could not help but be amused today. An exterminator came and let loose a gas that gave me unpleasant physical symptoms. After it was all over, I went into the bathroom and found a vigorous young roach perched on my toothbrush. I was showing more effects from the "exterminator" than it, and it easily evaded my lunge.

***

Engels, I believe, says somewhere that Darwin failed to distinguish between struggle to survive in a single environment and the adaptation leading into new environments. Critics of Malthus have pointed out that he created a false situation in that he claimed population was increasing faster than the food supply, when what was really happening was that population was increasing faster than a given type of economic system could make use of people. In other words, there was no shortage of food in a natural sense, there was only an ecological failure. Perhaps an analogy to human society exists here in the animal world. Cities allow more niches in which diverse talents can be manifest. Similarly, a biota that has arranged itself in ecological communities has reduced the struggle for existence so that more types can take advantage of a given region (law of divergence). Thus, diverse adaptive mutation is important, more important for life in general than straight-line evolution. Man's mental variability, which is not wholly cultural, has, in his cities, replaced physical evolution.

***

Saw a pigeon on the campus today: its feet carrying little feathered ruffles or teddy bear shoes. Obviously wild but sporting some remnant of high breeding in a fancier's coat—a fallen aristocrat.

Also one with an injured leg that used his wings to move when the other walked. He used to rest in the sun with his wings spread out, lying on his side in an ungraceful fashion but looking nevertheless well fed and managing to cope with his infirmity. Perhaps in winter he would suffer more.

The college campus was a better refuge for him than the city streets would have been and hurt his remaining foot less. Where he roosted and how, I had, of course, no idea. Sooner or later a cat . . .

There is something intensely pathetic about harmless animals dying alone. I shall never forget coming across the University of Kansas campus one summer evening and finding a dying turtledove on the walk. It had not been visibly injured, but had been perhaps poisoned. Its mate, in very obvious emotional distress, walked nervously about it and paid absolutely no attention to me as I squatted down to see if I could help. I lifted up the dying bird, whose eyes were already glazed, and placed it on the flat roof of a nearby shed where it might at least be safe from dogs or cats. All the time the female bird stood fearlessly at my feet and fluttered up to the shed roof to be beside her mate. It was hopeless. In the last light of evening I hurried away, asking myself questions I did not want to ask. Was there a nest? Were there young? By nightfall that affectionate, life-indifferent bird would be alone in the vast universe feared by us all. I did not go that way again in the morning. I knew too well what I would find.

***

December 11, 1955

A few nights ago some hoarded wisteria seeds exploded. Mabel [Mabel Langdon Eiseley, the writer's wife] heard them. When I got out to the living room, pods and seeds were scattered on the floor, and other things had been hurled out of the glass in which the pods had been placed. The seed pods explode with great violence by means of fibers contracting unequally, since the pods cannot be placed back together. All in all, it is a remarkable performance.

***

December 16, 1955

Looking out of a sixteenth-floor window of the Barbizon-Plaza Hotel in New York, I saw several pigeons turning round and round, apparently warming themselves in the warm air currents emanating from some chimneys or air vents in a roof immediately below me. Looking closer I discovered several such chimneys emerging from the wall on the side nearest to me. On each chimney sat a pigeon, its little bottom carefully tucked over the warmth. It was dawn in a gray way. The pigeons were ruffled up from the cold, their beaks buried in their feathers, but they held firm to their little individual air vents like men
warming their bottoms before a fireplace.

Later, descending to the street, I found clouds of pigeons in places where they were not to be found in rush hours. They were picking up bits of crust and other garbage in front of bars and grocery stores before the increasing traffic of the morning would force them aloft again. Obviously they have the ecology of the city well worked out.

There could be added here the brave way these small birds seek their living and survive. No mean feat.

***

May 9, 1956

At the Cambridge conference [psychologist] Jerome Bruner observed that Darwin's great observation lay in his placing all life on a common basis and governed by a common principle. At the same time the Darwinists tended to see man as the completed perfection, the blossom, so to speak, of the tree of life. Freud, taking off from Darwinian conceptions of change and imperfection, regards man as unfinished and containing in his mind the primitive as well as the new. Freud avoided the all-or-none idea of mental illness and thus recognized continuity.

***

It was the biggest battle line the world has ever known. It ringed the continents and was fought without mercy on the shelving threshold of the sea. The seed of man may have been there, but in any case the battle was lost. This and only this is the reason we are not today oaring soundlessly through coral gardens, hovering for safety under the wandering Sargasso weed.

I sometimes think of it, leaning over the rail of a coastal steamer at night when a shark fin cuts the water. I think of it even more when I scan an antique map or read those strange old tales of the medieval krakin—the giant squid that strangled ships in its fifty-foot arms. Yes, I think of it still, even when I put my nose up against aquarium glass and see a little octopus no bigger than a baseball exploring the neighborhood of my face with a friendly tentacle. I think how lucky we are and how much we owe to the cephalopods. I think of the wandering ways of chance and our brother the shark. I think of that million-year battle below the tides and the difficult metaphysical question of who the winner may have been. I do not know. But at least I stand here looking back into that awesome green world. I know that it was important to us long ago and that we sought to enter it. But the nostalgia I feel is very small and my sense of gratitude is very great. I would never knowingly injure an octopus.

Four hundred million years have passed since the vertebrates fought on the sea floor. They were the last of the great animal phyla (groups) to appear, and if any creature below the tides knows the place of their origin, it is the starfish. Or it may be that that dark, magnificent-lensed octopus eye remembers us. He is older than we and has changed less. He was there when we squirmed in the mud, when our mouths were jawless, when our spine was a rubbery rod and we were lucky to know light from darkness. He was there when a fish was something very close to a worm—and when to say that about a fish was the same thing as saying it about a man, because they were all contained in a mysterious creature with gill slits and a nerve cord on its back instead of its front. The nerve cord is still there, only swollen at one end. With it you interpret these lines.

There were no fish in the sea—not in Cambrian times. Outside, beyond the breakers floated and swam the rulers of the primal waters—the cephalopods. Sometimes after great storms, huge fif-

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There were no known species of squid to date but the great squid of long ago had not yet abandoned all their molluscan habits. They were shell bearers. In the shallow seas that invaded the continents of that day there was an immense and swarming life, but the fossil beds so nicely scattered with the shells of cuttlefish reveal no trace of fishes. For this there is a simple reason. Fishes—that great, swarming, multispecied group that stands in our minds as the epitome of sea life—arose in fresh water.

The earliest creatures clearly definable as fish are the ostracodermi. We find fragments of their remains scattered sparsely in the strata laid down in brackish marine estuaries. It is the first sign of the seaward movement of the fishes, and it is an abortive one. These fish are armored like medieval knights. Few were over a foot in length. Jawless scavengers, they were still mummifying the debris of stream bottoms and shuffling timidly through the silty darkness of the river mouths. No fish alive carries such dreadnought armor. Eurypterid sea scorpions the size of men had penetrated fresh water. For a hapless non- biting vertebrate, armor was the only answer—armor and the electric shock batteries that some carried concealed in their head shields. Flight into the seas was impossible. Out there, beyond the breakers floated the cuttlefish with waiting arms. Below on the sea floor crawled other nightmares.

It was the hour of the shark: no one knows where it began but the battle grew: the fishes were multiplying, building up toward some tremendous biological explosion. They had at last acquired jaws by the sacrifice of a gill arch. Armament races are as old as the world, and strange things are done when the need is desperate. The sixty-foot tiger shark and the most deadly jaws in the world were built from models that first raced out of the river mouths 400 million years ago.

Over the land the shadow of a million-year drought deepened. The pendulum of climate swung from torrential rain to the desiccation of trapped marshes and drying lakes. Floundering fishes in mudholes began to learn how to breathe air by desperate swallowing and the use of a little air sac behind the throat. The continental waters were inexorably contracting. The final battle was at hand.

I like to think it was there in a dying stream bed that we parted: the ganoid fish with the beginnings of the lung that would enable it to creep on slow fins up the mud banks toward the future and our ancient gray-nosed brother, which never developed an air bladder, turning downward toward the sea. It was the last time that we met to know each other, but we both survived. Ironically, the slime-mold life of those steaming marshes sticks to us still. We hate that grim sea- roving fin and the death it carries. We are from the same mud hole, devising death with the same mud puddle brains . . . .

As the only thinking mammals on the planet, perhaps the only thinking animals in the entire sidereal universe, the burden of consciousness has grown heavy upon us. We watch the stars, but the signs are ambiguous. We uncover the bones of the past and seek for our origins. There is a path there, but it appears to wander. The vagaries of the road may have a meaning, however. It is thus we torture ourselves. We go over and over that road and point to some strange quirk of change that affected human destiny. Was it chance? Was it fate? Was it God? The bones are silent, the oracles speak in riddles. Only the shining thread runs on and on. Today we carry it, but never in the planet's history has it tarried for any form of life. It is concerned with the becoming; never with the past; it is always just leaving the present, and the present, is briefly, very briefly, ourselves.

"Nevertheless there is a goal," we seek to console ourselves. "The thread is there—the thread runs to a goal." But the thread has a tangled maze. There are strange turns in its history, loops and knots and contractions. One thing alone it does not do. It never brings back the past.

From Part III (1966–1977)

February 4, 1969

Willemsdadt, Curaçao: On the edge of the city dump by the sea, I came upon the dead dog wrapped in burlap, buried at sea and drifted in by the waves, little more than a skeleton but still articulated—one delicate bony paw laid gracefully—as though its owner momentarily slept and would presently awaken—across a stone at the water's edge. Around his throat was an old black leather strap that showed he had once belonged to someone. This dog was a mongrel whose life had been spent among island fishermen. He had known only the small sea-beaten boats that came from Venezuela and littered shores like this to which he had been returned by the indifferent sea. Why amongst all that washing debris of tin cans, shoes, bottles, and cast-off garments was I so moved? Because this particular wasted garment

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had lived. Scenes of the living sea, which would never in all eternity be seen again, had streamed through the vibrant sockets of those vanished eyes. The dog was young, the teeth in its skull still perfect. It was of that type of loving creature who had gamboled happily about the legs of men. Someone had seen crudely to his sea burial—but not well enough, so he lay now where comes everything abandoned. But not without a pathetic dignity—the tide in its own fashion had brought him quietly at night and placed what remained of him upon the stones. There at sunrise I had stood above him in a light that he would never any longer see. Even if I had had a shovel, the stones would have prevented his burial. He would wait for a second tide to spirit him away or lay him higher to bleach starkly upon coral and conch shells, mingling the little time of his bones with all else that had once stood upright on these shores.

***

May 24, 1969

Comments re moon book and/or possible essays.

(1) First movement in animal world intended to leap space for energy. With the rise of mind and technology, this activity leads to space—leaping for the absorption of knowledge—though the discoveries may lead to sophisticated uses of energy once more. This, however, need not necessarily follow. Also the microscope and telescope can be a kind of mind-leaping through spaces denied us in the flesh. The same is true of the spectroscope.

(2) The stimulus of incompleteness (see one of my notebooks) never ceases in science, nor, by the way, in magic, which is, is it not, a similar stimulus seeking to control the actual by the supernatural.

(3) What is natural? ... May it not be that our space interests are forcing us to face a new set of questions involving time and the galactic reaches, i.e., nature in new or potential forms.

(4) Re perhaps my biography. My youthful isolation resulting in love of quiet and retreat as the animal... seeks hideouts and silence because noise increasingly (in the human world) represents the first aspects of possible danger and violence. Man with his voice began to change the natural world for animals long ago.

***

May 10, 1969

[Gilbert] Highet in the Migration of Symbols speaks of fear as a great educational force. Is this true far back among the
australopiths? Think it over. Did it grow with symbols and the ability to consider the future? Is there a combination between fear, upright posture, and language somewhere in this story of the first four million years? What pushed it further? Strangely, did the first grain masticators die out while the carnivores *Australopithecus africanus* or *Homo habilis* later turn to grains through fire? Also, the solitary animals largely rest when not active. Man’s intelligence (fear-based anxiety?) drives him perhaps into needless conflict; the energy climb is too steep, too sustained.

July 30, 1969

Note how in the Pocono woods a three-day steady downpour brings damp-loving forms far from their usual environment (the frog I placed in the little spring, for example, or the multitudinous sprouting of fungi). These events are brought about by the sudden slackening of the strands in the net of life. If long enough continued, ranges change or gene pools may shift.

***

Moon

This is an age of superlatives, but a superlative standing alone may be easily condemned as absurd even if it contains a modest element of truth. President Nixon fell into this trap when he enthusiastically endorsed the successful moonlight of the astronauts as the greatest event in history since the Creation. The remark was hailed for a day, and then Mr. Nixon was chided by the evangelist Mr. Graham, who reminded him of the birth of Christ. Even an agonistic would be forced to recognize that the emergence of Christianity profoundly altered the world view of the West and was destined to give rise to that belief in progress and the uniqueness of the historical process that has led on to the achievements of modern science. Great events are cheapened and made vulnerable simply by being isolated in a world made up of continuities and causal sequences. As an anthropologist, for example, I might with some reason argue that the development of language in the evolution of the human species was a necessary preliminary to history in any form and that no following triumphs of human ingenuity would have been possible without it. One could thus contend for the emergence of language as the greatest event in history. Similarly, a biologist might choose to argue that the atmospheric changes making possible the rise of the metazoa—the first many-celled animals—equally played such a role. The student of nature is confronted with innumerable novelties distributed through time but proceeding constantly toward an unseen and unique future. To use the isolated superlative as Mr. Nixon did is always to invite the mocking rejoinder “As compared with what?” In that rejoinder the oak must be reminded of the acorn cup, man, of the grassland whose evolution was a preliminary to his own appearance. Even the moon rocket waited, among other things upon the invention of the clock and the computer. The original creation of its occurrence may have been a genuinely singular event but scarcely anything thereafter. Men would be wise not to demean the term greatest by its debasement to the political uses of a single ephemeral generation.

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Man has grown fond of late of contemplating almost with submerged pride his ancestral descent from what he regards as a savage, carnivorous ape; this, his later history would imply, contains a grain, if not several grains, of truth. What is less flattering and less appetizing perhaps is his more genuine resemblance to that group of minute organisms known as slime molds. They can be seen devouring spoiled
bread or moving in unsightly blotches over spoiled oranges—fruit that in distant eye-narrowed perspective might be mistaken for diseased planets—rotten fruit circling in the plague-infected winds of the cosmic orchard.

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January 22, 1970

Anthropomorphizing: The charge of my critics. My countercharge: There is a sense in which, when we cease to anthropomorphize, we cease to be men, for when we cease to have human contact with animals and deny them all relation to ourselves, we... cease to anthropomorphize ourselves—to deny our own humanity. We repeat the old, old human trick of freezing the living world and with it ourselves. There is also a sense... in which we do create our world by our ability to read it symbolically. But if we read it symbolically, aloof from ourselves and our kindest impulses, we are returning to the pre-Deistic, pre-Romantic world of deprived Christianity—where man saw “fallen nature” with the devil slipping behind each tree. Modern anthropomorphizing consists in mining nature down to its ingredients, including ourselves.

***

Darwin’s... “law” of natural selection is paradoxical in that it is a nonprophetic law. It can only say—and then with certain notable exceptions—that life will change, but it cannot inform us in what particular direction... or whether it will lead to no future, i.e., extinction. Even with the final recognition of the periphery of secondary randomness based on the randomness of what has gone before—what we might call in other words historical probability—we still are called to a chance world of indefinite possible... futures. There is a statistical bias written into natural selection: the bias, or necessity, of constant survival if contingency is to remain important to life. “The nature of a probability hypothesis can be reduced to a speculation about scope,” as one writer has remarked. In the beginning many of Darwin’s critics assumed his “evolution” to be utter randomness in the sense that carrots and cabbages might have played a role in the human phylogeny. They overlooked the fact that Darwin’s realm of accident had parameters determined by historical probability; by the chances or accidents previously allowed survival through the screen of natural selection.

***

Nature, one may say, is the existent, but there must be included with it, and to this extent obscuring its edges, the potential, just as man once existed as mere potential in a tree shrew. Thus nature is metaphysically a kind of cosmic iceberg of which only the smallest part protrudes visibly into our understanding.

***

From a letter (October 14, 1970) to naturalist Hal Borland, referring to a despairing comment Borland had made:

Now about this matter of optimism and pessimism. I have to be an educator, though, as I have said before, the activity is growing more and more difficult. I felt it necessary to offer some kind of choice to man, but in reality, like yourself, I am deeply depressed about the human situation. I do not fear our extinction. What I really fear is that man will ruin the planet before he departs. I have sometimes thought, looking out over the towers of New York from some high place, what a beautiful ruin it would make in heaps of fallen masonry, with the forest coming back. Now I fear for the forest itself.

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Where Elephants Die

During severe droughts, they are “tethered” to their waterholes

Text and photographs by Gary Haynes

An emaciated elephant is lying in the shade of a thicket of small trees. My game scout, Morven Mdondo, says quietly, “I don’t think this one is dead,” but I step right up to it with my instant camera in hand and take its photograph. A very fresh dead one, I think. The camera clicks and whirs and spits out the developing print, and the elephant opens its eye, staring at me in alarm. It rises abruptly, and Morven and I take off running, the elephant racing behind us through the trees. I wonder breathlessly whether it will kill me or Morven first. My hat flies off. The elephant crashes right through a tree behind me. I hold on to the camera.

Morven veers off toward the open grass to our left. He cocks his automatic rifle but stumbles and falls. The elephant runs after me. I leap over the fresh carcass of a small elephant calf and look back to see the elephant drop to its front “knees” at full speed and repeatedly plunge its tusks into the calf’s body.

When it has flattened the carcass, it slowly rises and walks over to stand in the shade of some trees about twenty yards away. There it remains, as if dazed, for the rest of the afternoon. During the night the elephant moves off again, looking for water. I doubted it could survive another day.

A close call, one of several during my fieldwork in Africa between 1982 and 1986. I had come to Zimbabwe’s Hwange National Park to study African elephants in a free-roaming state. I was especially interested in finding the places where elephants died in great numbers during the dry seasons. Zimbabwe, like much of Africa, is subject to periodic droughts, and the years between 1981 and 1984 were the driest recorded this century. As a result, hundreds of elephants died around the few remaining water sources located in Hwange’s wilderness areas.

About the size of Connecticut, Hwange is the third largest national park in all of Africa. More than 400 species of birds and 100 species of mammals live in this huge preserve; in the early 1980s some 20,000 elephants roamed the park’s woodlands and scrub savannas. Hwange lacks the high mountains and huge open grasslands of the Serengeti or the Ngorongoro Crater of East Africa, but it has its own charm. Thick forests give way to rolling vleis (pronounced “flays”) where grass covers old drainage ways. Granite and sandstone koppies (pronounced “koppies”) stand high over otherworldly baobab and euphorbia trees in the northern part of the park. The dominant ground cover, however, is sand, usually gray or tan.

Rainfall seldom exceeds twenty inches a year, and during the March through November dry season, very little permanent water exists in the park. When Hwange was new and under development, in the 1930s, 1940s, and 1950s, the national parks authorities decided to drill boreholes in the central part of the park to provide year-round water. They hoped this would increase Hwange’s wild animal population and help turn the park into one of the world’s great game refuges. In those early days, only an estimated 2,000 to 4,000 elephants inhabited the preserve’s huge, untraveled wilderness. During the rains, many of the big mammals moved westward to the Makgadikgadi Pan area of neighboring Botswana, and during the dry season they returned to Hwange, concentrating in a sandy woodland with a few places where water could be found.

Today, this woodland is called the Shakwani Wilderness Block, named after one of the area’s eight water sources, all underground. These buried layers of water lie at the bottom of extinct stream channels, where surface water has not flowed for thousands of years, and in old clay-bottomed pans that have been buried by Pleistocene sands. Every year, Shakwani’s animal population must wait for the elephants to open up these water sources, for only the elephants are capable of digging the necessary five to eight feet down in the sandy sediments. Once the wells are dug, water slowly seeps into them. The elephants can then simply stick their trunks down into the seeps and draw up the cool, clean water.

No successful borehole has ever been sunk in the Shakwani Wilderness Block. As a result, elephants in the area today behave just as they did fifty or one hundred years ago when there was no national park. In the wet season, they enjoy the
A herd of elephants searches for water in Shakwanki seep, one of the few places in the wilderness sections of Zimbabwe’s Hwange National Park where water can sometimes be found during the dry season. The elephants dig wells, several of which are visible in this picture, and then wait for water to ooze into them. While waiting for a turn at a well or when the wells run dry, the elephants may mill around in the blistering heat, too weak to leave the seep and look for food elsewhere.
surface ponds and depressions that hold water, but after July or August they must either dig for water at the eight seeps or migrate to parts of the park that contain pumped pans.

Over the decades since the park was established, fieldworkers have noted that elephants died at these seeps once in a while. During very dry years, it was common to see up to fifty elephants standing around a seep, waiting for a chance to drink. The smaller elephants, whose trunks were too short to reach water, sometimes died in significant numbers. Many animals starved to death, since they were too weak to leave the seeps to find adequate food. vegetation around the wells having been long ago stripped to the ground. Stronger animals often prevented the weaker ones from using wells, and the weaker individuals succumbed.

Watching elephants suffer and die during drought is a terrible experience. Between 1982 and 1984, I witnessed dozens of fights over water “rights,” some quite violent although brief, and I saw hundreds of animals slowly lose condition and die. Elephants die quietly and usually alone. Too weak to find shade, they die down on their sides in the hot sun. Or they wander aimlessly, waiting for the coolness of evening. They do not whine or cry out, even when they are clearly feeling discomfort and pain. Only when they fight over water do they scream and roar in protest.

In severe dry seasons, such as in 1982 and 1983, the seeps are never empty of animal life. Elephants mill around for hours, and opportunistic lions, hyenas, and jackals brazenly stroll in daylight waiting for a fresh meal to drop dead. An occasional warthog, steenbuck, or sable antelope might venture toward the wells, hoping for access to one with water at the bottom. Carcasses and skeletons of elephants dot the landscape. Buffalo or kudu skeletons also lie about, the remains of animals that died earlier in the dry season. Large numbers of broken elephant tusks are found everywhere and are especially dense near the well holes. Tusk tips, flakes, and long chunks of the tusk shaft are broken off when elephants butt each other out of the way or clash head-on.

The largest die-off of elephants in my experience occurred at a seep called Shabi Shabi. Nearly 200 animals died in the dry seasons of 1982 and 1983, and most were under eight years of age. A few older females also died from the terrible stresses associated with drought. I spent about five months camping in the area during the drought, watching and recording the heartbreaking processes of slow death for the gray giants. Often my camp was overrun by elephants seeking shade in the heat of the day or looking for something to eat. Sometimes, in the dark of the night small groups of elephants would slip by me headed for the wells, hurrying almost desperately but as quiet as ghosts. Some nights I would wake, startled by the loud, long rumbling noises of elephants communicating with each other down near the wells, about 200 yards from my campsite. Shrieks and roars would silence a whooping hyena, and the night would be quiet again. In the morning the marabou storks and vultures would be trying to open up the still-warm carcass of another elephant that hadn’t survived the night.

At other times I saw animals that were not quite dead, but far closer to death than to life. Being unarmored and usually alone, I could do nothing for them except hope that their end came soon. They would lie in the sun next to the wells, and sometimes they would be trampled by other elephants jostling around the holes. Some dying animals barely had the strength to move their trunk tips and produce a weak rumbling noise when I approached them; they did not even protest as bird scavengers pecked at their ears and eyes. Others had the strength to rise and chase me, even if only for a few yards. The ones that chased me rarely lay down again the same day, and after a while, I concluded that if I could get them to rise, at least to get them out of the hot sun, they might have a better chance of survival.

I have returned to the park many times over the years following the die-offs, and I have explored miles and miles around the
Elephants may clash head-on over access to water, but the four young elephants at left, too small to dig a well for themselves, crowd together in relative peace. Below: As if by magic, every depression in the landscape is transformed into a pond when the rains return. Carcasses lying so near the ponds are poignant reminders of the hard times just passed, and almost certain to come again.

central seeps. I have found some skeletons that I believe are from the animals that chased me. I base my identification on their ages, their tusk shapes and lengths, and little else other than a gut feeling. Of course, I can't be entirely positive in my identifications, but it is sad to find a skeleton whose tusks look familiar. A few years back, these elephants lay down to die in some well-hidden spot only a few minutes walk from the wells, and they passed away without a companion, without a sound.

Up to 30 percent of the elephants in the Shawkani Wilderness Block died in the drought of the early 1980s. As grim as they are, however, die-offs have a useful function: they prevent the populations from growing too large. Die-offs were recorded in 1982, 1971, 1968, 1965, and many years right on back to the earliest days of record keeping in the present century. They probably occurred long before park boundaries were drawn and animals were protected.

Outside the wilderness area, in the larger, central part of the park, the situation is very different. There, the forty or so artificial water sources dug in the park's early days have led to a tenfold increase in the number of elephants in the last fifty years. In the 1970s, park ecologists realized that a growing population of elephants, compressed into an islandlike national park, spelled trouble. And yet the elephants cannot leave their island of safety. If they cross the boundary of the park, they are liable to be shot by poachers or farmers worried about their crops. Neither game capture nor translocation is feasible. Recently, Hwange found it necessary to cull this population of elephants.

Culling is a controversial way of dealing with elephant overpopulation and brings out emotional responses in just about everyone. The alternative to shooting elephants to reduce their numbers is simply to let a large part of the herd die off naturally, as happened at Tsavo National Park in Kenya in 1970. Many wildlife biologists argue that animal populations will reach stable or nondestructive levels if left alone, even if this requires not interfering with animals that are actively altering their habitats. But I do not think this is a valid option for Hwange. There, the vegetation is supported by very shallow soils or thick sands, and if the elephants are allowed to trample on, knock over, or otherwise devastate existing trees and ground cover, the vegetation might take centuries to recover. The elephants and other animals dependent on the vegetation would simply disappear. (The situation in other African parks is not necessarily comparable. Elephants in some parks are threatened by illegal ivory hunting and are in desperate need of protection, not reduction. Other parks may be able to recover quickly from habitat degradation caused by crowding, and thus the animals might be better off regulating their own numbers through natural mortality.)

My first-hand observations of the elephant die-offs at Shabi Shabi and other seeps has convinced me that culling makes more than just ecological sense; I feel it is the most humane course of action in Hwange. The animals that succumbed in the drought experienced an awful agony. Each animal took weeks to die. A highly developed social order broke down as herd groups fragmented in search of water and food. Adults fought with relatives and members of their own herds. Young animals were pulled away from water by their elder siblings and sometimes even by their own mothers. Weakened animals, trying to keep their stomachs full, suffered gut cramps from eating...
too much dry bark or wood. Death did finally come for many of these animals, but only after prolonged misery.

Are there other lessons to be learned from studies of the die-offs, besides the insight that it is more humane to cull than to let elephants perish slowly, while devastating the vegetation around them? I think another equally important lesson pertains to our understanding of fossil proboscideans (elephantlike species), especially those that are extinct, such as mammoths and mastodons.

These extinct species clearly experienced die-offs, some of which were massive, judging by the huge numbers of bones found together at some sites, such as Lamb Spring, Colorado, and Boney Springs, Missouri. But no one has yet shown conclusively what caused the mass die-offs and what their role in the extinction process was. Was the process a gradual one, taking many decades or even centuries, or did the mammoths and mastodons die out relatively abruptly? Were humans responsible for, or at least a significant factor in, the extinctions, or did the process have little to do with the increasing hunting expertise of early man?

Detailed comparisons of bones from both fossil proboscideans and the modern Hwange elephants have led me to believe that intense environmental stress was a trigger that human hunters took advantage of to drive mammoths and mastodons to extinction. At the end of the Pleistocene, the climate in the Northern Hemisphere changed dramatically—summer temperatures rose, winters became more severe, and evaporation rates increased greatly. Drought conditions forced many large animals to crowd together at remaining waterholes. Essentially "tethered" to these waterholes, they were relatively easy prey for hunters. Even without pressure from humans, many animals were unable to adjust to the changes. I see signs of stress and hard times in many of the fossil bones I have studied. The agonizing and tragic end of the extinct proboscideans has left its distinctive mark in bone assemblages, and sometimes I feel nearly the same helpless sadness that I felt watching elephants die in Shakwanki.

In Hwange, thirsty elephants kick or toss bones out of their way and trample the carcasses of their herd mates to reach water. These actions produce recognizable marks and fractures, the same kind of marks and fractures I see in the fossil bones. Elephants desperate for water also fight in head-on clashes and violently push each other around. I have seen hundreds of tusk tips broken during such fights, many distinctively shaped. Fossil collections, too, contain broken tusk tips, a sure sign to me that there was fighting and crowding thousands of years in the past. And when I see cases of dense bone beds, I draw the further conclusion that skeletons were continually or at least periodically being added to the site, an indication of severe or sustained environmental stress.

Most significant of all is the overwhelming preponderance of young animals in both the Hwange die-offs and many of the very largest late Pleistocene accumulations of mammoth bones. The death rate of subadult animals rises dramatically during droughts and other natural disasters, such as heavy flooding or harsh winter weather.

Each year since 1982, I have returned to the Shakwanki Wilderness Block for several months of fieldwork. For the last four years, the elephants have not died off in any numbers because Hwange has once again been receiving good rains in the wet season. Also, with the population considerably lowered by culling, the surviving elephants have gotten some breathing space. But evidence of the die-offs is still abundant. Every time I return, I discover new skeletons, most of them from small animals that had wandered away alone to find water or food or perhaps just peace and quiet. In 1985 I found the skeleton of the emaciated animal that had chased Morven and me. It had lain down on its left side to die. Most do, and I don't know why. It was lying to the west of some little trees, suggesting it had been seeking shade on the morning that it died, probably so quietly that no one heard it. I was unusually sad when I found it, but I have since gained heart from the thought that its bones might help us understand why elephants die and what must be done to help them survive in the world.

□
While they are not the only animals searching for water during the dry season, elephants generally have no trouble winning contests that arise over water rights. Here, an adolescent bull chases zebras away from a pumped pan.
Together We Stand . . .

Photographs by Alain Degré
Members of a meerkat colony greet the new day in their Kalahari Desert home. After a bitingly cold night huddled in their burrow, these mongooses emerge to gather warmth from the rising sun and prepare for a day of foraging.
While its companions search nearby for insects and the occasional lizard, a sentry keeps a lookout for predators.
Spurred into action by the sentry's alarm call, the meerkats drop everything and race for the nearest hole.

Emboldened by the safety of their hole, they turn to face the threat—in this case, a jackal. To drive the enemy off, they bark furiously and hop up and down.
Not all perceived threats are met with such bravado. Sometimes even an unusual sound is enough to send the animals rushing pell-mell into a burrow.
One of 17 stages involved in producing the new edition from Audubon's original plates for The Birds of America.
The first opportunity to acquire prints direct from John James Audubon’s own plates since 1838.

In the Ornithology Department of the American Museum of Natural History, there is one room which is only open by special arrangement. It is called the Audubon Hall.

Among the display of Audubon’s watercolors, prints, drawings, guns and buckskins, nothing is more treasured than the artist’s copper plates that hang on the walls.

To mark Audubon’s bicentennial, the Museum has decided to issue a new edition of six prints struck from these original double-elephant sized plates, last used in the early 19th century.

The first new edition since the 1830s.

The six prints in the new edition are: the Wild Turkey, Male; the Female Turkey and Young; the Snowy Owl; the Mallard Duck; the Canada Goose; and the Great White Heron.

Five years ago, the Museum began looking for a firm which retained the old 19th century skills of copper plate printing and coloring.

After a long search a firm was selected, Alecto Historical Editions of London.

An edition which is closer to Audubon’s intentions.

What may surprise many who appreciate Audubon’s work is that the artist, although delighted with the superb quality of the original engravings, was terribly disappoint-ed with the coloring of many of the prints.

Indeed in one of Audubon’s letters, he writes to his printer Robert Havell;

“These recent proofs are no more like my drawings than a chimney sweep is to your beautiful wife.”

The Museum and Alecto therefore went back to Audubon’s original watercolors, notes, letters and even bird specimens to produce this edition.

The results have not only surpassed our expectations but have also met with outstanding recognition among curators, art historians and Audubon experts.

The well known British naturalist David Attenborough wrote; “These new impressions of the 150-year-old plates could well be judged to be a finer representation of Audubon’s intentions than any produced during the artist’s lifetime.”

‘Living Bird Quarterly’, a scholarly journal published by Cornell University commented; “Many experts are judging the new edition to be superior to Havell’s original prints.”

A very limited edition.

Because of the extremely high value of the original plates and the possibility of stress to them, the Museum is limiting the edition to just 125 sets worldwide.

The plates will then be retired for at least half a century.

The set of six prints cost $36,000. (A 19th century set from the same plates fetched over $145,000 at auction at Sotheby’s in 1983.)

Already most of the edition has been claimed, the majority of the sets going to important collections in North America including the Library of Congress, the Boston Public Library, the McIlhenny Collection and the National Library of Canada.

Some sets have also been purchased by major corporations, including Dow Jones and the Southland Corporation.

We are now delighted to be able to offer the few remaining sets to individuals throughout the nation.

If you would like to receive a prospectus, please write to the Museum at the address below or call Sherry Goodman on (212) 245 5753.

The prints will be available for private viewing in major cities throughout the country during the next three months.

The plates will be coming back to the Museum where they will remain untouched for at least 50 years.
Return of the Pleiades

An Andean pilgrimage reflects ancient legend and modern change

Text by Robert Randall • Photographs by Norris Ogard

At close to 15,000 feet, the Sinakara Valley of southern Peru is so isolated that for most of the year it is home only to Andean condors and grazing llamas. During the week before Corpus Christi, however, music echoes off the snow-covered peaks while costumed dancers perform in the midst of thousands of pilgrims to the annual festival of Qoyllur Rit’i. As the late afternoon sun glances off the glaciers above, I gaze out at the spectacle, knowing that neither the thin air nor the long climb is enough to explain the uncontrollable pounding of my lungs and heart.

“Is this the first time you’ve come to Qoyllur Rit’i, gringo?” asks a Peruvian man who is wearing a down parka and hiking boots.

“No,” I reply, “I’ve been coming for eight years. And you?” Surprised, he answers, “Three years,” and then wanders off. I, too, am surprised. Eight years ago I saw no Peruvians of his class at this festival, and no one asked me how many years I had been attending. Yet, during the five-mile trek up to the valley, I have been asked this question at least five times.

Qoyllur Rit’i. For the indigenous peoples of the Andes of southern Peru there is a certain reverence to the name. In their language, Quechua, qoyllu means “pure white,” qoyllur is “star,” and rit’i is “snow.” The Star Snow. Held every year in late May or early June, the festival is a ritual of purification and transition. Eight years ago I had no idea of its meaning or of the significance it would attain in my own life. But I can still recall every step of my first pilgrimage.

After having trekked on my own for several days, I came to the village of Moyomarca, where I was invited to accompany the contingent that the villagers were sending to Qoyllur Rit’i. It was the Saturday before Corpus Christi (which falls on a Thursday), and I found myself walking on a trail with men carrying spears and wearing magnificent headdresses made from the feathers of jungle macaws. The women—wearing six to eight layers of skirts, each with colorfully woven borders—trotted along. Two drummers and two flautists played as we walked, never missing a note even as we climbed over several steep passes.

At nightfall we rested, chewing coca leaves and drinking cane alcohol to ward off the cold. After a few hours the moon rose over the mountain, someone blew a whistle, the musicians began to play, and we started off again. We walked the entire still Andean night, high up against the moon and stars, over ancient Inca roads. And always, from the ridges above or the valleys below, we heard the same music from other groups, whose feathered headdresses were silhouetted in the moonlight. (Like Easter, Corpus Christi is based on the lunar calendar, so there is always a moon to light the way.)

On Sunday morning we arrived at a town, and after a crowded truck ride, we hiked up to the end of the Sinakara Valley, the sanctuary for Qoyllur Rit’i. There, beneath the glaciers, hordes of pilgrims swarmed around an incongruous concrete temple. In the midst of the multitudes a small space had been reserved for the Moyomarquinos. That evening I settled into a heap with them to attempt sleep in spite of the bitter cold and the milling of hundreds of musicians and prancing dancers. I was exhausted, but the dancers danced in the bitter cold until morning.

People continued to arrive all night, and by midafternoon on Monday, when an icon of Christ was paraded about in a large procession, there were at least 10,000 in attendance, divided about equally between dancers and musicians, the women accompanying them, and other pilgrims and spectators. Most of those present were runa (people), as the indigenous inhabitants call themselves in Quechua. The majority of the dancers were feathered ch’unchus, like those from Moyomarca, runa dressed to represent jungle Indians. Most of the rest were qollas, symbolizing llama herders from the high plains to the south. According to tradition, the original qolla dance groups were also composed of runa villagers, but they had since been replaced by mestizos (people of mixed European and Indian descent). Their costumes included a flat hat, a white knitted mask, a woolen sash across the chest, and the skin of a baby llama on the back. In addition, each dance group was accompanied by one or two dancers dressed to represent bears—called ukukus in Quechua.

At two in the morning on Tuesday I was pulled from the huddle of warm bodies by one of these bear-men. He wore a heavy sackcloth, from which hung strands of black llama wool, and a white knitted mask with a small mirror on the forehead. A llama skin served as a wig. As I stared at this strange apparition, I remembered that I had made arrangements to accompany the ukukus on their night climb up to the glaciers. Hundreds of ukukus were blowing whistles or across the mouths of small bottles, and as we walked the sound reverberated throughout the moonlit valley. After an hour of steep climbing, we stopped at the edge of one of the glaciers and sat down to drink alcohol, chew coca, smoke cigarettes, and talk.
Despite my heavy hiking boots and the down vest beneath my poncho, I was colder than I had ever been in my life. Yet the ukukus sat there calmly, many with only tennis shoes or rubber-tire sandals on their feet. Finally, I asked them if they weren’t cold. “Of course we’re cold,” one replied. “Do you think we’re not human?”

As the glacial snow began to glow orange in the dawn sky, the ukukus rose, and linking woven slings together, they pulled each other in a long, snaking line up the glacier. Kicking steps into the ice, I followed these bear-men, not at all sure that they were human.

In Andean legends the ukuku is the offspring of a peasant woman and a bear. He is an amoral figure who, because he is uncivilized and tremendously strong, is feared by everybody. His grandparents try to rid themselves of him by sending him out on dangerous missions, but he always returns successfully. Finally, he is sent to a town that is terrorized by a condenado (the condemned soul of a person who has committed a mortal sin, such as incest or murder). After defeating the condenado, the ukuku is rewarded with the condenado’s house, lands, and daughter, and he becomes an exemplar of honesty and hard work.

The area around the sanctuary of Qoyllur Riti is said to be inhabited by many condenados who, in Sisyphean fashion, are condemned to climb the glaciers at night carrying a huge chunk of ice. I was assured by the ukuku from Muyomarca that these beings are often seen on the glaciers, the lower halves of their legs mutilated by their constant striving to reach the mountain top. They kill anyone, he said, who comes near them.

High in a frozen moonlit world, following ukukus up the ice, I nearly expected to come across a condenado. And I realized why the ukukus were the ones to climb the glaciers—only they were powerful enough to defeat the condenados and protect the sanctuary. Are the ukukus human? Yes and no. For the point of ritual is to transform people into something that is beyond the human, to make contact with the primordial spirit world.

After climbing to more than 16,000 feet, many of the ukukus lit candles and prayed as the sun rose. They then lined up behind a cross that had been brought up the day before and began to carry it down. At the foot of the glacier they chipped out huge chunks of ice, which they tied on their backs and carried in single file back down toward the sanctuary.

As I walked along, grateful for the warming sun, I saw that there was another long line of more than one hundred ice-laden ukukus descending from a glacier to the southeast. I was told that there used to be bloody ritual battles between the two groups—the qolla and ch‘unchu ukukus—that often resulted in one or more deaths. The blood spilled in these fights was believed to fertilize the snow, but the Catholic church banned the practice. Still, the sacrifice that the ukukus made in

Two qollas, opposite, whose masks suggest the faces of llamas, are part of a group that has planted a cross on the glaciers of Qollqepunku, a sacred mountain believed to recycle fertility and water from the lowland jungle. Some members of the group, below, light prayer candles on the glacial snow. Newcomers to the festival, their costumes deviate from those of the more traditional participants.
Bear-men known as ukukus, right, carry glacial ice and a cross down from the mountain. Peruvian flags are common at Andean festivals, since their colors are traditional symbols of fertility: white for snow, river foam, and semen; red for blood and the muddy waters of rivers in the rainy season. An ukuku, below, bears a chunk of glacial ice, thought to have medicinal and magical powers.

climbing the glaciers at night was a form of penance. Because it entails such rituals of purification, Qoyllur Rit'i is the only traditional Andean festival in which there is no drunkenness.

Back at our campsite, the women melted the ice to make a hot barley drink, which we all shared. Hugging my mug, I tried to make sense of what I had just experienced. I knew that snow peaks were considered to be gods, or apus, and I discovered that Apu Qollqepunku, whose glaciers we had just climbed, was the apu of healing. The ice is therefore sacred medicine that guarantees health during the year. In addition Qollqepunku is a mountain that rises almost straight up out of the jungle. According to Andean cosmology, Qollqepunku is responsible for recycling water and fertility up from the semipermanent rain forests and back down through the rivers that irrigate the crops.

The connection with the jungle was a mystery that haunted me as I followed ch'unchus and qollas away from the sanctuary. While most people went back down to the road, the Moyomarquinos and various other groups climbed up over another pass. In the late afternoon we reached a small chapel, where we stopped to eat and sleep. Whistles and shouts soon awakened me, however, and I opened my eyes to the rising moon. Shaking off my fatigue, I started off on one more night journey.

Beneath the great apus, which shone eerily in the moonlight, at least 1,000 shadowy figures formed a serpentine chain that seemed to link humankind to the gods. Walking behind the feathered ch'unchus, I thought about a local myth that told of the R'awpa machu, the predecessors of the present-day runa. These beings lived in the mountains by the light of the moon, but because of their arrogance, the god Ruwal created the sun, which destroyed many of them. The rest fled to the darkness of the jungle, giving rise to the jungle Indians (ch'unchus), while the Incas—the ancestors of the contemporary runa—took over the new sunlit world. Reflecting that all of the walking that we had done had been by moonlight, I wondered if we might also be headed toward a ritual destruction at sunrise.

As dawn dimly penetrated the frozen fog, I watched the long line of silhouettes pass through the mist: figures with feathered headdresses, strange hats, knit masks; figures carrying religious staves with crosses, wielding whips, hefting huge bass harps, playing flutes. All of them, including the women, lined up on a high ridge, dancing in place as musicians began
to play—first a few, but slowly joined by others on all sides until a great crescendo greeted the dawn and the dancers took off down the mountainside, forming interweaving lines that glittered in the light of the newborn sun. Far from being a ritual of destruction, the dance celebrated the transition from the night world of the awpa machu to sunlit civilization.

On the way to Cuzco that evening I sat in the back of a truck next to an ukuku who had pulled his knit mask over his face for warmth. Staring at the star-shaped mirror that ukukus traditionally wear on their foreheads, I asked him about its meaning. He replied, with a laugh, that if I looked at it I would find out. I saw myself, of course, but as I leaned back I also saw the other people in the truck, as well as the reflections of the brilliant Andean stars. I then fell asleep, puzzling over the mirror and the name Qoyllur Rit'i—The Star Snow.

My search for an explanation was to take me on another pilgrimage—this time through the labyrinths of Andean mythology and Inca history. It also led me into an anthropological squabble over syncretism. The syncretists hold that indigenous and Catholic beliefs have blended together to create a new Andean religion, while their opponents feel that the Catholic elements are merely ornaments pasted on an indigenous religion that hasn't appreciably changed since the conquest. After having climbed the glaciers with the ukukus and walked by moonlight with the ch'unchus, it was hard for me to believe in syncretism.

According to the Catholic church, the festival began with a miracle that occurred in 1780, when a young runa boy named Mariano Mayta was herding lamas in the valley. He suffered from loneliness and hunger, until one day there appeared another boy, a fair-skinned mestizo. The two boys became fast friends, and Mariano's flock multiplied miraculously. When his father saw this, he re-
warded his son by sending him to Cuzco to buy new clothing for both of the boys. Arriving with a sample scrap of his friend’s poncho, Mariano was told that only the archbishop had cloth that fine. When Archbishop Moscoso heard the story, he sent out a commission of church officials to investigate. Coming upon the young mestizo, they were blinded by his radiance. When one of them reached out to grab the boy, he was left holding a wooden crucifix. Mariano, thinking that they had killed his friend, was so griefstricken that he fell dead next to a rock, under which he was later buried.

Interestingly, 1780 was also the year that the indigenous leader Thupaq Amaru II, a friend of Archbishop Moscoso, led a rebellion against the Spanish crown. Because Thupaq Amaru advocated a return to Andean religion, Moscoso turned against him, and the revolt ended in the rebel’s gruesome execution and the repression of Andean customs. Since Qoyllur Rit’i takes place in what was the heartland of Thupaq Amaru’s territory, I wondered if the church had not used the Mariano Mayta legend in the attempt to seize control of a pre-Columbian ritual.

Similar stories lie behind religious festivals throughout Peru and explain a common phenomenon—the worship of rocks in the Andes. Sacred rocks are invested with miraculous powers, often because they are believed to be the petrification of mythical ancestors. The pilgrimage to Qoyllur Rit’i has always entailed the worship of the rock under which Mariano Mayta was supposed to have been buried. In order to eliminate religious confusion, earlier in this century the church had the rock painted with the image of Christ and finally, in the 1970s, constructed a huge concrete temple around it. This image is now called the Christ (or El Señor) of Qoyllur Rit’i.

Digging further back into seventeenth-century documents, I found that preconquest Andean harvest festivals were celebrated in conjunction with the disappearance of the Pleiades. At the end of April, when the earth moves around to the other side of the sun, this cluster of stars disappears from the night skies; it reappears in early June, when the stars are seen to rise at dawn. One name for the Pleiades was onqoy, or “sickness,” and the period of their invisibility was Onqoy Mit’a—a time of transition from one agricultural year to the next, when the earth turned sterile and the life force went into the underworld. The documents also cited complaints by priests that Andean people scheduled their harvest festivals to coincide with Corpus Christi in order to celebrate them under the guise of a Christian holiday. Since Qoyllur Rit’i also occurs at this time, it very likely had its origins in the Onqoy Mit’a.

With this data, I felt I also understood some of the significance of the festival’s
name. Qoyllur ("star") refers to the time of the Pleiades' return, the transition from sterility to fertility. Rit'i ("snow") is the sacred ice that signifies the transition from sickness to health. Similarly, the ukukus symbolize the transformation from savage animal to civilized human, while the ch'unchus reenact the transition from the moonlit world of the ñawpa mapcha to the sunlit Inca civilization. These cyclical transitions through time are reflected in the spatial cycle of energy and fertility from the snow-capped apus down to the jungle and back up again.

Rituals, in order to maintain their vital significance for a people, must also change in accordance with changes in society. At Qoyllur Rit'i the agricultural runa have traditionally represented themselves as ch'unchus, while they used qolla dancers to symbolize the llama-herding peoples from the high plains to the south. The ritual battles between the two groups are based upon historical reality, since famines often pressed the herders to come north to look for land and food.

Under Inca rule, the herders cared for immense numbers of the Inca's llamas and were rewarded with food supplies. After the conquest, however, a great many of these people became accomplished merchants, and their vocation drew them into mestizo society. As a logical development, the qollas at Qoyllur Rit'i are now danced almost exclusively by mestizos. The traditional competition between qolla and ch'unchu has thus evolved into a symbolic battle between the Western market economy and the traditional agricultural way of life. From the runa point of view, a qolla victory would signal the death knell for their pre-conquest religious and ecological vision.

On my eighth pilgrimage, as I watch the Peruvian in the down parka lose himself in the crowd, I wonder if the qollas aren't winning. The festival itself seems to be going through a transition—from Andean indigenous ritual to a combination of mestizo Catholic pilgrimage and tourist spectacle. I am given more reason to believe this as I sip hot ponche, a drink made from fava beans, in a makeshift restaurant of cut sod walls roofed with canvas. The number of these structures has increased each year. As I puzzle over how the industrial kerosene stove was brought up the mountains, a drunken mestizo in a three-piece suit asks me how many years I have been attending the festival.

I answer by asking why he asks, and he tells me that the more years I attend, the more miracles the Christ of Qoyllur Rit'i will perform for me. I find that he owns a small fleet of trucks and hopes to double their number. He is therefore sponsoring a brightly costumed group of nontraditional dancers from Puno, where he lives. This town is far to the south, and the dance group began to participate only seven years before. I refrain from mentioning that El Señor frowns on drunkenness and leave to find a place to set up my tent.

To get across to an open field, I have to go through an open-air market of machine-made goods, spread out across the valley floor on sheets of blue plastic. This is the first time that most of these merchants have come to the festival, so I imagine that it will be several years before El Señor will help them with their sales. Among the goods—everything from cooking utensils to baby dolls—are large quantities of tiny houses, television sets, automobiles, and trucks. These miniatures are traditionally found in religious festivals of the south. They have been brought here by merchants because many people believe that the purchase of one of them at a holy site means that the real thing will be acquired during the year. The idea stems from the pre-Columbian belief that certain stones in the shape of llamas or ears of corn contain the force that insures the fertility of livestock and crops. This is also the essence of the power of the sacred rock of the Christ of Qoyllur Rit'i.

As I pass by the toy trucks (miniatures of the ones my friend from Puno so desires), I realize that the festival is indeed becoming syncretic—but on a triple level. The Andean beliefs in fertility stones are being mixed with a capitalist fetishism that depends in turn upon the Catholic belief in the miraculous powers of Christ to assure material success.

As it gets dark, I observe that brightly colored tents occupy almost all of the dry camping ground available. A variety of backpackers share the ground with anthropologists, tourist groups, and three foreign movie crews. After wedging my tent in between several others, I find it difficult to sleep. The church loudspeaker constantly blasts out sermons interspersed with lists of the names of people who have
In recent years, merchants from the south, opposite, have begun selling toy trucks, houses, television sets, and other miniatures at the Qoyllur Rit'i festival. Many believe that purchasing such replicas at the pilgrimage site will help them obtain the real objects during the following year. Two men, below, display the items they hope to acquire. The possession of a truck for commerce is one of the few avenues to wealth for people from their region.

The next morning a group of mestizos Peruvians confront me, complaining that I am camped on a site they have used for four years. Do the eight years’ attendance of a gringo take precedence over the four years of Peruvians who also have no traditional connections to the festival? Whose ritual is this? Whose will it be in the future? Fortunately, we all recognize our alien status and make room for one another, as best we can.

During the day I notice that not only are there fewer ch'unchus than in previous years but also that there are fewer people altogether—perhaps no more than 5,000. Since the numbers of nontraditional mestizo dance groups and pilgrims have greatly increased, far fewer runa must be attending. On the lowest glacier young mestizos hurl snowballs amidst screams and laughter. In the afternoon, when the icon of El Señor is brought out for the procession, the Puno dance group is the first to follow it—a place that has always been reserved for the ch'unchus. And the next morning, when the ukukus come down off the glaciers, they are accompanied by numerous mestizos and gringos who seem to have no idea of the danger of the condenados.

Speaking to a church official, I discover that, along with several tourist agencies, the church has been considering the construction of a road up to the sanctuary. Isn’t this supposed to be, even in Catholic terms, a pilgrimage that entails penance and sacrifice? I ask. The official replies that the more pilgrims who can attend Qoyllur Rit'i, the greater will be its Christian influence.

Fortunately, no road is going to be built on the footpaths that lead through the isolated tundras to the final sun dance, and very few tourists or mestizos are prepared for the rigors of this trek. However, bad weather the year before led the Brotherhood to cancel the night walk because of the danger of icy descents. As far as I can determine, it was the first time in history that the walk had been cancelled, even though other years had seen equally bad weather. Safety is not a major concern in traditional rituals, since pain and even death may be sacrifices that insure health and fertility on a much larger scale.

Happily, the sun shines strongly this year, and I find myself walking again with the people from Moyomarca. When we stop to rest before the nighttime leg of the trek, I plunge with gratitude into the communal warmth of their bodies, and eight years of change are washed away. However, as we are eating, a member of the Brotherhood calls one of the Moyomarquinos away. He wants to know who I contributed money to the Brotherhood of Qoyllur Rit'i, a lay group formed in 1960 to serve as guardians of the festival. This has the secondary (or is it primary?) effect of drowning out the indigenous music. And many of the dance groups themselves are now accompanied by hired brass bands, which also overwhelm the more traditional flutes and drums.
am and what I am doing there, and he also demands a financial contribution from the villagers. Every year fewer runa come—not only because of the increased expense of preparations and transport, but also because of these demands for money on the part of the Brotherhood.

The Moyomarquinos aren’t sure if they will continue to send dancers for long. A road is being built to their village, and more young people are attending school and finding jobs in town. Sponsoring the festival used to bring prestige, but many of the villagers now prefer to spend their money on radios and other goods. Still, they say, it is impossible to imagine not coming—the Christ of Qoyllur Rit'i assures health and the fertility of the crops. Without this, no one would have any money at all.

I think about all of these changes as I follow the Moyomarca uuku through the frozen moonlight. When we stop to rest, he turns to offer me coca, and I briefly catch my reflection in the mirror on his forehead. Whatever the true meaning of this mirror, I suddenly see it as a symbol of how Qoyllur Rit'i reflects the complex changes affecting Andean society. The qolla merchants, the tourists, the mestizo pilgrims, the priests, the anthropologists—all influence the festival to the degree that they have influenced Andean culture as a whole.

At dawn, the dancers are again lined up, waiting for sunrise. The director of a French film crew walks up to one of the ch'unchus to position him in a better light. “There, just like that! Perfect!” he says in Spanish. “Now dance! Dance!” As he passes me, he asks in English, “Aren’t they magnificent? Have you ever seen anything like it?” “Never,” I shake my head sadly.

One of the Moyomarquinos grabs my arm. “Chaki, chaki!” he shouts in Quechua, meaning that I should begin the prancing dance step. Before I can say anything, I am dancing down the mountainside, following through the intricate patterns in a haze of elation. As the sun rises on a new world, I have to believe that runa traditions are still strong enough to survive the incursions of the qollas.
After a final, moonlight trek up into the mountains, dancers and other pilgrims prance down the slopes, greeting the morning sun. The event recalls the legendary dawn of Inca civilization.
The Bird That Farms the Dell

Australia's bellbirds cultivate and jealously guard a sugary resource

by Richard H. Loyn

The Dandenong Ranges near Melbourne offer a landscape of green hills, misty valleys, and a patchwork of native eucalyptus forests, fertile farmland, and red-soil market gardens. From forests across the hillsides come the tinkling calls of bell miners, a species of honeyeater commonly known as bellbirds. The scene is peaceful, and the calls of the bell miners are an integral part of its charm. But enter a large colony of bell miners, approach the birds more closely, and the tranquility is lost. The mellow distant tinkling becomes a cacophony of metallic noise interspersed with shrieks and squeals. There is no mistaking the message: this is bell miner territory. Trespassers get out!

The aggressiveness of bell miners is legendary. Theseanager-sized birds weigh only about an ounce, but will fearlessly attack much larger birds, including parrots, kookaburras, and even herons, gaining up, if necessary, to expel them from bell miner territory. Communal combativeness is only one facet of the bird's ecology, and more is being unraveled.

Long before I began my study of bell miners and the eucalyptus forest, many observers had noted an association between bell miner colonies and eucalyptus dieback. Wherever bell miner colonies were found, trees looked unhealthy and foliage was sparse. This connection was apparent throughout the bell miners' range in southeastern Australia, mainly broad foothill gullies with mean annual rainfall of thirty to sixty inches. One local theory held that bell miners were killing the trees by carrying a disease on their feet. Defenders of bell miners quickly countercharged that insects were killing the trees and that the insectivorous bell miners feeding in infested areas were possibly helping to control the pests. What was the real connection between the birds, the insects, and the trees? Were bell miners the villains or were they the heroes? As we eventually discovered, there was no black or white answer; the truth was complex and far more interesting than either of the factions had imagined.

A number of agents can be involved in eucalyptus dieback, including many species of defoliating insects, root-rot fungi, and domestic stock. In the gullies inhabited by bell miners, the main agents are several native insect species known as psyllids. As nymphs, psyllids attach themselves to leaves and feed by sucking sap, with the result that leaves fall prematurely. Nymphs excrete a sweet honeydew on which a black, sooty mold often grows, further damaging the foliage by obscuring the light. The nymphs grow by undergoing molts, eventually becoming winged insects. The nymphal stage occupies the longest portion of the psyllid life cycle, and several generations of psyllids are produced each year.

Various psyllids are found on particular species of eucalyptus trees, notably narrow-leaved peppermint, messmate, swamp gum, and manna gum, which commonly grow in the foothill gullies inhabited by bell miners. Psyllids are distributed worldwide, but a special feature of many Australian species is the sweet carbohydrate cover, called a lerp, that the nymphs build over themselves, apparently to protect them from dryness and other rigors of the environment. As nymphs grow, they "shed" their outgrown lerp and generate another. Large, shed lerps often fall to the ground and are so nutritious that aboriginal people are said to have collected them as food. Bell miners also prize lerps. Sometimes they eat both the nymph and the lerp, but often they carefully remove the lerp with their bill and tongue, leaving the nymph to grow another, equally nutritious lerp in one or two days.

Were bell miner feeding patterns responsible for the vigor of the psyllid population and indirectly the cause of tree damage? What role did the bell miners' notorious territoriality play? One way of clarifying the role of bell miners would be to move an entire colony and observe the effect of other, previously excluded birds on the insects and trees. By chance, this was accomplished by a local landowner who believed the story of bell miners killing trees and illegally shot the small colony occupying his property. Fortunately, he was observant and noticed that flocks of other birds soon arrived and began to eat the psyllids. After a while few psyllids remained, and the trees recovered. He re-
An Australian bell miner plucks a lerp, a sweet carbohydrate cover manufactured by an immature psyllid insect, from an infested leaf.

Ralph and Daphne Keller; Australasian Nature Transparencies
ported this to the local forestry office and hence to me at the Mountain Forest Research Station. With two colleagues, I decided to see if I could confirm the landowner's results by repeating the experiment. We selected a small colony of thirty-four birds for the first experiment. We caught them in mist nets and later released them thirty miles away in a larger area of suitable habitat with a preexisting colony of bell miners. Luring them into the nets required various ruses, including the use of taped calls. In the hand, the birds were as aggressive as they were in the bush, fighting and scratching with their orange feet if given half a chance. A juvenile calling from a net attracted cohorts of adult birds to its defense.

Even before we had caught the last bell miner other species of birds were flying in. The last bell miners tried vainly to expel them but were no longer able to defend the territory effectively. Gradually they stopped using the resonant bell calls and just screamed desperately as the intruders took over. The newcomers feasted on psyllids at a much greater rate than the bell miners had done, and after two months few psyllids remained. Most of the birds then departed, and now, both bird and psyllid populations were sparse and similar to those in adjacent healthy forest. We repeated the experiment several times, and except where nearby colonies of bell miners were able to occupy the vacated territory, the results were similar.

Before we removed the bell miners, the only other resident birds had been the few that could hide in dense understory, such as white-browed scrubwrens and eastern whipbirds. These birds knew how to survive in bell miner colonies, and their numbers remained about the same throughout the study. The incoming birds, however, belonged to many species, and the exact composition varied slightly between experiments. The main species were common forest insectivores, and in the two months following bell miner removal, the foliage was alive with small birds, such as spotted pardalotes (something like titmice), striated thornbills (abundant birds that feed like kinglets), and white-naped honeyeaters (which eat insects as well as nectar and honeydew). Even these small birds ate psyllids at a faster rate per bird than did the bell miners, suggesting that they were less selective and more inclined to take the small psyllids and lerps ignored by bell miners. And unlike many bell miners, they often pecked twice—once to take the lerp and once to take the psyllid nymph—leaving the nymph behind on relatively few occasions.

More surprisingly, flocks of parrots also appeared. There were crimson rosellas, a
common parrot of the forest, and eastern rosellas, more typical of open country. Rosellas usually feed on seeds, fruit, and buds, but here they ate psyllids, plucking an infested leaf, holding it in one foot, and scraping it through their bills to remove the juicy insects and lers. Per bird, the parrots' impact on the psyllid population was several times greater than that of the smaller, more numerous species. A few bark-gleaning birds—treecreepers and varied sittellas—also arrived and began cleaning up other insects along the trunks and branches.

When psyllid numbers crashed, the canopy fell silent, although a few insectivorous birds continued to visit the trees. In the next four years, psyllid populations remained low. The trees developed an impressive growth of new foliage and within two years appeared as healthy as the surrounding forest, with but a few dead trees remaining as a reminder of past trauma.

These observations helped elucidate the nature of the relationship between bell miners and dieback, with bell miners protecting the agents of this particular dieback, the psyllids, against predation by other birds. The bell miners made clear what we could hardly have demonstrated experimentally: that trees sicken and die when birds fail to control enough insects and that common forest birds can be very effective in restoring infested trees to health. While we had no way to enclose 100-foot-tall trees with bird-proof fences, the bell miners did it for us. Although they were insect predators themselves, by eating mainly lers and conserving nymphs, the bell miners failed to prevent or reverse a substantial buildup of psyllids.

Bell miners succeed in establishing and protecting their own rich food supply. This resource, the carbohydrate lers, would be scarce without the bell miners. Other birds immediately devour the lerp, plus the potentially productive nymph. Although defense of food supply is a function of territoriality in many animals, it rarely has such visible and demonstrable effects as in the bell miners' case. The birds that controlled psyllids in our experiments may have been practicing some degree of resource conservation in their own breeding territories, at a much lower level, but evidence is lacking. Perhaps they merely defend territories large enough to supply food at a rate determined by interactions—beyond their control—among insects, plants, and the environment.

Bell miners are true farmers: their territoriality turns the trees into producers of bird food via psyllids, but at the forest's expense. The bell miners achieve this goal by excluding other birds from their territories; occupying enough space that their own pressure on psyllid populations is controlled; avoiding eating small psyllids; and specializing in eating lers and honeydew rather than the psyllid nymphs themselves. Even in bell miner colonies, however, psyllid populations fluctuate. When numbers drop, bell miners feed more on other invertebrates, including spiders and various insects in the foliage, bark, and air. They also drink the nectar of eucalyptus and shrubs, although they are less skilled at this and less successful at defending flowering trees against other honeyeaters.

In the short term, this pattern of behavior is clearly advantageous and perhaps even vital to the bell miners. But over a period of years, trees may deteriorate so much that they can no longer support the necessary level of psyllid infestation. At this point, numbers of psyllids and bell
miners begin to decline, and the habitat is eventually abandoned, leaving an ugly collection of sick or dead trees. More often, bell miner colonies move before such a drastic situation is reached. A colony may progress along a creek or other suitable habitat, advancing on one front and allowing other psyllid-eating birds to occupy the vacated territory in its wake. In effect, the system is roughly analogous to a form of shifting agriculture, with psyllids and their renewable products (lerps and honeydew) being defended, managed, and harvested at a site until that site is no longer capable of supporting the required level of production. Then other birds (hunter/gatherers) move in and reduce the psyllid populations to original low levels. The bell miners develop new populations of psyllids as they progress, even if they have to leave some of their psyllid herds behind to be ravaged by the barbarian hordes.

Some bell miner colonies have been reported to remain in one place for as long as forty years, so there may be some environments in which trees can support a continuous high level of psyllid infestation. Some of the long-lived colonies, however, are in suburban habitats where other sources of food, such as flowering shrubs, are more important to the bell miners. In other cases, the colonies may be moving back and forth, allowing part of the habitat to “lie fallow” while other birds restore it to health. One of several birds that help perform this role in the Dandenong Ranges is the helmeted honeyeater, a rare endemic subspecies of the widespread yellow-tufted honeyeater. Living mainly on the edge of bell miner colonies, it is larger and brighter than the typical subspecies. These characteristics may have evolved partly as an adaptation to frequent fights with bell miners.

The bell miners’ system requires that the members of a colony cooperate in defending the territory and deterring other birds through sheer volume of sound. The system breaks down when bell miner numbers are reduced below a certain level, and presumably it would also break down if a population explosion put too much pressure on food supplies. Thus, as with all territorial animals, recruitment of young cannot be allowed to exceed a colony’s ability to expand into new territory. This may not pose major problems in continuous forest, where bell miner colonies occupy only a small portion of potential habitat. We do not yet know what mechanisms control population and recruitment in bell miners, but we do know that they have a communal breeding system. A bell miner colony consists of a number of clans, and when not jointly expelling persistent intruders or predators, birds from each clan occupy a home range. The birds nest throughout the year (but mainly in spring), and nonbreeding “helpers” often assist simultaneously at several different nests.

Recently Michael Clarke of Melbourne University found that helpers give more food to young birds that are closely related to themselves. This provides strong evidence for the operation of kin selection, that is, selection for behavior favoring close relatives. Clarke and others noted several reasons for bell miners abandoning colonies, including disease, encroachment by noisy miners (another aggressive honeyeater species), and attacks on psyllids by other insects. The fledging success of bell miners was found to be high (80 percent), although only 30 percent of nestlings remained in a colony after three months. Whether the other 50 percent died or tried to join other colonies remains unknown, but bell miners would most likely face grave difficulties outside the parental colony, while on their own turf, bell miners’ behavior actually helps to create suitable habitat.

So far our work has shed light on the interaction among bell miners, psyllids, and dieback, although we have not explained how bell miners regulate their numbers in a healthy, slowly moving colony. More importantly, we have not explained what determines the distribution and abundance of colonies or the severity of associated dieback or how the birds, insects, and trees coevolved.

Our findings—in some ways a guilty verdict for the bell miners—attracted local publicity. But the last thing we wanted was for the birds to fall victim to a barrage
of buckshot. Even though an especially valuable patch of forest suffering severe psyllid-induced dieback might be saved by removing bell miners, many other factors are also involved. Fortunately, the public was presented with a balanced view, emphasizing the value of other birds and the complexity of the forest system. The birds remain protected.

The role of other factors was underscored in mid-1983, when after two years of severe drought, the rains came, heralding a dramatic decline in psyllid populations. Bell miner numbers declined in parallel, as did those of some of the other psyllid-eating birds, such as pardalotes. During dry periods, trees under stress accumulate nutrients, such as nitrogen, in the foliage, and work in New South Wales has shown that this favors psyllid growth. The reported increase in bell miners in the Dandenong Ranges since about 1940 may owe much to the diversion of water for agriculture, leaving trees more susceptible to stress, especially during drought. Bell miner colonies in continuous forest are more localized and the effects of dieback less severe.

The rain was a healing in many ways. The effects of dieback became less evident, partly because there were fewer psyllids but perhaps also because trees were better able to continue growth despite infestation. Some bell miner colonies that had been stationary during the drought (with serious effects on the local trees) now began to move. This suggests another possible consequence of forest clearing. If, when forests are cleared, bell miner colonies become “trapped” at the end of a strip of forest and cannot easily progress into new areas, the trees in that strip will suffer. Also, bell miners can defend their territories more easily when surrounding forest has been cleared, and this may have swung the balance in their favor, again to the detriment of their patch of trees. In drier, more open country, noisy miners specialize in occupying such easily defended habitats. In either situation, habitat deterioration is more likely in a broken strip than in intact forest.

Many other factors could have altered the long-term balance in the settled environment of the Dandenong Ranges. Populations of competitors of, and predators on, bell miners have changed since human settlement began. There are now fewer goannas, or lace monitors; fewer snakes; no large native carnivorous mammals; but there are abundant feral carnivores, such as cats, dogs, and foxes. Pied currawongs—omnivorous jaylike birds—breed in continuous forest nearby but are found within the Dandenong Ranges only as winter visitors; they prey on nestlings, and in winter, flocks sneak quietly into bell miner colonies to eat psyllids, before fleeing with much noisy yodelling when the bell miners notice them. Arboreal mammals such as sugar gliders, which forage unmolested by the birds at night, include psyllids in their varied diet, but although they remain common, these mammals do not appear capable of reducing infestations. Introduced birds such as starlings have become abundant and compete with hole-nesting rosellas for nest sites, yet rosellas are still fairly common too. Any of these agents may have affected bell miner numbers and psyllid populations.

As a practical matter, we have found that overabundant bell miners and psyllids can be reduced locally by slashing or burning the understory and inducing bell miners to move with their psyllid herds to shrubbier forest with better nesting and roosting sites. But this solution is itself a problem and is appropriate only on a local scale. In general, we need more, not less, understory to attract insectivorous birds, especially in small patches of grazed forest in farmland, where populations of insectivorous birds are low and dieback from insect attack is a serious problem without any help from bell miners. Nevertheless, burning patterns always change with human settlement, and wildfire may be a major natural agent of control for bell miners. In February 1983, several bell miner colonies were burned in disastrous forest fires. While some individual bell miners survived, they were unable to remain in the barren, blackened waste that was once their forest.

We need a sense of humility. Human attempts to alter natural phenomena are often feeble and possibly irrelevant. The impact of a change in weather or a severe wildfire, for example, is often far more important. And in the meantime, the bell miners continue doing what they have always done, instinctively managing the mobile insect “farms” with which they coevolved and adding music to the hills until their territory is encroached upon and their pleasant tinkling becomes a call to arms.
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From Platter to Plate

Nouvelle cuisine has given us a new way to get dinner to the diner

by Raymond Sokolov

As foreigners horning in on France’s nouvelle cuisine, we are paying tribute to a very tricky change in another culture. But given the lead position that French cooking holds throughout the West, when the French turned themselves inside out in the seventies, advanced sectors of our own restaurant and catering world joined the bandwagon. There has been much confusion about the nouvelle cuisine; its claims of newness and simplicity proved problematic. The cuisine wasn’t really new but rather a fresh, almost perverse look at tradition. The rigid menu code of the past was subverted so that established terms came to mean something new. Words associated with meat, terrine, for example, were applied to vegetables. A navarin was no longer a stew of lamb but of lobster. The new dishes were innovations, not subverted out of a metaphysical shift in the conventional French food lexicon.

But the “new” cuisine’s special flavor could not be easily detected by people who were not steeped in the lingo of what had come before. To Americans, a lobster navarin was an entirely new creation, not an amusing edible pun imaginatively rooted in old-fashioned home cooking. This type of misperception led chefs to experiment with utter freedom and to produce anarchy at table. That period has largely passed, and we are now seeing the authentic metaphorical approach of the nouvelle cuisine applied to our traditions.

As for the cuisine’s other claim to fame, simplicity, here, too, confusion reigned. And still reigns. The ingredients are not simple but rich and often exotic. Their preparation is as intricate as anything in the old cuisine and mostly beyond the skills of a nonprofessional. Heavily reduced stocks without flour thickening are perhaps less tedious to prepare than the old flour-bound espagnoles, but they are out of the reach of all but the most obsessive home cooks. And the meticulous artistic arrangement of food on each dinner plate—the most obvious sign of a nouvelle cuisine dish—is the reverse of simple. Just compare this style with a plate of roast beef and two vegetables.

Perhaps that example is confusing be-cause the roast beef plate sounds heavy and the carefully arrayed nouvelle cuisine plate would have less on it and would be lighter. But it is certainly possible to think of traditional dishes that were austere but artlessly presented, such as sautéed fish with French fries, and nouvelle cuisine dishes that are rich yet visually graceful, strips of rare duck breast set in a mirror of purified brown sauce.

Nouvelle cuisine will almost always please the eye or at least force one to consider each new plate as a visual composition. The emphasis of the new method is on the look of the plate. The old cuisine put its visual emphasis on the look of the platter from which portions were derived. To get the complete picture, look at the dated color illustrations in the Larousse Gastronomique. You will rarely see an individual plate about to be set in front of a guest. Instead, there are platters contrived with decorative garnishes—artichoke bottoms filled with foie gras, crayfish eating their tails, and so forth.

Eventually, these edible tableaux were carved or otherwise parcelled out to individual diners. But by then the logic of the dish had been somewhat lost. For in this style of service, which lent itself best to banquetts, a waiter brought out each course on a platter or cart, exhibited it in the form it was meant to be seen, and then distributed it on plates. This method of getting food to the table was called Russian service. Was it really Russian? I have no idea. It emerged as a radical dining reform in the nineteenth century, triumphed and held sway in luxury establishments right into the 1970s.

Russian service depended very heavily on the labor of waiters. In establishments that practiced this method to the fullest, meals were served on a platter, banquet style, even if the diner was eating alone and had ordered something that could just as easily have been put intact on a plate in the kitchen and brought right to the table.

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**Oxtail Soup**

Two recipes for a first course at a January 1867 dinner for eighteen described in Mrs. Beeton’s Book of Household Management. (The soup is “removed” by the fish. The recipes are adapted freely from Mrs. Beeton. Quantities, as noted, are not for eighteen persons.)

1. Oxtails
2. Slices ham, diced
3. Tablespoons butter
4. Carrots, scraped
5. Turnips, peeled
6. Onions, peeled
7. Leek, trimmed, halved lengthwise, and washed thoroughly
8. One bunch celery
9. ½ teaspoon dried thyme
10. Sprigs parsley
11. Bay leaf
12. Whole black peppercorns
13. Cloves
14. Tablespoon salt

1. Cut up the tails. Wash them and put them in a stew pot with the butter over high heat. Brown on all sides. Add ham and brown.
2. Lower heat to medium and add the vegetables. Brown. Add thyme, parsley, bay leaf, peppercorns, cloves, salt, and 3 quarts water. Bring to a boil, skim, and lower heat so soup simmers. Cook 4 hours or until tails are tender.
4. Before serving, return soup to the boil, add tails, and simmer five minutes.

Yield: 10 servings

**Fried Filet of Sole**

1. 10 sole fillets
2. 3 egg yolks, lightly beaten
3. Bread crumbs
4. 6 tablespoons butter
5. Parsley
6. Lemon wedges

1. Dip each fillet in the egg yolk and then dredge in bread crumbs.
2. Melt butter in a 10-inch skillet. When foam subsides, sauté fillets over medium high heat until just cooked through.
3. Serve garnished with parsley and lemon wedges.

Yield: 10 servings
Instead, the sole meunière would be presented in a serving dish, then transferred to the plate at a buffet or rolling table near the dining table. The waiter might bone the fish and then add the sauce. Often, waiters performed crucial finishing stages of actual cooking at tableside. Despite all its elaborate to-and-froing, Russian service was originally considered a radical simplification of the form of service it replaced: French service.

French service evolved out of the smorgasbordish anarchy of medieval dining—a table-oriented, self-service meal with a bewildering number of dishes. Onto this basic structure was grafted an exceedingly complex order of, and service within, courses. Each stage had its own French name, and these names, slightly altered in meaning, came into English toward the end of the eighteenth century.

Roughly speaking, French service began as seven courses, collapsed for convenience into three that still included the separate categories of food from the original seven. The first course came in two stages: soup was served first or second; soup was set down in tureens at the corners of the table with hors d’oeuvres or side dishes next to them; when the soup was finished, it was removed and replaced with fish and entrees, which were lighter dishes that served as the entry to the next, main course. The dishes after the soup were called relevés, because the soup was "removed" by them.

The second French-service course contained, at a minimum, the rôts, or "roasts," sometimes called grosses pièces or pièces de résistance (because you had to wait for them). There followed entremets (literally "between foods"), other lighter concoctions that prepared for the third course, what we would call dessert. Dessert is the past participle of the verb desservir (to clear the table) and is the food you eat after the plates from the rest of the meal have been taken away. Over time, these categories shifted in meaning, and two of the terms came to be applied to the courses or types of food they had originally introduced. Entrees became main courses instead of their preludes, and entremets, similarly, became dessert. It appears that French service confused even those who had grown up with it.

Even in great houses with many attendants, meals with dozens of separate dishes were prone to mismanagement. As Abraham Hayword wrote in the 1830s:

"Servants, meaning to be very polite, dodge about to offer each entree to ladies in the first instance; confusion arises, and whilst the same dishes are offered two or three times over to some guests, the same unhappy nights have no option of others... Where there are more than four side-dishes besides flanks and removes, the entrees ought to be in duplicates at opposite corners. The true principle is few entrees but well-filled dishes; for if the entrees are first rate, the presumption is that each guest will eat of each. The [newer] service à la russe divides the opinion of the best judges; but once we saw it most pleasingly and originally put in practice..."

It took most of the rest of the century for Russian service to sweep away French service. With French service perished the simultaneous profusion of dishes, the architectural table decoration, and the sculptural set pieces that had marked the grandiose age of the first and greatest modern chef, Carême. Russian service, championed in the 1860s by the influential chef Félix Urbain Dubois, allowed people to eat one dish per course.

As a result, chefs turned to perfecting each individual dish, instead of concentrating on an array of dishes. This led to multiple garnishes and platters bristling with ancillary foods that were minidishes in themselves. In less than a century, dissatisfaction with these overdone platters led to a further reduction in the scale of food presentation. The nouvelle cuisine restricted itself to the individual plate.

One stage builds on the next. There is no discontinuity, no revolution. Nothing arises from nothing. Every so often, the chefs clean house in the name of simplification and then find new ways to complicate their task.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.
What Is a Whooping Crane Worth?

by Bryan G. Norton

As our society goes busily about the task of economic development, and in the process destroys the habitats upon which wild but economically useful species depend, it is essential that we have a measuring stick by which to gauge some of the fallout. But how does one gauge the value of wild species? Finding ordinary concepts of "worth" and "value" unquantifiable, economists and resource analysts face a difficult choice. Should they abandon the task of providing quantified answers that represent the value of wild living resources? Or should they reformulate the question so that it includes only those values for which reasonably hard, quantified data are available?

There are important reasons for collecting and analyzing the available quantifiable data. As Christine and Robert Prescott-Allen explain in their book, *The First Resource*, "Decisions are made on the basis of comparisons, and comparisons are made largely on the basis of figures." According to this reasoning, it is better to provide some quantification of benefits, however incomplete. Otherwise, the values of wild species will simply be ignored.

The Prescott-Allens have collected and analyzed huge chunks of hard data and produced a tour de force of data collection. Table 7.2, for example, provides in twenty-two pages of detail the "Periods of Domestication and Average Annual Values (1976–80) of 226 Crop Species Grown or Imported by the United States." If you want some basic or not-so-basic fact on the commercial exploitation of wildlife, you are more likely to find it in this book than anywhere else. I, for one, never knew that "half the entire U.S. output of sodium alginate is...used as a stabilizer in ice cream and as a suspending agent for milkshakes" or that an average of 908,961 Virginia opossum pelts were harvested in the years 1976 through 1980 and that their dollar value was $2,104,000. The Prescott-Allens are also inventive in drawing inferences from facts never before compiled in usable form. Some of this information is extremely important, such as: "After Canada, the biggest supplier to the United States of timber products is the tropical rain forest region of Southeast Asia." They also point out explicitly the considerable gaps in our knowledge of living resources.

While few will work their way from cover to cover, *The First Resource* is an important reference work. It rewards casual browsing with engrossing and charming facts, organized according to general commercial uses of wildlife (logging, fishing, trapping and collecting, wild genetic resources, pollination and pest control, and recreation). But the book's true value will be realized in the future. The authors have provided a systematic framework and an initial set of figures, baseline data against which we can measure future changes in the productivity of industries that use wild species. *The First Resource* fills an enormous void in the literature on resource analysis.

Despite the almost mind-numbing factual detail, the authors note that "the book is not intended to be comprehensive: we have limited its scope by focusing only on...those contributions at the levels of species and gene to which dollar values can readily be assigned." Since their data are based on actual purchases for specified years (1976–80), other uses and values of wildlife are unrepresented—for example, "ecosystem services" (benefits such as oxygen production, which we don't pay for) or just knowing that whooping cranes exist. The Prescott-Allens are well aware of these limitations. Their first chapter is a wise and humble discussion of exactly what their data show and do not show.

Because *The First Resource* includes only benefits represented in products and services that are sold in the marketplace, it is, strictly speaking, a commercial, not an economic, analysis. A full-fledged economic analysis, representing the full value that would be lost if a particular species were extinguished, must also include values for ecosystem services, the aesthetic and moral feelings the species evokes, and benefits from future uses of the species. If the species is lost, citizens would have to purchase these benefits from other sources or else experience correspondingly poorer lives. Economists must accordingly use "contingent valuation techniques" to assign figures to these benefits. Typically, they use questionnaires to determine what citizens will pay to protect the benefits involved, treating these amounts as stand-ins for actual payments.

The difficulties of setting a contingent value for a living resource are many. Consider the example of future-use benefits. Extinction is irreversible. If we decide to have a dam and give up a species, blowing up the dam will not bring the species back. Therefore, if we are to assign a value to future uses of a species, we must include uses that may emerge as a result of scientific and technological advances. These would be factored into a species' "option value," that is, the present benefit of holding open the possibility that a species we might eradicate may prove useful in the future. Setting option values thus requires citizens to indicate what they will pay to hold open unknown options.

Another problem is that economic analyses tend to consider species in isolation from their habitat. But species do not exist independently; they have coevolved in ecosystems. Consequently, even species that have no identifiable uses have value—they contribute indirectly through their support of other, useful species. Contributory values are especially difficult to evaluate because ecologists know little about the complexities of interspecific dependencies. Since we depend for our livelihood on communities of species and the benefits they provide, evaluating species in isolation may prove self-destructive.

By concentrating only on commercial values during a fixed period of time, the Prescott-Allens avoid many of the difficulties faced by economists who attempt to assess noncommercial use values, option values, and contributory values. More complete economic studies can use the Prescott-Allens' solid data as a point of
departure for the development of more adventuresome speculations about the value of species.

But in spite of the importance of the Prescott-Allens' data, some readers (including this one) will react to their book with considerable ambivalence. It is alarming to think that resource analysts may use quantified data—whether the hard but radically incomplete data presented in this book or the more complete but highly speculative data of full economic analyses—to determine which species shall be protected and which shall be let go. The authors, in their own call for preservation, hedge their bets: "The best preparation [for unpredictable events, both biological and socioeconomic] in the context of wildlife use is to have a safety net of diversity—maintaining as many gene pools as possible...." But then they add, and this is the worrisome suggestion, "particularly within those wild species that are economically significant or are likely to be." In September of last year, the Smithsonian Institution and the National Academy of Science jointly sponsored a National Forum on Biodiversity. One panel discussion was devoted to the questions, what is the value of biodiversity, and should it be evaluated in quantifiable terms? The panelists' answers fell into three broad groupings. Several economists argued that since decisions tend to be based on quantified assessments of costs and benefits, species preservationists should offer the best available dollar figures. The ecologist in the group, David Ehrenfeld, argued in opposition that species preservationists can make their strongest argument on moral grounds. He believes that proposing narrow or questionable dollar figures only confuses the clear moral case supporting maximal efforts at preservation. A third group, in which I count myself, argued that there is some value in providing quantified analyses of benefits for certain purposes, but cautioned that we must never forget that these evaluations represent only a pale approximation of the real contribution of wild species to human welfare.

Making decisions about preservation on the basis of commercial considerations is especially frightening when one considers the value of commercially useless species and that we ourselves depend on functioning ecosystems for survival. The situation brings to mind a fanciful analogy. Consider the following scenario: I have been in a terrible accident, and I wake up in a hospital bed on a life-support system. The hospital is short on funds, and its administrators are having a meeting at my bedside. They areproposing to sell a few spare parts from my life-support system at a yard sale. One of them says, "This equipment is so complicated, a few parts won't be missed." "How much do you think this part is worth?" asks another, pointing toward a piece of shiny metal. I try to see what the part is connected to, but it is screwed into a big metal box that looks important. "Or that one over there; it looks like it's just cosmetic," still another suggests. I almost agree, and then I notice that a main power line passes through it. "Stop! Not that one," I say. Just in time.

To treat the valuation of biodiversity as a search for hard data or as a set of interesting theoretical problems in welfare economics is one thing. But it is quite another to suggest that these incomplete or speculative figures provide a basis for decisions that will affect the functioning of the ecosystems on which we and our children will depend for life.

The Prescott-Allens do not discuss in detail the uses to which their data may be put. The concern then is not with the quality of their material, or with their own sensibilities about how to use it, but with the temptation of others to latch on to incomplete information and use it to make decisions our children may regret.

Bryan G. Norton, professor of philosophy at New College of the University of South Florida, has written extensively on environmental ethics and on attitudes toward wild species. He is the author of the forthcoming Why Save Natural Variety? and the editor of The Preservation of Species: The Value of Biological Diversity (both published by Princeton University Press).
Garden of the Gods, Illinois

by Robert H. Mohlenbrock

On hot, sultry summer days, a blue haze often hangs above the densely wooded hills of southern Illinois's Shawnee National Forest, providing an appropriately unearthly backdrop to a fairyland of rock formations known as the Garden of the Gods. Camel Rock, Monkey-face Rock, Anvil Rock, and Devil's Smokestack are some of the fanciful names visitors have given the shapes that make up this sparsely forested area. The rocks are of sandstone, laid down more than 300 million years ago, when the area was washed by an inland sea. A mantle of windblown soil subsequently covered the sandstone, but much of it has worn away, exposing the bedrock to erosion. One rock has been ground down to a perfectly flat surface; it is called Table Rock.

The exposed sandstone erodes very slowly as the iron oxide that cements the sand particles together gradually dissolves. Where water has moved along joints and bedding planes, tiny crevices have expanded into fissures, eventually creating intricately carved boulders, pinnacles, overhanging rock-shelters, and even tunnellike caves. In places, giant blocks of sandstone have separated from fifty-foot-high cliffs and slid downslope.

As a result of a poorly understood weathering process, targetlike patterns up to three feet across have appeared on some cliff faces. These patterns are made up of concentric ribbons of rock, known as liesegang rings, which project up to two inches above the intervening surface. The liesegang rings are saturated with iron oxide from the adjacent sandstone, rendering them relatively resistant to erosion.

Even where the sandstone at Garden of the Gods is not exposed, the soil is usually very shallow. Moisture and nutrients required for plant growth are at a premium, and summer temperatures often soar to more than one hundred degrees. The trees that are able to live on the ridgetops under these conditions grow exceedingly slowly, often taking on a gnarled appearance.

Blackjack oak and post oak are the principal deciduous trees, and the abundant red cedar is the only evergreen. A blueberrylike plant called farkleberry dominates the shrub layer. Beneath the
Camel Rock, one of the formations of eroded rock at Garden of the Gods, consists of sandstone laid down more than 300 million years ago, when southern Illinois was washed by an inland sea.

Byron K. Johnson
Garden of the Gods, Illinois

For visitor information write:
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woody plants, vegetation is sparse. Prickly pear, southern Illinois's only cactus, adds a desertlike touch, along with succulent-leaved sedums. A striking thick-leaved species is the Illinois agave, whose four-foot-tall flowering stalk bears two-inch-long green-yellow blossoms in early summer. Ridgetops with this assortment of plants dot southern Illinois between the Mississippi and the Ohio rivers, contrasting with the surrounding forest of oak and hickory. Because of their rocky nature and the general paucity of vegetation, these areas are referred to as sandstone glades.

In spite of its generally hostile environment, Garden of the Gods contains another, lusher kind of glade, characterized by a continuous carpet of plants—mostly grasses—and few trees. Some ecologists call this opening in the forest a sandstone prairie, because its chief grasses typify some of the prairies in America's heartland. Big bluestem is the most conspicuous of these, growing more than ten feet high by autumn. Nearly as tall are Indian grass and little bluestem; somewhat smaller are Canadian wild rye and tall dropseed. Several prairie wildflowers that bloom during the summer and autumn are also found among the grasses: Virginia bush clover, bristly sunflower, pineweed (a Saint Johnswort), goat's rue, and the flowering spurge.

Differing soil conditions apparently account for the contrasts between the glades. Soils beneath the scrub oaks on the sandstone glades are rarely more than one inch deep. In comparison, sandstone prairies arise where the soil is several inches deep and gets deeper each year as it incorporates more dead plant material. The sandstone prairie at Garden of the Gods slopes from north to south, dropping 200 feet over a distance of a quarter of a mile. A rocky cliff at the south end seems to provide enough protection from the wind to prevent rapid erosion of the soil.

"This Land" highlights the biological phenomena of the 154 U.S. national forests. Robert H. Mohlenbrock is Distinguished Professor of Botany at Southern Illinois University at Carbondale.

ERRATUM: The photo on page 61 of the April 1987 issue shows the common shooting star, not French's shooting star.
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At the American Museum

Middle East Month
June is Middle East Month in the Leonhardt People Center at the American Museum of Natural History. Each weekend, programs will feature dances from Kurdistan, Armenia, Israel, and Yemen, as well as slide lectures on Turkey, western Islamic culture, Kurdish fashion, and the history of veiled women. These programs are free, and seating is on a first-come, first-served basis. For a complete schedule call (212) 769-5315.

Jane Goodall and the Chimps of Gombe
As one result of the twenty-seven years she has spent studying chimpanzees, Jane Goodall has furnished scientists with some important clues to human behavior. She was the first to observe chimpanzees making and using tools, and she also found that their occasional hostile behavior sometimes leads to murder and cannibalism. Dr. Goodall will share some of her recent findings on Thursday, June 18, at 5:30 and 8:30 p.m. in the Main Auditorium. Tickets are $10 for members and $15 for nonmembers. For further information call (212) 769-5600.

Wildwood Wisdom
In his travels, naturalist Doug Elliot has collected stories, songs, legends, and lore that illustrate the ways in which people relate to nature. Elliot is a professional herbalist and root forager who once earned his living making and selling old-time remedies. This presentation, enlivened by Elliot’s harmonica playing, takes place Wednesday, June 3, at 7:00 p.m. in the Kaufmann Theater. Tickets are $3 for members and $5 for nonmembers. For further information call (212) 769-5600.

A Salute to the Harlem Opera House
Until its closing in 1938, the Harlem Opera House, built in 1889, was one of the premier showcases for black talent. On Saturday, June 13, at 2:00 and 4:00 p.m. in the Kaufmann Theater, a free program will feature a nostalgic look at what was once considered the greatest source of black entertainment. Performers will include dancer Buster Brown as M.C., dancer Tina Pratt, and composer Ram Ramirez. Slides and short films will highlight personalities of the period.

“On Tap” Extended
The Museum will extend its exhibition “On Tap: New York City’s Water Supply” through Sunday, August 2. Artifacts, lithographs, photographs, videos, and maps show the many sources from which New York’s water is drawn and how it reaches the tap.

At the Planetarium
“The Secret of the Cardboard Rocket,” a program for children ages 6 to 9, will be given Saturday, June 13, at noon in the Hayden Planetarium. The adventure begins when two young children build a cardboard rocket and blast off for a tour of the planets with a magical friend. After stops on the moon, Venus, and Mars, the children fly through Jupiter’s lightning storms and Saturn’s rings. For further information call (212) 769-5919.
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The Longest Day
by Thomas D. Nicholson

The first day of summer (June 21 this year), as we all know, is the longest day of the year. Then how come the sun rises earlier on June 15 than it does on June 21 and sets later on the 27th than on the 21st? Shouldn't the sun rise earliest and set latest on the "longest day"? Well, it does and it doesn't, depending on the kind of time you use.

Before clocks and watches were invented, time was told by the sun. When the sun was highest in the sky, it was noon—exactly midway between sunrise and sunset on every day of the year. But the sun is no longer used as a timekeeper. Clocks keep time only approximately in accordance with the sun, because the sun's motion isn't uniform throughout the year. The discrepancy between clock time and sun time is slight from day to day, but it is also cumulative. Clocks can lag behind or get ahead of sun time by as much as sixteen minutes; the difference increases or decreases with the sun's speed.

At the summer solstice, solar noon (when the sun is highest) is shifting rapidly later in the clock day. The sun is highest about two minutes before clock noon in early June and about three minutes after noon by the end of the month, so the mornings in clock time are growing longer and the afternoons shorter. The effect is to make the earliest sunrise occur before June 21 and the latest sunset several days after June 21.

Of course, this wouldn't happen if we still depended exclusively on the sun's movement to tell time. But if we did, think of all those cute little Swatch watches that wouldn't have been devised.

Events in the calendar below are given in local time unless otherwise indicated.

June 1: Bright stars bracket the crescent moon: Gemini's Pollux and Castor (last of the winter stars) are to the west and beneath the moon; Leo's Regulus (spring's leader) is to the east and above it.

June 2–3: In Leo both nights, the moon changes position, switching from right to left of Regulus.

June 4: First-quarter moon is at 1:53 p.m., EST.

June 5: The moon is just above the autumnal equinox at sundown.

June 7: Virgo's brightest star, Spica, is occulted by the moon at about 4:00 p.m., EST (hidden in daylight for us but visible in dark skies over Europe), and appears close to the moon tonight. Mercury is at greatest easterly elongation (to the sun's left) but well past its peak of brightness as an evening star.

June 8: Saturn is up all night in Ophiuchus. It is at its brightest for the year, as opposition from the sun moves it into the evening sky.

June 10: A nearly full moon is just above Antares, Scorpius's brilliant red star, sliding slowly past and covering it for observers in South and Central America at about 10:00 p.m., EST.

June 11: Saturn, Antares, and the moon (full at 3:49 p.m., EST) make an interesting threesome, each in a different constellation: Saturn is in Ophiuchus; the dimmer Antares is in Scorpius; and the moon is just entering Sagittarius.

June 12: Perigee moon (nearest the earth at about 8:00 p.m., EST) is surrounded by Sagittarius's teapot—the "spout" is to its right, the "handle" is to its left, and the peaked "dome" is above.

June 14: Moonrise is at approximately 10:30 P.M. By about midnight you should be able to pick out Capricornus (a bikini-shaped arrangement of dim stars) to its right.

June 18: Last-quarter moon (at 6:02 A.M., EST) is in Pisces, approaching the vernal equinox.

June 19: Venus watchers (the planet is a morning object, only an hour or so to the sun's right) will miss seeing it pass Aldebaran. Unfortunately, both the planet and the star are too low to see in the morning.

June 20: Jupiter is above the crescent moon this morning. The planet's increasing northerly declination and slow shift away from the sun enhance its appearance as a morning star in the months ahead. Mercury, entering its retrograde (westerly) cycle today, now closes rapidly with the sun.

June 21: Summer begins in the Northern Hemisphere at 5:11 P.M., EST, when the sun arrives at the summer solstice (midway between the equinoxes and at its most northerly position in the sky).

June 23: This morning will probably be our last opportunity this month to view the waning crescent moon. The next time we see the moon it will be in the western sky as a waxing crescent.

June 26–27: New moon is at 12:37 A.M., EST, on the 26th; apogee moon (farthest from the earth) is at 11:00 P.M., EST, on the 27th.

June 29–30: On both of these closing nights of June, the new crescent moon will again be in Leo near Regulus.

Editor's Note: The Sky Map in the April issue shows the evening constellations and stars for this month and gives the times and dates for use.
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Photographed in late June on Machias Seal Island, a few miles off the coast of Maine, this Atlantic puffin parent, with its “moustache” of fish, paused a second to gaze at the camera, before dropping down to feed the catch to its chick sheltered among the boulders. Rocky Machias Seal Island has none of the soft earth in which puffins typically burrow and nest. But nine hundred pairs of puffins breed there in summer, sharing the fifteen acres with arctic terns. At summer’s end, puffins leave solid ground behind and go home to the rough lap of the open Atlantic. They will spend the winter far from any shore, true mariners and the terror of small fishes.—J.R.

Photograph by Wayne Wegner
Anthropologist, educator, poet, and literary naturalist, the late Loren Eiseley (page 20) once described himself as “a creature molded of plains’ dust and the seed of those who came in covered wagons.” A native Nebraskan, he was educated in that state’s university system, but his days as a student were interrupted by a struggle with tuberculosis. Later, during the Great Depression, he spent a period as a drifter, riding the rails as a hobo. Eventually, he started graduate school and settled into a career in anthropology at Oberlin College and the University of Pennsylvania. Despite the demands of teaching, Eiseley flowered as a writer, his imagination and contemplative sensibility illuminating scientific themes. The Immense Journey, a collection of essays, was published in 1957. A year later came Darwin’s Century: Evolution and the Men Who Discovered It. Many more titles followed. He continued to teach and at his death in 1977 was Benjamin Franklin Professor and University Professor of Anthropology and History of Science at the University of Pennsylvania. Several years later, private journals were discovered. These, with selections from his correspondence and unpublished writings, make up The Lost Notebooks of Loren Eiseley, excerpted in this issue and to be published in August by Little, Brown and Co.
In the early 1940s, Alan L. Bryan (page 6), then a teen-ager in Fairbanks, Alaska, heard anthropologist Frochlich Rainey lecture on the entry of humans into America by way of the Bering land bridge. The topic has stayed with him throughout his professional career, during which he has surveyed or excavated sites ranging from Alaska to Patagonia. Recently, Bryan and his wife, Ruth Gruhn, investigated caves and rock-shelters near Xique-Xique, Brazil (the photo shows him holding a sieve at this site, as an assistant empties a bucket of soil). A professor of anthropology at the University of Alberta in Edmonton, Bryan edited Early Man in America from a Circum-Pacific Perspective (Edmonton: Department of Anthropology, University of Alberta, Occasional Papers No. 1, 1978) and the more recent New Evidence for the Pleistocene Peopling of the Americas (Orono: Center for the Study of Early Man, 1986). This summer, Bryan will participate in a symposium at the International Quaternary Research Congress in Ottawa, where scholars will discuss the distinctive Clovis projectile points associated with early New World big-game hunting groups. He is also organizing another symposium for the International Congress of Prehistoric and Protohistoric Sciences in Mainz, West Germany, to discuss alternatives to the view that Clovis hunters were the first Americans.

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In 1979, Robert Randall (page 42) was exploring trekking routes in Peru when he found himself near the site of the annual festival of Qoyllur Rit'i. His participation in the festival changed the direction of his life, leading him into ethnohistorical and ethnographic research on Andean cosmology. Born in Texas, Randall lives with his family in the Peruvian village of Ollantaytambo, where he is director of the Peru program of the Interlup School. Impressed with the way Andeans perceive the universe as a vast, interrelated network, Randall is concerned that Western society is eroding this vision at a time when it might provide a solution to the complex problems of ecological destruction and hunger the world is experiencing. For in-depth reading on Andean astronomical lore and the region's intricate world view, Randall recommends At the Crossroads of the Earth and Sky: An Andean Cosmology, by Gary Urton (Austin: University of Texas Press, 1981). For an analysis of the ways in which Andean myth and history have been transformed to accord with present-day political and economic realities, see "Of Bear-Men and Helen: Bear Metaphors and Male Self-Perception in a Peruvian Community," by Catherine J. Allen (in Latin American Indian Literatures, Spring 1983, pp. 38–51). To Defend Ourselves: Ecology and Ritual in an Andean Village, by Billie Jean Isbell (Austin: University of Texas Press, 1978), contains a comprehensive account of the social, political, and religious structure of an indigenous Andean village.

When Richard Loyn (page 54) first arrived in Australia from his native Britain, he found "a continent with wonderfully different flora and fauna, and a wealth of new things to be learned about it. The bell miner story has been one of those things." Loyn, who studied applied biology at Cambridge University, has worked in woodlands, forests, farmlands, mountains, and on the coast of Victoria, but forests are his specialty. In 1980, while working as a biologist at the Mountain Forest Research Station, he began to investigate the connection between the bell miners and the failing eucalyptus forest. He is currently a principal scientist for the Department of Conservation, Forests, and Lands in Victoria and does research on the forest, its creatures, and its natural and man-made challenges, such as fire and fragmentation. On the avian side, Loyn is helping to set up a system to monitor Australian bird populations, and he plans to continue to study bell miners and their cousins the noisy miners, as well as to unravel the ecology of the endangered orange-bellied parrot. An avid traveler, Loyn has visited and worked in Europe, the Americas, Southeast Asia, and Papua New Guinea. For further reading he suggests Birds of Eucalypt Forests and Woodlands: Ecology, Conservation, Management, edited by A. Keast, H.F. Recher, H. Ford, and D. Saunders (Sydney: Surrey Beatty and Sons, 1985). Other books of interest are ornithologist Ian Rowley's Bird Life (Sydney: Collins, 1975), which discusses the natural history of Australia's most prominent bird groups, and The Atlas of Australian Birds, by Margaret Blakers, S.J.J.F. Davies, and Pauline N. Reilly (Melbourne: Melbourne University Press, 1984).

Wayne Wegner (page 76) has a degree in environmental biology from the University of Windsor in Ontario and used to earn an honest living at various fishery and wildlife management jobs. Then, two years ago, he discovered his true vocation as a "nature bum (freelance wildlife photographer/writer)." He says that as a park ranger in Algonquin Provincial Park in Ontario, "I always seemed to be bumping into bears, moose, beavers, and loons, so I decided to try and capture their images on film. I'm still trying." Wegner, who saw his first puffin on an island off the coast of Scotland, shot this month's "Natural Moment" at Machias Seal Island, "the best place to see puffins in North America." Using a 300-mm lens, he took the photograph from a plywood blind twenty-five feet or so from the "sea parrot." Wegner has recently traveled coast to coast across Canada, gathering material for a book on the natural history of that country. Puffins are the subject of several books: R.M. Lockley's Puffins (Garden City: Anchor Books, Doubleday and Co., 1962); M.P. Harris's The Puffin (Calton, Staffordshire, U.K.: T. and A.D. Poyser, 1984); and most recently, David Boag and Mike Alexander's The Atlantic Puffin (Poole, Dorset, U.K.: Blandford Press, 1986).
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Expanding the frontiers of modern healthcare.
Jacques Luc Autran, founder of Seamen Without Frontiers, a philanthropic association, turned a fishing vessel into a floating hospital to bring healthcare and education to isolated societies, such as the islanders of the Maldives.

Preserving endangered species.
Stephen Kress’s innovative techniques successfully repopulated near-extinct colonies of birds on Maine islands and will soon be employed in attempted recolonizations in the south of Japan.

New insights into evolution.
Entomologist Pierre Morvan will organize an expedition to Nepal to study the effects of extreme geographic isolation on the formation of particular species, and will complete a book on the subject.

Religious teaching and environmental education.
Nancy Lee Nash will glean teachings about nature from Buddhist writings and incorporate them into an educational syllabus to be used in Thailand colleges.

Demystifying an ancient culture.
Johan Gjefsen Reinhard will explore the peaks and lakes of the Peruvian Andes to determine the role of those ancient religious sites in the formation of pre-Colombian society.

The Spirit of Enterprise, The 1987 Rolex Awards, a book about the five laureates’ projects, as well as 238 other outstanding proposals, is available in bookstores and from the publisher, Van Nostrand Reinhold.

Additional information about the awards is available from The Secretariat, The Rolex Awards for Enterprise, P.O. Box 178, 1211 Geneva 26, Switzerland.
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8 The First Americans Stephen L. Zegura
Blood Test

12 This View of Life Stephen Jay Gould
Petrus Camper's Angle

20 The Curse of Cadang-cadang Karl Maramorosch
What causes the mysterious "dying-dying" disease?

24 Bedouin Blues Text and photographs by Lila Abu-Lughod
The nomads pitch tents next to their houses and prefer sitting in them
because they are peaceful and nonconfining.

34 Outermost Otters Hans Kruuk
To endure the cold seawaters of the Shetland Islands, the animals need to take
freshwater baths regularly.

50 Appalachia's Art of the Useful Text by Charles E. Martin,
photographs by William Strode
If her handiwork seems too artistic, the maker can back away and say,
"It doesn't mean anything; it's only a quilt."

60 Deep Questions about Shallow Seas Kenneth E. F. Watt
The reefs teem with many different kinds of life. Why?

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88 Authors

Cover: Populations of reef fish, such as these blackbar soldierfish in the waters
of the British Virgin Islands, are affected by predation and violent wave action.
Photograph by Stephen Frink; The WaterHouse. Story on page 60.
Turkey Translated

In “Talking Turkey” (“A Matter of Taste,” March 1987), Raymond Sokolov mentions coming across something called a montgomery on the laundry list at the Pera Palas Hotel in Istanbul and asks what a montgomery is. It is a short jacket, with buttons, that ends at the waist, the type worn by British Field Marshal Montgomery during World War II. This type of military jacket became the fashion in Turkey—probably following Western Europe—in the mid-sixties, and the word, commonly used as mont, has since become part of the language.

MICHEL ALFANDARI
New York, New York

The Turkish quatrain heading Raymond Sokolov’s article is a paean to bread, testimony to the importance of the staff of life in the Turkish diet. My attempt at poetic translation produces the following:

Beautiful fragrant bread!
Chief thou art of pleasing foods.
Not to love thee cannot be,
Thou comrade of every meal.

Correcting several small errors in the text of the Turkish and adding the “sh” sound where an s with a cedilla should appear, it would read:

Güzel kokulu ekmek!
Shensin yemeklere bash.
Olmaz seni sevmemek,
Her yemek ekmek.

(Note that the a in “ash” is pronounced “ah.”)

NANCY BEECHER
Concord, Massachusetts

The quatrain quoted by Mr. Sokolov could be translated as follows:

Bread with the nice smell!
You are the best of all foods.
It is impossible not to like you.
The friend of every meal.

AYDIN ORSTAN
New York, New York

Proving Language Kinship

Merritt Ruhlen’s “Voices from the Past” (March 1987) is in several important respects not an accurate presentation of either the methodology of historical linguistics or of current thinking on the taxonomy of American Indian languages.

Ruhlen refers only in passing to the recent rejection of Edward Sapir’s 1929 classification of American Indian languages. But a key element in this rejection has been disenchantment with the practice of “proving” kinship among languages by the compilation of lists of similar-looking words. The assembly of such lists is no more than a tentative first step in demonstrating interrelatedness.

Attempts to unite all the world’s languages also have a long and at times dubious history. Similar-looking words for basic concepts and objects, turning up in otherwise unrelated or very distantly related languages, have been reported from several areas of the world—but are these automatically proof of “deep” kinship? At the very least, other possibilities should be considered, including the effects of long contact between people speaking unrelated languages. A universal drift toward forming words for certain things with the same phonetic sequences is also a phenomenon still insufficiently explored.

If American Indian languages have something to say about the peopling of the New World, the message is more likely in their exceeding diversity than in their supposed unity. Such variety betokens an enormously long and complex history for the peoples who speak (or spoke) them. A lot of unraveling must be done before we can even begin to speculate, on the basis of language distribution, about how and when these peoples reached the Americas.

JAMES RADER
New York, New York

The author replies:

It is true that the hypothesis of a vast Amerind family, encompassing most of the indigenous languages of North and South America, is currently considered controversial by many specialists. This judgment is perhaps premature, however, since the linguist Joseph Greenberg, who formulated this hypothesis, has only just published his evidence. In addition, Greenberg devotes the first chapter of his new book—Language in the Americas (Stanford University Press, 1987)—to an exposition of the many erroneous assumptions and claims made by scholars specializing in American Indian languages. I, too, have examined in some detail—in A Guide to the World’s Languages (Stanford University Press, 1987)—the aberrant character of recent research and how
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this approach actually led to retrogression rather than progress in the classification of Native American languages.

As for the numerous and detailed similarities that Greenberg has noted among the languages of North and South America, there is but one plausible explanation: common origin. Mr. Rader’s appeal to undocumented forces such as “universal drift” is without any scientific basis.

Fish Antics

Leaving aside the road to Mandalay, where the flying fishes play,” I would be interested in the criteria John A. Byers used to eliminate fish from the playable set (“Why the Deer and the Antelope Play,” May 1987).

It seems to me that anyone who has an aquarium has watched fish “play.” Many fish suddenly leave the surface, dart to the bottom, roll on their sides, and then drift back to the surface “as though they don’t quite understand what’s happening to them.” Others reverse the play by dashing from the bottom to the surface, where they flip their tails to roll the water before dashing back down. Occasionally they miscalculate and flip right out of the tank. Indeed, I have seen this activity set off copyright activity in other fish.

If you watch schools of fish from a dock, you also see seemingly playful behavior. Individuals will suddenly roll on their sides and even rub the bottom if it is shallow. Others will suddenly leave the group and dart like lightning, “in a path resembling a comet’s orbit,” back to the group.

There seems to be no actual feeding involved, but as with John Byers’s pronghorns, the activity would seem to improve feeding and escape ability.

**Richard S. Blake**

*East Falmouth, Massachusetts*

Detecting Mr. Right

John Alcock (“Letters,” April 1987) argues, contra Stephen Jay Gould (February 1987), that female orgasm may be an adaptation designed by natural selection to function as a sort of Mr. Right detector. Female orgasm, unlike male orgasm, inspires interest, debate, polemics, ideology, technical manuals, and scientific and popular literature solely because it is so often absent. In the modern Western world this absence tends to be viewed as a problem requiring therapeutic intervention, hence the question of the adaptiveness or non-adaptiveness of female orgasm has implications beyond the merely academic. If Alcock is right, successful therapy is likely to entail drastic changes in women’s lives, since a woman who is not regularly having orgasms during intercourse presumably can conclude that she is sleeping with Mr. Wrong or, at least, that the problem is not merely one of technique. If, on the other hand, orgasm is a nonadaptive potential that all female mammals possess, simple instruction and practice should suffice.

**Donald Symons**

*Professor of Anthropology*

*University of California, Santa Barbara*  
*Santa Barbara, California*

Other Syzygies

As a biologist, I have always been fascinated by the unusual scientific terms that I have encountered during my formal education and on a day-to-day basis. One of my all-time favorites is syzygy, which Thomas Nicholson described in “The Greeks Had a Word For It” (“Celestial Events,” May 1987).

I was somewhat surprised, however, when he stated, “Except for an obscure usage in Greek and Latin prosody . . . the word is used only in astronomy.” My introduction to the term was in an invertebrate zoology course. Syzygy is used to describe the adhesion of individual gregarines (protozoans of the class Sporozoa), a precursory action to the production of gametes.

**David E. Odell**

*Delmar, New York*

Webster’s Third Edition of the New International Dictionary says that syzygy is the state of being yoked together, from the Greek syzygos (yoked together, united), which in turn comes from syn and zygon (yoke), and gives nine definitions of the word, including those given by Nicholson, but also biological ones: “the immovable union and partial concrescence of two joints of an arm of a crinoid to form a single segment”; “the segment so formed”; and “temporary end-to-end union of gregarines.”

**Norman D. Levine**

*University of Illinois*  
*Urbana, Illinois*

For the information of Dr. Nicholson and others, the word syzygy has been used by mathematicians for more than a century in the theory of polynomial rings. The mathematical usage of the word was introduced by James Joseph Sylvester in 1853. As the mathematical definition of the first syzygy (and r-th syzygy for positive integer r) of a finitely graded module over a polynomial ring of n variables is quite technical, I will omit it.

**Leonard Nissim**

*Division of Science and Mathematics*  
*Fordham University*  
*New York, New York*
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Geneticists have uncovered a tangled picture of ancestral ties

by Stephen L. Zegura

For many biological anthropologists, the best type of evidence to establish when humans first migrated to the Americas and who they were biologically would be a well-dated skeletal population. Unfortunately, there are no human skeletal remains anywhere in the Americas generally accepted to be more than 11,000 years old, although many archeological sites and artifacts are thought to be of earlier date. An unknown number of centuries, and perhaps millennia, are unaccounted for, and the skeletons that could best reveal the details of migration from Asia across the Bering land bridge (if they were preserved at all) probably lie at the bottom of the Bering and Chukchi seas. But bones aren’t the only biological evidence of the first Americans’ origins: inferences can also be drawn from the genes of their living descendants.

The first Native Americans that Europeans saw were most likely the Eskimo inhabitants (“Skraelings”) of Greenland.

Baffin Island, Labrador, and Newfoundland encountered by the Norse explorer Eric the Red and his son Leif about A.D. 1000. The Vikings may also have met other peoples in northeastern North America, but of this we are less certain. Exploration in the fifteenth and sixteenth centuries, including the search for the Northwest Passage, increased European contact with Eskimos and provided definitive contacts with a variety of American Indian groups throughout the Americas. Because these people were not specifically mentioned in classical Greek and Roman works or in the Bible, their origins perplexed European religious authorities as much as they did Renaissance scientists.

By about 1740, modern principles of biological classification had begun to emerge, and during the remainder of the eighteenth century, Carolus Linnaeus, Georges Buffon, and Johann Blumenbach made the first systematic attempts to categorize human diversity. Focusing on temperamental and behavioral differences, as well as on such physical features as skin color, body form, and head shape, these three scientists recognized American Indians as one of several distinguishable geographical varieties, or races, of our species. Later taxonomists disregarded temperament and behavior because they did not yield to objective assessment by calipers or other tools, while cranial features took on increased importance. Toward the end of the nineteenth century, statistical methods were introduced into the study of human biological variation, becoming the hallmark of the British Biometrical School of cranial classification developed in the early 1900s. Over the years, myriad racial classifications were proposed, some of which distinguished Aleuts and Eskimos from all other Native Americans, primarily on the basis of anatomical features of the head and face.

In the 1930s and 1940s, biologists combined Darwin’s theory of evolution by natural selection with information from the fledgling discipline of population genetics. Anthropologists who had once sought to characterize races in terms of distinct physical types now, like biologists, began thinking in terms of populations. By 1950, gene frequencies calculated from blood group data had begun to supplant cranial features, skin color, and body shape in describing human populations, and evolution was defined as a change in a population’s gene frequencies through time.

During the next decade, several biological anthropologists abandoned all attempts to define separate populations. Instead, they studied human variation worldwide in terms of clines—the gradations of traits over geographical areas. The study of clines reserves judgment both on where population boundaries may be drawn and on which traits may be important in determining those boundaries.

A cline can be easily mapped, with the value or frequency of the trait represented by varied shading or crosshatching. For example, biological anthropologists have learned that the familiar A, B, AB, and O blood types, detected by antigen-antibody reactions, are determined by various combinations of three genes: A, B, and O, which occur at the same locus on human chromosome number 9. By tabulating blood types in different geographical areas, biological anthropologists can map the distributions of these genes. They have found, among other things, that the frequency of the B gene decreases in all directions from Asia.

Another development has been the application of electrophoresis. This laboratory technique, in which proteins are separated according to their mobility in an electric field, has provided information about blood components additional to those detected through antigen-antibody reactions. Today’s geneticists can therefore draw on a large body of data on Native Americans, mostly involving blood group antigens (including red blood cell components such as the ABO and Rh blood groups), proteins in blood serum, red blood cell enzymes, immunoglobulins (antibody molecules), and surface antigens of white blood cells. This arsenal of molecular data represents genes whose modes of inheritance are much simpler and better understood than those of complex traits such as skin color, height, and weight, which are determined by unknown numbers of genes, as well as by environmental factors. Additional genetic data include many traditionally tabulated traits determined by single genes, such as the ability to taste the chemical phenylthiocarbamate (PTC), the ability to excrete beta-aminosobutyric acid (BABA), and ear wax type, which may be either dry or wet and sticky.

The technical literature is full of what are called Mongoloid marker genes, European marker genes, African marker genes, and so on—genes specific to particular human groups. Similarly, there are a few genes that supposedly distinguish Aleuts and Eskimos from other Native...
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Americans. However, when one compares the various gene distributions across New World populations, the picture that emerges is one of discordant variation. Possibly, genetic drift (random fluctuations of gene frequencies in small populations due to chance events), gene flow (the transfer of genes between human populations by mating), and inbreeding (mating of relatives more frequently than would be expected by chance) have interacted with natural selection to change gene frequencies, obscuring what once may have been more easily discernable genealogical relationships. Blood group and other serological data seem to be especially sensitive to the effects of genetic drift and gene flow. Although heavily relied upon, their appropriateness for detecting long-term historical relationships within the human species is far from assured.

Sophisticated statistical techniques that combine the data from many genetic systems have not solved the riddle of how many major groupings of Native Americans exist today, let alone their exact origins in Asia or their time of arrival in the New World. There is little agreement among those closely involved with the collection and analysis of genetic data, other than a consensus that Native American populations are related to, and derived from, peoples in Asia. Unraveling millennia of history from twentieth-century genetic data thus turns out to be a challenging and highly speculative enterprise.

As genetic data began to accumulate in the 1950s and 1960s, the position that there were two major groups of Native Americans became the standard interpretation, just as it had been for the anatomical data collected during the two preceding centuries. These two, supposedly distinct, groups were the “American Indians” and the “Aleut-Eskimos.” Although there was much disagreement about whether further partitioning of these two groups was required by the genetic evidence, most scientists accepted this dichotomy as real and of importance in deciphering the early peopling of the New World. Anthropologist William S. Laughlin of the University of Connecticut, for instance, formerly proposed that the ancestors of the American Indians were hunters who occupied the interior of the Bering land bridge approximately 12,000 to 15,000 years ago, while the ancestors of the Aleut-Eskimos inhabited the southern coastal portion of the land bridge, exploiting rich marine resources.

By the 1960s and 1970s, many investigators had taken up the challenge of trying to decide if and how the large American Indian grouping could be partitioned. Some resisted any partitioning, believing that the American Indians formed a distinct race, while others regarded fine-grained local partitioning as essential. When worldwide distributions of human blood groups and other simple traits were published in 1976, no easy solutions were evident. For instance, there was a marked change in the frequencies of certain red blood cell antigens at approximately the latitude of the United States-Mexico border: south of this line, the A and B genes were virtually absent, and the Diego gene (part of another blood group system) was prevalent. With respect to many other types of genes, however, Central America seemed to represent the transitional zone, with gene frequencies roughly intermediate between those exhibited by North and South American Indian populations.

Despite this confusion, attempts have been made to divide the American Indian population into major groups of possible historical import. By far the oldest and most popular of these proposals recognizes a dichotomy between North American and South American Indians. A more recent proposal finds a dichotomy between groups speaking the Na-Dene languages (such as Athapascan) and all the rest of the American Indian populations, whether found in North, Central, or South America.

Meanwhile, there has been growing suspicion that the traditional scheme of two very distinct Native American groups (American Indians and Aleut-Eskimos) will not survive the closer scrutiny made possible by the collection of more extensive genetic data. Emőke Szathmary of McMaster University has been the most effective proponent of the iconoclastic view that the biological differences between Aleut-Eskimos and Na-Dene North American Indians are not as clear-cut as the previous literature suggests and that their similarities are more likely due to a common ancestry than to recent gene flow from intermingling. In her opinion, the ancestors of the Na-Dene may have been genetically closer to the groups that gave rise to the Eskimos than they were to any other Indian or Siberian population. This line of reasoning highlights the potential genealogical inaccuracy of terms such as American Indian, which lumps Na-Dene and non-Na-Dene groups together. Incidentally, just as there are disputes about whether and how to partition American Indian genetic diversity, so also there are those who disagree with the lumping of Aleuts with Eskimos.

Independent dental and linguistic data suggest that Native Americans fall into three groups—Aleut-Eskimos, Na-Dene Indians, and all other American Indians—and some theorize that their ancestors reached the New World as a result of two or three separate major migrations (see the contributions by Christie G. Turner II and Merritt Ruhlen to this series, January and March 1987, respectively). So far, however, genetic studies cannot conclusively confirm the group-

An 8,000-year-old skull, recently discovered in Florida, still contains brain tissue; its genetic material will be compared with that of living Native Americans.
ings, much less the presumed migrations. Some tantalizing support was reported from the study of Gm immunoglobulin distributions, but not everyone agrees that the conclusions are statistically valid.

Research designs involving the DNA of mitochondria (maternally inherited organelles within the cell) already exist to test the three-population hypothesis against plausible alternatives. The necessary Na-Dene and Aleut-Eskimo data for these tests are now being collected by several genetic laboratories. A rare opportunity for direct genetic comparisons of past and present human populations is available, owing to the recent discovery at the Windover site in Florida of well-preserved human brain tissue, which has permitted the cloning and examination of 8,000-year-old mitochondrial DNA.

Szathmary, Kenneth M. Weiss of Pennsylvania State University, and others are pursuing another line of evidence—the genetic susceptibility of Na-Dene, Aleut-Eskimo, and Siberian populations to the so-called New World Syndrome of metabolic diseases. These diseases, which are prevalent among many non-Na-Dene American Indian populations, include adult onset (non-insulin-dependent) diabetes, obesity, gallstones, and gallbladder cancer. The Aleut-Eskimos do not generally seem to be as susceptible to these diseases, but the evidence for susceptibility among the Na-Dene is more equivocal.

By now people have probably lived in the New World for somewhere between 500 and 1,000 generations. One possible scenario for the origins and subsequent divergence of Native American populations based on interpretation of the existing combination of genetic data goes as follows: The Asiatic forebears of the non-Na-Dene American Indians crossed the Bering land bridge sometime between 12,000 and 20,000 years ago and became the first Americans, with their descendants subsequently populating all of North, Central, and South America. The ancestors of the Na-Dene Indians and the Aleut-Eskimo population were later (and perhaps separate) arrivals from Asia, entering North America sometime between 8,500 and 12,000 years ago. Subsequent microevolution from generation to generation has presented us with a diverse array of Native American populations possessing the kaleidoscope of gene frequencies we observe today. With the collection of more and better genetic data from key populations, this scenario can be tested against alternatives, and the results compared with data from disciplines as diverse as linguistics, archeology, skeletal biology, and paleoecology.

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Petrus Camper's Angle

The grandfather of scientific racism has gotten a bum rap

by Stephen Jay Gould

I remember watching Toscanini, a little old man made even smaller on the tiny screen of our first television set. I understood nothing of classical music when I was nine, but Toscanini's intensity nearly moved me to tears—a man older than my grandfather and scarcely bigger than me, drawing such concerted sound from his players. I remember how he stepped off the podium after each piece and mopped his brow with a handkerchief.

Classical music had little currency in those days just before the long-playing record. In television's only other foray into this arcane world, we could watch the annual Christmas presentation of Menotti's opera *Amahl and the Night Visitors.* Amahl, the young cripple with a passion for embellishment, tells his mother that two kings are outside, requesting entry to their humble cottage. She chides him, laments his disinclination to speak truly, and sends him to the door again. Amahl returns to admit that, indeed, two kings do not stand outside. His mother rejoices, but Amahl proclaims: "There are three kings... and one of them is black."

I remembered this line when I started to visit art museums much later and soon realized that Menotti had been following an old tradition, not making a modern plea for racial harmony. One of the Magi is always depicted as a black man. This traditional iconography is not biblical, but a later interpretation. The gospel writers do not even specify the number of wise men who saw the star in the east and came to worship. Some early sources cite up to twelve, but the number soon stabilized at three. Later, this trio received names—Balthazar, Melchior, and Gaspar, first specified in a sixth-century mosaic in Ravenna—and then, symbolic interpretations. As these allegories moved from the specific to the general, the portrayal of one Magus as black stabilized. The three were first seen as kings of Arabia, Persia, and India, then (by the Venerable Bede, for example) as symbols for the three great continents of Africa, Europe, and Asia, and finally, as representatives of the three major human races: white, Oriental, and black.

I was reminded of this iconographical tidbit recently as I read one of the classic works of physical anthropology—the historical beginning of scientific measurement of the human skull. Petrus Camper, Dutch anatomist and painter, was born in Leiden in 1722. He studied both art and science, then trained as a midwife before receiving his degree as a physician. (Men may be midwives. The name refers to a person, male or female, who stays with [mit, as in modern German] a woman [wij] during birth—so the female end of the etymology refers to the mother, not the attendant.) In 1755, he became a professor of anatomy in Amsterdam and spent the rest of his comfortable life alternating between his country home and his professional duties in Amsterdam and Groningen. Camper, who discovered the air spaces in bird bones and studied the hearing of fishes and the croaking of frogs, was revered as one of the great intellects of Europe during his own lifetime. The busy life that such attention brings, made even more hectic by the political career that he forged during his later years, left Camper little time to write and publish his scientific studies. At his death in 1789, he left his major work on the measurement of human anatomy in manuscript. His son published this posthumous document in 1791, both in the original Dutch and in French translation. (I read the French, an edition printed in Utrecht, presumably by typesetters who didn't know the language, and so full of errors that I almost decided it might be easier to learn Dutch and work from the other version.)

This work bears an extended title, both characteristic of the age and expressive of the contents: *Physical dissertation on the real differences that men of different countries and ages display in their facial traits; on the beauty that characterizes the statues and engraved stones of antiquity; followed by the proposition of a new method for drawing human heads with the greatest accuracy.* Camper's treatise is remembered today for one primary achievement—the definition of the so-called facial angle, the first widely accepted measurement for comparing the skulls of different races and nationalities. Camper's facial angle is the traditional beginning of craniometry, or the science of measuring human skulls, a major subdiscipline of physical anthropology.

The human skull may be divided into two basic components: the vault of the cranium itself and the face in front. Camper's facial angle sought to specify the relationship between these two parts. Camper first drew a line connecting the ear opening with the base of the nose (the so-called horizontal, or "h-k" on his illustration of an African head). He then constructed another line joining the most forward projection of the upper jaw (the bottom of the upper lip in living heads, usually the edge of the incisor teeth on skulls) with the most protruding point of the brow above the eyes ("h-n" on his African head) and called ever since the facial line. Camper then defined the facial angle as the intersection of the horizontal (his basis of reference) with the facial line (roughly, the forward slant of the face).

In a general way, the facial angle measures the relative flatness versus forward extension of the face. A low value means that the jaws extend far in front of the
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The Museum and Alecto therefore went back to Audubon’s original watercolors, notes, letters and even bird specimens to produce this edition.

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Audubon Portfolio, Room 4, Central Park West at 79th Street, New York, N.Y. 10024.
Illustrations from Camper’s original work show lines for the facial angle of (left to right) an ape, a black man, and a Grecian head.

The facial angle soon became the first widely accepted tool for quantitative comparison of human skulls. It spawned an immense literature, a host of proposals for slight improvements based on different criteria, and a bevy of instruments designed to measure this fundamental aspect of human life. It also became the first quantitative device for establishing invidious comparisons, based on inherent distinctions, among human races. The early craniometricians reported that African blacks possessed the lowest facial angles (farthest forward projection of the jaws), with Orientals in the middle, and Europeans on top, with facial angles sometimes approaching 90 degrees. Since apes had facial angles even lower than blacks, and since the facial angles for ancient statues of Greek deities exceeded those of all living Europeans, the smooth ascent from monkey to majesty seemed assured. Historian John S. Haller writes (Outcasts from Evolution, University of Illinois Press, 1971):

The facial angle was the most extensively elaborated and artlessly abused criterion for racial somatology. . . . By 1860 the facial angle had become the most frequent means of explaining the gradation of species. Like the Chain of Being, the races of man consisted of an ordered hierarchy in which the Hottentot, the Kaffir, the Chiman, and the Indian held a specific position in the order of life.

I had never read Camper’s original definition of the facial angle or his own recommendations for its use and meaning. Neither had most of the nineteenth-century craniometricians who established the facial angle as a primary instrument of scientific racism (Camper’s posthumous work has always been rare and difficult to obtain). I am no longer surprised when the study of a neglected original shows, as in his case, that later interpretations departed from an author’s own intentions. Such stories cannot rank as news; they fall
Camper did not define the facial angle as a device for ranking races or nations by innate worth or intellect. He did not even approach the problem of human variability with motives that we would now recognize as scientific. In Camper’s day, anthropology did not exist as a discipline; science had not been defined, either as a word or as a separate domain of knowledge. Scholars often worked simultaneously in areas now walled off into separate faculties of universities. Such “cross-disciplinary” work seemed neither odd nor prodigious to eighteenth-century thinkers.

Camper was a professor of anatomy and medicine, but he was also an accomplished artist, good enough to win admission to the Painter’s Academy during a long visit to England (1748 to 1750). Camper defined his facial angle with the requisite precision of geometry and the quantitative preferences of science, but his motive lay in the domain of art. (He saw no contradiction, and neither should we.) We may now return to the issue of the black Magus and to Camper’s own statement about his intentions.

Camper tells us right at the outset of his treatise that his desire to quantify human variation first arose in response to a minor annoyance with Western painting. He had studied the black Magus in many classical paintings and noted that, while his color matched the hues of Africa, his face almost always displayed the features of European whites—a kind of Renaissance minstrel show with whites in blackface. (Since few Africans then lived in Europe, Camper reasoned that most artists had used white models, faithfully copying the facial features of a European and then painting the figure black.)

Camper wanted to prevent such errors by establishing a set of simple guidelines (lengths and angles) to define the chief characters of each human group. His treatise devotes more space to differences between old and young than to disparity between races or nations—for Camper was also distressed that the infant Jesus had often been drawn from an older model (no photographic surrogates to keep a baby’s image still in Camper’s day).

Yet Camper did not locate his immediate motive for the facial angle in descriptive anthropology of actual humans, but in a much loftier problem—no less than the definition of beauty itself. Like so many of his contemporaries, Camper believed that the cultures of ancient Greece and Rome had reached a height of refinement never since repeated and perhaps not even cap-

Into the category of “dog bites man.” And besides, maybe the later readings were correct and the initial proposal wrong—good insights for bad reasons are legion in the world of intellect.

The story of Camper’s own interpretation of his facial angle is interesting for another reason. The archeology of knowledge is a fascinating subject because it seeks new insights from our past. By cultural heritage and proven reliability, we approach problems in a set of stereotyped ways and often assume (following the cardinal sin of pride) that our modern conventions exhaust the domain of possible inquiry. We should study the past for the simplest of reasons—to increase our “sample size” in modes of thought, for we need all the help we can get. Camper’s own rationale is instructive because it departed fundamentally both from the sociology and the conceptual basis of modern scientific inquiry into human variability. We should recover and understand Camper’s reasoning both to pay proper respect to a fine thinker and to expand our own sense of possibility.

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able of recapture. (This is a difficult concept to grasp in the light of our later cultural preference for progress as a feature of technological history — old must mean inferior. But our forebears were not so encumbered, and ideas of a previous golden age, surpassing anything achieved since, had great power and attraction. The Renaissance (literally, rebirth) received its name from this conviction, and its heroes were trying, or so they thought, to recapture the knowledge and glory of antiquity, not to create novel improvements in art or architecture.)

Camper was obsessed with a particular issue arising from this reverence for antiquity. We can all agree, he states, that the great sculptors of ancient Greece achieved a beauty and nobility that we have not been able to match in our new art or often even to duplicate in simple attempts to copy ancient statues. One might take the easy route out of this dilemma and argue that Phidias and his brethren were just good copyists and that the people of ancient Greece surpassed all modern folk in beauty and proportion. But Camper had evidence against this proposition, for he noted that the few Greek attempts at actual portraiture (on coins, for example) showed people much like ourselves, warts and all. Moreover, the Greeks had made no secret of their preference for idealization. Camper quotes Lysippus’s desire “not to represent men as they are, but as they present themselves to our imagination.” “The ideal of Antique Beauty,” Camper writes, “does not exist in nature; it is purely a concept of the imagination.”

But how shall we define this ideal of beauty? Camper traces the sorry attempts by poets, artists, and philosophers throughout the centuries. He notes that, in the absence of a firm criterion, each field has tried to fob off the definition by analogy — poets exemplify beauty by reference to art; artists by reference to poetry. Explicit attempts often founded in nonsense, as in this example from 1584: “Beauty is only beautiful by its own beauty,” a motto that inspired Camper’s appropriate riposte, “Can there be a greater absurdity?”

And yet, Camper argues, we all agree about the beauty of certain objects, so some common criterion must exist. He writes:

A beautiful starry sky pleases everyone. A sunrise, a calm sea, excites a sensation of pleasure in all people, and we all agree that these phenomena convey an impression of beauty.

Camper therefore decided to abandon the overarching attempts that had always developed into nonsense and to concentrate instead on something specific that might be defined precisely — the human head.

Again he argues (incorrectly, I think, but I am explicating, not judging) that common standards exist and that, in particular, we all agree about the maximal beauty of Grecian statuary:

We will not find a single person who does not regard the head of Apollo or Venus as possessing a superior Beauty, and who does not view these heads as infinitely superior to those of the most beautiful men and women (of our day).

Since the Greek achievement involved abstraction, not portraiture, some secret knowledge must have allowed them to improve the actual human form. Camper longed to recover their rule book. He did not doubt that the great sculptures of antiquity had proceeded by mathematical formulas, not simple intuition — for proportion and harmony, geometrically expressed, were hallmarks of Greek thought. Camper would, therefore, try to infer their physical rules of ratios and angles: “It is difficult to imitate the truly sublime beauty that characterizes Antiquity until we have discovered the true physical reasons on which it was founded.”

Camper therefore devised an ingenious method of inference (also a good illustration of the primary counterintuitive principle that marks true excellence in science). When faced with a grand (but intractable) issue — like the definition of beauty — don’t seek the ultimate, general solution; find a corner that can be defined precisely and, as our new cliché proclaims, go for it. He decided to draw, in profile and with great precision, a range of human heads spanning nations and ages. He would then characterize these heads by various angles and ratios, trying to establish simple gradations from what we regard as least to most pleasing. He would then extrapolate this gradient in the “more pleasing” direction to construct idealized heads that exaggerate those features regarded as most beautiful in actual people. Perhaps the Greeks had sculpted their deities in the same manner.

With this background, we can grasp Camper’s own interpretation of the facial angle. Camper held that modern humans range from 70 degrees to somewhere between 80 and 90 degrees in this measure. He also made two other observations: first, that monkeys and other “brutes” maintained lower angles in proportion to their rank in the scale of nature (monkeys lower than apes, dogs lower than monkeys, and birds lower than dogs); second, that higher angles characterize smaller faces tucked below a more bulging cranium — a sign of mental nobility on the ancient theme of more is better.

Having established this range of improvement for living creatures, Camper extrapolated his facial angle in the favorable direction toward higher values. Voilà. He had found the secret. The beautiful skulls of antiquity had achieved their pleasing proportions by exaggerating the facial angle beyond values attained by real people. Camper could even define the distinctions that had eluded experts and made for such difficulty in attempts to copy and define. Romans, he found, preferred an angle of 95 degrees, but the ancient Greek sculptors all used 100 degrees as their ideal — and this difference explains both our ease in distinguishing Greek originals from Roman copies and our aesthetic preference for Greek statuary. (Proportion, he also argued, is always a balance between too little and too much. We cannot extrapolate the facial angle forever. At values of more than 100 degrees, a human skull begins to look displeasing and eventually monstrous — as in individuals afflicted with hydrocephalus. The peculiar genius of the Greeks, Camper argued, lay in their precise understanding of the facial angle — so that they could push its value right to the edge where maximal beauty switches to deformity. The Romans had not been so brave, and they paid the aesthetic price.)

Thus, Camper felt that he had broken the code of antiquity and offered a precise definition of beauty (at least for the human head): “What constitutes a beautiful face? I answer, a disposition of traits such that the facial line makes an angle of 100 degrees with the horizontal.” Camper had defined an abstraction, but he had worked by extrapolation from nature. He ended
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his treatise with pride in this achievement:
“[I have tried to establish on the founda-
tion of Nature herself, the true character of] 
Beauty in faces and heads.”

This context explains why the later use of 
facial angles for racist rankings repres-
ts such a departure from Camper’s 
convictions and concerns. To be sure, two 
aspects of Camper’s work could be in-
voked to support these later interpreta-
tions, particularly in quotes taken out of 
context. First, he did, and without any 
explicit justification, make aesthetic judg-
ments about the relative beauty of races—
never doubting that Nordic Europeans 
must top the scale objectively and never 
considering that other folks might advocate 
different standards. “A Lapplander,” he 
writes, “has always been regarded, and 
without exception throughout the world, 
as more ugly than a Persian or a Georgi-
gian.” (One wonders if anyone had ever 
sent a packet of questionnaires to the 
Scandinavian tundra: Camper, in any 
case at least, does not confine his accusa-
tions of ugliness to non-Caucasians.)

Second, Camper did provide an order-
ing of human races by facial angle—and 
in the usual direction of later racist 
rankings, with Africans at the bottom, 
Orientals in the middle, and Europeans on 
top. He also did not fail to note that this 
ordering placed Africans closest to apes 
and Europeans nearest to Greek gods. In 
discussing the observed range of facial 
angles (70 to 100 degrees in statues and 
actual heads), Camper notes that “it [this 
range] constitutes the entire gradation 
from the head of the Negro to the sublime 
beauty of the Greek of Antiquity.” Ex-
trapolating further, Camper writes:

As the facial line moves back [for a small 
face tucked under bulging skull] I produce 
a head of Antiquity; as I bring it forward 
[for a larger, projecting face] I produce the 
head of a Negro. If I bring it still further 
forward, the head of a monkey results, more 
forward still, and I get a dog, and finally 
a woodcock; this, now, is the primary basis of 
my edifice.

(Our deprecations never cease. The 
French word for woodcock—becasse— 
also refers to a stupid woman in modern 
French slang.)

I will not defend Camper’s view of hu-
man variation any more than I would pil-
lory Lincoln for racism or Darwin for sex-
ism (though both are guilty by modern 
standards). Camper lived in a different 
world, and we cannot single him out for 
judgment when he idly repeats the 
commonplaces of his age (nor, in general, 
may we evaluate the past by the present, if 
we hope to understand our forebears).

Camper’s comments on racial rankings 
are fleeting and stated en passant. He 
makes no major point of African distinc-
tions except to suggest that artists might 
now render the black Magus correctly in 
painting the Epiphany. He does not harp 
upon differences between human groups 
and entirely avoids the favorite theme of 
all later writings in craniometric racism— 
finer scale distinctions between “inferior” 
and “superior” Europeans. His text con-
tains not a whiff or hint of any suggestion 
that low facial angles imply anything 
about moral worth or intellect. He charges 
Africans with nothing but maximal depa-

ture from ideal beauty. Moreover, and 
most important, Camper’s clearly stated 
views on the nature of human variability 
preclude, necessarily and a priori, any 
equation of difference with innate inferi-
ority. This is the key point that later com-
mentators have missed because we have 
lost Camper’s world view and cannot in-
terpret his text without recovering it.

We now live in a Darwinian world of 
variation, shadings, and continuity. For 
us, variation among human groups is funda-
mental, both as an intrinsic property of 
nature and as a potential substratum for 
more substantial change. We see no dif-
fERENCE in principle between variation 
within a species and established differ-
ences between species—for one can be 
the other via natural selection. 

Given this potential continuity, both kinds 
of variation may record an underlying and 
basically similar genetic inheritance. To 
us, therefore, linear rankings (like Camp-
ner’s for the facial angle) quite properly 
smack of racism.

But Camper dwelt in the pre-Darwinian 
world of typology. Species were fixed and 
created entities. Differences between spe-
cies recorded their fundamental natures.
But variation within a species could only be 
viewed as a series of reversible “accid-
ents” (departures from a species’ es-

sence) imposed by a variety of factors, 
including climate, food, habits, or direct 
manipulation. If all humans represented 
but a single species, then our variation 
could only be superficial and accidental in 
this Platonic sense. Physical differences 
could not be tokens of innate inferiority. 
(By “accidental,” Camper and his con-
temporaries did not mean capricious or 
devoid of immediate import in heredity. 
They knew that black parents had black 
children. Rather, they argued that these 
traits, impressed into heredity by climate 
or food, had no fixed status and could be 
easily modified by new conditions of life. 
They were often wrong, of course, but 
that’s not the point.)

Therefore, to understand Camper’s 
views about human variability, we must 
first learn whether he regarded all humans 
as members of one species or as products 
of several separate creations (a popular 
position known at the time as polygeny). 
Camper recognized these terms of the ar-
gument and came down strongly and inci-
sively for human unity as a single species 
(monogeny). In referring to races with the 
technical term “variety,” Camper used 
the jargon of his day to underscore his 
conviction that our differences are acci-
dental and imposed departures from an 


essence shared by all; our races are not 
separated by differences fixed in heredity. 
“Blacks, mulattos, and whites are not di-
verse species of men, but only varieties 
of the human species. Our skin is constitu-
te exactly like that of the colored nations; 
we are therefore only less black than they.”
We cannot even know, Camper adds, 
whether Adam and Eve were created 
white or black since transitions between 
superficial varieties can occur so easily 
(an attack on those who viewed blacks as 
degenerate and Adam and Eve as neces-
arily created in Caucasian perfection):

Whether Adam and Eve were created 
white or black is an entirely indifferent is-
sue without consequences, since the pas-
sage from white to black, considerable 
though it be, operates as easily as that from 
black to white.

Misinterpretation may be more com-
mon than accuracy, but a misreading pre-
cisely opposite to an author’s true intent 
may still excite our interest for its sheer 
perversity. When, in order to grasp this 
inversion, we must stretch our minds and 
learn to understand some fossil systems of 
thinking, then we may convert a simple 
correction to a generality worthy of note. 
Poor Petrus Camper. He became the 
semiofficial grandpappy of the quantita-
tive approach to scientific racism, yet his 
own concept of human variability pre-
cluded judgments about innate worth a 
priori. He developed a measure later used 

to make invidious distinctions among ac-
tual groups of people, but he pressed 
his own invention to the service of abstract 
beauty. He became a villain of science 
when he tried to establish criteria for art. 
Camper got a bad posthumous shake on 
earth; I only hope that he met the right 
deity on high (facial angle of 100 degrees, 
naturally), the God of Isaiah, who also 

equated beauty with number and propor-
tion—he “who hath measured the waters 
in the hollow of his hand, and meted out 
heaven with the span.”

Stephen Jay Gould teaches biology, geol-
y and the history of science at Harvard 

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**The Curse of Cadang-cadang**

Tiny molecules cause big problems for coconuts

by Karl Maramorosch

In 1928, on little San Miguel Island in the Philippines, the Taylor sisters were shocked by the sight of coconut palms dying near a new cattle corral on their plantation. The Taylors, who owned San Miguel at the time, were perhaps most fond of their lovely garden of American flowers, but they recognized that the lifeblood of the island was its 250,000 coconut palms. Five years later, when nearly 25 percent of the palms had died, they called in Prof. Gerardo Ocfemia of the College of Agriculture in Los Banos. Ocfemia determined that the ailment was infectious and not caused by physiological conditions. Finding neither fungi nor bacteria, he put the cause down to a virus. But neither Ocfemia nor anyone else could save the palms. And the disease continued to spread rapidly: in the decade before World War II, it jumped from San Miguel to Luzon—the largest island in the Philippine archipelago—and later to several other islands.

Before long, the disease had earned the name cadang-cadang, which means “dying-dying” in Bicolano, a language spoken in the southeastern part of Luzon. Plantation owners throughout the archipelago learned to recognize the first signs of cadang-cadang: the appearance of tiny yellow or water-soaked greenish olive spots on palm fronds. As the leaves age, the number of spots increases. Gradually, fronds of an infected tree die and drop off. Eventually, only a tuft of small, erect, yellowish green leaves at the apex of the trunk remains, and finally that breaks off as well, leaving the empty, dead trunk.

Cadang-cadang is always fatal, the average time from onset to death being ten years, although some trees linger for up to twenty years. Reproductively, however, and therefore commercially, the palms die much earlier. After the first twelve to eighteen months of visible symptoms, a sick tree stops producing flowers. It is from the flowers, of course, that the coconuts come, so without flowers, a tree is of no use to the plantation owner.

One of the most devastating plant diseases known, cadang-cadang has so far killed more than 30 million coconut palms in the Philippines. At present, an additional 500,000 to one million Philippine palms succumb to the disease every year. For the Philippines, the world’s largest producer of coconuts, this is a problem that cannot be overemphasized. Half of the country’s export income comes from copra, the dried coconut meat from which coconut oil comes. This oil has many uses in industrialized countries, where it is used in the manufacture of soaps, margarines, synthetic rubber, and even hydraulic brake fluid. In the Philippines and other tropical countries that produce coconuts, the palms have many other uses often not appreciated by Westerners. In addition to the oil, which is sometimes the only source of fat in the diet, the trees provide lumber, and the leaves are used for making brooms, baskets, and hats and as thatch to cover roofs. Fiber from the husk of the coconut goes into carpets and mats, and the fibrous yarn is woven into ropes. On many atolls in the Pacific, human life would not be possible without coconut palms, which provide the only potable liquid and are the only source of building material and shade.

In January of 1960, I went to the Philippines for six months at the request of the Philippine government and the Food and Agriculture Organization (FAO) of the United Nations to study cadang-cadang and recommend control measures. During the following two decades, many of my colleagues from the United States, Germany, and Australia joined Philippine scientists in the search for the cause and vector of this palm killer. Cadang-cadang continued to devastate certain areas, but it was no longer spreading so fast, and in some areas it actually seemed to be confined to isolated pockets of infection. The disease, for example, did not spread throughout Luzon’s Laguna Province, an almost uninterrupted coconut forest. This pattern led to speculation that palms in disease-free parts of the Philippines were genetically resistant or that the means of...
transmission—whatever it might be—was somehow limited geographically. Most researchers agreed with Ocfemia’s view that the causal agent was a virus, and most thought that the vector was probably airborne. But no one was able to confirm or refute these hypotheses.

During my 1960 visit I made one observation that, being afraid of ridicule, I did not dare to mention in my report to the Philippine government or in any other publication. I noticed that the destruction of coconut palms occurred predominantly on plantations owned by people who spoke Bicolano as their mother tongue. Cadang-cadang also occasionally struck plantations of Spanish- or Basque-speaking owners but never those owned by Tagalog-speakers. The correlation was consistent, but since I, like my predecessors and successors at the FAO, was convinced that the disease was infectious and that it was caused by a virus, the observation made absolutely no sense. Neither the pathogen nor the as-yet-undetermined transmitting vector could possibly know or be influenced by the language of the owners of the plantations.

I returned to the Philippines in 1963 while conducting a worldwide survey of coconut palm diseases of uncertain etiology. I also visited Guam, where palms were dying of a similar disease, called tinangaja. An earlier typhoon had severely damaged most of Guam’s palms, but wherever I was able to inspect sick trees, they definitely resembled those suffering from cadang-cadang. Certainly nobody on Guam spoke Bicolano, so I tried to forget about the association of the disease on Luzon with that language. And in the years to come, I was distracted by exciting developments on a very different front.

Up until the early seventies, scientists believed that all palm infections were caused by bacteria, fungi, or viruses. Then, in 1971, a potato disease that results in small, spindly tubers was found to be the work of a startlingly different, recently discovered kind of disease agent, the viroid. Viroids are astonishingly tiny, much smaller than viruses, which were once thought to be the smallest infectious pathogens. Viroids are composed entirely of a low-molecular-weight RNA molecule. Unlike viruses, they do not have a protective protein coating, having too little genetic information to code for even a single protein. Once within a susceptible cell, however, a viroid takes charge, using the host cell’s metabolism—that is, its enzymes and biosynthetic machinery—to make more viroids. These viroids then invade other cells, and soon, the plant begins to look sick.

In the early seventies, several plant species—including some citrus trees, chrysanthemums, and cucumbers—were found to suffer from viroid diseases. Then, in 1975, Australian plant pathologist J.W. Randles discovered two viroidlike kinds of RNA in sick Philippine coconut palms, and cadang-cadang joined the growing ranks of viroid-caused infections. He later detected viroids in palms on Guam and, subsequently, working with Italian researcher Guido Boccardo, proved that the disease known on Guam as tinangaja was indeed very closely related to, if not identical to, cadang-cadang.

Viroids have now been identified as the culprit in a dozen or so plant diseases. Significantly, all of these diseases involve cultivated plants, and all were noticed for the first time in the present century, some as recently as last year—in plums in Japan and wheat in China. In striking contrast, viruses, protozoa, fungi, and bacteria have more familiar tastes—attacking all types of eukaryotic organisms—and have been causing problems for humans, animals, and plants for centuries. Eight hundred years ago, for example, the Chinese began propagating green-flowering peonies that became the favorite of an emperor of the Sung Dynasty; recently, a plant mycoplasma has been identified as the cause of the unusual green coloring. Romans apparently had to contend with wheat rust, a fungus-caused disease. Marks on Egyptian mummies have been interpreted as smallpox, and a museum in Vienna contains a 21-million-year-old reptile with what appears to have been chronic osteomyelitis of the spine, a bacterial infection. The causes of some of these ancient diseases have only been discovered in modern times; viruses, for example, were only properly identified as recently as ninety years ago. But that the diseases have been around for a long, long time is unquestioned.

Theodor Diener, of the U.S. Department of Agriculture, who discovered the first viroid in 1969 and coined the name viroid to describe the new pathogens, postulated that these diseases simply did not exist before 1900. The speed with which viroid-caused diseases spread, once discovered, lends support to this idea. Chrysanthemum stunt, for example, first noticed in the 1950s, was suddenly observed by chrysanthemum growers throughout the United States.

If viroid-caused diseases are of recent origin, are viroids new, too? Maybe, but not necessarily. Some of the known viroids have been found in wild plants, where they do not cause symptoms. Perhaps they exist in these and other natural hosts in a latent state and become pathogenic only when humans inadvertently transfer them
to cultivated plants. This sort of transfer could occur during grafting and various horticultural practices, such as cutting and even simple handling. If, as I believe to be the case, human activities have contributed to the induction of viroid-caused diseases into cultivated plants, we can expect that new viroid diseases will continue to appear in cultivated plants. We can also expect that viroids will be detected in various apparently healthy wild plant species and that viroids from some of these symptomless carriers will prove pathogenic to certain cultivated plants. (So far, the cadang-cadang viroid is the only one known to kill infected plants; other viroids cause symptoms—such as stunting, spotting, discoloration, and in the case of potatoes, deformed tubers—that render commercially grown plants as good as dead.)

The search for viroid diseases has been accompanied by detailed investigations into the viroids themselves. As early as 1973, the first electron-microscopic visualization of a viroid was published, and by 1976, powerful electron-microscopy magnification and sophisticated chemical methods had revealed that a viroid consists of a single strand of RNA in a closed circle. These studies culminated two years later in the determination of the complete chemical structure and sequence of building blocks—the nucleotides—of a viroid. Thus, in less than ten years, viroids became the first RNA pathogens to reveal their complete molecular structure.

But understanding the inner workings of viroids has not solved the more practical problem of how to control the diseases they cause. Little is still known about natural modes of transmission or about wild plant reservoirs. Cadang-cadang viroids, for example, have a narrow host range, limited to members of the palm family. No herbaceous hosts are known to be susceptible. As for transmission, three decades of searching for a possible vector have been uniformly unsuccessful. One good way to control a plant disease is to get rid of insects or other vectors, such as mites and nematodes, responsible for transmitting the disease. However, as long as the vectors, if there are any, remain unknown, no such measures are possible.

Another method of control—perhaps the best—is to develop a variety of plant resistant to the disease. Unfortunately, no palms resistant to cadang-cadang have yet turned up. Eradication, another standard procedure for the prevention and control of plant disease, has not succeeded either. Infected palms continually appear in plantations from which all sick trees have been removed. Cadang-cadang’s long latency period—that is, the one to two years, at least, that appear to elapse between infection and the first signs of the disease—has been blamed for this problem. Recently, however, Diener devised a technique to detect infected palms long before they develop symptoms; if this technique is regularly employed in the Philippines, it could go a long way toward reducing cadang-cadang losses.

To date, the most frequently suggested approach has been replanting. Replanting is simple, reliable, and cost-efficient—desirable attributes in a relatively primitive industry. And since cadang-cadang has been spreading comparatively slowly in recent decades and seldom affects trees that are less than ten years of age, replanted trees stand a good chance of surviving and bearing nuts for a time, albeit limited. This means that coconut copra production can be maintained even in affected areas, such as Luzon, where losses have been considerable.

Replanting, however, is inevitably a stopgap measure. The search for real control must continue. There is one possibility, at present theoretical, but one that might be applied successfully someday. Viroids, like viruses, often come in both mild and severe forms, or strains. Plants inoculated with the mild strain of a pathogen usually become resistant to the more damaging, severe form of the same pathogen. (How this works is not understood, but it appears to be a case of one pathogen interfering with another, rather than the kind of host response that exists in a true immune system.) If a mild strain of the cadang-cadang viroid could be found or artificially developed and introduced into healthy palms, this could “vaccinate” the palms and protect them from the naturally occurring severe form.

This sort of solution, even if feasible, would require time and money. What if there is, in the end, an easier way? Perhaps an identifiable, controllable vector exists after all. All the searches have focused on invertebrates; yet all known plant viroids appear to need only one thing to spread effectively—the helpful hand of man.

Over the years, my mind kept going back to the peculiar observation I made in 1960: that cadang-cadang struck Bicolano, not Tagalog, plantations on Luzon. I now believe that in this observation lies the key both to how the disease spreads and how it can be halted. Every trade has its essential tools, and on coconut plantations, it is the bolo, a large, single-edged knife used to accomplish a variety of tasks. Workers employ their bolos to cut steps into the base of a palm before climbing up to the crown, where nuts grow. Afterward, they use the same knives to cut the nuts off the palm. In places where flower sap (called todi or tuba) is also collected—for later fermentation into a strong and inexpensive alcoholic beverage—the bolos are used repeatedly to make incisions in the inflorescences. If a worker uses his bolo on a palm that already carries the cadang-cadang viroid, the contaminated knife can transmit the viroid to the next palm when steps are being cut into it, when nuts are being collected, or when flowers are tapped for tuba. When collecting tuba, workers usually link the crowns of several palms with wooden planks so they can move from one tree to another without descending to the ground. This might easily explain why clumps of palms often come down with cadang-cadang and also why distances between such clumps or isolated diseased palms can be considerable.

The workers and their bolos also help solve the mystery of why only plantations owned by Bicolano-speaking people have been ravaged by the disease. Simply put, Bicolano plantation owners prefer to hire “their own,” and similarly, Tagalogs hire mainly Tagalogs. The viroids, thus, contaminate Bicolano but not Tagalog knives. Unless a Tagalog plantation owner breaks with tradition and hires a Bicolano worker, the disease cannot jump the language barrier. Thus the link of the spread of the disease with the Bicolano language seems to make sense, after all. Just where the cadang-cadang viroids got their start may never be known, but there are clues here, too. The workers on San Miguel Island, where cadang-cadang first appeared nearly sixty years ago, were Bicolanos from Tabaco, a port in southeast Luzon, and it was in Tabaco a few years later that the disease first broke out on Luzon.

If bolos are to blame for the spread of cadang-cadang, they can also be the instrument of its control. All that would be needed is to decontaminate the knives, which could be done effectively and inexpensively by dipping them into a solution of sodium hypochlorite. This suggestion was made a few years ago, but I have not yet seen any containers of sodium hypochlorite being moved about in the plantations, and the disease continues to spread. Let us hope that this simple technique will soon be tested and, that it, together perhaps with such additional methods as the selection of tolerant or resistant breeding lines or the introduction of mild viroid strains to “vaccinate” the palms, will stop this devastating and costly plant disease.

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Bedouin Blues

Poignant lyric poems punctuate the intimate conversations of the Awlad 'Ali

Text and photographs by Lila Abu-Lughod

Safia, a middle-aged Egyptian Bedouin woman, talked about her divorce from the man she'd been married to for almost twenty years. The event she described had occurred a year before my arrival in the camp where I was to spend nearly two years doing fieldwork. She explained, "My youngest daughter was nursing in my arms when he left me. I was sick and tired. The man came up to me one afternoon as I sat by the oven, baking. He said, 'You're divorced.' I said, 'Thanks, that's just fine by me.' I didn't want him. I don't want anything from him except to build me a house to live in with my son. I didn't care when he divorced me. I never liked him."

Her tone of aggressive nonchalance did not surprise me. It was consistent with the way many people talked about their marriages, even when uncomplicated by problems such as divorce. Yet, two days later, as we were chatting with several other women in her household during a lull in the round of domestic activities, conversation turned to the whereabouts of her ex-husband, who was away on a trip. Safia suddenly began to recite a short and sad poem that conveyed a very different set of sentiments.

Memories stirred of the beloved should I release, I'm flooded by them

I remember that she had also volunteered to recite some poems when I had first shown her my tape recorder a couple of months earlier. These included the following:

Oh eyes be strong you cherish people and then they're gone

There was no doubt in the minds of all the women who subsequently heard the tape that this poem, which hints at the effort it takes to keep from crying, was about her ex-husband.

The incongruity between what Safia said in ordinary conversation and the sentiments she expressed in poetry was striking. But her case was not unique. I found that many people I got to know in this Bedouin community in Egypt's Western Desert conveyed feelings of vulnerability and attachment in the short poems that
Bedouin women rest momentarily in the doorway of their house. The young, unmarried girl (left) covers her head with a flowered kerchief as a sign of modesty, while the married woman (right) wears a black head cloth that can be used as a veil when necessary. Married women veil their faces, a sign of respect, in the presence of older men such as fathers, uncles, male in-laws, or strangers.

All photographs by Lila Abu-Lughod, Antire-Photo
punctuated their intimate conversations—feelings that they ordinarily denied. To understand this discrepancy, and the meaning of these often poignant lyric poems, I had to learn some important things about Bedouin personal ideals and standards of morality.

I had not come to Egypt to study poetry. When I arrived in the fall of 1978, I was interested in examining the patterns and meaning of interpersonal relationships, especially those between men and women, in a Bedouin society. Long fascinating to Westerners, Bedouins, the Arabic-speaking pastoral nomads of the Middle East, have been described in scholarly and popular accounts in terms of the public world of politics, feuds, heroic poetry, and nomadism. Hardly anyone had paid attention to the intimate world of personal and family life or to the world of women. This was the realm I wanted to explore.

I ended up living in a small community of recently settled Bedouins belonging to the tribes known as the Awdel ‘Ali (sons of ‘Ali), whose traditional territory extends along a coastal desert strip from Alexandria to Libya. Although many Awdel ‘Ali have become sedentary since the nineteenth century, until thirty-five years ago those who remained nomadic made a living in the Western Desert by herding sheep and planting barley. Before the railroads were built, the Awdel ‘Ali also organized camel caravans to transport dates from the major desert oases to the Nile Valley. Now they are involved in all sorts of activities, from the old one of raising sheep to the newer ones of tending groves of olive and fig trees and speculating in real estate. Many profit from smuggling and other, more legal entrepreneurial activities. The Awdel ‘Ali used to live in tents. Now, although most live in houses, they still pitch tents next to their houses and prefer sitting in them because they are peaceful and nonconfining. They used to ride on horses, camels, and donkeys; now they prefer Toyota trucks.

I was welcomed into the large household of a wealthy, charismatic tribal mediator as a sort of adopted daughter. I could occupy this position because I was not only a young, unmarried woman but also
Today's preferred means of transportation for Bedouins is the Toyota truck, below. These roomy trucks allow entire families—husband, co-wives, daughters-in-law, and numerous children—to travel together. The three horsemen, left, hired to celebrate a Muslim festival, hark back to an earlier time when wealthy and powerful men rode horses. Except for certain ceremonial occasions, Bedouins no longer ride horses. The faint English lettering across the top of the tent flap is an indication of the tent material's origin—burlap bags that have been cut apart and reassembled into fabric.

Because of the way I had been introduced to the family. As an anthropology graduate student bravely setting out to do research, I was greatly embarrassed when my father insisted on coming with me from the United States to introduce me. It took me a long time to fully grasp his reasons. Because he was of Arab background, although not a Bedouin, he was aware that in this culture a young, unaccompanied woman traveling on uncertain business would be an anomaly. I, of course, knew of the negative image of Western women, an image fed by rumors, films, and the frequent insensitivity of Western women to local standards of morality and acceptable social behavior. But I had assumed I would be able to overcome people's suspicions, first by playing up the Arab half of my identity and not identifying with Westerners, and second by behaving properly.

What I had not considered was that respectability was reckoned not just in terms of one's actions but also in terms of one's relationship to the larger social world. I had failed to anticipate that the Bedouins, for whom belonging to a tribe and family is paramount, would assume that a woman alone must have so alienated her family that they no longer cared about her. Worse yet, perhaps she had done something so immoral that they had ostracized her. An unmarried girl valued by her family would never be permitted to travel alone, unprotected and at the mercy of anyone who wished to take advantage of her. By accompanying me on my first visit to these families, my father laid to rest any suspicions about my respectability. They could see I was from a good family that cared about me. This helped them perceive me as an Arab and a Muslim, despite my poor Arabic, my American mother, and my unfamiliarity with their ways, and enabled them to accept me more easily as a daughter.

By putting me under the protection of a particular family, my father had assured my safety. But the flip side of protection is restriction, and I found that my daughterly role had some drawbacks. For the first few months I chafed against some of the subtle ways people restricted my activities. I was expected to live in the women's social world and could only go to households where the women in my family went. More important, I was expected to live in their moral community. This put tremendous pressure on me to learn the appropriate behavior for young women, especially concerning modesty.

At first I thought I should move back and forth between the women's world and the men's, but then I realized that in order to be trusted in either I had to declare my loyalties firmly. By accepting the women's world, which was more lively, relaxed, and intimate, I finally began to reap the unanticipated benefits of my status as an adopted daughter. I began to enjoy the personal pleasures of close companionship and a sense of belonging. My research also benefited. Because I participated in their everyday lives and could not force them to answer questions or talk about what did not interest them, I could learn how these Bedouins viewed their lives.

My first clue that poetry might be a rich source of information on the relation-
ships I wished to study came one day when a shepherd's wife, helping out by baking bread in our makeshift oven, suddenly recited a poem after a minor disappointment. I insisted she repeat it so I could write it down. That evening as I talked with my host about what I had seen and heard that day, asking him questions and getting explanations, I read him the poem. His kindly and pedagogical manner suddenly changed. Agitated, he demanded to know who had recited it. I hesitated, suspecting that I had unwittingly betrayed something important; but when I finally confessed that it was the wife of one of his hired shepherds, he was palpably relieved. He explained that the poem had to do with despair in love: the woman sang it because she had lost one husband and her present husband was old and about to die. I then understood that he had feared that one of his wives had recited the poem.

My host's reaction suggested to me that people took poetry seriously as a very personal communication of feelings. From my host's wife I gathered that the poems were somewhat confidential. She scolded me for my indiscretion in sharing this poem with her husband and warned me never to show women's poems to men.

Everyone seemed keenly interested in and moved by this type of personal poetry. Like Japanese haiku in their brevity and condensation of imagery, poems like the following were reminiscent of the American blues in emotional tone:

I wonder, is despair
a passing shadow or my companion
for life

I began to write or tape-record such poems whenever individuals recited them spontaneously in conversation or sang them. What was puzzling was that the sentiments expressed in the poems bore little relationship to the sentiments of ordinary life. Bedouin men and women had a propensity to joke about or deny concern in personal matters and to express anger in difficult situations. I interpreted this at first as defensiveness and thought of the poems as revelations of "true" sentiments.

But several things were wrong with my hypothesis. First, it failed to note that the poems through which Bedouins expressed what I thought of as their "true" feelings were highly stylized and conventional. Second, to label as defensive someone who expressed cool indifference to a love relationship was to impose Western psychological theories where they might not be appropriate. I had to consider what these reactions meant to the Bedouins themselves, which required understanding the place of romantic love in their society.

Americans expect romantic love to preoccupy young people, to be the basis for choosing a mate, and to remain the ideal of all adults in their intimate relationships. The Awlad 'Ali Bedouins view things quite differently. They are scandalized by what they perceive as the gross immorality of Europeans. They even feel superior to their Egyptian peasant and urban neighbors whose laxness in matters of sexual segregation and emphasis on the closeness of married couples they find improper and embarrassing.

Although a theme of songs and stories, romantic love is for the Bedouins some-
what immoral. There are serious consequences for an unmarried girl who is discovered to have a romantic attachment. And the public display of the proof of her virginity at the wedding ritual assures that she will be wary of romantic impulses. Love is not supposed to be the basis for marriages, which are arranged by families. This is not to deny that love can develop between husband and wife or that many couples can become close over the years. Their affection, however, will never be demonstrated publicly. For the Bedouins, the deepest kind of love is expected to be between family members—siblings and parents and children.

This attitude toward love and sexuality is at the core of the Bedouin moral code of honor. Sexual modesty or propriety is essential to personal honor and respectability in this community. The honorable woman or man maintains distance from members of the opposite sex except close relatives and denies interest in love or sexual matters. The sentiment associated with or thought to motivate this avoidance is hasham, which can be translated as modesty, embarrassment, or shame.

Modesty, for the Bedouins, refers to what we might think of as an internal state of shyness and embarrassment and to a set of behaviors, associated with these feelings, that conform to what could be called a code of modesty. The cultural repertoire of such behaviors includes not only sexual propriety but also requires modest demeanor and dress (covering the hair, the arms to the wrists, and the legs to the ankles) for both sexes. The modest person looks down, sits or stands formally, and does not eat, smoke, talk, laugh, or joke in certain types of social situations. For married women, veiling in front of certain categories of men, such as older relatives and in-laws, is also a mark of modesty. To act modestly is a matter of pride because it is considered a sign of respect for the social and moral system.

An important goal of socializing children, especially girls, is to teach them to be modest. I once heard a girl confide to her uncle's new wife, "To tell you the truth, I don't even know what this love is. I hear about it in songs, but I don't know
what they are feeling." The older woman responded approvingly, "That's my girl." If adolescent girls get carried away at a wedding, singing and clapping or hovering too near the bride, their mothers taunt them, "What are you so interested in? Are you looking forward to your own wedding day?" A girl is expected to cry when she hears that someone has come to ask for her hand in marriage; to be sad because she does not want to leave her family. The modest bride screams and tries to fight off the groom when he comes near her.

Even married women, to be respected, deny any interest in their husbands, not to mention other men. A woman rarely uses her husband's name, referring to him as "that one" or if affectionate, "the old man"; if she is being formal, she refers to him politely as "the master of my house/tent." At least in front of others, women are formal and distant with husbands. Although quick to admit the ubiquity of jealousy, the Bedouins still do not respect a woman who shows resentment if her husband marries a second wife. To complain if he seems to prefer her co-wife or spends more time with her indicates what Bedouins see as an excessive desire for the husband.

By the same token, men do not spend much time with their wives and rarely talk about them. They are ridiculed if they show too much concern. When Rashid's new bride ran away he sulked and looked miserable. His relatives teased and even scolded him. They encouraged and supported his later and more socially appropriate response, which was an angry search for someone to blame. He and his brother undertook an intensive investigation of the events preceding his bride's departure. When they had eliminated the possibility of some woman or child in the household having upset her, they began considering sorcery as an explanation. Rashid became convinced that his senior wife must have been responsible. A visit to the local holy man to divine the reason behind the bride's act confirmed this suspicion. In the face of opposition from many of the camp's women, Rashid persisted in blaming his first wife and refused to talk to or visit her.

After some negotiation and pressure from her family, Rashid's bride agreed to return. A day or so later, I was talking privately with him. I asked him how he felt, and he was noncommittal. But when I asked disingenuously if he cared to recite some poems for my collection, he offered the following:

Cooking with a liquid of tears at a funeral done for the beloved
Her bad deeds were wrongs that hurt yet I won't repay them, still dear the beloved

Any doubts I harbored about whether these poems expressed Rashid's personal sentiments regarding the situation were put to rest a few days later. It was evening, and he was sitting with his returned wife. He asked me to join them, requesting that I bring my notebook. "Read the talk of the other day," he said. I realized that he meant the poems. As I read them aloud, he seemed embarrassed and acted almost as if he had never heard them before. He looked blank when I asked him to explain them. The next day his wife confided to me that these poems were about her.

This incident highlights the other crucial aspect of honor, which is a kind of proud personal independence. Rashid's initial signs of attachment to this woman had nearly cost him his reputation. To be weak or dependent is shameful for a Bedouin. I came to realize that it was in light of Bedouin attitudes about the impropri-
Two married women are adjusting the center pole of a large ceremonial tent, left. Made of pieces of material stitched together in patchwork style, these tents are used for weddings, feasts, funerals, or whenever large numbers of people will be together. A group of children, below, listen with rapt attention to a cassette tape of Bedouin poetry. Cassette players have become enormously popular in recent years, and tapes of songs and poetry are passed eagerly from hand to hand.

but here are just a few suggestions. First, I think people are protected by the veiled and impersonal form of the poetry and the circumscribed contexts in which they recite it (they only recite poems in front of people they are close to). Second, by confining these feelings to the rigid form of poetry, Bedouins demonstrate a kind of mastery, and any kind of mastery is admirable. Third, it may be that people make their everyday conformity to the moral code more impressive by showing what powerful feelings they must master in order to live up to its ideals. Finally, reciting poetry seems to be a way of subverting the code of honor and modesty. By rebelling, in this limited way, against the demands of the system, individuals may actually enhance their honor because defiance is the ultimate expression of personal freedom. And as we saw earlier, personal independence is a linchpin of honor.

The place of poetry may be changing, though. When I returned to the Bedouin community in December 1986, just over eight years after I had first come to live with them, I noticed many changes. There were many more houses and some now had electricity. And one change was particularly interesting: the popularity of cassette players and tapes had risen dramatically. There had been a proliferation of commercial cassettes of Bedouin songs and poetry, many not of high technical quality, some practically homemade. Bought in the towns by the young men, they were passed eagerly from hand to hand. Listening to the tapes, one notices something odd—almost no women’s voices are heard. Respectable women would neither recite love poetry publicly nor would they dream of sitting with strange men to make a recording.

This is only one instance in which the traditional modesty code, when applied in new circumstances, has had a more restricting influence on women’s lives. Sexual segregation has ossified with the move from tents to houses. In the tents, a blanket suspended in the middle of the tent separated the men’s and women’s domains when men other than close kin were present. The blankets—unlike walls—were both temporary and permeable, al-
Tents allow for informal segregation; men on one side and women on the other. A blanket can be suspended in the middle of the tent should men other than close kin join the group.

Following the flow of conversation and information. Rooms don’t allow that. Also, in the settlements the likelihood that neighbors will be from different families is greater than it was in the isolated desert camps, where all the members were usually tied by family bonds. The number of unrelated visitors who come by to see the men of the community is also higher because men now have a wide range of business contacts. This means that, to maintain their honor, women have to be more vigilant in keeping out of sight; thus they spend more time veiled and confined to the women’s sections of the household.

For men, coming under the authority of the Egyptian state and shifting to a market economy has meant some erosion of personal and political independence. Yet most men try to take advantage of new economic opportunities, schooling for their children, and medical care, while resisting the imposition of governmental regulations, legal procedures, and taxes. Men have become more oriented to the world outside their community and more mobile in these days of Toyotas and Mercedeses. They now have cash, which is needed to buy most things, including food. Women, on the other hand, stay even closer to home. Their work has become less essential to the community’s economic survival—demoted to a devalued domestic sphere. And they have become financially dependent.

In the living rooms of their new houses, the men hang photographs of sheep and camel herds and lovingly burnish their old shotguns, now used only to hunt the occasional wild bird. Women, on the other hand, are not romantically nostalgic about the old days. They remember the hardships of herding, carrying water, chopping firewood, milking sheep, weaving, and pitching tents. What they do retain from the past is their passion for poetry. Yet with the arrival of commercial cassettes of the Bedouin blues, even this is changing. Women listen to and appreciate the tapes but do not make them. Poetry was always cherished as the voice of personal independence and the freedom to resist. Does its gradual takeover by men tell us what Bedouin women may be losing?
Stretched out comfortably on a bed of seaweed, a female European otter dines on an eel. The otters eat smaller fish (the bulk of their diet) less ceremoniously, without leaving the water or even changing their usual swimming position, except for a slight skyward pointing of the head to ease swallowing.

L. Campbell; NHPA
Outermost Otters
Disappearing over much of its range, the European otter still thrives on Shetland's rocky shores
by Hans Kruuk

At the edge of the water the old mother hesitates. Three babies are close behind her, having followed almost blindly all the way from the den where they were born, high on the slope. The sea is like a mirror, a rare event here in Shetland in early fall, and the animals are on the shore facing a small island only two hundred yards away. It is an island any otter would go for, with rocks and shelter, safe from disturbance.

The bitch slides into the water, almost like a snake, and looks back at the cubs—but they aren’t tempted. I have watched this family for weeks, and I know that these two-and-a-half-month-old cubs have not been near water before. The cubs whistle, and so does the mother. Whistle, whistle again; no change. Then the bitch returns to the shore and, without further ado, takes one of her offspring in her mouth, slides back in the water, and dives. Five seconds, ten, and she is up, firmly holding her cub, swimming straight across to the island. The other two cubs stay where they are, whistling, staring after mother, but not getting even their feet wet. Ten minutes pass before the bitch is back again, alone, immediately grabbing number two. She hurries across the sound, a V-shaped ripple in a huge landscape, whistles coming from both sides of the water now. The second party lands on the island, then disappears behind a rock; silence reigns.

The third cub sits, waits, whistles, walks, whistles. Twenty minutes, and still no mother. Whistling again, the cub walks into the sea, begins to swim frantically, head pointing up, whistling constantly, moving almost randomly. Within minutes, its direction takes it away from the island; fifty yards on it hesitates. I can hear it a long way off, and I am sure its mother can, too. But she does not show, tucked away with her other two cubs, between those safe rocks on the island. The lonely, abandoned cub turns round, struggling in the water. It turns again, swims in a small circle. All of half an hour later it is still there, swimming in that same circle, but very slowly now, whistling only faintly when at all, its head sometimes sinking underwater; the cub is exhausted. Then it stops, turns over, its legs showing above
the surface, and the little otter is now a corpse, floating on the water.

Rarely did my role of impartial observer hurt as much as on that occasion, but I felt I could not and should not do anything. The reason I spend so many hours observing otters on these remote islands 130 miles north of the Scottish mainland is to find out what happens to populations in places where they are relatively undisturbed by humans.

Although the otters I watch live in and around the sea, they are not sea otters but the European otter, *Lutra lutra*, a species found in both salt and fresh water. Unlike the conservation success story of its Pacific cousin, the recent history of the European otter is a disaster. Not long ago, otters were known from all lakes and rivers in Europe. The species is still common in Scotland and Ireland, and healthy populations can be found in a number of places—in parts of Spain, Portugal, Greece, Norway, and North Africa, for example. But elsewhere otters are disappearing, often rapidly. In England, where otters were regularly hunted with packs of hounds until the sixties, they are now exceedingly rare. Probably no more than a handful remain in Holland, Germany, Italy, and southern Scandinavia.

Tragically, we know precious little about why otters are disappearing over so much of their range. It may be because of pollution, because the landscape is changing as rivers are straightened and woods cut, because fish populations are declining, because of tourism, or even because of increased traffic on roads in otter territory. Undoubtedly, the mix of responsible factors will vary from place to place. In Sweden, for example, circumstantial evidence has suggested PCBs may be the chief culprit. Elsewhere, habitat loss may be critical. So far, however, no long-term studies of declining populations have been conducted. In fact, extremely little is known about the basic natural history of these shy animals. Only now are we beginning to ask simple questions about what they need in their day-to-day life.

Shetland—a small group of treeless islands often accused of being just a bog with rocky shores—is an otters' paradise. Between 1,000 and 10,000 animals live on the islands. I started work there about four years ago, with help from many quarters, including my colleagues Jim Conroy and Andrew Moorhouse and several students. We selected a study area, some twelve miles of coast on Shetland's mainland, where we found a cottage to serve as our headquarters, a place where we could live and work with otters on our doorstep. Since then, we have gotten to know over fifty different animals, some very well, some only fitfully; we have seen many families raised, and some flounder, we have seen thousands of fish caught by the otters, we have caught fish ourselves, we have dived the Shetland waters in dry suits and analyzed carcasses in our white lab coats.

At times, the list of questions we are asking seems endless. What limits the size of otter families? What do otters need from their environment, how do they set about getting it, and which of these re-
Otters frequently take a break from fishing to sleep or rest on shore or any convenient patch of seaweed, left. Their thick coats dry in minutes, requiring only a quick, vigorous shaking. Below: When their young ones begin to take solid food, mothers dive deep for bigger fish. This cub’s mother has succeeded in landing a lump sucker nearly half the size of her offspring.

Both photographs by Hugh Miles, Nature Photographers

requirements could be limiting the population? How do they get enough food and shelter? How does all this relate to how large an area each otter uses? How many otters can occupy such an area? And—of prime concern, given the decline of otters elsewhere—why and when do otters die?

The baby otter we witnessed being abandoned by its mother and then drowning was only one of more than seventy deaths that we knew about; just a week later, one of its little brothers was killed by a local farm dog. We discovered that abandonment of cubs is probably rather common and that Shetland otter females rarely rear more than one or two at a time.

About half of the dead otters we found had been killed by cars. There may not be that much traffic in Shetland, but what there is is pretty lethal. The interesting point about this was not so much the proportion that died because of traffic—that figure was biased because a corpse on a road is easier to spot than one in a bog. Much more significant was that these road kills occurred at any time of the year, in sharp contrast to all the otters that died of “natural” causes. The large majority of these died of disease or malnutrition, usually during one distinct period of the year: nearly three-quarters of these deaths occurred between March and June. That was also when all otters were in poorest shape—when body weight was lowest. Otters that died naturally were mainly either young (one or two years old) or old (some seven to ten years old), while traffic victims were usually healthy and middle-aged. We discovered this difference when we analyzed the growth rings in the dentine of the otters’ canines.

So there is a tough time of year, and not surprisingly, this also shows in the breeding pattern. Otters farther south, in England and mainland Scotland, breed at all times of year, but when we started to work out when Shetland cubs were born, it became clear that they usually come into this world in midsummer. The cubs stay in or near a holt, or den, for at least the first two months, which means that, with rare exceptions, we do not see otter cubs until the fall, when they begin to swim with their mother. Early the next spring, she abandons them, and they are on their own.

What is it that makes life so difficult for the otters during that critical period from the end of winter into early spring? We first considered the climate but found no easy answer there. Basically, the weather in Shetland is always lousy, with incessant wind and rain, but because the islands are very much affected by the Gulf Stream, the differences between seasons are actually far smaller than in England. Water temperatures, for example, only drop from 12°C in summer to 6°C in February, not a dramatic change. There is one commodity, however, that does show a big slump: fish. And to understand exactly what happens, we have to know much more about the feeding of otters.

Typically, an otter swims along the surface of the water while fishing, within 50 and rarely more than 150 yards away from the shore. Only the top of its head shows above the water. Without preliminaries the animal suddenly goes straight down, its tail flipping up. Half a minute later it comes up, empty-mouthed, close to where it went down. It lies quietly on the surface for ten seconds, then goes down again. After twenty-four seconds underwater this time, it pops up with a fish in its mouth. The otter eats the fish in the water, in its usual swimming position, its head pointing skyward. Only if the fish is big or awkward to handle will it be landed.

With our binoculars and telescopes, we can identify individuals; when otters eat in the water, their throats often show, and each animal has a characteristically shaped white or yellow patch. We also try, usually successfully, to identify the spe-
cies of fish the otter is eating; often we can even make a reasonably good estimate of its length. We have watched thousands of captures this way, at all times of year.

Otters have a reputation for eating anything fishy, and at first our animals appeared to fit the stereotype. But soon a pattern emerged showing definite preferences. The vast majority of fish eaten by otters are small, with an average length of between six and eight inches. Almost all prey fish are bottom-living species and active at night, which surprised us since Shetland otters hunt by day, in contrast to their more nocturnal brethren in mainland Britain. Apparently, during the daytime, the fish hide under stones and weeds, where they are easier to catch than when they are flitting about.

The most commonly eaten species is the eelpout, but butterfish and rocklings are also often taken, and together these three make up well over 80 percent of the prey. In winter, rocklings are taken most often, but overall, the eelpout is at the top of the list. Experimenting with tame otters in captivity, we found that they usually discover these fish visually, rummaging between and under stones and plants. When visibility is bad, otters also depend on their sense of touch, especially through their whiskers.

Only when I started diving myself, with a dry suit, did I realize how acute an otter's vision must be. I could spend half an hour underwater, delighted with myself for finding three fishes hiding; in exactly the same spot, I might see an otter come up every twenty seconds with eelpout after eelpout. That huge heaving mass of weeds, those hundreds of nooks and crannies, were clearly haunts where otters were completely at home, but where I was a perfect stranger.

When an otter has cubs to feed, her behavior gets more complicated. The male has nothing to do with bringing up the youngsters; that is strictly the female's concern. Almost as soon as the cubs start taking solids, they begin to roam around with their mother. They often wait ashore, somewhere between the rocks, while she dives, though sometimes small cubs stay in a holt.

Otters can handle only one fish at a time, so when a mother has to carry food back to the youngsters, it would be inefficient to take just a small eelpout. A female with cubs thus often swims to deeper water, twenty, thirty feet, or more. There, she may have to dive several times before catching anything at all, but a successful dive may produce a cod, ling, or conger eel, some nearly as big as she is. As every local fisherman knows, these species come close inshore only in the winter, just when cubs' nutritional demands on their mother are greatest. If, while fishing for her cubs, the mother catches smaller prey, she eats it herself while still in the water.

Watching otters dive and determining what they ate was crucial to understanding their ecology, but we also needed to get some measure of the fish populations in the area. The smaller species on which otters depend so heavily are easy to catch in fish traps with a funnel entrance; we left those out overnight in many different places, at all times of year. It was from those experiments that we discovered the dramatic slump in fish numbers: from February to April, our traps caught an average of 0.3 fish per day, versus 3 a day in August. The otters' behavior during this period corroborated our trapping results: during the lean months, only 25 percent of their dives were successful, compared with 36 percent at other times of the year. Most likely, some species of fish move to deeper water, out of reach of the otters.

Almost accidentally, we discovered another, contributory cause of mortality in our Shetland otters, one that came as a complete surprise. When analyzing the
carcasses of dead animals, we collected pieces of various tissues and hair to have them checked for organochlorides, PCBs, and heavy metals.

None of these chemicals were present in significant quantities in our otters— with the one, striking exception of mercury. Some of the animals that had succumbed during the lean period carried a concentration of mercury that experiments conducted elsewhere have shown to be lethal for otters. We now think that the mercury aggravates the effects of food shortage, perhaps causing the otters to starve before they would have otherwise. The most interesting aspect of this is that the mercury appears to be a hazard in which, for once, man has no hand: it occurs naturally in the otter’s main prey species, possibly originating in submarine volcanic activity at the edge of the Atlantic shelf. Joint effects of poisonous chemicals—some man-made—and food stress may well be important to otters elsewhere, too, a possibility we intend to investigate more closely.

We were also interested to see whether fish affected the distribution of otters along the Shetland coasts. So we put out our fish traps in different places along the coast, as well as at different depths. Our plan was to compare fish distribution with what we knew of the otters’. Simple enough, but the answers turned out to be more complicated than we had anticipated. Eelpout was most often associated with the more sheltered bays, but in general, the otters’ prey species were everywhere, and it made little difference whether we put up a trap in five or thirty feet of water, in the middle of a kelp bed or along the edge.

However, although we could catch fish all along the coast, otters did not. They had a clear preference for fishing in shallow water; 64 percent of all dives were in water less than ten feet deep. In these shallow waters, otters would often fish for a long time in one particular place and frequently come back to the same spot. Curious, we put our fish traps in those preferred fishing spots but found nothing special about them; we caught no more of the otters’ prey species there than anywhere else. But as soon as I armed myself with scuba-diving gear and looked at these places underwater, I noticed that they looked quite different; they were often along edges of kelp beds or they were shallows surrounded by deeper water or they were striking open patches right in the midst of huge kelp forests. What distinguished them was apparently not so much how many fish were there as the ease with which otters could get them.

Where shallow water is plentiful, each female and her family occupies a stretch of coast—her range—between one and eight miles long. The ranges center on sheltered bays, with their reliable supply of eelpout, but they also generally include more exposed regions of the coast, where various other kinds of fish can be found. Along one steep stretch of coast with very few shallows, the otters never fished in one place for long but always moved on, with long distances between dives. In all parts of our study site, males had much larger
Sprainting, or defecating, is often a family affair. Otters may spraint in the same place over and over again. Deposits on seaweed will soon be washed away; those on higher land often mount up into impressive piles. The purpose of these markers is not fully understood, although, unlike many other scent-marking animals, the otters do not seem to be saying “keep out.”

Hans Krauk

ranges than did females, just as is the case with many other carnivores. As far as we know, inland otters have considerably larger ranges.

We are beginning to see what an otter or otter family needs inside its range. But one aspect of the otters’ behavior that I find baffling is their tolerance of conspecifics. Having previously studied carnivores that forcibly evict any intruder from their turf, I still find it odd to see two otter families meet with hardly any overt aggression. Their ranges may overlap totally, cubs of one family playing with those of another, at the most only distantly related family. When two families first approach each other, there may be some hesitation in the mother otters, but none from the cubs. Rolling, chasing, sniffing, a family meet seems fun, a boisterous event that cannot be overlooked even if it happens a mile away. Why don’t they fight or defend their territory? Even males usually tolerate strangers. This is one of the questions I hope to be able to answer after watching otters in different areas.

Among these otters, the only distinctive association is the family, that is, the mother with cubs of the year. They stay close together, generally until the cubs are about ten months old, whistling to one another when out of sight, feeding, sleeping, grooming, even sprainting (defecating) together, until the female abandons the cubs and starts another litter. Males are not tolerated anywhere near newborn cubs, but when the little ones are a few months old, the mother allows adult dog otters, including presumably their father, to approach. These encounters are brief: a few sniffs, sometimes play, then each goes its own way again. In the last couple of months before the family splits up, we see more frequent meetings with males, the adults mating while cubs play around them. But generally, adults appear to meet rarely, even when living temporarily in the same range. Some otters are always on the move, passing through range after range; others may stay in an area for days, weeks, or a year. But whether transient or resident, when otters pass each other at sea, they tend to do so silently, separated by a wave, unnoticed or ignored.

The informal nature of the otter’s social system is reflected in its use of holts, too. I was used to the idea of a carnivore—say, a fox or a badger—having a territory with a single main den neatly in the center. But I had to abandon that idea in Shetland, where otters have many holts. These dens—consisting of an entrance hole, under a rock or in the peat, that opens up into a complicated tunnel system dug by the otters—can be found almost everywhere. Many are close to the shore, but some are high up on the hillsides, even on hilltops. In our small study area, with its twenty or thirty resident otters, we know of 120. The otters move continually among them. No animal or family has exclusive use of any holt, but unless two otters are of the same family, they would never use a holt at the same time. Cubs are born in an inconspicuous holt, usually far from water, with hardly anything to show there are otters inside. When they are two to three months old, the bitch takes them to the larger, coastal holts, where heaps of spraints betray the otters’ presence.

In a place like Shetland, you are very much aware of the importance of shelter, of protection against the cold, wet winds. Otters, despite their ability to jump in and out of the sea in a way that makes me shiver just looking at them, need shelter, too. This they find in their elaborate system of holts, but as Andrew Moorhouse discovered, holts are valuable for another reason: they contain fresh water. To understand why this is so important, we have to know about the animals’ insulation.

The fur of otters is very thick and dense, almost like a second skin; they need it because they have almost no body fat. To maintain the insulating properties of the fur, otters spend a great deal of time grooming and rolling, rubbing their fur on the seaweed or on the grass. But more is required than just grooming; they also need regular baths in fresh water. We found that captive otters that swam in a seawater pool and were then deprived of a freshwater bath soon became reluctant to enter the seawater again and sat shivering on the edge. But given the chance to take a dip in fresh water, they were perfectly happy to use the pool. In another test, we measured the effects of salt water on a piece of otter skin, first with and then without a freshwater wash afterward; salt water alone causes a dramatic drop in insulative capacity.

Every large otter holt has at least one “bath” in it. Even in holts far from water, on top of hills, with no fresh water in sight, we find at least one hole with smoothly polished sides, full of fresh, peaty water. So vital is their need to bathe that the otters use only coasts that have such freshwater facilities. Otters can drink anywhere, and even prefer drinking from little trickles close to the seashore, but the places where they can bathe have a much more restricted distribution.

Shetland otters have their problems: the seasonal shortage of fish, mercury in the food, the need for regular aubitions in fresh water. There are also humans, extracting oil and gas from the sea, creating pollution hazards. The oil business centers on the huge Sullom Voe Oil Terminal, where supertankers come and pick up their potentially lethal cargo. The terminal is an industrial environment, with its attendant grime and noise, and nearly ten years ago, a tanker accident killed dozens of otters and birds. But pollution controls are very strict now, and the otters are thriving. The animals can be seen at all times of day. They swim around tankers at berth, they sleep in pump houses, they tend to their cubs underneath the jetties, and the staff of the terminal delights in having them there.

On the whole, the animals are doing pretty well, and there is no need to worry about the species in Shetland. We are now beginning to ask questions about population on the Scottish mainland, in rivers and lochs surrounded by agriculture or wilderness, populations that are clearly threatened and decreasing in numbers. Many things will be different there, of course: the fish species the otters feed on, water conditions, seasonality. But thanks to the fabulous creatures we have been privileged to observe along these wind-swept coasts, at least we now have an idea of what kinds of factors may be important to otters everywhere and how to go about studying them.
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At odds with traditional construction, a chimney with four fireplaces stands in the center of a one-story house built in 1935. Each fireplace angles out into a room—the two adjacent rooms shown and two more behind. The unit was designed by Howard Acree, a resident of Floyd County, Kentucky, who was known for his fascination with technology and invention. His daughter, Barbara Acree Martin, is reflected in the mirror.
Appalachia's Art of the Useful

Where erratic behavior can undermine family status, personal expression has unobtrusive outlets

Text by Charles E. Martin • Photographs by William Strode

Built in 1935 in southeastern Kentucky, Howard Acree’s one-story, four-room frame house features a central chimney that vents four fireplaces. The central location of the chimney means each room has a fireplace angled across its inside corner, instead of standing midway along an interior wall, as is the overwhelming architectural preference in the area. Building a four-fireplace chimney was not the simple duplication of a two-fireplace chimney with back-to-back openings; a lot of figuring was needed in order to maintain structural strength. Although constructed by a professional builder—Howard’s brother-in-law Jones Martin—the chimney’s unique form was entirely Howard’s idea, a journey into what, by mental calculation, should work, rather than what, by imitating tradition, would work.

While the idea of tightly compressing four fireplaces into a single unit was seemingly utilitarian, it was also an act of creativity. Howard probably had never seen a chimney like the one he imagined, but he was not afraid to apply his own geometry without the certain knowledge of success. Always fascinated with technology, Howard bought the first radio, the first clothes washer, and the first automobile with an electric starter in his locale. He also dabbled with “inventing” by combining seemingly unconnected parts. His house fan, for example—a small Sears propeller and the motor from an old washing machine mounted on an empty dynamite box—brought in gawkers from all around.

In contemporary Appalachia, creative and artistic impulses are often expressed in utilitarian objects. To some extent, this channeling of individuality represents a holdover of the traditional agrarian worldview, which emphasized an economy of time and effort. America’s rural settlers, who lived without surplus and whose survival in an uncertain environment was always precarious, sought to combine the artistic with the useful. But this custom is now largely maintained by social pressures. Appalachia is already well through the process of shifting from the agrarian ideal to an industrial one, from few industrial and professional opportunities to many. In Knott County, Kentucky, where
I live, the images of mass culture have taken hold. Within the past five years Music Television and Home Box Office have become available, national fast-food restaurants have opened, and shopping malls have been constructed.

Knott County was created in the 1880s from the isolated sections of four other counties. Prior to the advent of coal mining in the mid-1920s, most families used the steep hillsides that make up all of the county's 352 square miles for planting corn and for pasturing. The agrarian life style demanded voluntary labor from family networks that approximated medieval communal societies. When houses and barns needed to be built, hillsides cleared of trees, or corn fields stripped of weeds, relatives would assemble to share the work and the huge ceremonial meal at day's end. If anyone fell ill, relatives were there to prepare food and tend to farm chores.

A 1939 business profile of Knott County shows only one clothing store and one gas station serving nearly 20,000 residents. About the same time, the first all-weather roads were constructed, bringing in more goods and services and allowing men to commute to coal mines. Electricity was brought to all areas of the county by 1949, followed by the general introduction of the telephone. As the roads improved and employment possibilities increased, particularly as a result of the federal entitlement programs of the 1960s, families abandoned farming, communalism, and the craft traditions farm life demanded, replacing them with more competitive and commercial mainstream values.

Although many social practices have changed in recent years—it is no longer obligatory, for example, to demonstrate kinship respect by naming a child after a revered relative (girls are now given such fashionable names as Heather, Nicole, and Danielle, and boys are named Jeff, Troy, and Kevin)—other traditional constraints persist, a vestige of the old cultural logic that emphasized historical continuity and the appearance of egalitarianism. Creativity remains subdued in this way. For the people of Knott County, their humanness dictates that they create in order to define themselves in relation to those around them, but their culture demands that they be discreet about it, that they hide the overt intent of their art in utilitarian forms, or what is more commonly referred to as folk art.

Cody Jacobs built his two-stall barn in 1936, cantilevering the loft to keep the lower exterior walls dry and to give him the storage space above that he did not need in the stalls, "nine square feet being enough for a horse or mule." Larger stalls would have meant longer logs and more work. Winter's cold winds, however, moved up Onionblade Hollow from the northeast, causing much discomfort to Cody's stock. Cody dropped board walls down from the overhangs on the north and east sides, creating a narrow, L-shaped hallway. He filled this space with "insulation"—fodder lowered from the loft, which his stock fed on through openings cut into the stall walls. By the time his stock had exhausted the fodder, warmer weather had returned.

Homemade sliding gates enclose the barn's entrance. According to Cody, "sliding gates stay put, the wind can't shut
them.” Cody’s gates hang from wooden pulleys, which run on tracks of 1½-inch pipe. The stall doors are fastened with 45-degree slide bars that fall into place automatically, preventing the doors from being left unlocked owing to forgetfulness.

Cody’s brother Otis (who lives just down Onionblade Hollow) also prides himself on his ability to innovate. His rat-proof corn crib, for example, sits four feet off the ground on stone piers capped by pieces of stone that are cut larger than the blocks making up the piers. Blacksnakes, squirrels, and rats cannot climb up around these large blocks. Otis says he arrived at this particular design principle after experimenting with lard cans turned upside down on top of log piers. Rats found themselves blocked by the walls and bottom of the metal container, but the metal quickly rusted. When asked where such ideas come from, Otis replied, “I don’t know. I just take it in my head.”

Otis’s notion of design forms appearing in his head is a common response, given even when a form has been freely borrowed. Others I have talked to say: “I just studied a while on that,” or “It’s the only one in these parts like it.” Perhaps this is self-delusion, but it’s also an indication of how important it is for these builders to have a sense of individuality. Otis elaborately joins horseshoes into door hinges, Rudell Thomas uses a twisted tree trunk for a stair railing, Boss Slone rounds the top of his chimney “’cause it’s prettier that way.” Lech Watson, family patriarch, “took it in his mind” in the 1930s to build a four-stall barn with aisles between each stall. His son Crafus says there were no others around like that and that his father “just wanted something different.”

Creativity in gardening becomes a striving for visual order and color balance; there should be few weeds, and the rows must be uniform and neat. Diane Hylton has a grape arbor around her garden and each year plants flowers (particularly sunflowers) and herbs between the rows of vegetables. Aside from being an inexpensive source of food, the garden becomes a large color montage that can be continually fussied over. Irene Slone prefers her patch plowed from side to side and then planted from front to back, improving, so she believes, its appearance when the vegetables begin to sprout. She also likes to
mix her colors and textures, planting the potatoes at the bottom of her hillside plot, followed by green onions (“which grow straight and tall”), peas (“a lighter green than, let’s say, the beans”), beets (“a mixture of red and green”), turnips, radishes, lettuce, and green beans (preferring dark green at the top). Still another gardener plants chives next to roses, and marigolds and dill among the vegetables. Jimmy Arthur plants bush squash and red peppers because “they look pretty,” but he never eats them. Jimmy also plants corn only in the far section of his patch so the rest of his plants can be seen from the road; the garden is carefully bordered with irises and dahlias. The appearance of people’s gardens is a common topic of summertime conversation, and it is a high compliment to be known as keeping a “pretty” garden.

I have talked with a number of local mountain musicians about their art, including one fellow who plays and sings and who, for the past eight years, has hosted the music segments of an annual folk festival. I asked him to recall those times when someone performed a piece in a particular style that may have surprised him by its originality. Since he tapes all performances, I thought this would be a good opportunity to hear what he considered an original instrumentation or phrasing, rather than what I might. “I don’t recall anyone ever doing that,” he replied. “Well, if it does come to you at some odd time of the day,” I said, “will you let me know?” “Sure, but I don’t think it’s going to happen. I don’t ever recall anyone doing that.”

How, then, is creativity expressed in “old-time” Appalachian music? It lies in the voice. The singer must show “feeling,” or “soul,” to be considered good, and it is through this that personal style is achieved. But what is “feeling”? My friend couldn’t define it, except to recall a story about country singer Ricky Scaggs: when Ricky heard bluegrass musician Carter Stanley perform and saw the tears running down Carter’s cheek onto his guitar, Ricky knew what feeling was.

Cooking is another area of personal creativity, with each customary dish varied slightly to accent what is thought to be individuality. When Loretta Arthur, Jimmy’s wife, fixes a salad, she arranges the
Cody Jacobs, left, plows a field for his vegetable garden. He will plant his potatoes during the new moon because, he says, then the roots will not grow deep, and the potatoes will be easy to dig up. A hinge made from old horseshoes, below, was fashioned by Cody’s brother Otis.

Tomatoes, peppers, onions, and cucumbers on top of the lettuce in a fancy pattern instead of mixing them in, because it “looks better that way.” Thelmarie Thornsberry places a whole orange inside a turkey to improve the taste of the bird and the stuffing. One woman cooks fryers with carrots, green beans, potatoes, and cabbage wedges on top. Not that unusual, but she feels it is, thus separating her from what she considers the commonplace. She also bakes five-layer fruit cakes with apple butter between the layers. The last step is to put the stacked and layered cake back into the oven to “brown.” This gives the cake an added texture that is appreciated by her family. “I’m the only person that I know of that does this,” she adds.

A local quilter is renowned for her skill at traditional design, perhaps giving her the confidence to experiment. She can easily move away from the customary symmetric patterns and make discordant ones, mixing plaids, floral prints, and stripes. And while quilting is normally a group endeavor, she works alone. As Mondrian used cubist squares and colors to generalize arrangements appearing in everyday life, she uses lines and colors to generalize quilting traditions. If repetitive squares are the structural components of a quilt pattern, then her quilts satisfy the basic conventions. But like a modern painter, she often avoids the predictable, exploring her power over the medium by testing the rules of her art form.

Other Knott County quilters occasionally produce quilts with disconcerting shapes and colors, perhaps also to achieve a private sense of individualism. But the daughter of one quilter surmises that her mother has on occasion made “ugly” quilts (the daughter’s term, by which she means the use of only blacks and browns) simply because she was bored with quilting, bored with the exacting criteria expected of quilters, and somewhat bored with life. Shortly after the last black-and-brown quilt, her mother entered the workforce and seemed much happier.

The quilters in my part of the country have an interesting habit I should mention: when you enter their homes, instead of seeing their latest works prominently displayed, you will find them hidden under a cheap bedspread, ostensibly to keep them clean. They also refuse to sell them, preferring instead to offer them as gifts to members of the immediate family.

There seems a reluctance in the county to produce a visible art devoid of function. The selection of paintings for sale at craft fairs is limited (many depict people working and workable objects). Other than these and still lifes occasionally displayed at the county library, a tradition of painting or sculpture does not exist.

The reason personal expression is so often embedded in the utilitarian is that the family radiates political and social power. Although the nuclear family is the basic social and financial unit, the majority of nuclear units form affiliations based on blood ties, marriage, geographical proximity, and common outlook. Security is achieved primarily by the group banding together to support political candidates who will later be expected to be helpful by extending political patronage.

Before election day, candidates for such offices as county judge, magistrate, court
A mailbox mounted on a plow, below, fronts a home in Letcher County, Kentucky. The late Chester Cornett built one of his four-rocker chairs, right, while being filmed for a documentary on his craft. The chair is decorated with an inscription for the occasion. As a result of Chester's national exposure, his neighbors began to see his eccentricity in a more positive light.

clerk, and jailer attempt to establish blood ties with as many voters as possible in the hope that kinship loyalty will override all other obligations (in the biannual elections there are usually some 120 candidates for the fifteen offices-at-large, which works out to about one candidate for every 118 voters). Political advertising for most candidates includes little mention of standard qualifications for office—educational record, military record, previous political offices and appointments. Instead, principal qualifications are the personal character of the office seeker and his family (the majority of candidates are male) and of his wife and her family. And since character is primarily determined by kinship ties, a typical advertisement lists an announcement of candidacy and then a genealogical record extending back two or three generations. When a political candidate lists his family tree, he is reasonably certain that the behavior of his ancestors will reflect favorably on him; he is also aware that his behavior today will reflect on his descendants tomorrow. After election day, the voters begin establishing ties to the winners (when in fact many did not vote for them) in hopes of receiving kinship loyalty in return.

Key members of a highly regarded family group can often influence the political choices of key members of other groups. A winning candidate will reward the man (and this also appears to be a male ritual) who can deliver not only his group's vote but also another's. Since Knott County's largest single employer is the county public school system (an intensely political organization), a large and respectable family group that can agree on a winning school board candidate might be rewarded with employment for many of its members. Supporting the right candidates for county judge and magistrate can mean getting the road and bridges leading out of the hollow repaired after spring rains. A family not unified, unable to influence key members of other families because of low status, usually finds the political structure unhelpful to it—the family's roads remain lined with ruts, and other families' sons are chosen over theirs for whatever employment is available (in an area where the unemployment rate hovers between 12 and 20 percent).

There are also risks. If the chosen candidate loses, the status of the group leader, as well as that of his family, suffers. Status can also be threatened if a family member violates certain behavioral norms: a person should be hard working, nondrinking, pious, and loyal. Erratic behavior can result in gossip, which can mean loss of family status, if influence over others, of an election, and of jobs. A family group's security, then, is tied to its willingness to monitor the behavior of its members in order to maintain its good name. "One of us can shame all the others," commented one woman I spoke to. "If I am shamed and a relative walks down the street, people will say, 'I know who that is, that's S—'s kin.' And how they feel about me determines their attitude toward her. If my reputation is good, they're going to love her; if it's bad, they're going to hate her from across the street."

The pressures of conformity come at the individual from three directions: from within (sensing the personal risks of controversy); from the family (which must protect its position in the local hierarchy); and from nonfamily members (who are on the lookout for odd behavior that might improve their own family's position). I do not mean to suggest that an aura of paranoia surrounds Knott County residents. People are no more watchful here by their neighbors than they would be in a metropolitan suburb. Folks are always interested in the doings of others, but the stakes are higher in this county.

The maintenance of every culture depends to some extent on the subjugation of the personal desires of its members. In Knott County, people generally accept this. There is pressure to get along with other group members since this suggests unity to the outsider. Although harmony is frequently broken as members vie for status within the group, a check is kept on argumentative tendencies, with gossip directed at outsiders and members not present. Loyalty to family also means being concerned enough with the group to take part in the continual house-to-house visits and thus avoid the eccentricity of seclusion.

Family members defer decision-making power to the group, abandoning or modifying a proposed action if it might be detrimental to the reputation of the group. The family makes decisions for its members based on a wider set of contingencies than the individual would normally in-
clude and always seeks to protect its long-range interests.

Some displays of creativity are unappreciated. A couple painted their window facings blue and neglected to hang curtains, saying that they thought the glass panes inside the blue facings were attractive. But when neighbors and family disagreed, curtains were hung.

A woman, newly married and unable to afford a cabinet for her dishes and canned goods, made one of heavy cardboard boxes. While she was particularly proud of her ingenuity and her ability to fashion furniture from generally overlooked items, her family, embarrassed by what they considered a display of poverty, pressured her into replacing the cardboard cabinet with a manufactured one.

A man who had recently returned to eastern Kentucky, after living a number of years outside of Appalachia, built a cinderblock house that, rather than facing the road as was the custom in the area, faced—front porch and all—toward the back hillside. He also painted the house an uncustomary color, in this case a bright orange instead of the conventional white, subdued green, brown, or gray. His neighbors laughed at his house and asked him what he was attempting to accomplish (face-to-face questioning in itself a sign of his questionable status). Friends began to avoid him, relatives pleaded with him to change his house. Social pressure finally won out, and he remodeled, opening a front door that faced the road, ripping down and moving the porch, and switching some interior walls. He has since been known as “the fellow with the house,” and it has taken his family some time to rebuild its reputation.

What residents do with their house is normally the creative activity generating the most gossip, since a house is easily visible from the road. A brightly painted house along Caney Creek elicited such comments to the owners as, “Did you get some paint on sale?” Another house with its red roof, white walls, blue trim, and green foundation produced a similar comment. A bright blue house near Carr Fork became known as the “Smurf House.” A friend told me of one house that was widely talked about: When the owners decided to install a window, they cut an opening both off center and at a sharp angle. Later, they built a porch that completely encircled the dwelling, making the structure look even more odd. My friend then added a postscript: “Do you know, the last time I drove by that house, they had torn it down after all that work and replaced it with a trailer.”

Despite the pressures to conform that families can generate, Knott County is not without idiosyncratic individuals. Eccentricity, including that demonstrated through creative acts—an underground house and a homemade helicopter, to cite two recent examples—is found mainly among older males in both higher and lower income levels. Perhaps there is freedom both in having money and not having it. Middle-income older males and young men of all income groups appear to be the most conforming—the former may be devoting all their energies to trying to maintain and gain status, and the latter may be the most emotionally insecure, fearing the long-term impact that deviation can cause. Women keep an even lower profile.

Toward the end of his life, Willie Owsley made baskets for a living. He also decorated the exterior of his house in an eccentric manner, covering the front with stones from all fifty states and cementing a variety of objects into the walls—dolls, marbles, horseshoes, statues, shells, a pistol, bottles, broken glass, and toy cars—that held meaning for him alone. “There’s plenty of work for a man if he’ll just pick it
Closely related butterflyfish and angelfish feed on the surface of a coral reef, near a sea urchin, in shallow Hawaiian waters. Although the different species eat the same food, they apparently do not compete.

James D. Watt
Deep Questions about Shallow Seas

Why is life there so plentiful and so diverse?

by Kenneth E.F. Watt

The awesome diversity of nature can, I suppose, be experienced in any natural area, but certainly one of the most striking settings is a tropical coral lagoon. When a snorkeler slips into the turquoise blue water, paddles over the yellow sands, and approaches the inner reef, the scene becomes a colorful, kaleidoscopic fantasy. Thousands of fish of nearly a hundred different species dart in and around the bizarre coral shapes. On the bottom and tucked into the countless nooks and crannies are an astonishing variety of invertebrates: sea cucumbers, crabs, shrimp, snails, and nudibranchs. As an ecologist, I have long pondered the causes of such diversity in living systems.

Since 1967, I have been seeking an explanation for the diversity of species in the waters around the Hawaiian Islands. At least 650 species of fish alone inhabit these shallow coastal waters. In ten hours of diving, a casual observer with an inexpensive field guide could easily distinguish forty species of fish at any richly populated site.

Why so many? Intensive field study suggests that traditional zoological explanations can only partly account for this great diversity. For several decades, zoologists have explained at least part of the diversity in nature with “Gause’s Principle,” named after a Russian ecologist who did laboratory experiments on competition between species a half century ago. Gause wrote, in 1934, that as a result of competition two similar species scarcely ever occupy similar niches, but displace each other in such a manner that each takes possession of certain peculiar kinds of food and modes of life in which it has an advantage over its competitor.

In other words, diversity comes about because each different fish has to specialize, to find its own niche where it can do better than its competitors. If one species competes, or overlaps, with another for the same food, one of them will lose out in time and disappear.

According to this logic, one would find great diversity only when species are unrelated (and therefore different in shape and feeding patterns) or closely related but exploiting different resources.
Three species of fish, left, feed on algae growing on a rock in the shallow waters near Poipu Beach on the south coast of Kauai. Different species often travel and feed together. Wary of the photographer, a group of fish, below, turns toward the protective ledges, crevices, and holes of a coral reef off Kauai. Most smaller fish in the reef community stay near holes and quickly dart into them when a predator appears.

Both photographs by Terry O'Halloran

To test these ideas in a natural setting, I have focused on a small bay immediately behind the Poipu Beach Hotel, on the south coast of Kauai, the westernmost of the main Hawaiian Islands. This bay is only 260 feet wide; the protected reef where the surf typically breaks is about 200 feet from the beach. My research over the past two decades has concentrated on an area about 100-by-100 feet just inside the crashing surf, in depths varying from two to ten feet.

So far, I have found two kinds of evidence that raise problems for Gause’s hypothesis. If Gause was correct, then, in a group of closely related fishes with identical resource requirements, I would expect to have found that, after some time, one species had driven out the others. By the same logic, I would have expected habitats with a large number of species to have fishes from many different families. Families are typically distinguishable from one another on the basis of major structural differences due to different life styles and food requirements.

Of the eighty-nine species that I observed in that small bay at some time over the past two decades, fourteen were the only representatives of their families. Many of these were unique and strange animals, such as the cornetfish, needlefish, spiny balloonfish, or spotted flounder. On the other hand, of the twenty-seven families of fish in the bay, just six comprised more than half (fifty-one) of the species. One of these families (the tangs) was represented by twelve closely related species, and another (the wrasses) had fourteen closely related species.

The more one scrutinizes these closely related species, the greater the challenge to Gause’s hypothesis. Many related species appear to have identical anatomy; the only obvious difference is in color, or color patterns. The unicorn tang is a very close relative of the smoothhead unicorn tang. The tail, body, eyes, mouth, and head are strikingly similar. And individuals of closely related species often show no awareness of their difference from one another. I have often photographed many species of butterflyfish congregating as though they were brothers and sisters, sometimes swimming in a wedge-shaped pattern, the underwater counterpart of a flock of flying geese, except that various species alternate along the arms of the wedge. Far from showing any evidence of aggression or competition, closely related species even forage together. A critic might argue that such observations are insignificant, because they only prove that these fish swim together. Perhaps when they arrive at a site where there is food, one individual feeds on one item, another individual feeds on another. This criticism does not hold up. I have watched closely related species feeding side by side, eating exactly the same food. Further, stomach-content analysis shows little or no difference in their diets.

One of three conclusions seems inescapable. Perhaps Gause’s widely accepted hypothesis is false. Or closely related species, while appearing to harvest the same resources, actually have different requirements so subtle or so obscure that we haven’t stumbled on to them yet. Or, these fishes are not competing for food because other factors are keeping populations low. To gain more understanding of the last possibility, I focused on four odd characteristics of the environment of these fish.

Predators in the bay are both numerous and diverse. Two of the most conspicuous are moray eels, a group represented by eighteen species in Hawaii, and jacks, a fish with twenty-five species in Hawaiian waters. Both types of predators are astonishingly fast, particularly for short bursts of about ten feet. The moray is streamlined; the fin structure and body shape of the jack remind me of a high-performance jet fighter. Both morays and jacks rocket suddenly from behind rock cover to snap up prey fish. Given the number, diversity, speed, and stealth of these predators, they must be an ever-present danger to all the other fish in the bay.

I also looked at habitat. Swimming along the coasts of tropical islands, I quickly realized that dense, diverse fish populations rarely live over smooth, flat bottoms (mud, sand, or bare flat rock). Rather, I found great species diversity in conjunction with highly structured and complex coral or rocky bottoms. Closer examination of habitats with extraordinary diversity of species revealed that these environments have numerous places in which fish can hide. Many species typically stay within inches of holes or cracks, which I believe, serve as refuges from predators and are critical to the survival of
many shallow-water oceanic species. To many fish, a diver in a black wet suit may look like a large predator, and my first view of many species has often been their tails as they rocket into a refuge after seeing me. (Many of my photographs are uninteresting portraits of disappearing tails.) Many species combine behavior and anatomy to make best use of a refuge. Some, such as the filefish, lock themselves into a hole by elevating their fins. The blenny enters backward and locks itself in by curling its tail forward. Anyone who spends long periods in shallow oceanic water observing fish will conclude that most of them have immediate proximity to a safe refuge very much on their mind.

Another attribute of sites that support many diverse species is vigorous wave and tide action for at least part of every twenty-four-hour cycle. As well as extremely violent wave action on occasion. Five hotels and a restaurant once stood close to the shore, within two miles of my study site. Hurricane Iwa, on November 23, 1982, eliminated the restaurant and one of the hotels, wiped out 170 rooms of a second, and did considerable damage to the remaining three. Every month, a few episodes of violent wave action churn up sediments and sweep many fish back and forth. When I try to observe the fish at those times, I feel as though I am in a giant food mixer. Many divers get seasick from the turbulent wave action, and others have been injured when they were swept into the reef.

Finally, I noticed a rapid turnover of fish in these habitats. I saw a few score individuals in the bay every day over a period of weeks, but I have seen no single individual for more than one summer. For example, in 1982, a group of eight red-shouldered tangs, each about seven inches long, lived in one hole in the reef; a corresponding group of the same species in the same hole in 1985 consisted of four five-inch and two four-inch fish. None of the eight residents of 1982 was left. Furthermore, of the several hundred individuals I see each summer, many made only a fleetingly appearance. Over two decades, I only saw an ornate butterflyfish in that little bay once—for a few moments in 1985. A four-spot butterflyfish turned up for a few days in 1969, as did a teardrop butterflyfish in 1978. The yellowtail wrasse, represented by one adult and one juvenile every year I visited from 1969 to 1982, was missing throughout the summer of 1985. Forty-one species seen in the bay prior to hurricane Iwa were not seen there afterward. Seven species spotted in the bay after the hurricane had not been seen there previously in the sixteen years of my observations.

In short, the fish community in Poipu Bay was not an example of a stable state, but an unstable equilibrium, with rapid turnover of species and individuals.

So how do these four characteristics—
tors. Thus, predation reduces the species that would be most abundant in the absence of predators and increases the relative abundance of other species. Yet predators are not likely to remove the last few individuals of any species because of the refuges and the vigorous wave action. Even a high-speed predator has difficulty being effective in violent water. This point comes home vividly to the underwater photographer trying to focus a camera in turbulent surf.

The waves have another role, in combination with the holes in the substratum. By chance, the holes come in a variety of sizes. If a particular fish species happened to become abundant, a large number of individuals of about the same size and shape would need a large number of one type of hole to survive. Since the number of any one cavity size is limited, predation and violent wave action would tend to remove a large proportion of any species represented by similar-sized fish. All observers notice a decline in fish after hurricanes. Storms reduce the relative numbers of species that otherwise might attain numerical dominance in a community. Hurricanes, which occur at least once every few decades in most tropical coastal habitats, prevent the development of stable equilibrium in aquatic communities.

Because of predator pressure and occasional storms, the number and size of holes in the substratum determine the number and size of fish that can survive for an extended period in any locality. The excess fish, which cannot find refuges, are likely to be removed by predation or violent storms. Putting it differently, predation and violent storms promote and sustain diversity. Without them, a few species would dominate the community and drive out everything else.

This interpretation is in harmony with experimental results and observations from many field studies. It has a curious philosophical implication. One normally thinks of predation and violent storms as negative factors in nature. Yet they can have a creative, stimulatory, variety fostering role in natural communities.

Curiously, this notion has been discovered independently in several fields and is becoming an important concept in general-systems theory. A new notion of the role of energy in evolution is typically associated with the Belgian scientist Ilya Prigogine. A view has emerged, based on his ideas, that a high rate of energy flowing through a system decreases its randomness (entropy), while its complexity (variety) constantly grows. In effect, a strong current of energy flowing through a complex living system serves to organize it. The agents of this energy current in shallow tropical seas of great structural complexity are the kinetic energy of the waves and the many predators.
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The Moon’s Highs and Lows

by Thomas D. Nicholson

Every nineteen years or so during this season, the full moon sinks low in our sky. Inveterate worriers seeing that phenomenon for the first time might think the moon is disappearing. It isn’t. This is just a cyclical event with an astronomical explanation.

If you had observed the full moon in July about ten years ago, you would have noticed that by approximately midnight it had climbed nearly a third of the way up the sky to its highest point for the night. But at midnight on July 10 this year, the full moon will be only about one-fifth of the way up the sky in the south; so low, in fact, that should the sky be at all murky, you might not see the moon at all. Even if you can see it, it will probably look dimmer, redder, and larger than the full moons you are accustomed to seeing. (The dimness and redness result from light scattered by our dust-filled air; the larger size comes from the moon’s low position—a low moon always looks larger.)

Why is the full moon so much lower than usual? The summer full moon is always lower, lower than other full moons during the year. That’s because the full moon is always opposite the sun, and the summer sun is near its highest point for the year. Accordingly, the full moon opposite the sun in July must be near its lowest for the year. But that doesn’t explain why the July full moon is so much lower this year than it was ten years ago.

As the moon goes around the earth each month, it moves above and below the plane of the earth’s orbit, or ecliptic, going from 5 degrees above to 5 degrees below. Twice a month the moon is exactly on the ecliptic, once when it crosses the orbit from below to above, and once when it crosses from above to below. These crossing points are called nodes. But the moon’s orbit also wobbles around slowly in space, and the nodes shift to the west along the earth’s orbit. It takes about nineteen years for the nodes to swing completely around.

The 5-degree tilt of the moon’s orbit relative to our may add to or reduce its tilt to the equator. Since our orbit is tilted by 23.5 degrees, the tilt of the moon’s orbit to our equator could range from 18.5 degrees at its lowest to 28.5 degrees at its highest. Ten years ago, the tilt was at its lowest; the summer full moon was only 18.5 degrees below the earth’s equator or 31.5 degrees above our southern horizon when the moon was highest during its nightly crossing of our sky. But in the past ten years, the moon’s orbit has swung halfway around the earth. On July 10 this year, when the full moon is at the lowest extreme of its orbit, it will be 10 degrees farther south than it was ten years ago; its highest point as it crosses the sky will be only 21.5 degrees above the horizon. That is why the full moon this July seems to be leaving the sky.

Events in the calendar below are given in local time unless otherwise indicated.

July 1: The crescent moon highlights Leo in the southwest after dark. Regulus is the star below and to the right of the moon; the circular group of fainter stars farther to the right outlines the Lion’s head (facing downward).

July 2: The moon is near the autumnal equinox at dusk. The crescent moon and the equinox (where the sun will be located on the first day of autumn) are nearly midway between the two bright stars Regulus (below) and Spica (above).

July 3: Mercury moves past the sun from left to right (east to west), becoming a morning object. This is the planet’s inferior conjunction, that is, it is in line with the sun but nearer to the earth.

July 4: Still in Virgo, the moon is at first-quarter phase at 3:34 a.m., EST. Spica is nearby and at 1:00 a.m. is covered by the moon (an occultation) as seen from the Pacific and East Asia.

July 6: Two 3d magnitude stars above the moon are Alpha and Beta Librae, the two brightest stars in the constellation of the Scales (the only inanimate object represented in the zodiac).

July 7: Tonight’s moon, in Scorpius, is the apex of a shallow triangle, with Antares and Saturn forming the base, from left to right in that order. The moon occults Antares, but this occurs below our horizon the morning of the 8th.

July 8: Saturn is above the moon as the latter advances slowly past the planet from right to left. They are nearest each other at about 8:00 p.m., EST.

July 10: Full moon, at 10:33 p.m., EST, is in the handle of Sagittarius’ teapot. The brightest stars of the constellation shine dimly through the moon’s light.

July 11: Perigee moon (nearest the earth) comes less than seven hours after
the full moon, strengthening the full-moon spring tide. Exceptionally high tides will occur today and tonight.

July 15: The waning gibbous moon is in Pisces, almost exactly at the vernal equinox when it rises tonight at about 10:00 P.M. The Square of Pegasus (four 2d magnitude stars that form a great box) is north (left) of the rising moon.

July 17: Last-quarter moon, near the border of Pisces and Aries, is at 3:17 p.m. EST. The moon is near Aries' two brightest stars, Hamal and Sheratan, when it rises after midnight.

July 20–22: The morning moon is in Taurus. It rises on the 20th just above the Pleiades (Taurus's compact star cluster, often called the Seven Sisters) and on the 22d near El Nath (the Bull's second brightest star), where the tip of Taurus's left horn would be.

July 23: Apogee moon (farthest from the earth) occurs at about 3:00 a.m. EST, and new moon (between the earth and the sun) occurs at 3:37 p.m. EST. Mercury reaches its greatest westerly elongation (to the sun's right) but is so far south of the ecliptic that the planet gives us a poor morning show.

July 27: With good weather, we might see the young moon in Leo just after sundown. As the moon sets, the star coming out nearby is again the Lion's Regulus.

July 28–29: Stay up late tonight (past 1:00 a.m.) if you want to see the Delta Aquarid meteor shower at its maximum. Even though the shower is a light one, the meteor count could be three times as great as that of an average night.

July 31: The moon ends the month in Virgo, again near the constellation's bright star Spica, which it occults early tomorrow, well below our horizon.

The summer Sky Map identifies the constellations and stars for the months of July, August, and September from latitude 40° north at the evening hours given below. To use the map, hold it vertically in front of you with south (S) at the bottom and match the lower half of the map with the stars you see facing south. As you face in other directions, roll the map to bring the corresponding compass direction to the bottom of the map.

The stars move westward continuously during the night. By morning (before dawn), stars on the western half of the map will have set, those on the eastern half will have moved into the west, and new stars (those of the winter evenings) will have risen in the east. The map represents the sky at about 2:00 a.m. on July 1; 1:00 a.m. on July 15; midnight on July 31; 11:00 p.m. on August 15; 10:00 p.m. on August 31; 9:00 p.m. on September 15; and 8:00 p.m. on September 30. Add one hour for daylight time. The map can be used for an hour or more before or after the times given and at latitudes about 10° north and south of 40° north.
Blackie's Hollow, Virginia
by Robert H. Mohlenbrock

Halfway up the side of a steep hill, Bob Glasgow, a wildlife biologist for Virginia's George Washington National Forest, pulled his green truck off the narrow gravel road and stepped out. I followed him through a thick forest of sugar maples and oaks down into Blackie's Hollow, a ravine carved by a stream that now flows only intermittently. Pausing briefly to examine a violet or two growing on the forest floor, we started up the other side of the ravine. The steep climb to the top was difficult because the rich soil was permeated with countless fragments of shale, but slender trunks of flowering dogwood and redbud were spaced just right to provide convenient handholds.

The ridgetop was flat for just two or three feet, then dropped at a 60 percent grade for several hundred feet to the meandering Cowpasture River in the adjacent valley. The footing was treacherous, for the ridgetop was covered by a thin (two- to six-inch) mantle of loose shale flakes, and a few weathered pines and gnarled chinquapin oaks were the only trees to interrupt the slope's rocky surface. This dry habitat, known as a shale barren, is one of many that dot the steep hills found on both sides of the Virginia-West Virginia border and as far northeast as central Pennsylvania. They generally face south, at an elevation between 1,000 and 2,000 feet, and are undercut by a stream.

Frederick Pursh and other early botanists explored some of these shaly slopes in the nineteenth century, but it wasn't until 1911 that naturalist Edward Steele coined the term *shale barren* and began to realize that many flowering plants that lived in the shale were unlike those found anywhere else. On the fifty-acre barren off Blackie's Hollow, where more than half the ground is devoid of plants, I spotted a buckwheat, a clematis, a rock cress, an evening primrose, a clover, and a groundsel—nearly half of the endemic species botanists have identified. Later, when I visited shale barrens farther north, I saw another kind of clematis and a wild onion, an aster, a goldenrod, and a phlox.

In 1951, ecologist Robert Platt, working from Emory University, analyzed shale barrens and found that although their surface is dry, a four- to thirteen-inch-thick soil layer beneath the mantle provides moisture for plant growth as well as a medium for roots. He also noted that during the growing season, the temperature at the shaly surface sometimes reaches 140°F, too intense for plant seedlings from the adjacent forest to survive. The seedlings of the shale barren endemics have apparently been able to adapt to this extreme heat, with the result that they reach maturity with little competition.

There have been several hypotheses to explain the origin of the barrens and their endemics. Geologists know that the shale and associated siltstone were formed about 400 million years ago. The real question is, did the shale barrens develop after the great glaciers retreated north at the end of the last Ice Age, which lasted from 1.8 million to some 12,000 years ago? Or did the barrens already exist before and during Ice Age times?

Some believe that as the North American glaciers advanced, the existing eastern deciduous forest shifted south, even reaching the Gulf of Mexico. In the hills of Virginia and adjacent areas, conditions became cooler and more moist. As a result, forest covered the ancient shale and siltstone, just as it today covers the more...
shaded northern slopes of the shale barren hills. As the glaciers retreated and the climate warmed, some of the southern slopes became barrens. If this is what happened, the dozen endemic plants were probably not present during maximum glaciation but arose during the last 12,000 years on the newly exposed areas.

Another hypothesis is that the Ice Age caused few major changes in the position or composition of the eastern deciduous forest. Proponents of this view believe that the forest was shaped some 15 million years ago but that a cycle of erosion of the softer shale and siltstone began about 13 million years ago, at which point the shale barrens began to develop. This suggests that the endemic shale barren plants could have emerged over a period of at least 10 million years. Since all the endemics are herbs that overwinter below ground, they could have survived the Ice Age winters.

A look at the endemics themselves seems to provide some resolution of this debate. Botanist Carl Keener of Pennsylvania State University has divided the endemics into two categories. Some shale barren species closely resemble plants that grow in the adjacent deciduous forests. In fact, some botanists do not consider all of them to be distinct species. For example, the shale barren onion differs from the common nodding onion of the forest only in its more round-tipped flower parts; its longer, more slender flower stalks; and its blooming time, which is two weeks later.

Similarly, there is a purple-flowered shale barren clematis, whose only obvious difference from the common Appalachian clematis is that the tufts of hairs attached to its fruits are white instead of cinnamon- or buff-colored. Other examples in this category are the shale barren rock cress, the shale barren goldenrod, and the shale barren aster. Since these endemics have not diverged a great deal from the nearby forest species that probably spawned them, they may have sprung up relatively recently. They also have the most restricted ranges in the shale barrens, possibly because they have not had much time to expand. Accordingly, Keener calls all these plants neoeendemics.

Some shale barren endemics, however, bear little resemblance to other plants of the region, and their closest relatives grow far away. The erect, nonclimbing white-tailed clematis, whose nearest relative is a clematis that lives on dry exposures in the Ozarks of Missouri and Kansas, is an example. At one time, there was probably one species of erect clematis that lived in barren habitats all across the eastern and midwestern United States. This species was then split into two isolated populations, which eventually diverged into two distinct species. The ice sheet that separated parts of the West from the East could have accounted for this split.

Other plants with this kind of distribution are the shale barren evening primrose, whose closest relative grows in the southwestern United States and Mexico; the Kates Mountain shale barren clover, which appears close to the buffalo clover from the Midwest and South; the shale barren buckwheat, related to Correll’s buckwheat from Texas; and the shale barren phlox, whose nearest relative may be a species that grows on the Colorado Plateau. Because these plants may have originated before or during the Ice Age, Keener calls them paleoendemics. His argument is not only that their closest relatives grow far away but that the plants themselves are more widespread on the shale barrens than the neoeendemics, probably because they have had much more time to adapt to this specialized habitat.

"This Land" highlights the biological phenomena of the 154 U.S. national forests. Robert H. Mohlenbrock is Distinguished Professor of Botany at Southern Illinois University at Carbondale.
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Serengeti Scenes

by Richard D. Estes

The scenes in this lovely book, originally published in Japan, affected me so much that my personal choice of a title would have been Rapture or Spell of the Serengeti. Never have I seen so many stunning photographs of African animals and landscapes in one volume. The 300 pages of color pictures reflect the Serengeti’s full splendor: one of the last places in Africa, or on earth, where wildlife has survived in its former abundance in a setting still largely spared the hand of man.

But I am not the one to give an impartial review of this book, for almost every picture evokes memories, accumulated over a quarter-century, of my own Serengeti experiences. How strongly, I asked myself, would this book appeal to Natural History readers without any great attachment to the region, who had never even been to Africa, let alone the Serengeti? In an effort to be objective, I undertook to evaluate the photography, taking into account composition, mood, clarity, and color reproduction. Opening the book at random, I rated a series of forty-six consecutive pictures on a scale of 1 to 10; twenty-eight scored superb (the equivalent of 9 or 10), seventeen good to very good (8 or 9), and only one fair. So, in my considered judgment as a photographer, the proportion of outstanding pictures in this book still seems extraordinary.

My appreciation of photographer Mitsuaki Iwago’s accomplishment is heightened by the realization that the pick of my own collection of perhaps 20,000 slides of the wildlife and scenery of the Serengeti and neighboring Ngorongoro Conservation Area, taken during six years in residence, would be no match for his. Iwago lived only a year and a half in the Serengeti. Only a master photographer could have produced a book of such quality in that time. Indeed, Iwago speaks of the “many thousands of shots” that a photographer shoots in six months or a year, of which only the best and most dramatic are ever printed.

I do know that Iwago pursued his subjects with great persistence and even achieved a certain notoriety among tour guides and researchers during the time he was concentrating on the big cats around Seronera, where the Lodge and Serengeti Wildlife Research Centre are located. In July, 1983, while leading a Serengeti tour of my own, I was told that the best way to find cheetah was to look for Iwago’s red Toyota—and I was warned that he would do his best to discourage other vehicles from coming near the animals he was watching. Sure enough, this was the way we found a cheetah family, after looking far and wide without success. And when
our driver tried to creep within camera range, the occupant of the red Toyota turned to stare at us through an enormous telephoto lens. It was quite disconcerting, like looking down the barrel of a bazooka.

We forgive you, Mr. Iwago. After feasting my eyes on your book, I think we are the ones who should apologize for interrupting your creative labors. I know only too well how maddening it can be to observe such glamorous animals as cheetah where the tour buses are plentiful.

I have seldom thought of a photographer as a great artist, but many of Iwago's pictures are as beautiful as fine paintings, as well-composed and uncluttered; the lighting so pure, the colors so intense in some and so subtle in others; the detail so exquisite they remind me of Wyeth paintings. Do these photographs also reflect a Japanese view of nature? Maybe it's only my imagination, but the artistic tradition of Japan seems to show through many of Iwago's Serengeti scenes.

Compared with most books of photography, which tend to be coffee-table size, this one is small, only 10½ inches wide by 8¼ inches high, yet it is surprising how well the small format works. Most of the pictures are horizontal rectangles that almost, or completely, fill the page, some stretch across two pages, and these include some awesome panoramic views. Sometimes, when two similar pictures are on facing pages, it is not immediately clear whether one is seeing one or two photographs, but this seems preferable to making the pictures any smaller.

*A few zebras graze amidst a herd of wildebeest*
As I leafed through the book, I took notes on some of the pictures that caught my attention because of their particular beauty or drama. I'll mention just enough to convey an idea of Serengeti's richness and variety; a cheetah family in the rain, the mother in the act of shaking a shower of water from her coat; a topi mother and calf standing in the rain; a rainbow arching across a two-page Serengeti panorama; two little bee-eaters perched on a branch (each feather perfectly sharp); a closeup of a zebra grazing, a yellow wagtail beside its chin; a rainwater pool filled to the brim with toads. There is also a series of fire pictures, especially a night view of fire burning in the hills and a pile of smoking dung (often the way fires that have been put out get a fresh start). Iwago has captured the weathered, ancient rocks of the Serengeti kopjes; a red sky and yellow sun setting behind an umbrella acacia; a classic anvil-shaped thunderhead, photographed at dusk. There is an incredible action shot of a lioness leaping through the water after an escaping wildebeest and one of courting lions atop a kopje. There is a series of memorable night shots: a lion couple strolling below a full moon, its light reflected in their eyes; a jackal with a wildebeest carcass all to it-
A mother topi and her calf hunch their backs against a downpour.

self; bloody hyenas eating a buffalo. There is a portrait of a huge hippo standing transfixed in a nearly dry pool; one of a tiny elephant calf tunneling between its mother’s legs; and, of course, numerous pictures of wildebeest armies on the move. The most gruesome pictures in the book are scenes of a lion fight to the finish, especially the death spasm of the loser as the winner bites through his skull, followed by a closeup showing the winner grimly holding on, after his rival’s eyes have turned opaque.

Naturally, no book is perfect. The flaw in this one is the text. Although the captions are correct, the text contains some misinformation about the animals. However, the same can be said of virtually every popular book and article about African wildlife that I have ever read—apart from those written by people who have studied the animals themselves or at least based their information on scientific studies. Anyway, Serengeti’s text amounts to only about 2,000 words and is unimportant. If truth is beauty, then Iwago’s pictures tell the truth about the Serengeti to a degree that may never be surpassed.

Richard D. Estes is a behavioral ecologist who specializes in African antelopes and other large mammals.
The Invisible Universe

Canadian astronomer Terence Dickinson will explore the world of black holes, supernovae, and quasars on Tuesday, July 14, at 7:30 P.M. in the Main Auditorium of the American Museum of Natural History. Astronomers have discovered that the universe is expanding and that already distant galaxies are becoming even more remote. Woven into the fabric of the universe is an invisible component greater than all the matter known to exist. Dickinson will discuss this invisible mass and offer possible explanations of its nature. Tickets are $3 for members and $5 for nonmembers. For further information call (212) 769-5600.

Naturemax

On Wednesday, July 1, the Naturemax theater will premiere two Imax films. Grand Canyon—The Hidden Secrets follows encounters between humans and the canyon, from the Native American's first descent into its vast depth to the present. Among the film's highlights are the recreation of the 1540 Coronado expedition and the reenactment of the 1869 explorations of John Wesley Powell and his crew. Chronos, using time-lapse photography and music by composer Michael Stearns, takes the viewer on a world tour and traces the development of Western civilization. These films will be shown as a double feature on Fridays and Saturdays at 6:00 and 7:30 P.M. Grand Canyon will also be shown daily from 10:30 A.M. to 3:30 P.M., every hour on the half-hour, and at 4:30 P.M. Wednesdays, Fridays, and weekends. For further information call (212) 769-5200.

People Center

The Leonhardt People Center will be closed for July, August, and September. Programs will resume in October.

Free Programs

Cuban and Dominican Music

Son, a Cuban musical form derived from African and Spanish rhythms, gained international popularity in the 1920s and 1930s. Son de la Loma, a group formed by Armado Sanchez in New York City, will perform various son styles. Los Amigos del Ritmo dispel the notion that merengue is all there is to Dominican music. They will present the rhythms of palos and congos (a devotion to the saints and the dead), maboba (a drum rhythm from the coffee-producing region of San Cristóbal), and gaga (a Dominican variation of Haiti's rara). Both groups will perform Wednesday, July 8, at 7:30 P.M. in the Main Auditorium.

Musica Jibara

Jibaros, mainly from interior, rural Puerto Rico, are primarily of Spanish descent, and their music is rooted in Spanish musical styles like aguinaldo (Christmas music), danza (court music), and various types of seis (six-couple dance). Sexteto Criollo Puertorriqueño will perform Saturday, July 11, at 2:00 and 4:00 P.M. in the Kaufmann Theater.

Cuatro Making

The cuarto, a ten-stringed instrument (similar to the guitar) is unique to Puerto Rico and typifies jibaro music. The delicate and complex art of cuarto making will be demonstrated by Antonio Ramirez on Saturday, July 11, at 1:00 and 3:00 P.M. in the Blum Lecture Room.

Seating for these programs is on a first-come, first-served basis. Tickets are not necessary, but seating is limited. For further information call (212) 769-5315.

Members' Program

In conjunction with a private viewing of "On Tap: New York City's Water Supply," Sidney Horenstein of the Museum's Department of Invertebrates will discuss highlights of the exhibition in Rivers Beneath the Streets. This program takes place Tuesday, July 28, at 7:30 P.M. in the Main Auditorium (the private viewing is at 6:00 P.M. in Galley 1) and is free to members. For further information call (212) 769-5600.

At the Planetarium

The Seven Wonders of the Universe, a Sky Show narrated by Burt Lancaster, will be extended through Monday, September 7. After a review of The Seven Wonders of the Ancient World, the program will go in search of the natural wonders of the universe from the great canyon of Mars to the rings of Saturn. For further information call (212) 769-5920.

Grand Canyon Theatre Venture

A Spanish conquistador in a scene from Grand Canyon—The Hidden Secrets, which will premiere Wednesday, July 1, in the Naturemax theater.
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Of Curds and Whey

Do some cheeses taste better if they start out as raw milk?

by Raymond Sokolov

In the beginning, all cheese was made from raw milk fresh from the cow or goat or sheep. Then came pasteurization and then refrigeration, and a primordial human activity lost both its purity of conception and its reason for being.

As recently as the settlement of coastal Oregon in the nineteenth century, the chief encouragement farmers had for making cheese was to preserve perishable milk and to reduce its bulk, so that the output of dairy herds ideally suited to the seaside meadows could be shipped conveniently to distant urban markets. Today, a major road connects the coast with Portland and the settled interior, but the Tillamook cheddar is still produced, even though the same milk could easily be trucked to town before it spoiled. Consumers want it. They like its taste, and most of them have never considered the practical and historical necessities that left Oregon with an established cheese industry.

Even cheese connoisseurs who knowingly probe a Camembert hoping to find the edge softer than the center (Camemberts ripen from the outside in) don’t spend much time pondering the romantic dawn of cheese technology. Cheese snobs, however, sniffle into their weeping Brie about U.S. legal restrictions on the use of raw milk in cheese making.

By raw, they mean unpasteurized milk, which to all intents and purposes is not approved for cheese making unless the cheese is aged at least sixty days. So the ban does not affect cheddar or Parmesan. Only fresh and soft-ripened cheeses come under the raw-milk interdict, but this health regulation outrages cheese snobs, who point heatedly to Mother Europe, observing with Laurence Sterne that they order things differently in France.

Some of the most sensible people you could wish to encounter believe that fresh goat cheeses and Brie and Camembert taste better inside M. Mitterand’s hexagonal-shaped country because they start out as raw milk.

There I was, reading along in the second number of Edward Behr’s fine new newsletter, *The Art of Eating*, when I caught this serious-minded Vermonter expounding this view: “No one will seriously argue that these cheeses have as good flavor as the unpasteurized ones, though they can be very good. Not every subtle change wrought by pasteurization can be compensated for by the cheesemaking that follows.”

Well, Laurie Chenel, the pioneer goat-cheese maker in Santa Rosa, California, argued very seriously when I visited her a few years ago that the raw-milk mystique was myth. She said she had prepared batches of pasteurized and unpasteurized goat cheese under otherwise identical conditions in Santa Rosa. And she saw no difference. I heard the same claim advanced recently by Marie-Claude Chaleix, Ms. Chenel’s teacher. Ms. Chaleix has emigrated from France and settled in Pine Plains, New York, in the Hudson Valley, where she is overseeing the goat cheese operation at Miles and Lillian Cahn’s Coach Farm.

The Cahn’s recently sold a handbag business and went into goat cheese hammer and tongs, with a mechanized, modern dairy and an ever-expanding herd of Alpine milch goats. Coach Farm even has a milking parlor with a revolving carousel and other modern conveniences usually seen only in the largest cow dairy farms and virtually unheard of in the funkier world of goat cheese.

So you would expect the Cahn’s and Ms. Chaleix to insist that their delicately granular, moist, and mildly tangy cheeses are as toothsome as they could be—even if the milk they started out as had never been pasteurized. And they do. But they are not

*The East Beaver Cheese Factory, circa 1906*
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just countering knee-jerk cheese snobbery with self-serving rhetoric. Ms. Chaleix not only has her cheeses to back her up but she asserts that slow pasteurization at a relatively moderate temperature does not vitiate the resultant cheese, while the high-speed, high-temperature pasteurization practiced in some places to save time and money could mar flavor. She also argues that the crucial difference in cheeses comes from the way they are made, from the refinement or lack of it in the cheese-making process.

All this makes sense, but so does the raw-milk mystique, I thought. Clearly, what was needed was an impartial test. But this was not easy to effect. The most obvious way to decide the question would be to hold a blind tasting of raw and pasteurized cheeses produced under identical conditions. This was inherently problematic. The only way to get the cheeses was to impose on a dairy, but only an expert fly on the wall could determine if the two batches of cheese had really been equally handled. Under no circumstances would such an experiment qualify as scientific.

As far as I know, none of the raw-milk mystagogues has attempted a truly objective comparison of truly comparable cheeses. Mostly, the antipasteurization crowd are relying on memories of cheese that was tasted at different times in different places. This is not a reliable method. Here is a self-refuting passage taken from Edward Edelman and Susan Grodnick's useful *The Ideal Cheese Book* (Harper and Row):

> The finest, most flavorful Bries are those made from unpasteurized milk. Unfortunately, United States Customs regulations prohibit the importation of any unaged cheeses made from unpasteurized milk. Once in a while, however, an importer quietly sneaks a few unpasteurized Bries past Customs. They are thinner than the pasteurized varieties and their flavor is more distinctive and a bit saltier, since salt is rubbed into the rind. Pasteurized cheeses are just dipped into a salt-water brine. The rinds of unpasteurized Bries are slightly brown and the cheese oozes a little more. Shipped out younger, these cheeses still have cores. They are brought in by air because they are more fragile and wouldn't stand up to the typical sea voyage.

No specific claim made by Edelman and Grodnick for the superiority of raw-milk Brie is the result of raw milk. Every one (with one possible exception) is the result of different treatment by the cheese maker: thinness, saltiness, brownness of rinds, earlier shipping and resultant cores (the not fully ripened centers favored in Europe), special, luxurious air freight. Isn't it obvious that all these differences
should affect flavor? Is it surprising that clandestine raw-milk cheeses exported in small quantities for an elite clientele paying a premium rate should be superior to the general run of export Bries, pasteurized or not? I haven't been able to find out why the raw-milk Bries ooze more than the others, but I strongly suspect that thinness of the wheel or some other aspect of Brie technology is behind this heavier weeping—not the rawness of the milk.

I can't prove it, of course, but I did manage to try one modest experiment. Ms. Chaleix gave me roughly a gallon of raw goat milk, all from the same tank. I returned home and pasteurized half of it by heating it to 135° F (the original and still quite legal Pasteur procedure) and then letting it sit for thirty minutes, after which I plunged the pot into cold water. Then I made cheese with both the raw and the pasteurized goat milk, by a process similar to the one below.

Both batches were smooth and palatable. There was a barely noticeable taste difference between them—a faintly stronger goaty tang in the raw-milk batch—which lasted only a day or so. By then, both batches had matured somewhat and had indistinguishable flavors, both very bland compared with commercial goat cheese. The pasteurized milk yielded more cheese, about 25 percent more.

What did this experiment prove? Basically only one thing: an amateur can make mediocre cheese at home. I would not dream of drawing sweeping conclusions from any test this informal. But my failure to produce distinguished goat cheese does make me think that Ms. Chaleix's argument about the crucial importance of the cheese maker is a strong one. Perhaps the trace of a flavor difference I detected for a brief period in my cheeses was significant, but I doubt it. I am more interested in the yield differential. Could it be that pasteurization increases yield generally? And isn't that a good thing, all other factors being equal? Which, of course, they aren't.

I would be interested to hear from readers who have access to raw milk, goat or cow, and wish to take what might be called the pepin challenge. Remnet, the natural enzyme source that encourages milk to separate into curds and whey, is available from New England Cheesemaking Supply Co., PO. Box 85, Ashfield, MA 01330. These days, cheesecloth is most widely sold in the automotive department of variety stores. It is apparently good for buffing car wax.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

**Cheesecloth or to a perforated mold and let drain another hour.
9. Cheese is now ready to eat. It will keep, covered, in the refrigerator for two to three days, longer if salted.
Yield: About 3/4 pound cheese

**Fromage Blanc


1/2 pound fresh cheese (see above)
1/2 cup heavy cream
1/4 cup sour cream
2 scallions, trimmed and finely chopped
1/2 garlic clove, minced
1/2 bunch parsley, finely chopped
Salt

Freshly ground white pepper

1. Put the fresh cheese in a serving bowl.
2. Mix together the heavy cream and sour cream (or substitute 1 cup of crème fraîche).
3. In a separate bowl, mix together the scallions, garlic, and parsley. Pour the cream mixture over the cheese. Then sprinkle with scallion mixture and salt and white pepper.

Yield: 4 servings as a first course or snack
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Tim Boyer
A Real Drag

With an abdomen full of eggs, even a short hop from one patch of grass to the next on a hot beach can be a long haul. So this female *Phymateus leprosus*, a grasshopper native to southern Africa, chose the cool of early morning to make her gravid way across the sands of a Mozambican seashore. Later in the day, the sand’s heat would have been intolerable. Even now she holds her body as high off the dune as she can. Does such exposure make her easy prey? These hoppers, known as stinking bush locusts, exude a bitter and foul-smelling chemical that is toxic to predators such as birds and is known to have caused the death of a child. When confronted, the insects display their red-and-black, yellow-spotted hind wings in warning (they are feeble fliers), hopping away only as a last resort. This one had already traveled some 250 feet when she was photographed. Unperturbed, she continued across the dune.—B.D.S.

Photograph by
Anthony Bannister

Six years ago, Hans Kruuk (page 34) discovered that the badgers he was studying on the west coast of Scotland were sharing their setts, or dens, with another member of the family Mustelidae—the European otter. Fittingly, once he had completed his decade-long research on badgers (see "The Case of the Clannish Badger," Natural History, December 1986), he turned to a study of the otters, specifically those living along Shetland's rocky shores. Not content with observing otters from the shore, Kruuk and his colleagues have also taken the plunge, investigating the otters' underwater world for themselves. When not otter watching, Kruuk can be found in Banchory, Scotland, where he is principal scientific investigator at the Institute of Terrestrial Ecology. For readers who are interested in learning more about otters, he recommends C.F. Mason and S.M. Macdonald's Otters: Ecology and Conservation (Cambridge: Cambridge University Press, 1986) and Hugh Miles's The Track of the Wild Otter (New York: St. Martin's Press, 1984), as well as the relevant pages in The Encyclopedia of Mammals, edited by David Macdonald (New York: Facts on File, 1984).
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AMNH/ANTARCTICA!

“A nice morning meeting,” is how Anthony Bannister (page 86) characterizes his encounter with the stinking bush located on a beach dune in Mozambique. He had just spent a night camping out on the beach, and the grasshopper was the first living thing he came upon during a morning stroll. Bannister was born in England but now resides outside Johannesburg, South Africa, with his wife and four children. After pursuing photography as a hobby for many years, he made it his full-time occupation in 1974 and has since published seven books and assisted in the production of several wildlife films. Bannister took this month’s “Natural Moment” with a Hasselblad and a 50-mm Sonnar lens.

Kenneth E.F. Watt (page 60) is a professor of zoology and environmental studies at the University of California at Davis. His usual research is computer analysis of historical data to obtain the equations for an ecological model of the world. Most summers, he spends a lot of time in the shallow waters off Pacific islands revisiting and observing his endlessly fascinating distant relatives and attempting to keep in good physical condition. The most complete handbook on Hawaiian fish is *Fishes of Hawaii*, by Spencer Wilkie Tinker (Honolulu: Hawaiian Service Inc., 1978). A thought-provoking paper on theories about tropical species diversity is “Diversity in Tropical Rain Forests and Coral Reefs,” by Joseph H. Connell (*Science*, vol. 199, pp. 1302–10, 1978).
The 1973 Arab oil crisis is a haunting reminder of the darker side of foreign oil dependence. Since then, America has turned more to electricity from nuclear energy and coal to help restore our energy security. As a result, these are now our leading sources of electricity and a strong defense against an increasing oil dependence that again threatens America's national energy security.

A dangerous foreign oil dependence

America imported four million barrels of oil a day in 1985. Last year that increased by another 800,000 barrels a day. The danger? Most of these new barrels come directly from OPEC. And the U.S. Department of Energy estimates that by year-end 1987, oil imports will be 30% higher than the 1985 level—an ominous trend.

U.S. Interior Secretary Donald Hodel recently warned that “OPEC is most assuredly getting back into the driver's seat” and our increasing dependence will be “detrimental to the country's economic and national security and its financial well-being.”

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Nuclear energy for a secure future

Nuclear energy is not just helping here in America. According to OPEC, nuclear energy has permanently displaced about six million barrels of oil a day in world markets. The lessons we learned in 1973 are lessons we can't afford to forget. Nuclear energy and coal can't offer us guarantees against another oil crisis. But the more we hear about the return of OPEC dominance, the more we need to remember the critical role played by electricity from coal and nuclear energy in fueling America's economy and protecting our future.

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THE Heartbeat OF AMERICA TODAY'S CHEVROLET
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In the Ornithology Department of the American Museum of Natural History, there is one room which is only open by special arrangement. It is called the Audubon Hall.

Among the display of Audubon's watercolors, prints, drawings, guns and buckskins, nothing is more treasured than the artist's copper plates that hang on the walls.

To mark Audubon's bicentennial, the Museum has decided to issue a new edition of six prints struck from these original double-elephant sized plates, last used in the early 19th century.

The first new edition since the 1830s.

The six prints in the new edition are: the Wild Turkey, Male; the Female Turkey and Young; the Snowy Owl; the Mallard Duck; the Canada Goose; and the Great White Heron.

Five years ago, the Museum began looking for a firm which retained the old 19th century skills of copper plate printing and coloring.

After a long search a firm was selected, Alecto Historical Editions of London.

An edition which is closer to Audubon's intentions.

What may surprise many who appreciate Audubon's work is that the artist, although delighted with the superb quality of the original engravings, was terribly disappointed with the coloring of many of the prints.

Indeed in one of Audubon's letters, he writes to his printer Robert Havell:

"These recent proofs are no more like my drawings than a chimney sweep is to your beautiful wife."

The Museum and Alecto therefore went back to Audubon's original watercolors, notes, letters and even bird specimens to produce this edition.

The results have not only surpassed our expectations but have also met with outstanding recognition among curators, art historians and Audubon experts.

The well known British naturalist David Attwood wrote: "These new impressions of the 150-year-old plates could well be judged to be a finer representation of Audubon's intentions than any produced during the artist's lifetime."

"Living Bird Quarterly", a scholarly journal published by Cornell University commented; "Many experts are judging the new edition to be superior to Havell's original prints."

A very limited edition.

Because of the extremely high value of the original plates and the possibility of stress to them, the Museum is limiting the edition to just 125 sets worldwide.

The plates will then be retired for at least half a century.

The set of six prints cost $36,000. (A 19th century set from the same plates fetched over $145,000 at auction at Sotheby's in 1983.)

Already most of the edition has been claimed, the majority of the sets going to important collections in North America including the Library of Congress, the Boston Public Library, the Mellenthin Collection and the National Library of Canada.

Some sets have also been purchased by major corporations, including Dow Jones and the Southland Corporation.

We are now delighted to be able to offer the few remaining sets to individual throughout the nation.

If you would like to receive a prospectus, please write to the Museum at th address below or call Sherry Goodman at (212) 245 5753.

The prints will be available for private viewing in major cities throughout the country during the next three months.

The plates will be coming back to the Museum where they will remain untouched for at least 50 years.
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Cover: Perched on goldenrod blossoms, a predatory ambush bug is poised to take flight. Photograph by Dwight Kuhn. Story on page 34.
All Quiet on the Surtsey Front

In the early morning of November 14, 1963, the violent eruption of a submarine volcano took place in the North Atlantic about twenty miles south of Iceland. The eruption spewed clouds of steam and black volcanic ash high into the sky. By the next day volcanologists realized that a new island was forming from primary rock on the ocean floor. Spectacular thunderstorms, lightning displays, and tornadoes accompanied the birth. The island was soon named Surtsey for Surtur, the fire-possessing giant of Norse mythology.

After about two months of continuous eruptions, the island had risen to an altitude of approximately 670 feet. Lava flows began about five months after Surtsey's birth.

During the summer of 1964, Julian Kane, a geologist who wrote a cover story on Surtsey for the March 1967 issue of Natural History, flew over the island and reported that “every minute or so, bright red fountains of lava shot up dozens of feet above the water...falling as darkened, glowing fragments that tumbled down the black slopes.” The lava flows stopped in May 1965, and by June 1967, Surtsey was dormant. It was then about one square mile of craters, lava cliffs, and glassy sand beaches. Back in 1965, even before its quiescence, the government of Iceland had proclaimed Surtsey a nature reserve restricted primarily to scientists who wanted to study the gradual development of life there.

The first living organisms on Surtsey were probably bacteria found in 1964 in the ash deposits close to shore. In May of the same year, the fly Diamesa zernyi was collected. The following summer, five other species of flies, as well as midges, a mite, and two species of moth, turned up.

Grasses were found on the beaches beginning in the mid-1960s, carried to the island from neighboring islands or from the Icelandic mainland. The first vascular plant to flower along the shore was the sea rocket, seen in 1965. Common chickweed appeared in 1970, and cotton grass was noted in 1971. New species of vascular plants have appeared periodically; today there are about twelve. By summer 1967,
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there were moss colonies of Funaria hygrometrica and two kinds of lichens.

Sea gulls were seen circling the island as early as spring 1964. Kittiwakes may have been the first birds to set foot on Surtsey between eruptions. That summer, the great black-backed gull and the glaucous gull occupied part of the flat sandy beach and were joined by the arctic tern.

Migratory birds often land on or around Surtsey during their seasonal flights to and from Iceland and Europe. By 1967, twenty-nine species of migratory birds had been observed. The first seabirds nested in crevices in the cliffs and lava rocks in 1971. They were the fulmar and the black guillemot. Today five species of birds nest on the island, the only higher animals living there.

Despite the patches of grass, moss, and lichens, Surtsey remains largely barren. According to Sveinn Jakobsson, an Icelandic geologist at the Museum of Natural History in Reykjavik, erosion by wind and sea is changing the island’s shape, and compaction of the volcanic ash below sea level is causing it to sink slowly. But there are no signs that it might erup soon again. Jakobsson believes that Surtsey may survive for the next thousand years.

Making Whoopers

In April, the sole breeding population of wild whooping cranes, now 110 strong, left its wintering grounds at Aransas National Wildlife Refuge in Texas for breeding grounds in Wood Buffalo National Park in Canada’s Northwest Territories. The birds undertake the 2,600-mile migration in flocks of three to seven, sometimes traveling in family groups. The adults nest in May, and by summer’s end, wildlife biologists will know whether the number of new chicks sets a record, as it has in the past three years. Of the twenty-one whooper chicks that fledged at Wood Buffalo last summer, twenty arrived safely at the refuge on the Texas gulf coast. (The other, which detoured and wintered in Oklahoma, was expected to find its way back to Canada.)

All whooping cranes alive today are descendants of the remnant population of fifteen birds counted at Aransas in the winter of 1941–42 (see Natural History, February 1982). The discovery of the birds’ breeding site in 1954 aided conservation efforts, but according to David Blankenship, a biologist for the National Audubon Research Department in Rockport, Texas, Wood Buffalo is an outpost at the extreme northern edge of the cranes’ former breeding territory, which covered the prairies of central Canada and the United States.

Wet weather, a boon for the cranes, was forecast for Wood Buffalo this summer. The birds, which mate for life, build elevated nests of bulrushes in marshy areas. Wet conditions make nest mounds less accessible to ravens and foxes, which devour eggs, and to wolves, which prey on young cranes. Weather is now thought to be a primary player in the species’ survival. During the dry summer of 1981, only three chicks hatched.

Since 1975, a second population of whooping cranes has been in the making at Grays Lake National Wildlife Refuge in Idaho. Fostered by nonendangered sandhill cranes, some twenty-six Grays Lake whoopers spent this past winter with sixteen to seventeen thousand sandhills at Bosque del Apache National Wildlife Refuge, ninety miles south of Albuquerque on the Rio Grande. Eggs for the cross-fostering program are imported from Wood Buffalo and from the Patuxent Wildlife Research Center in Laurel, Maryland, which houses a breeding group of thirty-eight captive whoopers. Although whooping cranes lay two eggs, usually only one survives. Scientists cull the second egg for cross-fostering, so that both the natural and the foster parent can raise a whooping crane. The foster young follow the established sandhill migration route, but they apparently recognize their “whoopeness” and will seek one another out among thousands of sandhills.

Three problems currently plague the Grays Lake program. Although the oldest of the fostered whoopers are of breeding age (the birds can live more than thirty years and may not breed until the age of six), none have yet mated. Droughts in Idaho have taken a toll; last year only two of the eleven fosterlings that hatched survived. Finally, female whoopers are less likely than males to return to Grays Lake after leaving New Mexico in spring. Each year several females wander or stay with sandhills in other areas. According to Rod Drewien of the University of Idaho, who tracks the birds en route, finding strays entails aerial surveys of thousands of square miles over western states. Of course females that are located, captured, and brought to Grays Lake will remain there for the summer.

Wildlife specialists in the United States and Canada hope to eventually establish a third population of wild cranes somewhere in the eastern third of North America. One Florida site being assessed might host a group of nonmigratory cranes, which would be spared the hazards of seasonal travel.

Despite the vicissitudes of the past few years, biologists are optimistic that the Aransas–Wood Buffalo crane population will continue to grow and that the Grays Lake whoopers will begin to pair, mate, and raise healthy chicks. For now, everyone is hoping for rain.

Zoologist Archie Carr, Jr., whose most recent work on sea turtles was covered in this column in June, died May 21 at his home near Micanopy, Florida. He was 77 years old.
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Cliff Notes

Rock artists may have left their mark in Brazil more than 30,000 years ago

by Niède Guidon

In 1963, the mayor of São Raimundo Nonato, a village in the interior of northeastern Brazil, paid a visit to the Paulista Museum of the University of São Paulo. After carefully perusing the archeology exhibits, he asked to speak to the director of the museum. He wished to report that in his district there were numerous rock-shelters covered with paintings that the local citizens attributed to the original native inhabitants, who were believed to have populated the area shortly before the Portuguese arrived in the sixteenth century (some were absorbed into the colonial population, but the majority of them were killed).

Since I was then one of the museum’s archeologists, I was put in charge of receiving this visitor and evaluating his information. The photographs he produced appeared to be of a previously undocumented type of prehistoric painting. The following year, 1964, I left São Paulo to begin work in Paris, but when I finally was able to get to São Raimundo Nonato for a brief survey in 1970, I was quickly convinced of the need for systematic exploration. The rock-shelter art appeared to have been a long and complex tradition. Most of the figures were painted in red, using red ochre; other colors were yellow, black, gray, and white. Depicted were animals (deer, armadillos, lizards, rheas, crabs, jaguars), people, trees and other objects, and various abstract signs. The figures, grouped in niches or on flat areas of rock-shelters, were sometimes organized in compositions that represent such themes as hunting, sexual intercourse, or childbirth. Certain compositions cannot be identified but seem related to ceremonies or mythical subjects. In 1973 and 1975 I returned for longer surveys, identifying more than 100 decorated rock-shelters. Today some 260 archeological sites are known (240 with rock art), and the region is the target of a French-Brazilian research effort that now involves about thirty-five specialists in archeology, geology, ecology, and related fields.

São Raimundo Nonato lies in one of the most beautiful and wild regions of South America. For 120 miles, cliffs up to 800 feet high form a spectacular border between two contrasting geological zones: a plain to the southeast and jagged mountain masses (serras) to the northwest. The plain consists of granite, gneiss, and other igneous and metamorphic rock, with outcrops of limestone. The plateau is composed of sedimentary rock, primarily layers of sandstone and siltsite, with occasional beds of conglomerate containing quartz and quartzite pebbles. Erosion has hollowed out canyons and valleys within the mountainous terrain, and the cliffs harbor numerous rock-shelters containing evidence of human activity—paintings, engravings, and sometimes stone tools and pottery.

Except for isolated patches of forest in a few of the deeper canyons, the vegetation covering the plateau, valleys, and plain consists of nettles, thorny plants, and short, twisted trees. This is called caatinga, an Indian word that means “white forest.” In the dry season, when most of the plant species shed their foliage, the countryside assumes pale purplish tones. The only evergreens that interrupt the immense stretches of branches and thorns are joaueiros and juremas, trees that offer a little shade to the traveler.

The climate is semiarid. The rainy season is from November to March, but the rains often do not come until January. Some years the clouds pass over the region from east to west throughout the rainy season, depositing their moisture in the Amazon basin. Such dry spells can last as long as seven years. When this happens, some of the inhabitants, who live by family farming and by raising goats, must leave home temporarily to seek work in São Paulo, Brasília, or Pará.

When it does rain, there are cloudbursts—all the rain that was missed in the preceding months or years may pour down in a few hours. The narrow, deep canyons are transformed by powerful torrents that sweep up everything in their path. Fortunately, our local guides know where to climb to swiftly reach the safety of the plateau. They have more than once saved the lives of crew members.

These guides and the other local workers who have participated in our research have been essential to its success. They are the ones who know how to find the valleys hidden in the recesses of the mountains, the decorated rock-shelters and caves, and the sites of ancient villages whose inhabitants practiced slash-and-burn agriculture and made pottery. They have also taught us how to live in this dangerous habitat—they know where to find water, and they spot the rattlesnakes that lie in our path. By now we suffer with them when the rains do not come and exclaim “What a nice day!” when we see the December sky fill with black clouds.

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NH-3
tions, we concentrated on the rock art itself. We started digging at the base of various painted walls, to uncover material that would enable us to date the different art styles we identified. The first results came from applying the carbon 14 method to vegetable carbon that came from hearths. These samples ranged from 10,000 to 3,000 years in age. In 1980, we obtained additional dates at two sites for early layers, ranging in age from 25,000 to 12,000 years. These dates added a new dimension to our work, since they challenged the generally accepted notion that people entered the New World by way of the Bering land bridge shortly before 12,000 years ago.

From 1982 to 1985 we carried out extensive excavations at one of these early sites, the Toca do Boqueirão do Sítio da Pedra Furada. This is a very large sandstone rock-shelter (about 230 feet long), elevated some 65 feet above the plain in the 300-foot-high cliffs of the Serra Talhada. More than one thousand painted figures line the back wall. Protection from the elements is afforded by the slant of the wall, but the floor area within the drip line is relatively narrow (20 to 40 feet, front to back).

We have classified the prehistoric art in the vicinity of São Raimundo Nonato into six traditions—three of painted figures and three of engravings. A tradition is defined primarily by the kinds of figures involved and their relative numbers. Within traditions we can also distinguish styles according to how the figures are drawn and by the painting or engraving technique. Most of the art of Pedra Furada is in what we call the Northeast painting tradition, widespread around São Raimundo Nonato. It is characterized by the prominence of human figures, which are almost as numerous as those of animals, and by the small number of trees, objects, and signs. The themes of these compositions usually cannot be identified with confidence.

The excavation at Pedra Furada started out at the foot of a large panel of figures and covered a relatively small area (10 by 23 feet). We began finding archeological remains right beneath the surface. The clustering of stone artifacts (tools and waste flakes) around such structures as hearths and food storage pits, and the separation of these structures by archaeologically sterile areas, induced us to enlarge the surface of the working site. In 1985, the excavation covered 2,700 square feet and was 15 feet deep.

The strata are well defined by sandy sediments that formed as the sandstone walls of the rock-shelter disintegrated. Within the layers we have found overlapping floor surfaces, demonstrating a succession of human occupations. Those higher up were used by the authors of the Northeast rock art tradition. This cultural phase, which we call Serra Talhada, lasted from about 12,000 to 6,000 years ago, in other words, from late Ice Age times (which ended about 10,000 years ago) right on into the modern epoch. A briefier phase, dated to about 5,000 years ago, succeeded it and may correspond to another painting tradition that we call the Agreste.

Beneath the Serra Talhada materials we found the earliest remains, which we call the Pedra Furada phase. Stone artifacts were quite plentiful and were found undisturbed in association with hearths. The hearths often consisted of stone circles made from chunks that had fallen from the cave wall; in other cases fires were lit in pits or directly on top of stone slabs. Charcoal samples from the hearths yielded a consistently ordered series of twelve carbon 14 dates that ranged from 32,000 to 17,000 years ago. (The gap of at least 5,000 years between the Pedra Furada phase and the later Serra Talhada phase may reflect disuse of the site but does not mean the region was uninhabited. At the nearby rock-shelter Toca do Sítio do Meio, for example, we found artifacts dated from 15,000 to 12,000 years ago.)

Generally the hearths lie near the back wall of the rock-shelter, on the most level part of the ground. In early times this was a quite narrow area, as the surface sloped downward to the plain just six to ten feet away from the back wall. In places, ash and charcoal from a hearth spilled over the embankment, forming a trail down the

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Most of the rock art at Pedra Furada dates from 12,000 to 6,000 years ago.

slope. The floor space became wider for later occupants, as deposits built up and out over the early layers.

The most ancient possible vestiges of painting dated so far are some red marks found on chunks that fell from the rock-shelter wall and were found within layers 32,000 to 27,000 years old. These pale traces cannot be deciphered because they are too fragmentary and damaged by the elements. More clear-cut dated evidence of painting comes from the end of the Pedra Furada phase, 17,000 years ago. This is a single hearth around which have been found a few stone artifacts. Some pieces of wall with red stain were found in this layer. One of the fallen chunks, used to border the hearth, bore two straight, parallel lines on its underside. Several pieces of red ochre and yellow ochre have also been found in the Pedra Furada phase. Based on these finds we can say that the antiquity of art in the Americas approaches that of Europe, Africa, and Australia.

We unearthed no remains of bone or unburned wood in the Pedra Furada phase. Bits of branches, leaves, seeds, and bones were found at higher levels of the site, but conditions in the lower layers were not conducive to the preservation of such organic remains. The acid soil, as well as the water that infiltrates along the sloping bedrock, may be responsible for the lack of such remains in the earlier levels.

Raw material for manufacturing stone tools was available very near the site. Streams that drop from the top of the cliff during the rainy season have deposited two large accumulations of quartz or quartzite pebbles on either side of the rock-shelter. Comparison of the pieces found inside the excavated zone with whole or naturally broken pebbles found nearby demonstrates that the rock-shelter occupants were selective in transporting stones back to the site.

The stone artifacts are made out of whole pebbles or out of flakes. The beginning of the Pedra Furada phase is distinguished by a wealth of points obtained by two, three, or four convergent flakings. The blows were delivered with a hammerstone, rather than with a bone or wooden hammer—a relatively primitive method. These points were found along with chopping tools, saw-toothed implements, gravers, notched pieces, and retouched flakes. Knives, small tools flaked on both sides, and scrapers appear later on, about 25,000 years ago. Flakes and other refuse from the working of stone are found throughout the deposits.

Based on the types of artifacts found and their location, we believe that Pedra Furada was a temporary campsite and not a permanent habitation. There is evidence of only three kinds of activities: rock painting, flaking and retouching of rock, and cooking and eating of food. The traces of these three activities are always associated with hearths. If this had been a permanent habitation, we would expect to find more types of activities and structures represented, sometimes superimposed in the same zone.

We found a great deal of flaking waste but few finished stone tools at Pedra Furada. This suggests that the stone was worked at this site because the source of raw material was nearby but that the finished tools were then taken to a more...
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permanent village, probably located on the plain. The absence of bone and wood implements and other organic debris in the Pedra Furada phase may further reflect this specialized use of the site, although as mentioned, conditions were not conducive to their preservation.

Each hearth was used several times, the quantity of ash and charcoal testifying to intense activity. Occupation of the rock-shelter was thus regular but not necessarily continuous. Small groups probably stopped at the site according to the rhythm of their movements about the land, each time building a new hearth or reusing an old one.

Pedra Furada is only one of the sites we have explored in the vicinity of São Raimundo Nonato and is not the only one to yield such ancient dates. Our progress at some sites, however, such as the rock-shelter Toca do Sítio do Melo, is stymied by the presence of large fallen blocks that cover the lower layers. Heavy mechanical equipment could remove these obstacles, but so far we have been unable to bring any in because the region is remote and the sites are difficult to reach.

We are also searching for permanent habitation sites in the valleys and on the plain. The traces of some prehistoric villages reveal agriculture and pottery use and are therefore presumed more modern than the Pedra Furada cultural phase. Last year, however, we found three surface sites with only stone artifacts; these may prove to be villages of the Pedra Furada people.

Because the area near São Raimundo Nonato is so isolated, no researchers studied there before us. When we started out, we knew nothing about the region's geology, vegetation, animal life, and climate. Since 1978, however, we have been recording present-day climatic conditions and collecting herbs, seeds, fruits, and animal skeletons. Some rock-shelters and caverns located in limestone outcrops on the plain have yielded the bones of Ice Age animals, and samples of fossil pollen are being prepared with a view to reconstructing the ancient climate.

Certain geological formations and a paleofauna that included giant sloths, horses, camels, and early llamas already indicate that the countryside in the past was quite different from what it is today. No horses, for example, could now survive in the caatinga with its thorny, dense vegetation. Apparently, before 11,000 years ago, the climate was more humid, and the countryside consisted of prairies and stands of tropical rain forest. Even today, in deep, narrow canyons that retain moisture during the dry season, we have found typical rain forest plants.

Recently we began making a series of test pits in caves and rock-shelters located in limestone outcrops within a radius of twelve miles around Pedra Furada. The calcareous nature of these sites is more favorable to the preservation of bone. We have already obtained remains of horses and giant ground sloths associated with stone artifacts, ocher, and hearths. The charcoal from these finds has not yet been dated, but we can affirm that there were groups of early hunters who pursued horses and ground sloths and probably other Ice Age animals we have recorded for the region—large camels, gliptodonts, and giant armadillos, as well as peccaries, deer, birds, and small to midsize rodents. Our hope is that before long we will also uncover the bones of some of the early Brazilian hunters themselves.

Charcoal from an early hearth yielded a date of 30,000 years before the present.

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An Universal Freckle

Ethnologists have their own reason to celebrate the bicentennial

by Stephen Jay Gould

Rumor has it that something big happened in Philadelphia exactly 200 years ago. Posters, parades, and propaganda all proclaim the bicentennial of our Constitution, hammered out in lengthy compromise during the long, hot Philadelphia summer of 1787. I will not begrudge this event its proper place in the annals of human liberty, but Philadelphia in 1787 means something else in my parish of evolutionary biology—for there, on February 28, at a meeting of the American Philosophical Society, the Reverend Samuel Stanhope Smith delivered his “Essay on the causes of the variety of complexation and figure in the human species.” Historian William Stanton has characterized this essay as “the first ambitious American treatise on ethnology and long a standard work in the United States. It even attracted the attention of European savants—no mean accomplishment for an American book in the eighteenth century” (The Leopard’s Spots, University of Chicago Press, 1960; Stanton and I chose the same striking line from Smith’s essay as the title to our chapters on his work).

The myopia of special interest often leads to such idiosyncratic ranking for the relative importance of events and people. I insist that Thomas Jefferson was a paleontologist, Vladimir Nabokov an amateur taxonomist of butterflies, and Billy Sunday a mediocre outfielder for the long-suffering Chicago Cubbies (hey, he hit .291 in 1887 and even smacked three homers when they were as rare as three-toed horses). Philadelphia in 1787 belongs to the birth of American ethnology—in other words, we the people.

Parochialism can limit and distort our perspective across time, as well as among professions. When we view the past only in the light of modern concerns, we inevitably commit major errors of substance and emphasis. Such errors often arise when we impose a modern taxonomy of people or concepts upon the past—when we place a person or an idea into a category that simply didn’t exist in its own time.

Since we view evolution as the great watershed of biological thinking, and since we retain our lamentable habit of scanning the past for heroes (defined as precursors of modernity), we eagerly abstract passages from pre-Darwinian texts that seem to recognize the truth of evolution. The authors of these disembodied snippets then become heroes of modernism, but I wonder if they don’t lose more in misrepresentation than they gain in approbation.

Samuel Stanhope Smith is America’s primary case for this intellectual form of killing by kindness. Science was a minimal enterprise in colonial and early republican America, and we need all the heroes we can get. Smith has therefore become the primary example of an American pre-Darwinian evolutionist because several misinterpreted passages in his 1787 essay can be read favorably in a later light. Yet Smith spoke from another world with a different taxonomy of concepts. His own categories didn’t even include the possibility of evolution. Smith’s world was also an interesting place; it merits our understanding, not our depredation for our own parochial purposes.

The title page of Smith’s essay lists him as “professor of moral philosophy in the college of New Jersey.” He later became president, while his institution took up the new and more distinctive name of Princeton. Smith’s essay on human variation makes two central points: first, all humans belong to a single species and descend from an initial pair; second, our racial and national variations are responses to differing climates and conditions of life. These variations can therefore be modified or reversed, albeit slowly, over several generations when populations move to different climates or adopt new habits of life.

The benign myth of Smith as a proto-Darwinian arises from three arguments that he used to support this thesis. First, he claimed that racial variations, as adaptations to prevailing climates, had arisen by a process of change from the original human form. He noted the direct effect that climate imposes upon us: “The heat of summer darkens the skin, the cold of winter chafes it, and excites a sanguine color.” He then argued that these minor and reversible changes can be accumulated over generations to a substantial and inherited effect; tropical climates will encourage the development of permanently black skin. “Every sensible difference in the degree of the cause, will excite a visible change in the human body.”

Second, Smith supported a theory of heredity that explained how changes impressed directly by climate could be rendered permanent in succeeding generations. This incorrect theory, the “inheritance of acquired characters,” holds that useful traits, developed by sustained effort or impress during an organism’s lifetime, may be passed directly to offspring by altered heredity. This theory usually goes by the name of Lamarckism because Lamarck invoked it in the first important evolutionary treatise of modern science, his Philosophie zoologique of 1809. This designation is both unfair and ironic. La-
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Lamarck did not invent Lamarckism. Inheritance of acquired characters was the standard view of heredity in his day, a virtual folk wisdom. The essence of Lamarck's theory lay elsewhere, and he had many sensible and interesting things to say (see my column of March 1985 on the flamingo's smile, for example). But, since the inheritance of acquired characters is incorrect, and since this style of inheritance later received the name Lamarckism, we blame the founder of evolutionary studies for the common view of all his contemporaries.

In any event, Smith presented a fine epitome of Lamarckism, emphasizing the vital point that continuously impressed adaptive characters might become hereditary, but not such sudden accidents and mutilations as the loss of a leg or the amputation of a tail. (Thus, when Weismann later cut off mouse tails for many generations, and never achieved any reduction of tail length in offspring, he didn't disprove Lamarckian inheritance—textbook claims to the contrary—any more than Jewish male infants do by continuing to develop foreskins after several thousand years of circumcision.) Smith also cited his "Lamarckian" belief to establish the primary correlation of color and climate:

Color and figure...are created, not by great and sudden impressions, but by continual and almost imperceptible touches. ...They are transmitted to offspring, and augmented by inheritance.... National features, like national manners, become fixed after a succession of ages. They become, however, fixed at last. And if we can ascertain any effect produced by a given state of weather or of climate, it requires only repetition during a sufficient length of time, to augment and impress it with a permanent character. The surname countenance will, for this reason, be perpetual in the highest latitude of the temperate zone; and we shall forever find the swarthiness, the olive, the tawny and the black as we descend to the south.

Third, Smith advocated a general philosophy of imperceptibly gradual and continuous change entirely in keeping with Darwin's later proclivities. Armed with Darwin's own philosophy, and Lamarck's own theory of heredity, Smith bathed himself in the anachronistic glow of the two men most closely associated with evolution. How can we view him as anything but a precursor of later truth? "In the beginning," Smith writes,

permit me to make one general remark which must have occurred to every judicious inquirer into the powers both of moral and of physical causes—that every permanent and characteristic variety in human nature, is effected by slow and almost imperceptible gradations. Great and sudden changes are too violent for the delicate constitution of man, and always tend to destroy the system. But changes that become incorporated, and that form the character of a climate or a nation, are progressively carried on through several generations, till the causes that produce them have attained their utmost operation. In this way, the minutest causes, acting constantly, and long continued, will necessarily create great and conspicuous differences among mankind.

I was led to Smith's essay by last month's reading of Petrus Camper (when I then remembered the transient bicentennial angle, I realized that I had to work pronto). Camper, Smith's contemporary across the Atlantic, has also been misread (unfavorably for presumed racism in this case) as an evolutionary precursor. Yet I recognized the almost cruel irony that Camper's own world view placed truly evolutionary interpretations well beyond the pale of conceivable thought. Since Smith shared Camper's philosophy, his false name as precursor must suffer a similar rebuttal—thus freeing him for proper appreciation of his genuine talents and importance.

Camper and Smith both took the problem of human variation as their subject. In the mind-set of our own times, variation is irreducible and primary. When I pick up a handful of snails, I see their differences. Variation, moreover, is the raw material of evolutionary change. Thus, differences both define the present state of a population and provide the source of any future alteration. An acknowledgment of variation, accompanied by a theory of adaptive change in response to climate, should therefore brand anyone—Smith in particular—as an evolutionist.

But Smith inhabited a different world with contrary presuppositions. Darwin's revolution had not arrived, and the old Platonic view of essence or type still dominated biological thought. Species were not defined by their variation but as idealized forms, each permanently separate, by fundamental nature or essence, from all others. Variation might be a reality of life, but it ranked as confounding nuisance in any effort to define the world's created species. Variations were often called, in a technical usage of the times, accidents. When an eighteenth-century biologist picked up a handful of snails belonging to a single species, he tried to abstract a single essence from the accidental varia-
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did support a political theory of universal brotherhood based on common biological heritage, but his justification lay firmly in the concepts of anti-Darwinian essentialism that identified our variation as necessarily devoid of true evolutionary import.

Since all humans share a common essence, Smith argued that our variations can only represent more or less of common properties, not the presence or absence of unique features. Skin color, for example, has a universal basis, and the same cause that raises freckles on a white person darkens a black person from head to toe:

Freckles are seen in all shades of color. They are known to be created by the sun; and become indelible by time. The sun has power equally to change every part of the skin, when equally exposed to its action. And it is, not improperly, observed by some writers that color may be justly considered as an universal freckle.

These shared features reach different states of intensity among disparate peoples because they are so strongly subject to direct modification (with later inheritance of these acquired characters) by two immediate factors of environment—climate and conditions of life. Smith's notion of environmental power extended beyond the tired old argument that tropical climates produce dark skin, for he sought to explain the totality of both obvious and subtle differences among people as expressions of environmental impress. Consider two examples of his theory and the extent of his confidence in its shaping power.

Smith argued that the entire range of Oriental features could be understood as responses to the cold, inhospitable, and wind-swept world of the Asiatic tundra. Cold contracts the aperture of the eye, producing the Oriental slant—"the intensity of the frost concurring with the glare of eternal snows." Meanwhile, the pressure of lower jaw against upper (a clenched against cold extended continually over generations) causes the face to spread at its sides and forces the cheekbones up. As for flattening of the nose:

The inhabitants of frozen climates naturally drawing their breath more through the nose, than through the mouth, thereby direct the greatest impulse of air on that feature, and the parts adjacent. Such a continual stream of air augments the cold, and by increasing the contraction of the parts, restrains the freedom of their growth.

The impressive size of the cranial vault is not so much a favorable sign of unusual intelligence as a relative expression of the only source of potential warmth amidst so much contraction caused by cold: "The superior force of life and warmth in the brain that fills the upper part of the head, will naturally increase its size, and make it overhang the contracted parts below."

As a further example, adding the second force of life style to the primary influence of climate, consider the multiple sources of African blackness. The tropical sun ranks first, but its effects are manifold. Solar intensity colors the skin but also produces greater thickness. This denser covering blocks the escape of bile, and bile turns black on exposure, thus increasing the darkness of skin.

To this double whammy of sunburn and bile, we must add the rude effects of savage life style, tending to darken the skin further. Exposure and misery haunt the ignoble savage:

A naked savage, seldom enjoying the protection of a miserable hut, and compelled to lodge on the bare ground and under the open sky, imbies the influence of the sun and atmosphere at every pore. He inhabits an uncelebrated region filled with stagnant waters, and covered with putrid vegetables that fall down and corrupt on the spot where they have grown... The vapor of rivers, the exhalations of marshes, the noxious effluvia of decaying vegetables, fill the whole atmosphere in an unimproved country, and tend to give a dark and bilious hue to the complexion. And the sun acting immediately on the skin in this state will necessarily impress a deep color.

Add to this the indelible impress of colors used to daub or tattoo and the effect of smoke from poorly ventilated dwellings—"these causes will render it impossible that a savage should ever be fair." So much for romantic illusions of the Rubáiyát where (so long as we have bread, wine, and companionship) even wildness would be close enough to paradise.

These arguments may strike us as silly today, but they do capture the primary contrast between Smith's monogeny and the polygeny of his opponents. Those who viewed races as separate species invoked the same traits as examples of permanent, essential differences marking bridgeless gaps of quality between white and black or Oriental. By arguing that all these traits lie on continua of direct molding by climate and life style, Smith affirmed human unity by branding our variations as accidental play upon a common essence.

The gradual production of variation by continuous environmental modification also underscored a political point central to the argument of most monogenists (remember that the word science did not yet exist and that the modern taxonomy of separation between scientific and moral or political issues did not trouble Smith's search for a unified personal philosophy): if inhospitable climates and savage life
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styles could drive a wedge of difference between people, then an amelioration of environment could bring us together again.

We must not carry the argument too far to an optimistic absurdity of immediate perfectibility. Racial differences, for Smith, are not superficial, capricious, or immediately expungeable. Black skin is not a sunburn, ready to be blanched by a winter indoors. Our differences may have been impressed by climate, but the process occurred gradually over many generations and entered our inborn constitutions by inheritance of acquired characters. Still, if undesirable traits were fashioned by continuous impress, they may be reversed and even abolished, slowly over many generations, by an improved environment.

Smith cited the case of a young Indian exposed to the salubrious effects of polite society as a student at Princeton. The distinctive characters of ancestry had not yet been completely erased, if only because he had lost precious time by spending his first fifteen years in native haunts. But his sojourn among the more fortunate had already expunged "that vacancy of eye, and that lugubrious wildness of countenance peculiar to the savage state." Smith opined that an equalization of life styles might eventually efface all differences between Caucasians and Indians in their common American climate: I have received the most perfect conviction that the same state of society, united with the same climate, would make the Anglo-American and the Indian countenance very nearly approximate.

Smith did not believe that a melding of African and European features could go quite so far in America; for a greater difference in climate and a ruder life style, both deeply impressed by so many generations of Lamarckian inheritance, had forced blacks so far from the ideals of white perfection. At least some measure of "the negroe color" had probably been "rendered almost perpetual."

Still, Smith hoped for a substantial amelioration if the bonds of slavery could be loosed and blacks accorded a measure of social and economic equality. He felt that the process had already begun because slaves living as domestic servants seemed lighter of skin and straighter of hair than their compatriots laboring in the fields. (Smith did not recognize, or chose not to mention, a more obvious explanation based on a brutal reality of slavery—offspring of mixed blood born as a result of coercion and rape.)

The great difference between the domestic and field slaves, gives reason to believe that, if they were perfectly free, enjoyed property, and were admitted to a liberal participation of the society, rank and privileges of their masters, they would change their African peculiarities much faster.

Just as we must not use false hindsight to cast Smith as an evolutionist before his time, we should also recognize that he was no modernist on the subject of racial equality either (anachronism is equally misleading in scientific and moral spheres). Smith did take a radical posture for his time (he actually advocated inter-marriage of white and black as a way to beef up the population density of frontier settlements). Yet, consistent as he was in stressing both malfeasibility of all racial differences and the need for equality of opportunity (he castigated Thomas Jefferson for speculating that black disadvantages might be irrevocably innate), Smith did not doubt the evident superiority, both aesthetic and intellectual, of cultured whites.

Civilization grafts its benefits directly to produce a more beautiful body:

The conveniences of clothing and of lodging—the plenty, and healthful quality of food—a country drained, cultivated, and freed from noxious effluvia—improved ideas of beauty—the constant study of elegance... give cultivated an immense advantage over savage society in its attempts... to beautify the human form.

The rudeness of savage life also condemns the uncivilized to stupidity:

The mental capacities of savages... are usually weaker than the capacities of men in civilized society. The powers of their minds, through defect of objects to employ them, lie dormant, and even become extinct.

Smith continues with his strongest depreciation (a passage that illustrates the limits of egalitarianism in the eighteenth century—remember that Smith maintained a radical view for his time on the subject of equality in human potential):

Savages are praised by some writers for the same reason that a Monkey is—a certain imitation of the action of men in society, which was not expected from the rudeness of their condition.... There is something so peculiar and so stupid in the general countenance of savages, that they are liable to be considered as an inferior grade in the descent from the human to the brute creation.

Smith's views on the inferiority of savages also illustrate why his theory is no precursor to Darwin. In Smith's system, humans are created in a state of perfection. All later change, under the influence of climate and life style, can only be seen as a limited and reversible degeneration from this original essence.

We are created in perfection and then fall away as poor climates and rude life styles impose their baleful effects. But the salubrious influence of civilization can help us to recover our original perfection. "The effect of climate," Smith writes, "is augmented by a savage state of society and corrected by a state of civilization." Civilized people are "most nearly in that perfection which was the original design and idea of the creator."

We note, in these passages, the deeper, comprehensive aim of Smith's treatise. He did not view his essay as a work of science in the modern sense—as an empirical ethnology without moral messages (overtly expressed, at least). Smith's intellectual world had different taxonomic boundaries, and fields now viewed as logically immiscible (the "inesis" of fact and the "rightness" of ethics in particular) flowed together in his vision. Smith viewed his monogenic theory more as a source of political values than as a statement about anthropology.

The doctrine of one race... renders human nature susceptible of system, illustrates the power of physical causes and opens a rich and extensive field for moral science.

For if our physical differences are degrees of degeneration imposed by climate and life style, and if civilization can restore a people to the original perfection of Eden, then we must struggle to form a society that will extend corrective blessings to all people. The fact of human biological unity might become the ideal of social harmony if we can improve and remake all people in the light of liberty and civilization.

The pliancy of nature is favorable to the unions of the most distant nations, and facilitates the acquisition and the extension of science.

And so, when we finally reach the bottom line of Philadelphia in 1787, the last day of February at the Philosophical Society did not really differ in import from the efforts at Independence Hall a few months later. Smith wrote to extol the practical benefits of securing "the blessings of liberty to ourselves and our posterity"—the eventual erasure of divisive differences among human races. Samuel Stanhope Smith struggled to understand the human constitution, and for one primary purpose: in order to form a more perfect union.

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

What do quasars and colliding galaxies have in common?

by Stephen P. Maran

IRAS, an artificial satellite that worked for only ten months, racked up a remarkable list of achievements in its short operational life. Not only did its sensors reveal a new class of objects named the IRAS galaxies but it also appears to have solved major questions surrounding the mysterious origins of quasars and starbursts.

A joint project of NASA, the Netherlands Agency for Aerospace Programs, and the United Kingdom’s Science and Engineering Research Council, IRAS was launched from Vandenberg Air Force Base in California on January 25, 1983. Aboard the spacecraft, an insulated container resembling a giant thermos bottle held about 125 gallons of liquid helium, which cooled the satellite’s telescope and sensitive infrared detectors. As it scanned the sky, IRAS’s 24-inch telescope mapped the locations and brightnesses of hundreds of thousands of previously undetected objects that glow in the infrared region of the electromagnetic spectrum. Infrared rays at many wavelengths of interest are absorbed by the earth’s atmosphere. They can, however, be observed from space or, in some cases, from high-altitude jet aircraft and balloon observatories.

As IRAS circled the earth, its precious supply of liquid helium gradually evaporated. By November 21, 1983, the helium was exhausted and the infrared detectors could no longer be cooled. This ended IRAS’s survey of infrared radiation from the universe. Fortunately, the survey covered all regions of the sky and a steady stream of important findings is still emerging as astronomers analyze the great store of measurements amassed in the ten months of orbital operations.

Unlike ordinary galaxies such as the Milky Way, which shine predominantly in the visible light spectrum, the new galaxies discovered by IRAS produce more than 95 percent of their total energy in the form of infrared radiation. The brighter the IRAS galaxy, the more likely it is to have close neighbor galaxies with which it has recently interacted or is now interacting. Many IRAS galaxies are colliding pairs, and the tidal force of the collision may rip stars and gas clouds out of one of the other galaxy or concentrate the gas in localized regions. Sometimes, one galaxy swallows the other, a process known as merging, or galactic cannibalism. The more luminous the IRAS galaxy, the more likely it is to be in a colliding system.

According to David B. Sanders, a galaxy investigator at CalTech, about one-quarter of the IRAS galaxies that are about 30 billion times more luminous than the sun are in double, or colliding, systems. Two-thirds of the IRAS galaxies that are even brighter, about 100 billion times more luminous than the sun, are double, or colliding, galaxies. And those in the very brightest group, known as the ultraluminous IRAS galaxies, which have 500 billion or more times the solar luminosity, are almost 100 percent colliders, or pairs. Sanders’s study and other related work indicate that when galaxies come close enough to each other to collide or at least exert great tidal force, strong infrared radiation is the result. That is the case when one or both of the colliders are spiral galaxies. Ultraluminous IRAS galaxies are so bright that they rival or equal the brightest observed quasars as the most luminous known objects in space.

A quasar is a compact object that generates intense radiation at the center of a so-called host galaxy. A quasar can create up to 1,000 times as much energy as the rest of the galaxy, which may consist of hundreds of billions of stars distributed over a region perhaps 100,000 light-years in diameter. Yet a typical quasar is no more than a few light-years in diameter and may be much smaller. Scientists believe that the heart of a quasar may be a supermassive black hole, a highly condensed object with a mass hundreds of millions times greater than that of the sun. Supposedly, the energy released by the quasar is liberated as matter flows inward toward the black hole.

It is striking that studies of quasars since 1983 with ground-based optical telescopes have revealed that many of the nearer quasars are located in host galaxies that (like the ultraluminous IRAS galaxies) appear to have undergone a recent collision or near-collision with another galaxy. Because these quasars are relatively near the earth, they are seen as they appeared in a fairly recent epoch, when the light that is now reaching our telescopes first left them. Statistical data on quasars, however, show that at more remote times, early in the history of the universe, quasars were much more prevalent. Accordingly, the assumption has been made that quasars erupted, for whatever cause, early in time and then died down as they ran out of fueling gas. Thus, some have theorized that collisions of nearby quasars rekindled quasars by providing fresh gas to fall into the supermassive black holes that allegedly exist at the centers of host galaxies.

While this view does not necessarily see collisions as the original causes of quasars, some astronomers have suggested that all or many of the more numerous distant quasars may have been triggered by collisions of their host galaxies with galaxian neighbors or interlopers. Such collisions
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might remain unobserved because they are so far away that the host and possibly neighboring galaxies, hundreds or even a thousand times dimmer than the quasars, are too faint to be seen with today’s telescopes. This “colliding galaxies theory” of quasars may explain why there appear to have been many more quasars in the distant past; namely, because of the expansion of the universe, galaxies are farther apart now than they were in primeval times and thus less likely to collide.

Starburst galaxies—spiral galaxies characterized by intense, star-making activity—have been recognized as a distinct class for over a decade, but IRAS told us more about their origin. Just as the likelihood that a detectable galactic collision is in progress appears to increase with the luminosity of IRAS galaxies, the rate of star formation in those galaxies also appears to increase with luminosity. Star formation rate is judged from comparison of the far infrared brightness (brightness measured in the longest infrared waves), as measured by IRAS, with the brightness of the galaxy as observed in the radio emission of the carbon monoxide (CO) molecule. The far infrared brightness measures the heating of interstellar dust by hot young stars (at least, that’s one interpretation), while the abundance of CO is a measure of the gas available to form stars. Most of the interstellar gas that gives rise to stars is in the form of molecular hydrogen, H₂, but H₂ is hard to detect in its normal state, so astronomers use the readily observed emission from CO as a tracer for molecular clouds. Sanders and others have found that ordinary starburst galaxies, such as Messier 82 in the constellation Ursa Major, are producing new stars at up to ten times the rate of normal spiral galaxies like the Milky Way, while the bright IRAS galaxies, including the object Arp 220, at about 250 million light-years from the earth, form stars at up to fifty times the rate of ordinary galaxies.

These statistics have recently led many astronomers to the conclusion that there is a causal connection between galactic collisions and the occurrence of quasars and starbursts. Other astronomical observations are consistent with this assumption. Quasars are just the most extreme examples of so-called active galactic nuclei. Weaker active nuclei in many spiral galaxies mimic quasars in several respects, most notably in their compact size and in the appearance of their spectra, and they may therefore also harbor massive central black holes.

Notable among these objects are Seyfert galaxies, named for the late American...
astronomer Carl Seyfert, who first recognized them. The IRAS survey showed that many IRAS galaxies are Seyfert galaxies, and photographs made with ground-based telescopes reveal that a significant fraction of Seyfert galaxies is involved in galactic collisions. Finally, many Seyfert galaxies turn out to have starbursts. A good example is NGC 1068, a well-studied Seyfert galaxy that is located about 59 million light-years from the earth. Observations with radiotelescopes in New Mexico and elsewhere reveal that it has a central quasarlike radio source from which two striking jets of erupting matter emerge. Infrared measurements show that a starburst is under way in a disk-shaped region within NGC 1068. Recently, the Millimeter Wave Interferometer, a radiotelescope consisting of three 34-foot-diameter dish antennae at the Owens Valley Radio Observatory (OVRO), near Big Pine, California, revealed that there is an unusual concentration of molecular gas in a doughnut-shaped region of this disk, extending from a radius of about 2,900 light-years from the center to about 7,800 light-years. This molecular ring was reported in January 1987 by CalTech astronomers Steven T. Myers and Nicholas Z. Scoville. They suggest that the ring formed by gas falling in toward the center of NGC 1068 is a result of a "close encounter or merger with another galaxy."

Other Millimeter Wave Interferometer observations suggest the view that there is a causal connection between starbursts, quasars and other active galactic nuclei, and colliding galaxies. The radio astronomer Annia I. Sargent, with other colleagues at CalTech, has mapped the distribution of molecular gas in Arp 299, a pair of colliding galaxies, at about 1.37 million light-years from the earth. She finds that the gas is not distributed evenly over the galaxies but rather is concentrated in two regions. One region is at the nucleus of one of the colliding galaxies, where other radio observations have found a quasar or quasarlike object. The other gas concentration, according to Sargent, "spans the region of overlap" between the colliding pair, where a starburst is in progress. Perhaps gas concentrated by the effects of the collision is funneling into and fueling the quasar at the center of one galaxy, while gas clouds, bumping into one another in the overlap region, experience shock waves that cause them to break up and condense into stars. More and more investigators believe that galactic collisions produce starbursts in this way.

As commonly occurs in astronomy, new observations raise tantalizing questions at the very time they help solve some old problems. Do galactic collisions merely provide gas to fuel quasars or can they also produce the hypothesized supermassive black holes at their centers? The latter has been suggested, but there is no clearly demonstrated physical mechanism to substantiate it. On the other hand, the nuclei of some ultraluminous IRAS galaxies seem to contain both quasars and starbursts. As Daniel Weedman, a quasar investigator at Penn State, has pointed out, a likely aftermath of a starburst is the swift formation of a cluster of compact dead stars (neutron stars and small black holes) as the most massive new stars rapidly evolve through supernova explosions to their final states. The members of such a cluster, rather than a supermassive black hole, might be the attracting objects that suck gas toward the center of the host galaxy and produce the observed phenomena of quasars.

Stephen P. Maran is a senior staff scientist in the Laboratory for Astronomy and Solar Physics at NASA's Goddard Space Flight Center in Greenbelt, Maryland. The opinions expressed are his own.
The Rise and Fall of the American

For 45 million years, North America was the land of the hyracodonts, amynodonts, and rhinocerotids

by Donald R. Prothero

One day in early December of 1850, a package was delivered to Joseph Leidy in his Philadelphia study. Its contents were to prove startling. A pioneering scientist in the study of American fossil mammals, Leidy had been receiving shipments of fossils since 1847 from collectors working in the wild Dakota territory. Some contained fossils of typically American mammals, such as dogs, cats, rabbits, peccaries, and deer, although these fossils were often such early types that they could barely be recognized for what they were. Others held remains of extinct animals with no living descendants. (Leidy's knowledge of anatomy often enabled him to describe what these strange beasts might have looked like.) Some parcels contained the bones of mammals with extant relatives on other continents but not previously known to have lived in North America. These included primitive horses and camels. On this particular day, Leidy's package of fossils was of the last group: it contained teeth and an upper jaw of what was unquestionably a North American rhinoceros.

Leidy exhibited the bones at the next meeting of the Philadelphia Academy of Natural Sciences. There he gave the rhino the scientific name Rhinoceros occidentalis, or "Western rhinoceros." Throughout the remaining twenty years of his scientific career, Leidy continued to receive rhinoceros fossils from the Dakotas, Oregon, California, Nebraska, Texas, and even Florida. (Florida is among the few states east of the Mississippi that have any terrestrial fossil deposits from the geological time of American rhinos.) Leidy and his contemporaries went on to give descriptions of many other rhinoceros fossils. By the turn of the century, the picture was becoming clear. Rhinoceroses had not only lived in North America, they were
Rhino

The plains of western Nebraska in the late Miocene hosted great congregations of mammals. In Charles Knight’s depiction of a 10-million-year-old scene, forerunners of the American pronghorn (left) and of the modern horse (right) graze, while giraffecamels stretch to browse the treetops. Center stage, a herd of the North American rhino Teleoceras takes to the placid water. Knight painted this mural for the American Museum of Natural History in New York in 1930.

Rhinos have one of the best fossil records of any North American mammal, fully as good as that of the horse. Unlike horses, however, rhinos exploited a wide variety of ecological niches and took many forms, from sheep-sized runners to hippo-like grazers. In North America, rhinos were the largest herbivores until 15 million years ago, when mastodons began to share that niche. (Nearly every continental ecosystem has a large mammalian herbivore that can eat the highest-growing, toughest vegetation and is relatively protected from predation by its size.) Indeed, the evolutionary history of rhinos is typical of many groups of North American mammals: early diversification and experimentation; then specialization into distinct lineages; finally, extinction, usually during a major climatic change.

When we think of rhinos today, the first thing that comes to mind is their horn. But because rhino horns are composed of agglutinated hair, rather than bone, they are not often preserved as fossils (horns, however, leave rough, bumpy areas where they were attached to the skull). Moreover, most extinct rhinos were hornless.
The size of a Great Dane, Hyracodon raced across the grasslands of the Dakota Badlands some 30 million years ago. The hyracodonts, one of three main rhino lines to evolve, were long-legged, efficient runners.

AMNH

Paleontologists recognize fossil rhinos chiefly by their distinctive teeth and by features of the skull. In most other respects, the very earliest rhinoceroses bear little resemblance to living rhinos.

Rinos are members of the order Perissodactyla, or the “odd-toed” hoofed mammals. Their closest living relatives are horses and tapirs. Unlike the even-toed pigs, sheep, deer, camels, and cattle, rhinos, horses, and tapirs have feet with either one or three toes. Early rhinos were sheep-sized mammals that were widespread in Eurasia and North America in the middle Eocene, about 50 million years ago. At that time, the world was much warmer and more tropical than it is today. There were no polar icecaps. The Eocene climate was so mild that alligators and semitropical plants lived in Alaska. In temperate Eurasia and North America, the climate and vegetation were similar to those of tropical Mexico today. The inhabitants of this environment showed few of the specializations of modern rhinos, horses, or tapirs. Instead, they were primitive mammals with low-crowned teeth, for browsing leaves, and short limbs with a full complement of five toes. The best known of the early rhinos was *Hyrachyus*, which looked much like its close relatives among the early horses and tapirs. From this primitive, unspecialized ancestor, rhinos diverged into three major lines during the late Eocene. Two of these families flourished for about 10 million years and then became extinct. The third is the family of the living rhinoceroses.

The first branch to emerge from the basic rhino line was the amynodonts. In the late Eocene, amynodonts rapidly joined the ranks of the largest land mammals in North America and Eurasia. By the Oligocene, some 37 million years ago, they had become very specialized. In North America, they were represented by the stocky, hippolike river dweller *Metamynodon*. Remains of this animal are so characteristic of the river-channel sandstones of the Badlands of South Dakota that these beds are known as the *Metamynodon* channels. Amynodonts disappeared from North America about 30 million years ago but persisted in Eurasia until about 15 million years ago. One group of amynodonts, the cadurcodonts, developed a short trunk, or proboscis, much like that of a tapir or elephant. Presumably, they lived in the forest and browsed with their snouts, as tapirs do today. The last surviving amynodont, *Cadurcotherium*, vanished from Pakistan and Burma at about the time that mastodons emigrated from Africa, where they had been evolving in isolation for millions of years. Perhaps amynodonts were driven to extinction by competition from mastodons or from the more advanced rhinos that had appeared in Asia by this time.

While the squat, semiaquatic amynodonts wallowed and browsed in the riparian habitats of Oligocene North America and Asia, the second major branch of rhinos was evolving. These were running rhinos, or hyracodonts. Small and unspecialized through the late Eocene, they differed only slightly from their ancestor *Hyrachyus*. One key difference distin-
guished hyracodonts from all other rhinos: their limbs, and especially their feet, were elongated for more efficient running.

By the Oligocene, the environment of the rhinos had changed. Worldwide cooling in the early Oligocene was triggered by the beginning of glaciation in the Antarctic. Naturally, the vegetation in the temperate climates changed in response to this cooling. In what is now the Dakota Badlands, the fossil soils tell the story. As described by Greg Retallack of the University of Oregon, the early Oligocene soils were formed under thick forests, which by the late Oligocene, were broken up into mixed forest and open savanna.

Most archaic animals did not survive this change. Some animals that were better adapted to this new habitat diversified. Rhinos succeeded by diverging into distinct ecological niches: the aquatic amynodonts could be found wallowing in the river channels; the running hyracodonts probably frequented the open savanna.

**Hyracodon** was about the size of a Great Dane and slightly larger than *Mesohippus*, the horse of its time. **Hyracodon** vanished from North America about 28 million years ago, but in Eurasia, its relatives had specialized in a different way—they had become gigantic.

And gigantic they were! The largest rhino—and the largest land mammal ever to live—was *Paraceratherium* (also known as *Baluchitherium* or *Indricotherium*), which could browse, giraffelike, in the tops of trees twenty-five feet high and may have weighed twenty-five tons. The Museum found some of the best fossils of these giants on the famous central Asian expeditions to Mongolia in 1922. In one place, they found all four legs of this beast buried and fossilized upright, exactly where it had sunk into quicksand and died. Even as a weighty mammalian record holder, *Paraceratherium* retained the hallmarks of its running hyracodont ancestry. The limbs were long, and the three toes of each foot were still elongated, although such a beast clearly didn’t need to run from predators. Most large animals, such as elephants and dinosaurs, have short, compressed toes designed to sustain their great weight. The long legs and toes of *Paraceratherium* are a good example of how vestiges of inherited anatomy can be retained even when no longer used for their original purpose.

While amynodonts and hyracodonts adapted to aquatic, running, or giraffelike life styles, the main rhino branch remained relatively unspecialized. What we call true rhinoceroses, the family Rhinocerotidae (the only surviving rhino family), also developed in the late Eocene; the first known rhinocerotid fossil on this continent was found in Oregon and dates to about 40 million years ago. Apparently they, like many species before and since, immigrated across the Bering Strait from Eurasia and continued to develop in both the Old and New World. The first North American rhinocerotid was not much larger than *Hyracodon*, but it already had the key features of a true rhinoceros.

In the Oligocene, the most common true rhino in North America was Leidy’s first rhino, *Rhinoceros occidentalis*, now
Some rhinos emigrated to North America, others evolved here, but all were descendants of Hyracus (see chart right). Rhino lines died out in North America, but the rhinocerotids survived in Eurasia and gave rise to the modern rhinos. In contrast to its contemporary, the swift, savanna-dwelling Hyracodon, Metamynodon, below right, was a stocky, semiaquatic inhabitant of Dakota streamside walls, wallowing in Badlands rivers and browsing on succulent shoots of riparian vegetation.

known as Subhyracodon occidentalis (a misnomer because this rhino was not a hyracodont at all). Nearly horse sized, hornless, and quite unspecialized, it apparently lived in the forested glades around the rivers of what is now South Dakota. By the late Oligocene (about 30 million years ago), Subhyracodon had evolved into the first horned rhino, Diceratherium ("two-horned beast"). With paired horns on the tip of its nose, Diceratherium represents one of two different groups of rhinos that independently evolved paired nasal horns. After the extinction of the amynodont and hystyrids families, it was the undisputed king of late Oligocene North America. The period from about 28 to 21 million years ago was the time of least diversity of rhinos in North America. The solitary reign of Diceratherium ended in the earliest Miocene when another rhino appeared on the scene. A recent immigrant from Europe, Menoceras was sheep sized. Although it also had paired horns on the tip of its nose, they were very different from those of Diceratherium. Instead of the long nasal ridges seen in true Diceratherium, rounded knobs on the tips of its nasal bones supported Menoceras’s horns. Additional anatomical evidence shows that Diceratherium and Menoceras were not very closely related. The paired horns on the nose are a good example of evolutionary parallelism. Nevertheless, confused by the similarity, most scientists erroneously called Menoceras “Diceratherium.”

Menoceras is best known from the famous bone beds at Agate Springs National Monument in western Nebraska. In the early part of this century, thousands of fossils of this little rhino were collected by many museums. A typical Agate slab is a solid network of rhino bones. Bob Hunt of the University of Nebraska has analyzed the population structure of the Agate rhinos. The relative numbers of adults and juveniles show that the assemblage represents death at normal rates and under normal conditions and then concentration of the bones by river action.

A few million years after Menoceras arrived in North America, there was another wave of immigrations from Eurasia. It brought the two dominant groups of Miocene rhinos, the aceratherines and the teleoceratines, which drove Diceratherium to extinction through competition for the large herbivore niche. About 18 million years ago, these groups drove Menoceras to extinction, too. Like the horses and most Miocene mammals, both immigrant rhino groups soon developed exceptionally high-crowned teeth for grinding abrasive grasses, which rapidly wear teeth down. This was essential, since the Miocene environment had changed from the mixed forest-savanna of the Oligocene to a world of broad, grassy plains with little foliage to browse on.

Miocene rhinos had to evolve a different set of specializations for this new environment. Typically, rhinos occupy two ecological niches in the savanna. One niche is that of a browser, which selects small amounts of high-quality vegetation. It pulls down tender leaves and shoots, often with a prehensile lip. The African black rhino lives this way to this day. The other niche is that of a grass eater, or grazer. Rather than select high-quality leaves, it mows grass in large quantities to obtain its nutrition. Grazers often have square lips (like the African white rhino) and exceptionally high-crowned teeth.

From the early Miocene onward, two rhinos are usually found in most fossil localities in North America: a hippolike grazer (usually Teleoceras) and a prehensile-lipped browser, feeding on leaves and brushy vegetation (usually the aceratherine Apelelops). These browser-grazer pairs are a common pattern in rhinos wherever they are found in savanna environments, such as existed in North America throughout the entire Miocene. Miocene rhinos of Eurasia also show similar browser-grazer combinations, although different genera of rhinos are represented.

The aceratherines were nearly always hornless and tended to retain their primitive skeletal proportions, with relatively long legs. Their specialization is evident in their snout. The nasal notch on the skull became deeply incised, leaving room for the attachment of snout muscles that apparently controlled a prehensile lip or even a short trunk. The teleoceratines, on the
other hand, became highly specialized for an aquatic life style much like that of a hippopotamus. *Teleoceras* had a stout, barrel-shaped body with shortened, stumpy limbs—a better hippo than the hippo itself. Except for a small horn on the tip of its nose, it looked more like a hippo than a rhino. Its bones are found by the thousands in ancient river deposits all over western North America.

The most amazing discovery of *Teleoceras* was made by Mike Voorhies of the University of Nebraska in 1977. Unlike the Agate Springs lode of fossils, Voorhies’s find was the site of a catastrophic die-off. Eighteen complete *Teleoceras* skeletons were found in their death pose, buried in volcanic ash in eastern Nebraska—a true rhino Pompeii. *Teleoceras* appears to have been a social, herding beast, unlike the living rhinos, but like hippos. There were some mothers with calves at their sides, and others with unborn fetuses. Grass seeds were found in the throat cavities, evidence that *Teleoceras* was a grazer. This strengthens the analogy with the hippopotamus, since modern hippos spend their days sleeping in the river and nights roaming the banks, feeding on grass.

North American Miocene rhinos exploited other ecological niches as well. Although *Teleoceras* was the dominant hippolike grazer, other rhinos have tried this aquatic life style. Just as *Metamyxodon* lived this way in the Oligocene, one species of the aceratherine genus *Peraceras* also developed a heavy-bodied, hippolike form in the middle Miocene. Apparently less successful, it lasted only a few million years and was restricted to northern regions with few *Teleoceras*, such as South Dakota and Montana.

Along the swampy shoreline of the Texas gulf coast lived dwarf species of *Teleoceras* and *Peraceras*. These dwarf rhinos are analogous to the pygmy hippopotamus, which lives today in forested areas in central Africa not inhabited by its full-sized relative. In addition to the pygmy hippo, the forest species of the African elephant and Cape buffalo are also small. Dwarfing appears to be a common evolutionary response of a large sa-
vanna grazer in adapting to the restricted, browsing diet in the denser forest.

After almost 50 million years of dominance, the rhinoceros dynasty came to an end in North America about 5 million years ago. An extinction at the end of the Miocene wiped out not only rhinos but also most of the deerlike animals, pronghorns, and most of the once-diverse camels and horses. Recent data from deep-sea-floor sediment cores have provided an answer to the mystery of the Miocene extinctions. A major expansion of the Antarctic ice sheet trapped vast amounts of seawater as ice; this caused cooling and lowered the sea level worldwide. Sea level dropped so severely that no water flowed through the Strait of Gibraltar, and the Mediterranean became a gigantic salt lake. When it had completely evaporated, a deep basin covered with more than a mile of salt and gypsum remained. These severe changes in temperature, sea level, and oceanic salinity had a devastating effect on most life on land. American rhinos were among the most notable victims.

Only in Africa and Eurasia did relatives of the present-day rhinos survive. They included *Coelodonta*, the woolly rhino depicted by Ice Age peoples, and the Siberian *Elasmotherium*, with a single enormous horn on its forehead. Although many cold-adapted Ice Age mammals, such as the mammoth and bison, successfully crossed the Bering land bridge to North America during the Pleistocene, from about one million to 10,000 years ago, rhinos did not. No one has yet developed a convincing explanation for this curious fact.

The five species of surviving rhinos—the white and black rhinos of Africa and the Indian, Sumatran, and Javan species—are magnificent creatures, but their numbers are a pitiful remnant of their once worldwide distribution. Sadly, these long-successful animals are now on the brink of oblivion as poachers push them inexorably toward extinction. Perhaps by the end of the century, a few horns ground down as supposed medicines in the Orient or carved up into dagger handles for status-conscious Yemenite men will be all that is left of this amazing family.
One of the last of the North American rhinos, Teleoceras frequented rivers and lakes, as had Metamynodon 20 million years earlier. Squat, barrel-chested, and hippolike, Teleoceras was a grazer, mowing vast amounts of grass with its specially adapted high-crowned teeth. A site in eastern Nebraska has yielded complete fossil skeletons of Teleoceras that were killed and buried by volcanic ash. The remains of calves and unborn young found with the group of adults suggest that these rhinos were social beasts that lived in herds.
Guerrillas of the Goldenrod

Among ambush bugs, females do the bushwhacking while males do the freeloading

by Larry G. Mason

In late summer, a honeybee probes for goldenrod pollen: long, quick tongue flicks in and out as the bee goes from flower to flower. Suddenly a forelimb reaches out of the petals, a claw like a crab's takes hold of the bee's tongue. The bee opens its wings, scrambles over the flower to escape, but only gets to the edge of the flower head. The captor's hold is too strong. Now a long beak probes for the bee's soft neck, finds its mark, and injects its poison. The struggle ends quickly. An ambush bug, Phymata americana, has claimed another victim.

Angular, yellow-and-black, just a third of an inch long, armored well enough to withstand the repeated stings of a wasp, yet good flyers, ambush bugs spend most of their time sitting nearly motionless within flower heads waiting to prey on insects foraging for pollen and nectar. Some close looking in a field of goldenrod or Queen Anne's lace may reveal bees, wasps, or hover flies hanging from flowers at unnatural angles. Most will be in an ambush bug's strong grasp, the captor sucking the life out of its captive.

In recent years, I have studied how ambush bugs capture prey, and which prey they prefer, in fields around Albany County, New York, and in other localities in New York and Vermont. These are often open fields flanked by woods that are slowly being thinned by suburban real estate developments. Ambush bugs thrive where woods are cut down and weedy areas allowed to grow wild with goldenrod and Queen Anne's lace. Honeybees and yellow jackets also do well in these disturbed surroundings and are important prey for ambush bugs. (While I would like to say I chose the sites on the basis of prey availability, I did not. Ambush bugs, like gold and goldenrod, are where you find them.) Ambush bugs live just a summer. Eggs remain dormant among the leaf litter throughout the winter. In May, the eggs hatch, and the green nymphs emerge, well camouflaged by the vegetation. By the end of July, the insects have grown into adults and soon begin to mate. Before ambush bugs mate, however, they often eat together, the male sitting atop the female, enjoying the prey she has cap-
An ambush bug perches on a flower head and waits for prey. When a bee, wasp, or fly comes by foraging for pollen or nectar, the well-armored bug uses its powerful claw to grab the larger insect. This young adult, hatched in early spring, will grow more yellow and harder to spot amidst the summer bloom of goldenrod.
Ambush bugs thrive in open fields on the edges of woods. Where several species of goldenrod grow, blooms come at different times during the summer, providing a continuous supply of food for bees and flies and consequently a continuous supply of prey for ambush bugs.

Since you can see the prey that’s been caught by ambush bugs, a look at a large number of their victims gives an overall picture of what is taking place amidst the goldenrod. A great convenience for sucking, predatory insects like ambush bugs is that the external skeleton of their prey provides a “bowl” for the kind of “bug soup” the predator makes of its prey’s internal organs. Predators can hold the prey for a substantial period of time while they inject the enzymes that liquefy the bug’s insides, then draw the resultant fluid through their beaks as if through a drinking straw. The entomologist finds this a convenience as well, since the external features of the prey are undamaged, and the prey is held long enough to be identified and measured.

Since I rarely saw prey being caught, the circumstantial evidence became important: what can be said about the captor from the way it holds its prey? The first thing I noticed was that most of the captors are females. Female ambush bugs are larger than males, and their claws are disproportionately large. Ambush bugs need only one claw to catch and hold prey three to four times their size, such as yellow jackets, butterflies, or bumblebees. The other claw is available to fend off counter-attacks. Even the young, which are wingless, have large claws. A newly hatched ambush bug is like a kid wielding boxing gloves many sizes too big, yet within minutes of hatching, the ambush bug can catch a fruit fly.

The victims of female ambush bugs are most often caught by the tongue or antennae, sometimes by a front leg, but hardly ever by the posterior end. This shows that the female attacks from her place in the flower heads of goldenrod and Queen
A male ambush bug hangs onto a female’s back as she holds a fly and feeds (a male is distinguished by the dark markings on its head). One or more males often jump onto feeding females and share in the catch. Such coupling for the purpose of eating may eventually lead to mating. These are a West Coast species of ambush bug, Phymata pacifica.

E.S. Ross
Anne's lace as the prey comes toward her or walks by—by ambush, not by chase.

The ambushes I have seen in my twenty years of observation were always by females. Males are most often in motion atop the flower heads and take prey however they can. In all my time in the field, I saw only one male actually take prey and that was when a small, solitary bee was blown into his grasp as he roamed over a flower head. He seized it, killed it, and fed on it; but serendipitous predation is very different from the sort of thing the females do. I have found males holding prey by the front half of the prey's body about as often as by the rear half. Males simply grab whatever part of the potential prey is closest to them.

Not only are females the bigger and better hunters among ambush bugs, but the prey they take is larger than that of the males. Males usually take very small, solitary bees, wasps, flies, and beetles. In addition to these, females take large honeybees, drone flies, and yellow jackets. In the absence of much information on the behavior of these bugs, I used to cite the familiar ecological saw that natural selection favors different food types for males and females in populations of some species. A given area may then support a larger number of individuals, and some areas might become usable that would not otherwise support a population of the species. But there is more to the story than just that.

The males spend much of their time wandering over the flowers, searching for females. During this search, they sustain themselves on whatever prey they can find. Once they locate a female, they often freeload, sharing the female's catch. A male and a female ambush bug take part in a relationship rare among insects: a more or less prolonged liaison without actual copulation, which has been called coupling. Male and female sit together on the flowers, the slightly smaller male atop the female. From this position, the couple may progress to sharing food, at which point the male moves forward and sinks his beak into prey caught by the female. But coupling freeloaders don't necessarily become mates. A second (or even a third) male and occasionally a female may share in a meal. When goldenrod blooms late in the summer, females fly to it from other less-productive plants and capture larger prey. Then males catch less prey on their own and rely more on freeloading than hunting.

Copulation occupies only a small proportion of the time a given pair spend together. When a male locates a female, he takes up the coupling position atop her. The female is passive: there are no obvious signs of rejection or encouragement. When the bugs finally copulate, they are side to side, wedged up against each other.

Ambush bugs mate repeatedly throughout the season and produce many small batches of eggs. Sociable tendencies such as coupling and food sharing may have evolved because mating must be synchronized with the ripening of eggs. Females provide the food and allow the males to freeload in order to insure that their eggs are fertilized at the proper time.

All these interactions may require a complicated communication system. Ambush bugs are tolerant of one another's presence and appear to be constantly in communication with one another, even as they couple for extended periods and copulate. Males, wandering over the flower heads seeking females, nod at a rate of about five times a second, rubbing their beaks back and forth over a row of little thickenings on their undersides. This does not create an audible sound, but rather a vibration carried through the stems and leaves on which the bugs rest. Such communication may dictate when coupling comes to copulation, for I have seen them make similar movements while mating.

Studies in a related species show that not only do individuals communicate with one another, they hardly ever stop. Effective communication evolves in a predatory animal to keep track of other predatory animals hunting in the same territory—dogs bark at other dogs for this reason. Courting and competing males also need their "songs." And males and females have to come together to feed and mate. Studying the language of these insects would explain much about their sociability and sexual interactions.
The green-backed herons of Suizenji Park in Kumamoto on the Japanese island of Kyushu have turned bait fishing into something of an art. Summer visitors to the park's pond, the herons carve out territories that provide them with several vantage points from which to fish. This heron (Ardea striata, a species also common in the eastern United States) usually takes its post at a preferred spot and then looks around for bait. It may catch flies, grasshoppers, or cicadas; probe muddy ground for earthworms; pick up leaves, twigs, berries, bark, or moss or simply choose from a nearby miscellany—perhaps a feather, a cracker, or a piece of styrofoam. With this array of items, a heron is equipped, in anglers' terms, to fish with live bait, lure, or fly.

With bait in beak, the heron targets its victim. Crouching, it casts the bait in the water. If the fish "bites," the heron lunges. Generally, less than a second elapses from the time bait hits the water to the instant the heron strikes. An item that fails to attract a fish is sometimes retrieved and reused on the spot or carried off for a try elsewhere. While bait fishing takes advantage of the high
sensitivity of fish to objects striking the water's surface, aim is important. Items thrown from a height of more than five feet seldom hit the mark.

On a few occasions I watched herons fashion twigs into suitable lures. If a twig was too long, the heron held it with its feet, broke it in half with its beak, and tossed one piece into the pond. These instances of tool making are unknown in bait-fishing green-backed herons in North America and Africa, which use only ready-made lures.

The herons that used bait most often were those relegated to fishing over open water, because their territories offered few well-placed rocks from which to prey, unseen, on fish. The importance of stealth is also apparent in juveniles' poor record with any kind of bait. Their general failure to crouch as they cast the bait seems to make them conspicuous to the fish, and the young birds sometimes resort to eating the insects and earthworms themselves. With practice, they can be expected to perfect their technique and join the more sophisticated anglers of Suizenji Park. □
A Dead Chief's Revenge?

Scientists now understand the mechanics of the deadly Cameroon gas burst one year ago, but the trigger is still a mystery

by Haraldur Sigurdsson

Thursday is market day in Nyos, a time when people of the region flock to the village to sell their produce and often to spend the night with friends. The valleys around Lake Nyos, which is about two miles from the village, are renowned for their fertile soil, yielding abundant crops of beans, plantain, rice, corn, yams, cassava, and potatoes and some avocados and mangoes.

Suddenly, at about 9:00 in the evening on the market day of August 21, 1986, an explosive convulsion took place in Lake Nyos and propelled a huge fountain of carbon dioxide into the air. Denser than air, the gas cloud flowed into Nyos and other settlements in the surrounding valleys, up to fourteen miles from the source, killing 1,746 people and more than 8,300 animals. Some survivors of the disaster attribute it to the wrath of their dead tribal chief, who on his deathbed in 1983 ordered that his best cattle be driven off the sheer cliffs above Lake Nyos as a sacrifice to the spirit of the lake, Mami-Water. But the chief's family failed to honor his last wish, and many today believe that the 1986 calamity was an expression of the chief's posthumous displeasure. The disaster attracted worldwide attention, and scientists from many countries traveled to Cameroon to study the lake in order to determine a more realistic cause of the eruption.

Lake Nyos is in the hilly grasslands of western Cameroon, within the so-called Cameroon volcanic line: a string of volcanoes that extends 900 miles from the South Atlantic Ocean to the northeast, along the border of Cameroon and Nigeria. The lake occupies a volcanic crater about 5,000 feet in diameter and 680 feet deep, which was last active about 1,000 years ago.

Four days before the lethal event, local cattle herders noticed unusual bubbling on the lake's surface, which prompted twenty-five of them to move to a distant village. There were also unconfirmed reports claiming there was an emission of foaming water and vapor from the lake two to three weeks earlier. At about 4:00 P.M. on August 21, remaining herdsmen heard strange bubbling sounds and saw the slight emission of vapor from the lake. At about 8:00 P.M., villagers in Cha, four miles northwest of the lake, heard two loud noises, followed by three rumbles at about 9:00 p.m., when activity built up to the climactic disaster.

The 1986 lethal gas burst from Lake Nyos was, in fact, the second time in recorded history that a gas burst from a crater lake had occurred in an extinct volcano. The first such event took place on August 15, 1984, when a cloud of gas burst out of Lake Monoun, also in Cameroon, killing thirty-seven people. At the request of the Office of Foreign Disaster Assistance in the U.S. Department of State, I traveled to Cameroon early in 1985 to investigate that event, with Joseph Devine, then a graduate student in oceanography. We were joined by Cameroonian geologist Felix Tchoua in our study of the lake and its surroundings, and we collaborated later with William C. Evans and others from the U.S. Geological Survey in the chemical analysis of water and gas samples.

The eastern part of Lake Monoun contains a submerged crater, which is about 1,200 feet wide and 300 feet deep. Our study of the lake showed that its deep waters contained very high levels of dissolved carbon dioxide, held in solution by the high pressure at that depth. The gas had chemical characteristics indicating that it could only have come from the earth's mantle (the layer of the earth that underlies the forty-mile-thick crustal rocks). We were convinced that the gas was gradually seeping into the bottom of the crater lake from fractures and faults in the neck of the old volcano and that the gas had accumulated in the lake over a long period of time. A fresh scar on the eastern rim of the crater showed where a landslip had rushed into the bottom of the submerged crater the night of the 1984 lethal event. We proposed that the landslip had upturned the density stratification of the lake (the amount of CO₂ in different water layers) and stirred up the CO₂-rich bottom water. When the CO₂-rich water reached shallower water levels and therefore lower pressure, the carbon dioxide was suddenly released with explosive force. This started a chain reaction, as the accompanying frothing reduced the density of the water, further decreasing the solubility of the gas remaining in solution in the lake. The resultant gas burst produced a cloud of CO₂ that flowed away from the lake and over a nearby road. Before sunrise the next morning, thirty-seven villagers on their way to work or market unknowingly walked into the
A few days after the eruption of Lake Nyos, its normally blue water remained discolored. The slightly reddish brown staining was caused by a ferric hydroxide precipitate. That, in turn, resulted from unoxidized iron, formerly in solution in the oxygen-poor deep lake water, becoming oxidized when the deep water rose to the lake's surface in the 1986 eruption.

Peter Turnley, Black Star

visible and odorless cloud of CO₂ and quickly died of asphyxiation.

We first suspected that the disaster was connected with an underwater volcanic explosion on the crater floor, but neither the chemistry of the water nor of the gas was consistent with any volcanic input other than the gradual seepage of CO₂ into the lake. The Lake Monoun event was thus a new natural phenomenon that defied classification, since it was neither a purely volcanic nor a lake phenomenon.

When we had completed our research on Lake Monoun, we had a fairly complete picture of this process and submitted our results for publication, but we had no inkling that this unique process would be repeated so soon and with such disastrous consequences in Lake Nyos. The fountain that rose out of Lake Nyos in 1986 consisted of a foam of water and expanding carbon dioxide. The plume of water rose 260 feet into the air and, as it cascaded down, washed soil and vegetation from the lake's shores. The gas separated from the water in the fountain and must have reached well over 300 feet above the lake, because dead cattle were found on the slopes at that height. Since CO₂ is about one and a half times denser than air, the
Carbon dioxide from the Lake Nyos eruption flowed along the valleys of the Mbam and Kumbi rivers, see map below, asphyxiating many people along the way. Opposite: Low-lying clouds drift across a river valley near Lake Nyos.

Carbon Dioxide Gas Flow

Gas flowed down the valley from the lake into the village of Nyos. On its way, it knocked down corn stalks, banana plants, and small fig trees. People in Nyos were apparently killed almost instantly while resting or sleeping in their mud-brick huts and thatched houses.

The earth’s atmosphere normally contains 0.03 percent carbon dioxide. Inhalation of air mixed with only 10 percent carbon dioxide leads to coma and death in about ten to fifteen minutes, and inhalation of air with 40 percent CO₂ causes nearly immediate death. Only 4 of 1,200 inhabitants survived in Nyos, so the gas flow must have been very concentrated.

Part of the gas flowed to the west from Nyos into the nearby village of Cha, causing more fatalities. The gas continued to flow north along the Mbam River valley, past the villages of Fungom, Bu, Kwoshing, and Fang, causing fatalities at Mashi, fourteen miles from Lake Nyos. Gas also traveled northeast from Nyos, to Kam and the village of Subum, where about 300 died; it then continued along the course of the Kumbi River, up to fifteen miles from the lake. About 5,000 people and all animal life in an area covering twenty-four square miles were rendered unconscious by the gas cloud that spread along the two valleys.

Some 3,460 were hospitalized but regained consciousness a few hours later; others remained unconscious for up to three days. Many were disoriented, had difficulty walking, and experienced a drunken sensation at first. The lethal cloud still lingered in the area a day after the gas burst, killing a number of children who wandered into gas pockets, which being heavier than air, clung to the low river valleys. A motorcyclist from Wum, forty miles to the west, traveling to Cha at 6:00 A.M. that day, noticed dead animals and a human corpse just outside the village. He then lost consciousness. Waking up about three hours later, he returned to Wum to report his strange experience to the world outside the disaster zone.

The largest numbers of dead were males and elderly people. More than half the survivors were children younger than fourteen; many children regained consciousness the next day and found themselves in bed with their dead parents. Sixty percent of all survivors were females. (Doctors do not know why males were more vulnerable than females.) The distribution of survivors was completely random: outside the village of Nyos, survival was not always directly correlated with distance from the lake.
Skin damage on about 5 percent of the victims and survivors was similarly random. Some had very large blisters on their extremities and torsos, whether the affected areas were exposed or clothed, whereas others in the same hut had no skin damage at all. A number of people suffered severe burns, most likely the result of losing consciousness while squatting near a cooking fire. At first it was suggested that the skin blisters were due to acids or toxic chemicals in the gas cloud. This hypothesis was discarded, however, since clothing and vegetation were unaffected. The only other explanation that has come forward is that the blisters were a possible consequence of the coma or very deep sleep into which the victims and survivors alike fell. Similar skin damage has been observed in hospital patients with coma induced by drug overdose or carbon monoxide poisoning.

There were obvious similarities between the Lake Monoun and the Lake Nyos gas bursts, and I was quickly convinced that all the deadly gas in both events had come from within the body of the lakes. Several scientists felt, however, that the scale of the Lake Nyos calamity and such observations as skin damage, which they speculated could have been caused by sulfuric acid derived from volcanic gases, indicated that a volcanic explosion on the lake floor had occurred at Nyos and that the lethal CO₂ was of direct volcanic origin. This controversy was hotly debated by 200 scientists from twenty nations at the International Conference on the Lake Nyos Disaster, held in Yaoundé, the capital of Cameroon, in March 1987. The result was that virtually all the chemical, medical, and physical phenomena could be accounted for by the hypothesis of a gas burst from the deep waters of both lakes. While the unlikely process of a volcanic eruption on the lakes’ floors could not be directly disproved, the conference of scientists applied the time-proven principle of Ockham’s razor: “Do not use a complex explanation when a simple one will suffice.”

Thanks to an international research effort and the finely tuned instruments of science, we now understand almost all aspects of the Lake Monoun and Lake Nyos disasters. Some of this knowledge comes from very simple but critical observations of the lakes’ levels, while other evidence is derived from sophisticated measurements of the chemistry of the gas and water of the lakes.

In our first studies of the lakes, we recovered samples of deep water in bottles that were closed by remote control, but when those samples were brought toward the surface and lower pressure, the gases that normally dissolved at higher pressures effervesced and formed expanding gas bubbles that invariably popped our sampling bottles open. On our expedition to Lake Nyos early in 1987, Evans, of the U.S. Geological Survey, and I were able to collect samples of bottom waters in steel cylinders that we closed by remote control from our inflatable dinghy. When brought to the surface, the steel cylinders contained a sample of the lake under a pressure of about twenty atmospheres, the water pressure at the lake bottom, and a representative amount of the gas dissolved in water at that depth. Those samples showed that the lake was about 25 percent saturated with CO₂ after the explosion.

No studies of Lake Nyos had been made before the lethal gas burst, so we had no idea what the lake’s original gas content might have been, but we suspected that on the evening of August 21, 1986, it had to be close to saturation, and that CO₂ had foamed out like champagne from a just-opened bottle. Fortunately, the Cameroonian geologist Emmanuel Gamjehad had observed that the lake level dropped by about three feet during the gas burst. This was not due to water loss, as no water flood was noted during the event. We therefore deduced that the drop in the lake’s level was due entirely to the loss of CO₂ from the water and that the missing volume corresponded to a loss of about 2 million tons of CO₂. Since that amount represents about 80 percent of all the CO₂ that the lake could theoretically hold in solution, we believe that the lake was saturated with carbon dioxide before the gas burst. These values indicate that the volume of released gas was probably about 35 billion cubic feet at atmospheric pressure, which is sufficient to form a fifty-foot-thick pure CO₂ layer over the twenty-four-square-mile area affected. There was obviously a good deal of mixing of air and carbon dioxide during the burst and subsequent gas flow, and consequently, the volume of the active lethal gas cloud was much larger.

Carbon dioxide is the main gas that escapes from the earth’s mantle, which is also the source of magma, or molten rock, that erupts from volcanoes. Studies by the French scientists Michel Javoy and François Pineau have shown that CO₂ from the mantle is released primarily from the underwater chain of volcanoes making up the global system of midocean ridges and that this carbon output amounts to about 240 million tons per year. In that context, the Nyos burst constituted less than 1 percent of the annual output of carbon from the earth’s mantle and had no effect on the proportion of CO₂ in the earth’s atmosphere, which currently contains about 380 parts per million of this gas.

When studies of the water temperature in Lake Nyos were carried out, the lake was discovered to have been cooled by the gas burst. The cooling amounted to a change from about 75° to 73°F, which represents approximately 100 trillion calories of heat extracted from the water. This
cooling was yet more evidence against the volcanic explosion hypothesis but provides, on the other hand, support for the hypothesis of a large-scale degassing of CO₂ from the lake. When gas escapes from a liquid and expands in response to a decrease in pressure, the gas cools; this process forms the principle behind most of our domestic and industrial refrigeration systems. As gas expands, it pushes against the surrounding liquid in the form of bubbles, expending energy, which results in a drop in temperature. The efficiency of refrigeration depends on the speed of the gas release and the degree of heat exchange between the rising gas bubbles and the surrounding water. If the gas rises rapidly to the surface of a lake, there is little or no heat exchange between gas and water, and the CO₂ gas cloud may emerge at the surface at a temperature of -108°F, which is cold enough to form dry ice. That represents an extreme case, however. The heat exchange is likely to be more efficient when the temperature of the emergent gas cloud is near 32°F—the freezing point. The lower temperature of Lake Nyos is an indication that the gas burst was very rapid and that the gas cloud must have been very cold when it burst out of the lake.

The discovery of the refrigeration effect of the gas burst immediately raised the possibility that the mysterious skin damage that could not be accounted for either by acid or heat burns, might have been caused by frostbite. What could be more bizarre than hundreds of frostbite victims in tropical Africa as a result of the natural refrigeration action of a gas burst from a crater lake? However, the gas mixed with the atmosphere was probably so quickly warmed to near-ambient temperatures that it could not have caused frostbite. One of the six survivors from Nyos, a sixteen-year-old youth, told us he felt a wave of cold air flow through his hut before he lost consciousness on the night of August 21. Other survivors had no recollection of cold but reported feeling "heat inside," presumably because of the inhalation of carbon dioxide, difficulty in breathing, and the onset of asphyxia.

In the case of Lake Monoun, we feel confident that the gas escape was caused by a landslide that brought gas-rich bottom waters to shallower levels, but what could have triggered the gas burst at Lake Nyos? Any triggering mechanism would have had to cause the upward motion of CO₂-saturated deep water, leading to release of the gas. At present we do not have the evidence to help us choose the most likely of several possible answers. Rock falls from the vertical 650-foot-high granite cliffs on the west side of Nyos are common, and a large rock fall could have upset the stratification of the lake waters. Another possibility is that if the deep waters were saturated with CO₂, a small additional input of the gas from springs on the lake bottom would have led to supersaturation, possibly causing the sudden outburst. Once bubbles had formed, a chain reaction would have been set in motion. When oxygen-poor deep waters rose to the surface, they would have contained some unoxidized iron in solution. As these waters became oxidized at the surface, the iron would have formed a ferric hydroxide precipitate that would have stained the surface layer of the lake reddish brown for days or weeks after the event. Such a phenomenon was, in fact, reported at Nyos. The iron particles have now settled out, and Lake Nyos is currently clear and calm, populated by hundreds of white cattle egrets that feed on the abundant tadpoles that appeared after the gas burst.

Cameroonians distinguish two types of lakes in their land. "Good lakes" are a source of fish, easy to get to, and good for bathing and water supply. "Bad lakes" are difficult to reach, yield no fish or other products, change color at times, and are inhabited by bad spirits such as Mami-Water. The local people today put Lake Nyos in the second category. The 3,460 evacuees have not been permitted to return to their villages. In the meantime, their fields have become overgrown with weeds, and their huts need repair after the torrential storms of the rainy season from June to September. The evacuees have lived for more than eight months in ten villages thirty to sixty miles away from their homes, unable to carry on their agriculture, restless and unhappy. Government officials and experts have decreed that the area cannot be reoccupied until scientific studies have been carried out to estimate the risk. This is a predictable position for the authorities to take, since no one wants to assume the responsibility for returning the population to a potentially dangerous area. However, in view of the enormous population pressures in Africa today, any vacant, fertile land creates
Domestic cattle were also the victims of the Lake Nyos eruption. Many animals appear to have died almost instantly while standing around their owners' huts.

Peter Turnley: Black Star

a vacuum that soon fills with industrious people willing to face any risks. The immediate problem of inadequate food is a disaster that families face every day.

Lake Nyos still contains 25 percent CO₂. If relatively simple measures were taken, however, the lake could be made safe and the region could be repopulated. These include the removal of a 130-foot-high natural dam at the north end of the lake that would reduce the lake's volume by about 35 percent and also reduce its gas-storage capacity. The removal of the dam would be a field experiment that would induce a small gas burst that could be monitored and studied by scientists and thus provide a better understanding of such bursts. A large-diameter pipe should then be installed from the bottom of the lake to its surface, to continuously drain the gases from deep water. The pipe would contain the sole outflow from the lake and would drain gas-rich bottom water when fresh surface and rainwater flow into the lake in the rainy season. This system would insure that high gas levels could never again build up in the deep waters of Lake Nyos. The same measures applied in Lake Monoun would similarly make that lake safe.
A Funny Thing Happened on the

An evolutionary ecologist ponders the origins of America’s “jackalope”

by Daniel S. Simberloff

At first blush, jackalopes—those horned rabbits that adorn picture postcards from Nebraska to California—seem to be as American as apple pie. Douglas, Wyoming, a town where you can buy an official permit for a jackalope hunt and where preserved specimens of the animal are on display in many store windows, calls itself the jackalope capital of the world. A large statue of the animal stands in the town’s main street, and Douglas has gone so far as to celebrate an annual Jackalope Day. Local lore has it that LeRoy Ball, who owned the LaBonte Hotel in Douglas, first displayed a jackalope in 1829, but the animal was quickly derided as a fraud and Ball was labeled a liar. Folklorists who have considered the evolution of the species often assume it is the invention of an imaginative taxidermist. Ed Herschler, governor of Wyoming from 1975 to 1986, distrusted the Ball legend, probably because Ball’s original jackalope cannot be located today. In an official proclamation of May 15, 1985, Herschler stated flatly that the first jackalope was concocted by a Douglas taxidermist, Doug Herrick, in 1939.

Like many things American, however, the jackalope may have European origins. In 1662, Gaspar Schott, a Jesuit in what is now Germany, published Physica Curiosa sive Mirabilia Naturae et Artis, depicting a pair of frolicking, horned hares, Lepores cornuti, that so closely resemble the jackalope they would be right at home in Douglas. Schott’s conception appears to be part of a tradition in southern Germany. In Bavaria, one can find mounted specimens, postcards, and entire books on the habits of a fictitious animal known as the wolpertinger. Although some drawings include parts of other animals, the basic wolpertinger is a jackalope pure and simple, with the horns of a deer on the body of a lagomorph—a plant-eating mammal of the Lagomorpha, the order that includes rabbits and hares.

Although bestiaries abound with chimerae, taxidermists and postcard photographers produce rather few. Aside from the jackalope, the beazel (a fur-bearing trout) of Montana, Colorado, and Wyoming and the buffaroo of Australia’s Northern Territory are the only two commonly seen on postcards and the latter clearly derives from the jackalope. Even the ferocious guyascutus, a half-wolf, half-wild pig that first appeared in American folklore in the midnineteenth century and is sometimes claimed as native to Idaho, never graced a postcard.

Is it sheer coincidence that the horned rabbit is the basis for two mythical creatures on two continents, one dating back more than three hundred years, the other going back more than a century? Could two fanciful taxidermists have arrived at exactly the same conception? Would a Jesuit priest depict a chimera as factual? Was LeRoy Ball really a liar? Maybe not. One possibility is that Ball, or whoever introduced jackalopes to the United States, knew about the wolpertingers. There would then be one tradition, not two, but that tradition might nonetheless be founded on a fiction.

Another possibility is that there really are two traditions, both with the same biological foundation. In 1933, biologists Richard E. Shope and E. Weston Hurst reported in the Journal of Experimental Medicine on tumors in eleven of seventy-five wild cottontail rabbits found in Iowa and Kansas, noting that the afflicted animals were popularly known in that part of the country as horned, or warty, rabbits. In 1947, Kenneth C. Rowe, another biologist, included a drawing in an article he published in the Journal of Mammalogy showing a cottontail that had been shot in Missouri and had eight horns on various parts of its head. The article further described other horned cottontails found in the state as early as 1931. Shope and Hurst determined in their journal article that the horns, or warts, on the animals they studied were benign tumors caused by a papilloma virus (theirs was the first demonstration that a virus can cause a mammalian tumor). They also infected domestic rabbits with the virus.

Papilloma viruses cause benign growths on humans and many other mammals; some of these viruses, including the rabbit virus, have been associated with malignancies. Domestic rabbits infected with the cottontail virus are even more susceptible to malignancies than are the cottontails themselves. In the wild, the virus is contagious; rabbits spread it by scratching each other or by sharing a den; ticks that infest the animals are the vectors. But the growths are not always hornlike; many infected rabbits have growths on the front of the face, below the ears, or on the inner thighs, abdomen, neck, and shoulders. These growths are often asymmetrical and there may be more than two on a single rabbit. Nonetheless, some infected rabbits look remarkably like the animals drawn by Schott in the seventeenth century. Furthermore, the virus, which is particularly prevalent in the Mississippi valley, is also found in central Europe. One might, therefore, hypothesize that both the German wolpertinger and the American jackalope were inspired by papilloma-infected rabbits.

Yet the concept of the jackalope may have still other geographical origins. For example, nonhorned animals impersonating horned ones is a common theme in African folklore. In these tales, fake horns
Way to the Taxidermist

The bodies of these jackalope specimens come from rabbits and hares, the antlers from deer (not antelope); the postcards are from Wyoming, Colorado, and Texas.
allow such nonhomed animals as dogs, wolves, foxes, and jackals to enter gatherings of horned animals to learn their secrets or to prey on them without calling attention to themselves.

In the folklore of the Ila-speaking peoples of Zimbabwe, a hare dons wax horns that melt when it sits too near a fire, and a Guadeloupe folk tale describes a rabbit wearing horns crafted by a smithy. The jackalope or the wolvertinger, or both, may derive from this oral African tradition. These tales were widely known: in "Brother Wolf and the Horned Cattle," written in 1883, Joel Chandler Harris's Uncle Remus described a wolf fashioning horns from sticks to attend a meeting of horned animals. Although the entire African theme might have been inspired by papilloma-virus-infected animals (the virus is also found in Africa), the African tales probably couldn't have spread early enough to have influenced either Caspar Schott in 1662 or LeRoy Ball in 1829. It would also be a striking coincidence if both men had adopted the less-common rabbit version of the subject instead of the more usual dog, wolf, and fox versions.

A rather different biological basis for horned rabbits has occasionally been proposed by scientists, most recently in 1984 by biologist Brian K. Hall. He speculated that the occasional appearance of these hornlike structures might be an atavism, although he conceded that the fossil record is too meager to help test this notion and that the horns might have been caused by a pathogen. Since rabbits share no recent common ancestor with horned animals and the effects of papilloma virus have been established, the likelihood is that if there was indeed a model in nature for the horned rabbits in the German, American, and African folk traditions, it was a diseased rather than an atavistic animal.

Once the jackalope arose, however, it evolved in predictable ways: it became bigger and bigger and ever more fierce. The Nebraskan version is known as the warrior rabbit, and some Wyoming literature refers to jackalopes "as big as trees in the Tetons," while postcards depict humans mounted on horse-sized jacka-

From The Art of Natural History, by S.P. Dance
Horned hares, left, sport under a leopard in a bestiary of physical curiosities published in the seventeenth century by Gaspar Schott, a Jesuit priest in what is now Germany. Below: This illustration, from an early nineteenth-century French encyclopedia, may represent an ancestor of the jackalope.

These developments play on the popular perception of rabbits as quintessentially passive and harmless animals, the antithesis of aggression and threat. The attack of the killer rabbit in Monty Python and the Holy Grail (1974) is simultaneously startling and hilarious precisely because of the association of a cute bunny with rampant, bloody destruction. A giant jackalope may also seem threatening. Perhaps all jackalopes were likewise a product of sheer humor, with no biological inspiration at all, just the whimsy of someone familiar with rabbits and antelope and who had access to a taxidermist. Certainly the perpetuation and proliferation of the concept, especially in the American West, must be ascribed to the inherent humor of the idea and the reality that rabbits and hoofed animals are familiar fauna of the region.

A final note on taxonomy: The postcard jackalopes of the American West have antlers instead of horns and are actually jackamuledeer, easily recognized by their bifurcated, equally branched antlers. Antelope antlers have a single main horn with one short prong projecting forward (thus the name “pronghorn”), while white-tailed deer have a main horn with several long branches. Of twenty postcards that I have seen, seventeen are jackamuledeer, one is a jackawhitetail, and only two are true jackalopes. The part-human, part-animal Pope-alope depicted on one postcard is a “popilloma”-induced Pope-amuledeer with characteristically forked antlers, and the bassalope that turned up recently in the comic strip “Bloom County” is a basset hound with horns more like those of a mule deer than an antelope. Mule deer are more common in the U.S. than antelope and the bifurcating horns are flashier, so it is no surprise that jackalopes are rarer than jackamuledeer. The relative paucity of jackawhitetails is puzzling, given the abundance of white-tailed deer. The mule deer is a more typically western species, although white-tailed deer do live in most of the range of jackalopes. Jackrabbits, especially the white-tailed jackrabbit, are the most common model for the jackalope body. I have never seen an antelope jackrabbit as the basis for a jackalope, but
Jackalopes occasionally have a cottontail body and sometimes that of a domestic rabbit. Jackrabbits are larger than cottontails and domestic bunnies, and they are not pudgy. Perhaps their size accounts for their more frequent representation in the greater part of jackalope anatomy, although all three are prevalent in areas where jackalopes frequently appear.

In my smaller sample of wolpertingers on postcards and models in curio shops, I have seen the bodies of both hares and domestic rabbits sporting red- and roe-deer horns. One example of a wolpertinger in Munich was an intercontinental combination of a U.S. mule deer and a European domestic rabbit.

The particular components of these folklore creatures do not constitute conclusive proof or disproof of the viral hypothesis of the jackalope's origin. Although effects of the papilloma virus have been observed only on cottontails and deliberately infected domestic rabbits, these animals look sufficiently alike to all but specialists to inspire visions of horned jackrabbits.

Many scientists have recently begun to speculate about whether new species can be created by the viral transport of DNA from one host species to another. The jackalope may be an example of a new species produced by a virus acting in a completely different way—one in which the vector is imagination.
Buffaroo are predictably Australian. The giant jackalope, lower right, is a rare specimen, having the pronged horns of an antelope rather than the antlers of a deer.
Deceit and Corruption in the Blueberry Patch

How does a potentially juicy fruit become a shriveled “mummy”? by Suzanne W.T. Batra

Just as ripening peaches, plums, and cherries fall prey to deadly brown rot, blueberries are often victims of a related fruit disease, caused by the ominous-sounding mummy berry fungus. Belonging to the genus Monilinia, mummy berry blights and kills leaves, flowers, and shoots and mummifies fruit, turning budding blueberries into white, inedible kernels.

Because Monilinia fungi are a force to be reckoned with—they cause more than $100 million worth of crop damage a year—my husband, Lekh Batra, a mycologist, has been studying their ecology and control for the U.S. Department of Agriculture. While working with the fungus in blueberries (some Monilinia species attack related wild fruit, such as cranberries), he noticed that flies and bees were sometimes attracted to wilted, infected blueberry leaves. Naturally, he asked me, his resident entomologist, why. As a bee specialist, I was skeptical, so I went to his field site for a look. There, I found that he was right; bees and other insects were alighting on wilted leaves and licking them intently. Oddly, healthy leaves were not licked. Thus, we decided to collaborate on the puzzle of the leaf-licking bees. This apparently straightforward problem turned out to be far more intriguing, and time-consuming, than we ever imagined, and the bees became the key to the secret of the mummy berry’s success.

The mummy berry fungus has an unusually complex life cycle. It attacks different parts of the host during different phases of its own development. In early spring, just as the last snow melts, old, mummified berries that have overwintered on the ground in leaf litter, and harbor the fungus in its resting stage, produce minute, brown, mushroomlike cups. These are borne on slender stalks, about one inch long, that push up through the moss, leaf litter, and other organic material beneath blueberry plants. The cups eject clouds of light, dry, long-living spores, called ascospores, that rise on sunwarmed spring air currents and settle on the blueberry leaves. Hyphae, or threadlike growths, spring from the ascospores, penetrate moist, tender leaf tissue, multiply, and in a few days, cause the infected leaves to wilt, discolor, and die.

A second type of spore, called conidia, is then produced on the upper surface of these wilted leaves. Conidia are relatively heavy, coated with a sugary substance, and unlike ascospores, viable for only two hours. Some may be blown in the wind, but most manage to reach the host’s flowers by a surprising method that Lekh and I were later to discover. Once in the blueberry flowers, conidia produce networks of hyphae that penetrate the flowers’ ovaries causing them to develop into hard, white, inedible mummy berries rather than into succulent blueberries. These mummy berries fall to the ground where they rest until they, in turn, produce cups the next spring.

We did our research in a suburban wood lot near our Greenbelt, Maryland, home, which shows that there are still discoveries to be made right under our noses. In the wood lot, both highbush and lowbush blueberries, and their relatives the huckleberries and deerberries, grew as understory shrubs among the oaks, tulip trees, and scrub pines. Like their cultivated cousins, these wild blueberries were vulnerable to the mummy berry fungus.

Because the fungus actively infects leaves and flowers for approximately ten days each spring, I was able to observe the insects’ peculiar behavior for only short periods. Allowing for cold, rainy days when there was no insect activity, and for other commitments—this work was not part of my official USDA duties and so was an extracurricular project—I was able to spend just three days a year studying mummy berry and pollinators in the field. So our progress was slow, and unraveling this little mystery required six years. Each year we thought of new theories and eagerly awaited spring to test them.

After Lekh first showed me the insects licking infected leaves, I spent the next two springs determining just which species of insects were involved and observing their behavior to find out why they were there. The leaves were licked by ten species of native bees, including sweat bees, digger bees, and cuckoo bees; three species of flies; two species of butterflies; and black carpenter ants. (Much later I discovered that honeybees also licked the infected leaves.) All but one of these species were also normally seen visiting blueberry flowers. Their many routine visits to the flowers were erratically interspersed with brief stops to lick leaves. When insects alighted on infected leaves, they briefly but intently licked the matted gray conidia, which was usually covered with a shiny secretion. While on the leaves, the insects were alert, flighty, and difficult to photograph or observe closely, in contrast to their calm, deliberate behavior when they were preoccupied with probing for nectar deep within flowers.

Insects were evidently the agents that carried the short-lived conidia from the leaves to the flowers, but this idea needed to be confirmed. The next winter, we examined insects that we had caught and preserved under both a light microscope...
and an electron microscope. We found that the distinctive mummy berry conidia were abundant among blueberry pollen grains on the insects’ hair, body, mouthparts, legs, and in their stomachs. We also found conidia on the stigmata of blueberry flowers that had been recently visited by leaf-licking insects. Lekh discovered that hyphae can only penetrate the ovary of a blueberry flower if they are carried in by pollen tubes, which grow from the pollen grains that fertilize the ovary. Therefore, the insects must carry both the pollen and the spores and must deposit them simultaneously.

During the third spring, we set up an experiment to test our hypothesis that conidia are disseminated primarily by insects and not by wind, as botanists previously thought. We hand pollinated four hundred flowers to insure that fruit would develop (since blueberries require cross-pollination by insects) and covered them with bags to exclude most insects (but not the wind, tiny mites, or thrips). Only 10 percent of the bagged flowers became infected and formed mummy berries. Sixty-three percent of our control group—an equal number of normal, insect-pollinated, unbagged flowers on other branches of the same bushes—yielded mummy berries. These findings shed light on the mechanics of mummy berry transmission but still did not tell us why pollinating insects were attracted to infected leaves in the first place or why the mummy berry fungus has such a complex life cycle.

The behavior of the insects, particularly the bees, provided the first clues. Honeybees are well known to collect some types of fungus spores, such as the reddish, powdery spores of rust fungi. These bees, acting as though the spores were pollen grains, pack them into their pollen baskets and transport them back to the hive. Our wild bees, however, did not attempt to collect the blueberry leaf conidia like pollen grains; instead, they eagerly licked the mat of conidia as if taking the nectar of a flower. Bees were never seen licking healthy leaves, and we suspected that sugars were being secreted by the damaged, infected leaf tissue (a process known in other types of plant fungus infections). Lekh took samples from infected leaves to H.M. Fales, a chemist at the National Institutes of Health. During the fourth spring, he and Lekh performed an analysis that clearly revealed the presence of sucrose, glucose, and fructose. These same sugars are secreted by healthy blueberry flowers to attract pollinators.

Sugars alone, however, may not be enough to attract bees. Plants have also evolved brightly colored and scented flowers to add to their allure. Furthermore, unlike honeybees, which often feed on honeydew and other sugars, as well as nectar, the native bees I observed never ingested sweet deposits other than flower nectar. There seemed to be something else in the leaves that caught the attention of pollinators.

Both the behavior of the insects and the color of wilted leaves provided clues. Diseased, wilted blueberry leaves are generally discolored in a fairly uniform pattern. The edges of a leaf may remain green, but the middle turns brown, often with a bluish to violet cast. This “target” surrounds the central, gray patch of conidia. To us,
mimicry among edible and inedible, distasteful species of butterflies, and I retained an interest in the subject. I thought that perhaps the UV-reflective, diseased leaves were mimicking the host’s flowers. When I put the new photographic equipment to work, it revealed previously invisible UV patterns of various flowers, and to my satisfaction, also confirmed my suspicion that parts of the blueberry flower, as well as the conidial mat and portions of diseased leaves, reflect ultraviolet rays. To the insects, the flowers and discolored leaves shine like beacons in the forest against a background of UV-absorbent, green leaf tissue and dark, moist soils.

By the sixth spring, we had determined how and why the mummy berry fungus uses floral mimicry to deceive pollinators. The insects are drawn to the disguised leaf as if it were a blueberry flower. The mimicry is complex and involves the insects’ sense of sight (the UV light), taste (sugars produced along with conidia), and perhaps smell (the infected leaves’ teallike odor). Certain species of orchids are well known for their mimicry of the shapes and odors of female bees and wasps; male insects load up on pollen when they attempt to copulate with the flowers. This two-species interaction involves deceit by a flowering plant and exploitation of its pollinator. But our backyard, weekend research led us to an unusual three-way case that included a host, a parasite, and the latter’s insect vector. Our finding that a fungus can so modify its host as to “trick” the host’s beneficial pollinators into spreading a ruinous disease is, so far, unique. The closest behavioral parallel may be the relationship between a species of snail that acts as a host for a kind of parasitic trematode flatworm. The trematode invades the snail’s tentacles, causing them to swell, become banded, wriggle, and thus resemble an edible grub. These modified tentacles are readily eaten by songbirds, the trematode vectors.

*Monilinia* has evolved a complicated but successful strategy that helps it to thrive. Perhaps our six-year probe into the fungus’s life and times will make the curse of the mummy berry less costly for U.S. fruit growers and consumers.

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this looks nothing like a blueberry flower, which has a green to bluish green calyx above the drooping white to pink petals. Also, the diseased leaves have a teallike odor, while blueberry flowers smell sweet, and healthy leaves smell grassy. Nevertheless, insects alighted upon and probed blueberry flowers and diseased leaves in much the same way. Zigzagging, they flew upwind, alighted at the top, that is, on the calyx of the flower or on the petiole of the leaf, walked downward while smelling with their antennae and extending their tongues, and turned around to enter and feed in the flower, or in the case of the leaf, turned to lick the sugary conidia. During the winter, I had been reading some research papers on the ways insects and plants communicate using ultraviolet patterns, which are invisible to humans. Suddenly, the thought occurred to me that the violet-tinged blueberry leaves, as well as the bluish green calyces, may reflect UV light, which is highly attractive to insects. I ordered the necessary photographic equipment and eagerly awaited the fifth spring to test this idea.

As an undergraduate, I had worked on
An Advocate for Nonpersons

By Joseph L. Sax

In 1972, Christopher Stone wrote a law review article called “Should Trees Have Standing?—Toward Legal Rights for Natural Objects.” The article was later published and became a widely acclaimed book. Stone called attention to a profoundly important oddity in the legal system: in order to get courts to protect nature, human plaintiffs had to sue and demonstrate that they would be hurt (by such acts as the destruction of a forest or the damming of a river). Wouldn’t it be better, Stone asked, to permit the challenge to be brought on behalf of the natural object itself? Not only would we circumvent a legal fiction, but we could directly face the question of legal rights for natural objects.

Despite its popular appeal, Professor Stone’s book faced heavy professional criticism. If natural objects had legal rights, he was asked, what exactly are these rights, and what are they rights to? Does the Delaware River have a right to continue downstream, rather than being diverted to New York City? Do trees have a right not to become chairs, and does coal yearn to remain underground? Such questions typified academia’s response to its most acerbic. Honest scholar that he is, Stone has obviously been struggling with those questions for many years. Earth and Other Ethics is his considered response.

The central question of the book is what, if any, moral obligation should we feel toward “nonpersons” (Stone’s awkward general term for all things and creatures other than human beings) beyond the obligation to safeguard our own interest, as in food supply or health protection. To understand the issue, Stone asks us to imagine that in a will we have been left as trustees of a lake. The question is what the trustee would be obliged to do, “assuming that the will failed to spell out in detail any specific obligations, such as ‘stock with carp’ or ‘keep free of algae,’ and simply said in general terms, ‘take care of my lake after I’m gone.’”

This is a question calculated to test the philosophic powers of an Aristotelian, and there is nothing in Earth and Other Ethics to suggest that Stone has joined that august company. As a volume of moral philosophy, the book is a fizzle. At its worst it bulges with pretentious phrases, such as “the moral salience of membership entities” and “the moral considerateness of nonpersons,” by which Stone means the obligation people have to protect nature. The book is also loaded with academic superwords like teleological, deontological, and transitivity. And Stone seems unable to resist speaking of “norms that try to capture essences . . . whether the river’s ‘riverhood’ was being endangered.”

Plainly Stone got in over his head, and his book suffers for it. Yet he is an original and imaginative writer, and he has some interesting things to say, buried though they are in overblown philosophical jargon. With enough patience, a reader can cull from these many pages the makings of a provocative and original essay on how to think about the preservation of animals and other natural objects.

The animal rights literature, he observes, which has been at the center of much of the philosophical debate in environmental circles, has diverted our attention from a very important issue. Animal rights theorists have focused almost exclusively on whether an ape or a snail has rights and whether there are differences between such animals or between an ape and a graviely brain-damaged human. Whatever the answer to those questions, Stone notes, it is perfectly possible to have moral responsibilities toward things even though they may have no rights. One might well have some moral obligation to save a great painting from destruction, although surely the painting feels no pain (one common test) and otherwise has no rights. The same might be said of the suffering animal or the endangered species. Stone’s point is an important one that needs iteration. We should not be misled into thinking the debate over rights is all there is to the moral obligation question in environmental protection.

This leads to what seems to be the central message of the book: that our thinking about obligations has been exclusively focused on human beings and has improperly limited us. Because humans do have rights, and because our obligations to one another are formulated in terms of rights, we find it difficult to think about having obligations toward something that does not have them. Stone makes a nice point in this respect, using the well-known example of the bison left by the Park Service to drown in Yellowstone Lake, an example of natural management that dismayed tourists who witnessed the animal’s last agonies. It would be possible to imagine a system of moral obligations, he notes, in which we would say that we are duty bound not to put the bison in jeopardy (luring it to the dangerous lake, for example), yet also say that once the bison, on its own, went out on the lake, we had no duty to save it—indeed, that in such cases we should let nature take its course. Certainly this is a plausible view. Yet it is a view of moral obligation that is unimaginable applied to other human beings. We would unhesitatingly save a drowning person.

Stone’s larger point is that we should be receptive to what he calls a pluralistic moral view (having different notions of obligation to bison than to humans). He elaborates upon the possibilities of this pluralism in a variety of ways. One familiar argument of skeptics about moral obligations toward nature is a form of reducere ad absurdum. Must we, they ask, refrain from squashing a pesky mosquito or refuse to pull up the hapless carrot from its earthy home? Stone suggests that a diverse but coherent set of moral obligations could be formulated based on the differing characteristics of various animals. We know that whales have the capacity for pain, intelligence, and sociability and show evidence of an emotional life, he says. A higher level of obligation might be adopted toward them than toward

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Earth and Other Ethics: The Case For Moral Pluralism, by Christopher D. Stone. Harper and Row, $18.95; 320 pages.
plankton or earthworms, which appear to have no such characteristics. Toward such lower life forms, it may suffice to assure the preservation of the species. At the same time, we may owe less to the whale than to human beings because whales lack the human capacity to make commitments or moral choices or to act fairly or unfairly.

These strike me as plausible views, but I would characterize Stone’s work as an essay, precisely because he never works through a defense for the distinctions he makes. He is doing little more than working backward from his (quite conventional) intuitions: we should protect species from extinction, even earthworms; whales and dogs and other higher animals should not be treated cruelly; people are entitled to greater protection than even the most intelligent animals. At some points he is rather explicit in stating his conclusions in the most conventional and familiar terms. His ultimate principle seems to be reverence for all life in all its forms, an appealing moral stance but hardly one that is demonstrated or even elicited by anything in this book.

One of the few points that Stone elaborates on specifically is what he calls proximity. The idea is that the more like us in characteristics, or the closer in space, the greater the obligation. In this respect, we would have greater duties toward the whale than toward the snail. Another version of the proximity theory is that we might have greater obligations to our neighbors than to people at the other end of the earth. This is an interesting suggestion, but it is to put it mildly, controversial. If proximity is a basis for moral claims, it will immediately occur to readers that many of those most concerned with preserving wildlife populations in Africa or tropical ecosystems are very far away from the object of their concerns. Do the claims of local people to exploit local resources have a moral right to prevail? One would have expected a book with the aspirations of Earth and Other Ethics to explore such questions seriously and at length.

It does not. Stone blandly asserts, for example, that “morality might require a single principle at play that simply discounts for distance: The votes of ten Americans to save the whales that pass through native waters outweighs the contrary preferences of one hundred persons far away.” The author commits only a few sentences to such extraordinary propositions. He says that if values like community and friendship are important, then giving more to those with whom it is possible to have such relations could be morally justifiable. As to the injunction to treat each person equally, he says that it “has obvious appeal, as a principle. But to treat the remote on the exact same terms as one’s neighbors is fraught with conceptual problems, depreciates community as an independent good, and sits poorly with the requirement that a practical ethics be ‘liveable.’” In a book of several hundred pages that purports to be a philosophical work, such casual treatment of grave questions is simply unacceptable.

If Professor Stone had aspired to do less than hobnob intellectually with Immanuel Kant and other philosophical superpowers and instead had sought to explain his views in direct and common-sense fashion, he might have produced a book of estimable value. He is thoughtful, intelligent, and original. He is willing to ask questions that most writers haven’t the courage to pose: he asks what it feels like to be a river, if earthworms suffer, and wonders if a whale has preferences. And he dares to boldness: “Perhaps,” he says, “the depth of our ignorance itself is a source of moral obligation.”

But one cannot simply be daring and original. Hard questions demand harder thinking than is to be found in Earth and Other Ethics. The puzzle left by Stone’s earlier book remains unsolved.

Joseph L. Sax is a professor at the University of California at Berkeley, specializing in environmental and public land law. He is the author of Mountains Without Handrails: Reflections on the National Parks.
Get Ready for the Dog Days
by Thomas D. Nicholson

The hot sultry days of August in the North Temperate Zone are often called "dog days." Anyone seeing stray dogs lolling around in the merciless August heat, desperately looking for a bit of shade in which to take refuge, will think the name is most appropriate. But dog days are not any more pleasant for humans than they are for dogs.

The dog days are not named for the canines they seem to affect, although the name does derive from a legendary dog. The bright star Sirius (brightest of all the stars in our nighttime sky) in the constellation Canis Major (the Greater Dog) is known as the Dog Star. The sun passes north of Sirius in early July (its closest approach to the star), and by the beginning of August has moved far enough east of Sirius so that the Dog Star can be seen in the morning before twilight brightens the sky.

That makes sense so far, but most sky watchers who know the Dog Star think of it as a winter object, in its best viewing position on winter nights. We don't usually see it at all in summer, at least most of us don't. Just barely a morning star in August, Sirius doesn't climb very high in the sky before daylight begins.

After its impressive appearance in the winter each year, Sirius disappears as an evening object in early April, as the earlier moving sun brings daylight into the part of the sky where the star is located. For several months it is invisible, above the horizon only in daylight or bright twilight. But when the sun moves far enough past Sirius in August, the bright star climbs sufficiently high above the eastern horizon to be seen before the dawn sky brightens and hides it. That's when Sirius's "day in the sun" begins, in the sense that its year as a visible star in the night sky begins: a year starting in early August and ending the following April. So what we really celebrate in August isn't sleepy dogs, but the reappearance of the Dog Star in our sky before sunrise, an event known as its heliacal rising.

That may not signify much today, but there was a time when the heliacal rising of Sirius was cause for celebration. In ancient Egypt, astute sky watchers noticed that the beginning of the annual Nile flooding, so important for the fertility of the otherwise arid Nile Valley, took place each year just after they could first see Sirius in the morning sky. That was a crucial piece of information, signaling the beginning of the earth's productive season. It led to the reliable organization of life around the regular coming and going of seasonal events. The heliacal rising of the star marked the beginning of the year in the earliest Egyptian calendar.

If things hadn't changed over the millennia, we might wish each other Happy Dog Days in August instead of Happy New Year in January.

Events in the calendar below are given in local time unless otherwise indicated.

August 4: The moon is very close to Scorpius's bright red star Antares just after sundown. It occults the star as seen in parts of the Southern Hemisphere. The bright object to their right is Saturn.

August 5: A close encounter (visually speaking, of course) with the moon may help viewers locate Ceres, the first asteroid discovered. Close to its opposition from the sun (on the opposite side of the earth from that of the sun), when it is brightest, Ceres is easy to see with binoculars. Focus on the moon at the end of twilight and look for the asteroid a few moon diameters to the right of the moon.

August 8–9: Perigee moon (closest to the earth) is at 2:00 p.m., EST, on the 8th; full moon at 5:17 a.m. on the 9th. Both boost the tides and reinforce one another in combination. Perigee spring tides on August 9 will be quite strong.

August 12: The Perseid meteor shower is to meteors what Old Faithful is to geyers. This is the shower to see. On any morning from the 9th to the 15th, you can count 25 or more meteors per hour and up to 50 at the shower's maximum on the 12th. The best hours for meteor watching are from 1:00 a.m. until dawn so you will have to stay up late or get up early.

August 13–14: Jupiter is working its way into the evening sky, although it is still a morning star. Look near the moon these nights until dawn. The moon skips past Jupiter in daytime on the 14th.

August 16: Last-quarter moon is at 3:25 a.m., EST, just as the moon is about to leave Aries and move into Taurus. Look above the moon before dawn to see Taurus's compact star cluster, the Pleiades.

August 19–20: Saturn completes its retrograde motion (westerly through the stars) on the 19th; on the 20th, Jupiter begins its retrograde motion and Mercury is in superior conjunction (in line with and
Celestial Events

beyond the sun). Each of these events signals a change for the planet involved: the end of Saturn’s retrograde motion forecasts its departure from the evening sky; the beginning of Jupiter’s retrograde motion marks its entry into the evening sky; and Mercury’s superior conjunction designates its change from a morning star to an evening star.

August 21: Apogee moon (farthest from the earth) is virtually in line with Pollux and Castor. The sun is far enough east for the stars to be seen more easily in the morning, but note how slim the crescent moon is. Next time you see it, the moon will be an evening object.

August 23: Venus has its turn at superior conjunction, returning to the evening sky, where it will be an attractive object come autumn.

August 24: New moon is at 6:59 A.M., EST.

August 25: Mars is behind the sun today and becomes a morning star.

August 26: We should begin to see the new crescent moon tonight.

August 28: The moon occults Spica for the second time this month, but again is invisible to us. The event occurs in the daytime sky over the southern United States and South and Central America. The moon will still be close to the star when we see it tonight.

August 29–31: The early crescent moon fattens, stays up later, and appears higher nightly as the end of August approaches. It reaches first-quarter phase at 10:48 P.M., EST, on the 31st, when it is once more near Antares, occulting the star later over the eastern world.

Editor’s Note: The Sky Map in the July issue shows the evening constellations and stars for this month and gives the dates and times for use.
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Columbus’s Biggest Discovery

Sweet potatoes, winter squash, rhubarb, and manioc were all new to Genoa’s favorite son

by Raymond Sokolov

Some years ago, a few friends and I tried to decide who we thought was the most important figure in the history of food. We only considered people we could actually identify. The real pioneers of gastronomy are all unknown, of course—those mute, inglorious Prometheuses of the edible who first boiled water, first made dough rise with yeast, first dared to eat a sea urchin’s orange innards. But it didn’t make sense to lionize Anonymous. And we decided we weren’t going to pick a chef, not even Carême. Food was too wide a field to be presided over by a cook.

It would have to be someone who had fundamentally changed the flavor and content of human survival. Appert came to mind, Nicolas Appert (1750–1841), the inventor of canning. But he was too mundane to be our universal hero. Someone mentioned Julia Child. Important, we thought, not only for English-speaking cooks but as a model for anyone trying to spread food information with precision from one culture to another. And yet she had not truly remolded the meals of millions. We wanted a Napoleon. An alimentary Moses.

In a flash, we saw it. Columbus was our man. Yes. Christopher Columbus alias Cristóbal Colón alias Christoph Colombe alias Cristoforo Colombo. The man behind Columbus Day, Columbus Circle, and Columbus, Ohio. The man in the middle of pre-Columbian art and the Columbian Exposition.

Columbus is everybody’s hero. Have you ever met anyone who didn’t admire him? Is there any sentiment detectable anywhere against the celebration of the Columbian quinquecentennial in 1992? I suggest to you that anti-Columbianism is the last undiscounted radical position left to provide them by royal decree of their Catholic Majesties Ferdinand and Isabella. Supplemental foraging began on the high seas. In those fateful September days before history’s most momentous landfall, the voyagers aboard the Pinta, the Nina, and the Santa Maria caught a crab, a tuna, and several dolphins.

Almost immediately after the discovery of the West Indies, contact with natives took place and with it the exchange of foodstuffs—molasses for fruit and other plants.

On the first voyage, food specimens were collected, and much attention was paid to unfamiliar foods. A diary refers to purslane and amaranth, mussel shells, large, tasteless snails, birds that inspired the voyagers to hunt them, unfamiliar beans, turtle, winter squash, honey, sugar cane, rhubarb at St. Thomas, allspice and wild cinnamon, conchs, and “livestock of every sort.” Various roots “like turnips” or with a chestnut taste can be identified as cassava (manioc) and sweet potato, respectively.

The sweet potatoes inspired the fullest written comment about food from the first voyage: “... like great carrots that they grow and plant in all these countries and it is their living and they make bread of it and it has the flavor proper to chestnuts.”

In exchange for such unfamiliar bounty, Columbus gave his hosts bread and a “bottle of orange water” and no doubt much else. In turn, and fittingly just at Christmas time, Columbus was presented with three ducks and a banquet consisting of three kinds of sweet potatoes, rock lobster, game, and other meat.

Accounts of subsequent voyages provided an even fuller sense of the brave new world of the American tropics, through fifteenth-century Spanish eyes. As you read this description, try to guess the modern vernacular names of the two fruits: “There are trees... which give a fruit like the apricot, which is full of small seeds like the seeds of a fig, red as scarlet, which the

CORRECTION: In last month’s column the wrong temperature was given for legal pasteurization. In New York State, the minimum temperature is 150°, in other states it is somewhat lower.
inhabitants eat but to us it is none too good.... There are also some like the artichoke plant but four times as tall, which give a fruit in the shape of a pine cone, twice as big, which fruit is excellent and it can be cut with a knife like a turnip and it seems to be very wholesome.

The first is probably a guava or a papaya; the second a pineapple. Later in the same letter, we read about another "fruit" of subsequent economic and gastronomic importance: "In those islands there are also bushes like rosebushes which make a fruit as long as cinnamon full of small grains as biting as pepper; those Caribs eat the fruit as we eat apples."

The man has tasted a chili, perhaps Capsicum frutescens. He also took the time to set down the classic procedure for turning manioc into bread: "They shred those turnips on certain stones which look like cheese graters... then they put on the fire a very large stone on top of which they place that grated root and they shape it in the form of a cake and use it as bread and it keeps for 15 to 20 days, which bread several times was very handy for us."

There is also a report on the results of some horticultural experimentation done with seeds brought from Europe. Spring melon, cucumber, Old World squash, and radishes flourished. Onions, lettuce, other salad plants, and scallions failed, except for parsley. "Wheat, chickpeas and beans in ten days at the most grow nine inches; then all at once they wilt and dry."

Columbus brought his own livestock from Spain and successfully bred pigs, cattle, horses, sheep, and goats. His men went native, though, and consumed parrots and local wild pigeons with gusto, as well as a reptile, probably an iguana. The Indians ate dogs, snakes, lizards, spiders "as large as chickens," all manner of seafood, including oysters and sea urchins, and maize.

The real beginning of transatlantic culinary cross-fertilization is described by another man in a letter to the duke of Milan. He exclaims about the virtues of sweet potatoes: "When eaten raw as in salads, they taste like parsnips, when roasted, like chestnuts, when cooked with pork you would think you were eating squash. You will never eat anything more delicious than Asses (sweet potatoes) soaked in the milk of almonds."

There it is: New World meets Old in this typically medieval Spanish use of almond milk. The voyagers must have brought indispensable almonds with them. Soon, they would return home and usher in the modern era in the Spanish kitchen. New World spices would supplant the antique, oriental mixture called salsa fina. Similarly, the tomato would join the onion in that most typical of Spanish culinary preparations, the sofrito, a prefried flavoring combination added to countless dishes in Spain and Latin America today. U.S. supermarkets with a Hispanic clientele sell bottled sofrito. Brave new world indeed.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.
Little Wambaw Swamp, South Carolina

by Robert H. Mohlenbrock

A visit to the Francis Marion National Forest, a few miles north of Charleston, South Carolina, is like a trip back through history. Before the Civil War, nearly one hundred plantations occupied this territory, their owners taking advantage of the low-lying land and cheap slave labor to become wealthy from rice farming. When slavery was abolished, the rice industry collapsed. The remains of the earthen dikes and floodgates that once controlled the flow of irrigation water are now barely detectable. Piles of rubble overgrown by dense vegetation are all that’s left of Watahan Plantation; the only remnant of what was once the Mepken Plantation is a drive lined by live oaks draped with Spanish moss.

The forest also contains several sites and ruins from the Revolutionary War, for this is where Gen. Francis Marion and his band of partisans developed the art of guerrilla warfare after the British drove the Continental Army out of South Carolina. Marion and his men harassed the British supply lines leading inland from Charleston to North Carolina; they would then disappear into nearby coastal swamplands for protection. Marion was so adept at these stealthy maneuvers that he became known as the Swamp Fox. One of his swampy havens may have been Little Wambaw Swamp, today part of a 5,223-acre area managed as wilderness by the Forest Service.

The swamp is a coastal plain depression that serves as a collecting basin. The outskirts of the swamp are covered part of each year with shallow water. Here the archetypal swamp trees—bald cypress and water tupelo—begin to appear, but the forest contains a variety of trees: water oak, laurel oak, red maple, sweet gum, and a scattering of cottonwood, hackberry, and loblolly pine. The undergrowth is often so thick that it impedes passage. Shrubby hollies, wax myrtle, and saw palmetto grow above a colorful understory of pickerelweed, lizard's-tail, and wild iris.

Boggy depressions called pocosins dot the periphery of the swamp and support several kinds of evergreen shrubs (see "This Land," June 1985, "Croatan National Forest, North Carolina," for further
Cypress trees with flared trunks at water level are adapted to growth in flooded areas.

Photographs by David Muench
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information on these habitats). At Little Wambaw, the pocosins are dominated by sweet bay and large gallberry. Pitcher plants and wild orchids commonly grow in the acidic soil.

If you are not preoccupied with watching out for cottonmouths and several other snake species, you may catch a glimpse of parula, Kentucky, prothonotary, black-throated green, and hooded warblers and of red-eyed and white-eyed vireos, as well as hear the distinctive call of the pileated woodpecker.

In the center of this wilderness, sixty swampy acres are dominated by bald cypress and water tupelo trees. In places, the water stands up to three feet deep throughout the year. Where sunlight penetrates the dense canopy, duckweeds may form green patches on the water, and here and there the purplish frond of a mosquito fern floats on the surface. Fallen logs may harbor their own rich flora of mosses, pink Saint Johnswort, swamp beggar-ticks, and water horehound.

The bald cypress and the water tupelo are the trees best adapted to the continuously flooded conditions of the deepest recesses of the swamp. Physiological experiments conducted on trees that grow in water show that these two varieties are the most capable of absorbing adequate amounts of nitrogen, phosphorus, potassium, and calcium from the saturated soil.

Bald cypresses, water tupelos, and other trees that grow in standing water often develop the familiar characteristic of swollen, seemingly "buttressed" trunks. These buttresses do not give the trees additional anchorage, however; the trunks taper to normal diameters below the water level. The swelling is greatest in the narrow zone where the trunk is nearly always in contact with both water and air; this may be a special circumstance that favors extra growth.

Another well-known but unexplained feature of the bald cypress is its tendency to form the blunt-tipped, conical woody structures known as knees that usually project above the water level in the swamp a short distance from the main trunk. The water tupelo may also form kneelike projections, particularly in the southernmost part of its range. The knees are actually roots that begin as small swellings on the upper surface of a horizontal root and grow very rapidly. Susceptible to a wood-rotting fungus, the knees often become hollow as they age.

A theory that has been around for more than a century is that the knees carry out an active exchange of gases, enabling the trees that live in standing water to "breathe." Microscopic examination of the texture of cypress knees, however, reveals no openings like those found in leaves or stems (called stomata and lenticels, respectively). Botanist Paul Kramer and his colleagues at Duke University, seeking to test the theory of gas exchange a few years ago, covered cypress knees with inverted oil cans and sealed the bottoms of the cans with wax. After periodically testing the gases within the cans, they concluded that the exchange of gases by cypress knees was negligible.

Since bald cypresses planted outside of standing water rarely produce knees, some botanists have suggested that the knees help support the trees in their watery habitat. These trees do grow more than 100 feet tall, with their roots embedded in unstable muck, so the idea that the knees serve as anchors is at least plausible.

Recently, botanist Clair Brown of Louisiana State University noted that the knees contain large quantities of starch. Apparently, glucose manufactured in the leaves of the bald cypress is transported to the knees, where it is converted into starch until it is needed. Perhaps, therefore, these enigmatic structures are really energy storehouses.

"This Land" highlights the biological phenomena of the 154 U.S. national forests. Robert H. Mohlenbrock is Distinguished Professor of Botany at Southern Illinois University at Carbondale.
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At the American Museum

Arabian Night
The Ramzi El-Edibi Dance Company presents a program of music and dance Thursday, August 13, at 8:00 p.m. in the Kaufmann Theater at the American Museum of Natural History. Among the pieces are “Jerusalem,” a veil dance based on the Turkish rites of the whirling dervishes; a stick dance, “Egyptian Mood”; “The Syriac Line Dance”; and “Shish Kebab,” which both mocks and revels in the ritual showing-off between the sexes. The musical accompaniment is performed on the oud, a lute-like instrument, and a single quill. Tickets are $8 for members and $12 for nonmembers. For further information call (212) 769-5600.

At the Planetarium
The Seven Wonders of the Universe, a Sky Show narrated by Burt Lancaster, will be extended through Monday, September 7. After a review of the Seven Wonders of the World, the program will go in search of the natural wonders of the universe from the great canyon of Mars to the rings of Saturn. Premiering Thursday, September 10, at 1:30 p.m., Cosmic Illusions, the Planetarium’s newest Sky

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Surf’s Up

When the white sands and rocky outcroppings of their crowded rookeries on San Nicolas Island, seventy miles southwest of Los Angeles, get too hot, sea lions, like other southern California natives, head for the surf to cool down. They swim out in groups of fifteen to twenty and more, then ride the waves back toward shore. Before a wave breaks, they often throw themselves up out of the curl, make a half gainer, and swim out to catch another, bodysurfing for an hour or more at a time. These are mostly young pups, though some older males and females take time to ride a few waves on their way in from feeding grounds. Most adult males inhabit the island only in the early spring when they come to breed. The population on San Nicolas is then some 16,000 sea lions. Pups are born from late May to July. The adult males migrate in summer to coastal feeding grounds as far north as British Columbia. From San Nicolas, the females swim sixty to eighty miles offshore to feed on anchovy, whiting, and squid, leaving young pups to chase fish among the kelp beds and cavort in the surf.—B.D.S.

Photograph by
Stephen Leatherwood
Earthviews
Authors

Born in Brazil to a Brazilian mother and a French father, Niède Guidon (page 6) received a bachelor's degree in natural history from the University of São Paulo and her subsequent archeological training at the University of Paris. In 1963, while an archeologist at the Paulista Museum in São Paulo, she learned of the prehistoric rock-shelter art near the village of São Raimundo Nonato. She is now directing a French–Brazilian interdisciplinary project to trace the interaction of humans with the environment in that part of Brazil from Ice Age times to the present. In the future she plans to trace the carrying capacity of this habitat and its consequences for the development of social complexity. Guidon is a lecturer at the Ecole des Hautes Etudes en Sciences Sociales in Paris. For further reading on prehistoric art she recommends Rock Art of the American Indian, by Campbell Grant (Golden: Outbooks, 1981), Australian Aboriginal Art, by Frederick D. McCarthy (Sidney: Australian Museum, 1962), and Treasures of Prehistoric Art, by André Leroi-Gourhan (New York: Abrams, 1980).

Donald R. Prothero (page 26) has mined the “bone beds” of the American Museum of Natural History, as well as the rich fossil lodes of the Dakotas, Nebraska, Wyoming, and Montana. “As a graduate student at the American Museum in 1976,” says Prothero, “I saw a whole floor of unstudied fossil rhinos and realized that hardly anyone knew anything about them.” Under the guidance of Earl Manning, Prothero pieced together the big picture of North American rhino evolution. Prothero, who earned his doctorate in geological sciences from Columbia University, is now an assistant professor of geology at Occidental College in Los Angeles. Much of his research involves fossil mammals of the late Eocene and Oligocene, a time of tremendous climatic change. He has used magnetic stratigraphy to correlate changes in mammal species with the worldwide climatic record. A practitioner of the arts as well as the sciences, Prothero is a gourmet cook and an avid trombonist. He is currently completing a book on North American rhinos. Other books of interest are R.J.G. Savage and M.R. Long's Mammal Evolution: An Illustrated Guide (New York: Facts on File, 1986) and Esmond and Chryssee Bradley-Martin's Run, Rhino, Run (London: Chatto and Windus, 1982).

A brief reference to ambush bugs in the writings of Jean Henri Fabre, an entomologist who wrote early in this century, piqued the interest of young Larry G. Mason (page 34). Now, after twenty years of studying the bugs, their predatory behavior still lures him to explore goldenrod fields each summer. Although Mason has done fieldwork throughout New York and New England, most of his work on ambush bugs is done very near the State University of New York at Albany, where he has been a professor of biology for the last twenty-one years. There are no books that give much attention to ambush bugs, Mason says, but readers with an interest and a nearby field of Queen Anne’s lace or goldenrod, should have no trouble finding the bugs and their victims. Handle them gently, Mason warns. If provoked, they bite.
By the time he was sixteen, Haraldur Sigurdsson (page 44) knew he wanted to be a volcanologist. He grew up in Iceland, a volcanic island, and that, he says, "had everything to do with the decision." Sigurdsson, who earned a doctorate in geology from the University of Durham in England in 1970, has been a resident of the United States since 1974. Now a professor of oceanography in the graduate school of the University of Rhode Island, he spends a lot of time on fieldwork, making expeditions to Mexico, Italy, Iceland, West Africa, and the West Indies to study volcanoes. He also goes on oceanographic cruises to study the geochemistry of volcanic rocks from mid-oceanic ridges and submarine volcanoes. Sigurdsson has written about his findings several times for Natural History, most recently as coauthor of "To El Chichón and Back" in the July 1985 issue. He also wrote "In the Volcano," March 1982, about camping on the floor of his favorite volcano, Soufrière on Saint Vincent Island in the Caribbean. "Living inside the crater," he said, "was like being inside a giant gun barrel." To learn more about volcanoes in general, these books would be useful: Volcanoes, by Robert Deckler and Barbara Deckler (New York: W.H. Freeman and Co., 1981); and Volcanic Activity and Humn Ecology, edited by Payson D. Sheets and Donald K. Grayson (New York: Academic Press, 1979).
Hiroyoshi Higuchi (page 40), a biologist at the University of Tokyo for the past ten years, first learned of the sophisticated fishing techniques of Japanese green-backed herons in 1983 from a friend and fellow bird photographer, Teruo Sakanashi. In the summer of 1984, Higuchi accompanied Sakanashi, a native of Kumamoto, to that city's Suizenji Park to document the herons' bait-fishing behavior. A graduate of the University of Tokyo, Higuchi wrote his dissertation on the ecology and behavior of varied tits. As a visiting scientist at the University of Michigan at Ann Arbor this year and next, Higuchi wants to travel as much as possible to study American birds. He has found that the green-backed herons of south Florida, also bait fishers, make use of far fewer bait options than their Japanese counterparts. Two pertinent books recommended by Higuchi are Benjamin B. Beck's Animal Tool Behavior: The Use and Manufacture of Tools by Animals (New York: Garland, 1980) and Donald R. Griffin's Animal Thinking (Cambridge: Harvard University Press, 1984). Sakanashi, who took two of the heron photos in this issue, died suddenly last fall, at the age of thirty-nine.

The Robert D. Lawton Distinguished Professor in the Department of Biological Science at Florida State University in Tallahassee, Daniel S. Simberloff (page 50) spends much of his research time studying evolutionary ecology and biogeography, the branch of biology that deals with the geographical distribution of plants and animals. A large part of his research takes him out of the laboratory and into the field. Simberloff, who earned his doctorate in biology from Harvard University, is a dedicated conservationist. In a previous article for Natural History ("Big Advantages of Small Refuges," April 1982) he wrote on how to stem or at least slow down the annual global extinction rate of animals and plants. Readers who want to satisfy their curiosity about jackalopes might canvass postcard racks in stores west of the Mississippi and perhaps start their own collections.

Using a 300-mm lens, Stephen Leatherwood (page 76) photographed this month's "Natural Moment" from a bluff overlooking the San Nicolas Island beach, some fifty yards from the frolicking sea lions. He has spent the last twenty years observing, writing about, and photographing marine mammal behavior. A senior staff biologist at Hubbs Marine Research Center at Sea World in San Diego, his work in marine animal conservation has also taken him to Sri Lanka, where he is associate director of the Center for Research on Indian Ocean Marine Mammals. There he worked on the problems faced by developing nations whose traditional fisheries go against the conservation policies of developed nations. Leatherwood is coauthor, with Randy Reeves, of the Sierra Club Handbook of Whales and Dolphins and is now at work, with Reeves and Brent Stewart, on the Sierra Club Handbook of Seals, Sirensians and Others. Other projects include a children's book and a book on bottlenose dolphins. His photos have appeared in his own books, in magazines, and on posters and calendars. He has two children and a cat named Wart.

A research entomologist with the USDA since 1974, Suzanne W.T. Batra (page 56), who earned her doctorate from the University of Kansas, has devoted her whole career to studying bees. She stresses that one need not go far to find good research subjects. Her article grew out of fieldwork done in her backyard, and while she interrupted her full-time, paid research for seven years to raise two children, she kept working by studying insects close by, including bees in a playground. Batra's next project is a study of Africanized honeybees. She recommends W. Wickler's Mimicry in Plants and Animals (New York: McGraw-Hill, 1968).
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Cover: A juvenile great gray owl stretches its wings. Photograph by Michael Quinton. Story on page 32.
Albrecht Dürer’s Angle

In “Petrus Camper’s Angle” (“This View of Life,” July 1987), Stephen Jay Gould discussed the impact of a facial measure—the angle between the horizontal and the forward slant of the face—used by Camper in a posthumous treatise. Camper stressed that artists must take this angle into account when depicting the different races. He also argued that this angle provided a quantitative measure of European ideas of human beauty.

Gould allowed Camper’s claim for originality, but more than 250 years earlier, the German artist Albrecht Dürer had illustrated and discussed an almost identical facial angle in his Four Books on Human Proportion (1528). Moreover, Dürer’s two renditions of blacks—the black Magus in the Adoration of 1504 and the silverpoint drawing of Katharina in 1521—reveal his longstanding awareness of racial differences in facial structure. The Four Books on Human Proportion was so widely read that it is difficult to imagine that Camper was unaware of its existence. Camper then must shoulder some of the blame for his posthumous reputation as “the grandfather of scientific racism.” If he had not so vehemently staked his claim of originality, we might now be considering Dürer as the unwitting great-grandfather of scientific racism.

STANLEY DAVID GEDZELMAN
City College of New York
New York, New York

A Matter of More Than Taste

In “Of Curds and Whey” (“A Matter of Taste,” July 1987), Raymond Sokolov explores the controversy over whether pasteurization of milk adversely affects the taste of cheese produced from it. Readers should be aware of the reasons cheese is pasteurized before they consider taking the “blind taste test” Sokolov suggests.

Milk can become contaminated with disease-causing organisms as it is forming within an animal’s mammary gland or during the milking process. Pasteurization is a process designed to destroy these organisms and thus prevent those who consume milk and milk products from becoming infected.

Tuberculosis was the disease that led to pasteurization ordinances. Tuberculous infection of the spinal column of children was acquired by drinking raw milk and was a frequent cause of “hunchbacks” in the nineteenth century. Brucellosis, known as undulant fever in humans, has frequently been associated with consumption of raw milk and soft cheeses made from raw milk. Although seldom fatal, the fever, weakness, and headaches it causes may recur for years despite treatment.

Dairy animals can readily be tested for brucellosis and TB, but other diseases are not easily detected, and raw milk and milk products may infect consumers with Salmonella, Campylobacter, and Q fever. An unusual 1985 outbreak of listeriosis was traced to improperly prepared Jalisco cheeses and cost many lives. The only safe cheeses are those made from pasteurized milk or aged at least ninety days. I hope this consideration will outweigh any real or imagined difference in taste.

ROBERT C. BRADY
Washington, Indiana

Field Guide Dissent

I am a beginning bird watcher and own copies of both A Field Guide to the Birds, by R. T. Peterson, and The Audubon Society Field Guide to North American Birds, and I am weary of reading (and hearing) the praise of the former and/or the derision of the latter (“Reviews,” May 1987).

These comments are always made by experienced “birders,” who in their time have become able to identify types of birds at a glance. I will readily agree that, for these people, Peterson’s guides are the best choice. However, I have yet to hear or read the same comments from beginners, such as myself, who don’t know a finch from a sparrow, people who truly appreciate the idea that with an Audubon guide one can look for a small, gray bird with a reddish spot on the back of its head. I have seldom been confused by an Audubon guide, while I find the use of Peterson’s hallowed volumes frustrating.

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Pelicans vs. Pesticides

In 1970, a single brown pelican came to nest on Anacapa Island, once the site of the largest brown pelican colony in California. Two years later, the use of DDT was banned: studies had shown that when pelicans ate fish contaminated with the pesticide, the shells of their eggs were so thin they were crushed during laying or incubation. Meanwhile, in the Mississippi River, the pesticide endrin was poisoning both brown pelicans and the fish on which they fed. Where 50,000 brown pelicans once nested, there were nearly none. In 1973, with only Florida birds secure (DDT was never a threat to pelicans there), the brown pelican was placed on the U.S. endangered species list. Recovery began almost immediately after the ban of DDT. In January 1982 we reported that levels of DDE, the toxic chemical residue of DDT, had already declined in the waters surrounding Anacapa Island (“A Brown Study of the Brown Pelican”). Stocked by breeding pairs from Florida, colonies of brown pelicans were reestablished in Louisiana. Texas populations, down to 35 birds in 1974, were on the increase.

A recent check shows that progress has continued. This year in Texas, 300 nesting pairs of pelicans raised 500 young to fledging. Five to six thousand birds now nest in Louisiana on islands south and southwest of New Orleans. And in 1985 on Anacapa and nearby Santa Barbara Island, 6,194 pairs of birds produced 7,928 young.

Despite these successful breedings, sanctuary biologist John Gustafson of the Endangered Species Program of California’s Department of Fish and Game says the birds should not yet be taken off the endangered species list. Human disturbance of brown pelican habitats remains an impediment to the birds’ full recovery. On Isla Coronado Norte, a Mexican island south of Anacapa, Mexican commercial fishermen disturb the brown pelicans by camping where the birds nest. This, says Gustafson, may be forcing birds to crowd onto other islands. In Texas, David Blankinship of the National Audubon Society said the brown pelicans of Corpus Christi Bay are often disturbed by boat and ship traffic. And there is always the threat of oil spills.

The lesson of the pelican’s recovery, says Gustafson, is that a species can recover when its habitat remains intact. Most of the species on the endangered list, he adds, are not so lucky.

Above and Beyond the Auroras

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up in the ionosphere, that layer of the earth's atmosphere that extends from 40 to as much as 400 miles above the planet's surface.

Auroras result from the interaction of huge amounts of energy from the solar wind and the earth's magnetic field. The solar wind is made up of streams of charged particles that flow outward from the sun at high speeds. When these particles slam into the earth's magnetic field at a speed of about 300 miles per second, they speed up even more. The earth's magnetic field funnels them into the atmosphere, which then glows. That glow is the aurora. The collision also distorts the magnetic field, shaping that part of it known as the magnetosphere into a cometlike cylinder that points away from the sun.

The October 1977 Natural History featured a detailed description of the chemistry of the auroras. At that time they had been extensively investigated from the ground and with instrumented balloons and rocket probes. But in August 1981, two NASA high-altitude satellites, Dynamics Explorer 1 and Dynamics Explorer 2, were launched into elliptical orbits around the earth. Dynamics Explorer 1, in an orbit of about 185 to 13,500 miles above the earth, was equipped with cameras to record continuous images of auroral activity. This enabled scientists for the first time to see the auroras simultaneously from above and from the ground. Dynamics Explorer 1 has already sent more than 500,000 images back to Earth and is still sending more.

Dynamics Explorer 2 in a somewhat more circular and lower orbit, from 185 to 680 miles, was not equipped with cameras but carried instruments designed to make fine measurements of the earth's magnetic field and the auroras. This satellite burned up on entering the earth's atmosphere in February 1983.

Among the things scientists learned from the two Dynamics Explorers was that fountains of ionized gases (charged gas molecules) flow upward from the earth into the magnetosphere in what scientists call polar winds. Researchers previously believed that the main source of ionized gases in the magnetosphere was the solar wind. Now they are trying to determine which contributes more to the magnetosphere, the solar or the polar wind? Dynamics Explorer 1 also showed that the area encircled by the auroras, known as the auroral oval, is bisected by an arc. The arc has been dubbed the theta because together the oval and the arc resemble the Greek letter of that name. The significance of the theta has yet to be determined.

Meantime, an instrumented Swedish satellite, the Viking, was launched in February 1986 to take photographs of the aurora borealis, the northern aurora, above the North Pole. And as part of the upcoming International Solar Terrestrial Program there are plans to launch more instrumented satellites in the 1990s for further study of the magnetosphere and the auroras. Questions scientists hope to answer are: What energizes the polar winds? What role do the auroras play in shaping the earth's weather? And what does the magnetosphere contribute to global weather patterns?

Louis Frank, the principal photographic investigator on Dynamics Explorer 1, says another question is, What pathway do the solar wind particles take after colliding with the earth's magnetic field and before creating the auroras?
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The Ginsberg Experiment

*Archeology can be bone-breaking work*

by Dennis Stanford

The fall of 1975 in northeastern Colorado was especially cold and stormy. Along with other archeologists from the Smithsonian Institution, I was laboring in farm country near Idalia, trying to complete the excavation of a bison killed 10,000 years ago by early hunters. On Halloween night, a telephone call came from Gary North, a heavy-equipment operator working in our vicinity, who told of finding countless mammoth bones while digging an irrigation pit. The brisk early morning found us at the Selby farm, not sure if we should regard this diversion as a trick or a treat. There were indeed mammoth bones aplenty, frozen solid into clay deposits beneath a soil layer we knew to be at least 12,000 years old. Conventional wisdom decreed the site was too old to contain any signs of human presence, but the impending construction work induced us to set aside the bison kill in an effort to salvage the mammoth remains.

North’s work was temporarily discontinued, and he took a similar contract on the Dutton farm, just a few miles to the south. Shortly after beginning this second job he stopped by the Selby farm to report that he had encountered more mammoth bones. A brief examination of the new finds indicated that once again the bones were too old to be considered related to human activity. Nevertheless, in an effort to collect some of the better fossil specimens, my crew spent a day following North’s massive Terra-Rex scraper, removing bones as they were revealed. An exceptionally fine mammoth jawbone was discovered. While excavating this specimen, we found a portion of a mammoth rib right next to it. It had been split lengthwise by several blows to its front edge and was beveled at one end to a highly polished point. We could not overlook the possibility that it might be a prehistoric tool.

Further investigation revealed that the stratigraphic horizon that contained the mammoth jaw and the rib lay beneath an archeological level containing Clovis artifacts, named for a site near Clovis, New Mexico, and thought by most scholars to have been made by the earliest people in North America. These big game hunters manufactured stone spear or dart points that were bifacial (shaped by flaking on...
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both faces) and had thinned, "fluted" bases, apparently for insertion into the split end of the shaft. Whereas Clovis sites have been radiocarbon dated to about 11,500 years ago, the rib and the animal remains we had found seemed to represent an earlier human presence. The implications were exhilarating!

That evening, as a High Plains norther blew about, we huddled around the heater in our camp, examining the rib. Rumors out of the Canadian Yukon suggested there had been pre-Clovis people who had relied primarily on bone tools (see William N. Irving's article "New Dates from Old Bones," February 1987). We knew, however, that most scholars were skeptical of the evidence. Thus began the odyssey of the mammoth rib. Carefully packed, it traveled with me to scientific meetings all that winter. A show-and-tell was in store for anyone willing to listen. Although many people questioned whether the rib really originated in a pre-Clovis layer as claimed, all who examined it agreed that it was a tool fashioned by a human being.

To make our case, we needed to find other early tools, preferably some made of stone. In subsequent excavations, mammoth and other animal bones were unearthed whose curving, "spiral" fractures indicated they had been broken shortly after death (drying changes the properties of bone so that it either crumbles or breaks into roughly rectangular fragments when struck). The mammoth leg bones had definite areas of impact, where hard objects had crashed down upon them with sufficient force to break the massive bone walls. Fragments of these leg bones resembled flint artifacts in the way they had been flaked. Bone flakes were polished as if they had been used. Yet after several field seasons, nothing beyond this possible bone evidence was discovered in the 17,000- to 12,000-year-old pre-Clovis level that established a human presence.

Apart from the absence of stone tools, three questions nagged us: Were Ice Age people capable of breaking and flaking the massive bones of mammoths? Would the resultant flakes have been useful as tools? Could natural phenomena have created similar or identical specimens? To assess human ability to alter mammoth bone, pieces equivalent to those we had discovered had to be replicated by hand. The usefulness of the freshly made tools needed to be tested. And possible natural explanations had to be examined in the field.

Enter Ginsberg, an African elephant resident in Boston's Franklin Park Zoo. One tragic afternoon in the winter of 1977-78, she died from a cerebral hemotoma, brought on by a broken leg. Her body was transported to the National Zoo's research station in Front Royal, Virginia, to serve as a substitute mammoth in experimental butchery and bone tool manufacture studies. Because of unusually frigid weather, her remains kept until a research team was assembled and a plan of action devised.

To make the most of this opportunity, experiments were designed to address questions we archeologists had about both Clovis artifacts and our possible pre-Clovis technology. The Clovis problems included testing the effectiveness of replicated Clovis points for penetrating the tough hide. We also wanted to try butchering the elephant using the same points, as well as with a larger type of Clovis artifact. On the pre-Clovis side of the ledger, we sought to break fresh leg bones and test the sharp edges of the resultant fragments as butchering tools. Some leg bones were to be flaked and the sharp flakes used as knives. We were also curious to see if bone projectile points would have sufficed to bring down a mammoth.

Both scholars who favored the idea that pre-Clovis hunters had manufactured and used bone tools and those who discounted our evidence were invited to disassemble the carcass. The more skeptical folks failed to show, but about ten people, including myself, Robson Bonnichsen, and
several other archeologists adept at flint
knapping worked diligently to carry out
each of the experiments. As we gathered,
a light snow dusted the elephant carcass,
helping us imagine we were Ice Age hunt-
ers. After five days of cold, strenuous
work, in which we bloodied our tools and
hands, we began to look the part.

Our mock hunting convinced us that
both bone and flint projectile points could
have caused mortal wounds in a mam-
moth, especially if propelled by hunters
equipped with spear throwers. Admit-
tedly, Ginsberg’s remains were semi-
- frozen and thus we did not re-create a
completely natural situation. In fact, for
us to have learned the depth of wounds
with certainty, only an experiment on a
living beast would have sufficed, for skin
and flesh immediately change tension and
resiliency after death. But we concluded
that spears with long, slender bone points
or even wooden tips would have made
lethal weapons.

Microscopic examination of edge wear
on Clovis points had previously suggested
they sometimes doubled as butchery tools.
Our experiments demonstrated that a
Clovis point hafted to a spear’s detachable
foreshaft makes an excellent knife. The
foreshaft serves as a handle and the edges
are extremely durable.

We also tested some large, bifacially
flaked ovoid artifacts made of various
cherts, replicas patterned after finds from
a Clovis cache in Montana known as the
Anzick site. These bifaces, which are
about eight inches long and two inches
thick, were generally regarded as
“blanks” for manufacturing the charac-
teristic points, which are two to four
inches long and much thinner. Scholars
reasoned that the blanks were made at or
near the chert quarries, the makers remov-
ing most of the superfluous weight so that
a larger quantity of useful raw material
might be transported long distances, to
be completed into finished tools when
needed.

When our experimental bifaces were
hafted to handles, however, we found that
they were excellent butchery tools in
themselves, better in fact than the Clovis
points. Their long, sinuous edges cut more
rapidly and with comparatively little ef-
fort. The edges were remarkably durable
and required little maintenance. Usually
the butcher wore out before the tool; often
all that was required to revitalize an edge
was a change of personnel.

Epoxy casts were made of these bifaces
before and after they were resharpened
so that the edge wear and attrition could be
tracked. We also photographed them un-
der a ballistics microscope. These records,
coupled with recordings made by com-
puter plotters wired to the tools during
use, have provided controlled data for
wear-pattern studies.

The only complete examples of the
larger bifaces are from Anzick and from a
site in Idaho. Both collections are caches
consisting of numerous bifaces, Clovis
points, and other artifacts. A few incom-
plete examples have been found at other
Clovis sites. Why are these tools so rare if
they function so well? Probably because
they were used as cutting tools and as raw
material stock until they became small
and thin enough to be converted into pro-
jectile points. Thin flakes were removed
when needed for making other tools, such
as scrapers and gravers. Once the remain-
der was fluted and rehafted, its usefulness
continued in a dual capacity as both pro-
jectile point and knife. This economy and
versatility were especially important to
hunters who traveled on foot, carrying
their tool kits with them.

During testing of the Clovis artifact

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replicas, one of Ginsberg’s leg bones was finally exposed. The periosteum, a membrane tissue, was scraped off so the leg would break more easily, but the bone remained attached to the carcass. As we watched with anticipation, Robson Bonnichsen lifted a twenty-one-pound stone high overhead and threw it down onto the leg. The tough bone did not break. Bonnichsen tried again and again, and at last, on the fifth blow, the bone broke into three pieces. As our cheers echoed down the Shenandoah Valley, we quickly examined the spiral fractures and the impact depression: they were identical to those present on the Dutton and Selby specimens.

A sharp bone fragment was used to chip out the inner tissue from the leg bone. This tissue resembles a honeycomb and contains highly nutritious marrow. When it is heated, it yields large amounts of butter fat. Present-day elephant hunters in Africa extract elephant bone marrow in a similar way, but with metal tools. The bone we used as a tool developed a highly worn and polished point, similar to the pointed rib from the Dutton site.

The next stage of the experiment required flaking the bone to produce sharp knives. First a piece of bone was shaped, as a flint knapper would a stone core, so that it had a flat striking platform on top. Then the bone was struck on this platform with an elk antler baton to remove long thin flakes from the side of the core. The flakes came off easily and in shapes that resembled flint flakes. Occasionally the blow was not forceful enough, and the resultant flake broke off, leaving a step on the core. Subsequent flakes could not be driven beyond that step; the same problem arises with stone work. Thus, the bone core had to be “cleared” by taking off an extra large flake that removed the step fracture. Then, once again, useful bone flakes could be produced.

The bone flakes were extremely sharp and with some effort functioned very well as cutting tools. Their edges didn’t last as long as those of stone tools, however, and they could only be resharpened by grinding. Grinding is a time-consuming process, so anyone using such a tool would presumably manufacture another instead.

Why, if bone tools were less efficient than stone tools, would prehistoric people have manufactured them? There are several possible reasons. Early immigrants to the New World would not have been familiar with suitable flint sources, thus they would have placed a premium on materials in hand. Bone may also have been a standby during winter, when stone sources were covered with snow and frozen in the ground. More important, a bone tool is more durable when twisting or prying tasks are to be performed. Stone tools break immediately when subjected to these stresses. Eskimos know this and have a flexible tool kit containing both bone and stone knives. I suspect that if pre-Clovis peoples were present in the New World, they made use of both raw materials.

The Ginsberg experiment demonstrated that humans could have killed and butchered a mammoth largely without the aid of stone tools, and that they could have controlled the flaking of mammoth bone as a raw material. But were the prehistoric bone “artifacts” from Dutton and Selby actually produced by human beings? To address this question, Gary Haynes, in Zimbabwe’s Hwange National Park, investigated how carnivores and scavengers altered elephant bones and how bones in various states of preservation were affected by animal trampling and other natural events. (An article by Gary Haynes, “Where Elephants Die,” appeared in the June 1987 issue of Natural History.) Haynes’s work has demonstrated that much of the evidence formerly considered a sign of human handiwork is mimicked by a variety of natural causes. Spiral fractures, for example, may result from gnawing or trampling.

Haynes has similarly studied the condition and distribution of recently deposited mammal bones in undisturbed wilderness areas of northern North America. In addition to the effects on bones of hunting and feeding by timber wolves and brown bears and of trampling and wallowing by moose and bison, he has considered the effects of turbulent streams, soil pressure, and freezing and thawing. As a result of his work we can no longer assume that apparent impact scars, flaking, localized abrasion and polishing, or unequal dispersal of skeletal parts is a result of human activity. But to date, Haynes has not reported finding any examples of bone cores. So far, therefore, the bone cores we have found continue to confirm human workmanship.

The distribution of the bones at the Selby and Dutton sites is similar to what we expect would accumulate around water holes, where animals might be killed by carnivores or die from other natural causes. In addition to mammoth bones, we have found the remains of horses, bison, camels, sloths, peccaries, and some smaller mammals. Some of the animals were apparently devoured by four-legged carnivores, but some may have been killed or scavenged by humans, and perhaps the remains of these meals were cleaned up by other scavengers. When the damage produced by natural events is superimposed on bone butchered and discarded by people, sorting out the causes and sequences of bone modification is difficult, perhaps impossible.

Bone flaking seems to have been a technological tradition in the Old World since early Stone Age times, and flaked mammoth bones are found at most of the major Clovis sites. The absence of stone tools, however, continues to cloud the interpretation of the Dutton and Selby sites. Today, we are not certain that even our original mammoth rib was used by a prehistoric hunter. In the process of being enlightened, we have become more cautious; but the odyssey will continue.

Using a baton of elk antler (at top), a participant in the Ginsberg experiment flakes elephant bone.
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When I was researching my field guide to the national forests, a resident of Arizona encouraged me to inspect Sycamore Canyon, a small-scale Grand Canyon about twenty miles southwest of Flagstaff. The route on my first approach soon narrowed to a one-lane gravel road, passing scenic White Horse Lake and meandering across the top of the Colorado Plateau through ponderosa pine forest. It ended at Sycamore Point, an overlook perched on the Mogollon Rim, the southern edge of the plateau. Three thousand four hundred feet below, Sycamore Creek shimmered at the bottom of its canyon like a silver thread.

Sycamore Canyon is a designated wilderness area in parts of the Coconino, Kaibab, and Prescott national forests. Its 55,937 acres lack roads, so the only way to get a first-hand look at the canyon is by trail. There are six entrances along the eastern and southern boundaries of the wilderness. I entered at Packard Place, the southernmost point, near where Sycamore Creek joins the Verde River.

The trail, which parallels Sycamore Creek for much of its way, is dwarfed by the colorful rock walls that tower above. In places, all seven of the canyon’s major geological formations are visible. Lowest, and hence oldest, is a thick layer of gray limestone deposited by a sea that covered the area some 400 million years ago. Occasional pinkish beds of rounded grains of quartz are intermixed in this gray rock.

Following withdrawal of the sea more than 300 million years ago, the brilliant red sandy shales and sandstone of the Supai formation were formed, in some places nearly one thousand feet thick. This red rock is a prominent feature of Oak Creek Canyon, a few miles to the east, described in “This Land,” January 1985. Then, in succession, thick layers of buff-colored Coconino sandstone, white Toroweap sandstone, gray Kaibab limestone, and red Moenkopi sandstone were deposited on the Supai. Later, gravels washed down from the higher Bradshaw Mountains to the south and covered much of the Moenkopi sandstone.

Finally, 60 million years ago, volcanic eruptions followed by major uplifting of
Sycamore Canyon Wilderness

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the area triggered abrupt changes. Lava flowed from the volcanoes and formed a hard cap of dark basalt over the region, while faulting drastically altered the configuration of the Colorado Plateau. During the Pleistocene, which began 1.8 million years ago, Sycamore Creek and its tributaries began the relentless cutting action that exposed all these formations.

Sycamore Canyon is host to a variety of vegetation communities. There is a difference between the west side, where conditions are cooler and more moist, and the east side, which receives the direct rays of the afternoon sun. High on the west side are forests of white fir, Douglas fir, and ponderosa pine. On the east side of the canyon, nearly pure stands of ponderosa pine dominate north- and west-facing slopes, while a shrubby community known as chaparral appears on the southern slopes. Deer, elk, black bear, mountain

lion, and wild turkey frequent all these forested slopes.

Along Sycamore Creek, where water is more plentiful, a forest of deciduous hardwood trees has developed. The type and density of the woody plants vary with the width of the canyon. Arizona ash, often growing in dense stands, dominates the narrowest parts of the canyon. Beneath the ash, next to the creek, are hundreds of plants of Arizona alder. Other trees include hackberry, box elder, Arizona walnut, and Arizona sycamore, from which the canyon takes its name. Cottonwoods and willows, common species along river banks, are rare because the narrow parts of the canyon receive less sunlight and are subjected to cold air that accumulates in the canyon bottom.

In areas along Sycamore Creek where the canyon broadens, increased sunlight permits the vigorous growth of mesquite, catclaw acacia, and shrub live oak; and cottonwoods and willows turn up with a little more regularity. Finally, in the broadest sections, which provide good growing conditions for a wide diversity of species, Goode's willow and Fremont's cottonwood dominate, the latter sometimes growing nearly 100 feet tall. Red bats and pipistrelles use both trees for their summer roosting sites, and summer tanagers and zone-tailed hawks nest among the upper branches. This habitat is also home to Arizona gray squirrels and small, long-tailed, raccoonlike animals called ring-tailed cats.

Although only twenty-one miles long and seven miles across at its widest point, Sycamore Canyon does resemble the mighty Grand Canyon, nearly seventy-five miles to the north. The vegetation may be denser, but the rocks are just as colorful and represent a very similar geological history, with the same sequence of formation. One thing Sycamore Canyon does lack are the crowds that descend on the Grand Canyon. Fewer than a thousand people enter the wilderness during the entire year.

"This Land" highlights the biological phenomena of the 154 U.S. national forests. Robert H. Mohlenbrock is Distinguished Professor of Botany at Southern Illinois University at Carbondale.
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The Godfather of Disaster

*Scientific gadflies lurk in the dusty pages of history, waiting to bite away at our biases*

by Stephen Jay Gould

Lemuel Gulliver, marooned by pirates on a small Pacific island, lamented his apparently inevitable fate: "I considered how impossible it was to preserve my life, in so desolate a place; and how miserable my end must be." But then the floating island of Laputa appeared and he rode up on a chain to safety.

The Laputans, Gulliver soon discovered, were an odd lot, with an ethereal turn of mind well suited to their abode. Their thoughts, he noted, "are so taken up with intense speculation" that they can neither speak nor hear the words of others unless explicitly roused. Thus, each Laputan of status employs a "flapper" who gently strikes the ear or mouth of his master with an inflated bladder full of small pebbles whenever his lordship must either attend or answer.

The Laputans are not catholic in their distractions; only music and mathematics incite their unworlly concentration. Gulliver finds that their mathematical obsession extends to all spheres of life; he obtains for his first meal "a shoulder of mutton, cut into an equilateral triangle; a piece of beef into rhomboïdes; and a pudding into a cycloid."

But mathematics has its negative side, at least psychologically. The Laputans are not lost in a blissful reverie about the perfection of circles or the infinitude of pi; they are scared. Their calculations have taught them that the "earth very narrowly escaped a brush from the tail of the last comet... and that the next, which they have calculated for one and thirty years hence, will probably destroy them." The Laputans live in fear: "When they meet an acquaintance in the morning, the first question is about the sun's health; how he looked at his setting and rising, and what hopes they have to avoid the stroke of the approaching comet."

Jonathan Swift, as usual, was not writing abstract humor in reciting the Laputans' fear of comets. He was satirizing the influential theory of a political and religious enemy, William Whiston, hand-picked successor to Isaac Newton as Lucasian Professor of Mathematics at Cambridge. In 1696, Whiston had published the first edition of a work destined for scientific immortality of the worst sort—as a primer of how not to proceed. Whiston called his treatise *A New Theory of the Earth from its Original to the Consummation of all Things, Wherein the Creation of the World in Six Days, the Universal Deluge, and the General Confagration, as laid down in the Holy Scriptures, are shewn to be perfectly agreeable to Reason and Philosophy.*

Whiston has descended through history as the worst example of religious superstition viewed as an impediment to science. Whiston, we are told, was so wed to the few thousand years of Moses' chronology that he had to postulate absurd catastrophes via cometary collisions in order to encompass the earth's history in so short a time. This dismissal is no modern gloss but an old tradition in scientific argument. Charles Lyell, conventional father of modernity in geological thought, poured contempt upon Whiston's extraterrestrial and catastrophic theories because they foreclosed proper attention to gradual, earth-based causes. Lyell wrote in 1830:

[Whiston] retarded the progress of truth, diverting men from the investigation of the laws of sublunary nature, and inducing them to waste time in speculations on the power of comets to drag the waters of the ocean over the land—on the condensation of the vapors of their tails into water, and other matters equally edifying.

But Whiston did not only suffer the abuse of posthumous reputation; he became an object of ridicule in his own time as well (as Swift's satire indicates). His contemporary troubles did not stem from his cometary theory (which resembled several others of his day and did not strike his fellow intellectuals as outré) but from his religious heterodoxies. Whiston's public support of the Arian heresy (a denial of the Trinity, and the consubstantiality of Christ with God the Father) led to dismissal from his Cambridge professorship (as Newton, his erstwhile champion, and a quieter, more measured exponent of the same heresy, remained conspicuously silent). Resettled in London, Whiston was tried twice for heresy and, though not formally convicted, lost most of his previous prestige and lived the rest of his long life (he died in 1752 at the age of eighty-four) as an independent intellectual, viewed as a prophet by some and as a crank by most. In the eighth plate of Hogarth's *The Rake's Progress,* set in the mental hospital of Bedlam, an inmate fills the wall with a sketch of Whiston's scheme for measuring longitude.

Despite continual rejection of Whiston, from his own time to ours, we must still grant him a major role in the history of science. The French historian Jacques Roger ended his article on Whiston (in the *Dictionary of Scientific Biography*) with these words:

His writings were much disputed but also widely read throughout the eighteenth century, and not just in England. For example, Buffon, who summarized Whiston's theory in order to ridicule it, borrowed more from him than he was willing to admit.... It
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The well known British naturalist David Attenborough wrote: “These new impressions of the 150-year-old plates could well be judged to be a finer representation of Audubon’s intentions than any produced during the artist’s lifetime.”

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may be said that all the cosmogonies based on the impact of celestial bodies, including that of Jeans, owed something, directly or indirectly, to Whiston inventions.

Moreover, we must not forget the early acclaim of his contemporaries. Whiston was, after all, the man chosen as his successor by the greatest name in all the history of science: Isaac Newton. In my copy of Whiston’s *New Theory* (the second edition of 1708), a Mr. Nathaniel Hancock who bought the book in 1723, has inscribed on its title page, in a beautiful, flowing hand, the following judgment of Whiston by John Locke:

I have not heard any one of my acquaintance speak of it, but with great commendations (as I think it deserves) . . . He is one of those sort of writers that I always fancy should be most encouraged; I am always for the builders.

Comets were in the air in late-seventeenth-century Britain. In 1680, a great comet had lit the skies of Europe, followed two years later by a smaller object that sent Edmond Halley to the drawing boards of history and mathematics. He concluded that it would return in seventy-six years, and his contemporaries were passing through the early countdown when Whiston wrote his book. Moreover, the seventeenth century had been a time of extraordinary change and tension in Britain—the execution of Charles I, Cromwell’s Protectorate, the Restoration, and the Glorious Revolution to mention just a few of the tumultuous events of Whiston’s age. These happenings fostered a revival of millennial thought—a scrutiny of the prophecies in Daniel and the Revelation, leading to a conclusion that the end of this world lay in sight, and that the blessed millennium, or thousand-year reign of Christ, would soon begin. Since comets had long been viewed as harbingers or signals of great transitions and disasters (literally, “evil stars”), Whiston chose a propitious time to implicate comets as the prime movers of our planet’s history.

Whiston’s *New Theory* tried, above all, to establish a consistency between the two great sources of truth, as defined by his countrymen: the infallibility of Scripture and the mathematical beauty of the cosmos, so recently revealed by Newton. Whiston began his account of our planet’s history by summarizing his method of inquiry in a single page, entitled *Postulata*. The first two statements illustrate his attempt to join Moses with Newton:

1. The obvious or literal sense of scripture is the true and real one, where no evident reason can be given to the contrary.
2. That which is clearly accountable in a natural way, is not, without reason, to be ascribed to a Miraculous Power.

Comets became Whiston’s *deus ex machina* for rendering the cataclysmic events of Genesis with the forces of Newton’s universe.

Consider Whiston’s descriptions of the earth, from cradle to grave, with each of its five principal events tied to cometary causes:

1. The Hexameron, or Moses’ six days of creation. Whiston prefaced the body of his work with a ninety-four-page “Discourse Concerning the Nature, Stile, and Extent of the Mosaic History of the Creation.” Here, he attempts to preserve the literal sense of Scripture (first postulate above) in the light of Newton’s nearly infinite universe. How could all this vastness be made in six days, and how could our earth, one tiny speck in one corner of infinitude, be the focus of everything? Whiston devotes his preface to a single argument: Moses is describing the origin of the earth alone, not the entire universe; moreover, he has tailored his words to describe not the abstract properties of nature’s laws, but the visual appearance of phenomena as an untutored observer might have witnessed them on the concealin" surface of our planet. With these provisos, it all happened exactly as Genesis proclaims.

The earth began as a comet, and the chaos described in Genesis 1 (“and the earth was without form and void”) represents its swirling atmosphere. Whiston’s contemporaries did not know the true size of comets, and many assumed, as he did, that comets might be of planetary dimensions, and therefore suitable for transc...
formation into a planet. Whiston wrote:

Tis very reasonable to believe, that a planet is a comet formed into a regular and lasting constitution, and placed at a proper distance from the sun... and a comet is a chaos, i.e., a planet unformed or in its primeval state, placed in a very eccentric (orbit).

To transform this comet, with its highly elliptical pathway, into a planet, God needs to render its orbit more nearly circular. The chaotic atmosphere will then clear and precipitate to form the solid surface of a planet. Whiston's attitude toward miracles (temporary suspension by God of his own natural laws) remained ambiguous. His second postulate stated a preference for natural explanations, but only when possible. He never did resolve whether the change in orbit that converted our cometary ancestor into our present earth had been a true miracle (accomplished by the immediate agency of God's own hand) or a natural event (the result of gravitational influences exerted by another body moving through the heavens according to Newton's laws). But since Newton's laws are God's laws, Whiston remained unconvinced that it made a difference either way—the transition from comet to planet occurred either by God's direct action or by laws that God had established in full knowledge of the later, desired result.

In any case, once the comet's orbit had been adjusted to its planetary pathway, the events of Genesis 1 would proceed naturally, as viewed by an observer on earth. The creation of light on the first day represents an initial clarification of a formerly opaque atmosphere (so that a brightness always present could finally be perceived). Similarly, the "creation" of the sun and moon records a further lightening of atmosphere.

This fourth day is therefore the very time when... these heavenly bodies, which were in being before, but so as to be wholly strangers to a spectator on earth, were rendered visible.

Meanwhile, the products of this former atmosphere settled out by order of density into a series of concentric layers—solid at the center, water above, and a solid froth on top—to form the earth.

If all this activity still seems a bit much to compress into a mere six days, Whiston added an argument to increase our confidence. The original earth underwent no diurnal rotation on its axis but maintained a constant position as it revolved around the sun. The nearly equatorial Eden therefore experienced a year divided into halves: one of day; the second of night. Since we define a "day" as a single alternation of light and darkness, the days of Genesis 1 were all a year long—not a vast span for the work accomplished, but a giant step in the right direction.

2. The Fall, and expulsion of Adam and Eve from Eden. The pristine earth stood bolt upright with no seasons, tides, or winds to disturb its primeval bliss. But "as soon as Man had sinned... and as God Almighty had pronounced a curse on the ground, and its production, presently the earth began a new and strange motion, and revolved from west to east on its own axis." This axis tilted to its present inclination of some 21 degrees, and the earth began its diurnal rotation, with days, nights, winds, and seasons. Whiston ascribed this change to a cometary collision:

Now the only assignable cause is that of the impulse of a comet with little or no atmosphere, or of a central solid hitting obliquely upon the earth along some parts of its present equator.

3. Noah's flood. All the great works in this late-seventeenth-century vogue for...
We shall easily see that a deluge of waters is by no means an impossible thing; and in particular that such an individual deluge . . . which Moses describes, is no more so, but fully accountable that it might be, nay almost demonstrable that it really was.

4. The coming conflagration. The prophetic books of Daniel and Revelation speak of a worldwide fire that will destroy the current earth, but in a purifying way that will usher in the millennium. Whiston proposed (as the Lapatans feared) that a comet would instigate this conflagration for a set of coordinated reasons. This comet would strip off the earth’s cooling atmosphere, raise the molten material at the earth’s core, and contribute its own fiery heat. Moreover, the passage of this comet would slow the earth’s rotation, thus initiating an orbit so elliptical that the point of closest approach to the sun would be sufficient to ignite our planet’s surface. Thus, Whiston writes, “the theory of comets” can provide “almost as commensurate and complete an account of the future burning, as it already has done of the ancient drowning of the earth.”

5. The consumption. As prophecy relates, the thousand-year reign of Christ will terminate with a final battle between the just and the forces of evil led by the giants Gog and Magog. Thereafter, the bodies of the just shall ascend to heaven, those of the damned shall sink in the other

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direction—and the earth's appointed role shall be over. This time a comet shall make a direct hit—no more glancing blows for diurnal rotation or near misses for floods—and knock the earth either clear out of the solar system or into an orbit so elliptical that it will become, as in the beginning, a comet.

Our conventional, modern reading of Whiston as an impediment to true science arises not only from the fatuous character of this particular reconstruction but also, and primarily, from the recognition that Whiston invoked the laws of nature only to foster a predetermined goal—the rendering of biblical history—and not, as modern ideals proclaim, to chart with objectivity, and without preconception, the workings of the universe. Consider, for example, Whiston's reverie on how God established the laws of nature so that a comet would instigate a flood just when human wickedness deserved such a calamity.

That Omniscient Being, who foresaw when the degeneracy of human nature would be arrived at an unsufferable degree of wickedness... and when consequently his vengeance ought to fall upon them; predisposed and preadapted the orbs and motions of both the comet and the earth, so that at the very time, and only at that time, the former should pass close by the latter and bring that dreadful punishment upon them.

Yet such a judgment (of Whiston by us, not of the earth by God) seems singularly unfair and anachronistic. The problem, as so often in intellectual history, is one of changing taxonomies. We dismiss Whiston because he violated ideals of science as we now define the term. But, in Whiston's time, science did not exist as a separate domain of inquiry; the word itself had not been coined. No matter how we may judge such an enterprise today, Whiston's mixture of natural events and scriptural traditions defined a primary domain at the forefront of scholarship in his time. We have since defined Whiston's New Theory as a treatise in the history of science because we remain intrigued with his use of astronomical arguments but have largely lost both context for and interest in his exegesis of millenarian prophecy. But Whiston would not have accepted such a categorization; he would not even have recognized our concerns and divisions. He did not view his effort as a work of science, but as a treatise in an important contemporary tradition for using all domains of knowledge—revelations of Scripture, history of ancient chronicles, and knowledge of nature's laws—to reconstruct the story of human life on our planet. The New Theory contains—and by Whiston's explicit design—far more material on theological principles and biblical exegesis than on anything that would now pass muster as science.

Moreover, although Whiston later achieved a reputation as a crank in his own time, he wrote the New Theory at the height of his conventional acceptability. He showed the manuscript to Christopher Wren and won the hearty approval of that greatest among human architects. He then gave (and eventually dedicated) the work to Newton himself, and so impressed Mr. Numero Uno in our current Pantheon of scientific heroes that he ended up as Newton's handpicked successor at Cambridge.

In fact, Whiston's arguments in the New Theory are neither marginal nor oracular, but preeminently Newtonian in both spirit and substance. In reading the New Theory, I was particularly struck by a feature of organization, a conceit really, that most commentators pass over. Whiston ordered his book in a manner that strikes us as peculiar (and ultimately quite repetitious). He presents the entire argument as though it could be laid out in a mathematical and logical framework, combining sure knowledge of nature's laws with clear strictures of a known history in order to deduce the necessity of cometary action as a primary cause.

Whiston begins with the page of Postulata, or general principles of explanation cited previously. He then lists eighty-five "lemmata," or secondary postulates derived directly from laws of nature. The third section discusses eleven "hypotheses"—not "tentative explanations" in the usual, modern sense of the word, but known facts of history assumed beforehand and used as terms in later deductions. Whiston then pretends that he can combine these lemmas and facts to deduce the proper explanation of our planet's history. The next section lists 101 "phænomena," or particular facts that require explanation. The final chapter on "solutions" runs through these facts again to supply cometary (and other) explanations based on the lemmas and hypotheses. (Whiston then ends the book with four pages of "corollaries" extending God's power and scriptural authority.)

I call this organization a conceit because it has the form, but not the substance, of deductive necessity. The lemmas are not an impartial account of consequences from Newton's laws but a tailored list designed beforehand to yield the desired results. The hypotheses are not historical facts in the usual sense of verified, direct observations but inferences
based on a style of biblical exegesis not universally followed even in Whiston's time. The solutions are not deductive necessities but possible readings that do not include other alternatives (even if one accepts the lemmas and hypotheses).

Still, we must not view Whiston's New Theory as a caricature of Newtonian methodology (if only from the direct evidence that Newton himself greatly admired the book). The Newton of our Pantheon is a sanitized and modernized version of the man himself, as abstracted from his own time for the sake of glory, as Whiston has been for the sake of infamy. Newton's thinking combined the same interests in physics and prophecy, although an almost conspiratorial silence among scholars has, until recently, foreclosed discussion of Newton's voluminous religious writings, most of which remain unpublished. (James Force's excellent study, William Whiston, Honest Newtonian, Cambridge University Press, 1985, should be consulted on this issue.) Newton and Whiston were soul mates, not master and jester. Whiston's perceived oddities arose directly from his Newtonian convictions, and his attempt to use Newtonian methods (in both scientific and religious argument) to resolve the earth's history.

I have, over the years, written many essays to defend maligned figures in the traditional history of science. I usually proceed, as I have so far with Whiston, by trying to place an unfairly denigrated man into his own time and to analyze the power and interest of his arguments in their own terms. I have usually held that judgment by modern standards is the pitfall that led to our previous, arrogant dismissal—and that we should suppress our tendency to justify modern interest by current relevance.

Yet there is a valid sense in which old arguments can have a special meaning and importance for modern scientific debates. Some issues are so broad and general that they transcend all social contexts to emerge as guiding themes in scientific arguments across the centuries (see my latest book, Time's Arrow, Time's Cycle, for such a discussion about metaphors of linear and cyclical time in geology). In these cases, old versions can clarify and instruct our current research because they allow us to tease out the generality from its overlay of modern prejudices and to grasp the guiding power of such a primary theme through its application to a world that we can treat more abstractly, and without personal stake.

Whiston's basic argument about comets has this character of instructive generality. We must acknowledge, first of all,
the overt and immediate fact that one of the most exciting items in contemporary science—the theory of mass extinction by extraterrestrial impact—calls upon the same agency (some versions even cite comets as the impacting bodies). I am most gratified that, as I write this essay (June 1987), the last major piece may be falling into place to validate the Alvarez theory that a large extraterrestrial object struck the earth some sixty-five million years ago and triggered, or at least greatly promoted, the late Cretaceous mass extinction (the sinea qua non of our own existence, since the death of dinosaurs cleared ecological space for the evolution of large mammals).

The Alvarez theory has had an interesting history in less than a decade since its initial proposal. Luis and Walter Alvarez made a gutsy prediction in their original article: extrapolating from just three sites, they argued that a layer of enriched iridium (an element rare on the earth’s surface but more common in extraterrestrial bodies) would be found worldwide and synchronous with the time of extinction. Seven years later, the worldwide iridium layer is an established fact (affirmed in nearly 100 localities from rocks in all environments). Alvarez’s detractors no longer argue that nothing catastrophic happened at the end of the Cretaceous; they claim instead that the iridium represents a rapid epoch of intense volcanism (some magmas of the earth’s interior do contain sufficient iridium). The search then turned to other criteria for determining whether an iridium layer is extraterrestrial or volcanic in origin.

This argument has been going back and forth for a year or two, but just last month, Bruce F. Bohor, Peter J. Modreski, and Eugene E. Foor announced (Science, May 8, p. 705) a powerful affirmation of the Alvarez interpretation. When subjected to enormous pressures, quartz alters its crystal structure. Grains of shocked quartz have long been used as criteria for impact (extraterrestrial objects or nuclear bombs); volcanoes, so far as we know, do not generate pressures this intense (claims for “shocked quartz” at volcanic sites involve far less change in crystal structure affecting far fewer grains). A few examples of shocked quartz had been reported from the iridium layer before, but Bohor and colleagues now report intensely shocked quartz grains as a general feature of this stratum (from a range of environments in five European sites, a deep-sea core in the North Pacific, and a locality in New Zealand). These data strongly favor the old Whistonian notion of extraterrestrial impact.

But the Alvarez theory is not the main reason why we should pay attention to Whiston today. After all, the similarities may be only superficial; Whiston made a conjecture to render millenarian prophecy; the Alvarezes discovered a surprising fact to explain an ancient extinction. Guessing right for the wrong reason does not merit scientific immortality. No, I commend Whiston to modern attention for a different and more general reason—because the form and structure of his general argument embodies a powerful abstraction that we need to grasp today in our search to understand the roles of stability, gradual change, and catastrophe in the sciences of history.

Whiston was led to comets for an interesting reason rooted in his Newtonian perspective, not capriciously as an easy way out for the salvation of Moses. Scientists who work with the data of history must, above all, develop general theories about how substantial change can occur in a universe governed by invariant natural ways. In Newton’s (and Whiston’s) world view, immutability and stability are the usual consequences of nature’s laws: the cosmos does not age or progress anywhere. Therefore, if substantial changes did occur, they must be rendered by rapid and unusual events that, from time to time, interrupt the ordinary stability of things. In other words, Whiston’s catastrophic theory of change arose primarily from his belief in the general stability of nature. Change must be an infrequent fracture or rupture. He wrote:

We know no other natural causes that can produce any great and general changes in our sublunary world, but such bodies as can approach to the earth, or, in other words, but comets.

A major intellectual movement began about a century after Whiston wrote and has persisted to become the dominant ideology of our day. Whiston’s notion of stability as the ordinary state of things yielded to the grand idea that change is intrinsic to the workings of nature. The poet Robert Burns wrote:

Look abroad through nature’s range
Nature’s mighty law is change.

This alternative idea of gradual and progressive change as inherent in nature’s ways marked a major reform in scientific thinking and led to such powerful theories as Lyellian geology and Darwinian evolution. But it also established an unfortunate dogma that fostered an amnesia about other legitimate styles of change and often still leads us to restrict our hypotheses to one favored style falsely viewed as pref-
erable (or even true) a priori. For example, the New York Times recently suggested that impact theories be disregarded on general principles:

Terrestrial events, like volcanic activity or change in climate or sea level, are the most immediate possible cause of mass extinctions. Astronomers should leave to astrologers the task of seeking the causes of earthly events in the stars [editorial, April 2, 1985].

Perhaps they will now grant this paleontologist equal power of judgment over their next price increase.

The world is too complex for subsumption under any general theory of change. Whiston's model of stability, punctuated now and then by changes of great magnitude that induce new steady states, did not possess the generality that he or Newton supposed. But neither does Lyellian gradualism explain the entire course of our planet's history (and Lyell will have to eat his words about Whiston, just as the Times must now feast on theirs about the Alvarezes). Whiston's general style of argument—change as an interruption of usual stability—is on the ascendency again as a worthy alternative to a way of thinking that has become too familiar, too automatic.

On the wall of Preservation Hall in New Orleans hangs a tattered and greasy sign, but the most incisive I have ever seen. It gives a price scale for requests by the audience to the aged men of the band who play jazz in the old style:

<table>
<thead>
<tr>
<th>Traditional Requests</th>
<th>$1</th>
</tr>
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<tbody>
<tr>
<td>Others</td>
<td>$2</td>
</tr>
<tr>
<td>The Saints</td>
<td>$5</td>
</tr>
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</table>

Preservation Hall guards against too frequent repetition of the most familiar with the usual currency of our culture—currency itself. Scholars must seek other, more active tactics. We must have gadflies—and historical figures may do posthumous service—to remind us constantly that our usual preferences, channels, and biases are not inevitable modes of thought. I nominate William Whiston to the first rank of reminders as godfather to punctual theories of change in geology.

Funny, isn't it? Whiston longed "to be in that number, when the Saints go marching in"; in fact, he wrote the New Theory largely to suggest that cometary impact would soon usher in this blessed millennium. Yet he is now a soul mate to those who wish to hear a different drummer.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.
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The Neighborly Great Gray Owl

Other large raptors are fiercely territorial. Why does this bird of prey share its hunting grounds and nest within hooting distance of its fellows?

by Evelyn L. Bull and Mark G. Henjum

As the last rays of sunlight edged up the hillside, we could see the dark form of a male great gray owl gliding into a stand of conifers. Instantly, the silent forest erupted with a chorus of high-pitched shrieks from five recently fledged owlets perched in the trees. Undaunted, the male flew to the nearest owlet, delivered a mountain vole, and left the trees as soundlessly as he had entered. His mate, stationed in a white fir a short way off, looked on, surveying her brood, ready to protect them from predators.

Not three hundred feet away and certainly within earshot, a second female occupied a Douglas fir. She had fledged three young from her nest and had already entrusted them to her mate for the remaining two or three months of their upbringing. Within one hundred feet of her, a solitary male, which had taken up residence in this stand of trees in early summer, perched in a leaning white fir. He was less than two miles from the nest where he had been born the previous year.

In our five years of studying great gray owls, we had observed such scenes before and felt they were remarkable. We knew that in other, similar species—great horned owls, barred owls, spotted owls—individuals and pairs do not go about their business in such comfortable proximity. Unlike great grays, other large owls advertise their ownership of hunting and nesting territories by calling loudly and by driving out intruders of their own species. And breeding pairs rarely raise young within a mile of one another. Intrigued by the seeming neighborliness of great grays, we decided to study just how social they were and to find out what advantages they might derive from being markedly less territorial than most other species.

Great grays are the largest owls in North America (twenty-two inches tall with five-foot wingspreads) and typically inhabit the forested northerly latitudes of our continent and Europe. The population we were studying lived in an area we called Spring Creek, a land of ponderosa pines, Douglas firs, larches, and grassland situated about fifteen miles west of La Grande, in northeastern Oregon. To get an objective picture of the territoriality of the
Great gray owls nest from twenty to sixty feet above the ground, usually in a snag or on a platform of sticks that has been built and abandoned by other raptors. Since great grays are not strongly territorial, two or more pairs may nest near one another if suitable, ready-made nesting sites are clustered. Pairs typically hatch one to four young; the brood pictured here is about three weeks old.
In a threatening posture, an adult, right, guards eggs that have been laid in a snag. Below: Males provide virtually all food consumed by their incubating mates and newly hatched young. The main prey items for the great gray owls of Spring Creek, Oregon, are mountain voles and pocket gophers.

owls in Spring Creek, we gauged distances between their nests, found out how often they reused nest sites, and used radio tags to follow their whereabouts and behavior. We kept records for five nesting seasons, March to July, from 1982 through 1986. During that time, at least eight pairs made sixteen nesting attempts in our twelve-square-mile study area.

Great grays don't begin nesting until they are two to four years old. In March, the breeding adults typically start calling within 400 to 500 feet of the tree that contains their nest. Calls—a series of low-pitched hoots—are probably a means of notifying others that a site is already occupied, and thus probably indicate some degree of territoriality. Fortunately for researchers, both male and female great gray owls respond to imitations of their calls, and this responsiveness provided us with a way of pinpointing their locations. Several times we found nests separated by less than 400 yards. This finding was espe-
cially interesting to us since investigators in Canada, Finland, and Sweden had noted eight cases of great gray pairs nesting within 100 yards of one another. This evidence led us to believe that defended territories are quite small, perhaps confined to the nest tree or to the immediately adjacent area.

We operated on that assumption until we encountered two females using the same nest. We knew that the one we had dubbed Ziggy was mated to Zoomy. She had taken over an old goshawk nest in a larch tree in 1983, when we radio-tagged her. In early March of 1984, we spotted Ziggy and a female without a radio, Phantom, both perched near the tree that contained Ziggy's 1983 nest. Phantom began to sit on the nest in mid-March, while Ziggy stayed close by. Two weeks later, Phantom left the nest, and we assumed her breeding attempt had failed. Within ten days, Ziggy was sitting on that same nest, and in time she successfully raised one young. It is unusual, but not unknown, for male owls to have more than one mate. Such polygynous behavior has been observed in northern saw-whet owls in Idaho, barn owls in Utah, and hawk owls in Norway. Jeff Marks, of the Snake River Birds of Prey Research Project, found three female saw-whets mated to the same male and nesting in the same territory. But we
never found out whether Ziggy and Phantom had the same or different mates. Being mated to the same male would help explain the proximity of the females, but if they had had different mates, sharing the same nest would indicate a complete absence of territoriality.

The next year Ziggy associated with the same male, but nested up the hill some 350 feet from the old site. Phantom was also in this vicinity, in consort with a male we had not previously encountered. On one occasion, we saw the two males collide in midair combat some 200 feet from Ziggy’s nest, perhaps defending their nearby territories. Both owl pairs failed in their nesting attempts that year, but at the end of the nesting season, we frequently saw them within several hundred yards of each other. These observations helped us to refine our picture of great gray territoriality; they suggested that defended areas were limited to the nest tree and immediate vicinity, and even then only when nesting was under way.

Great grays are not strongly tied to a specific territory year after year; pairs often change nest sites between years within the same general area. In the sixteen nesting attempts we observed between 1982 and 1986, 37 percent of pairs used the same nest for two successive years, 13 percent nested within one-quarter mile of the previous year’s nest, and 50 percent nested from one-quarter to two and four-fifths miles away. Although all the birds nested within the same twelve-square-mile area—we called it a “neighborhood”—at least half changed nest sites and territories from one year to the next.

The hunting behavior of paired adult males also pointed to a lack of territoriality. We observed four males, from nests within half a mile of one another, hunting in the same general area. Not uncommonly, we saw two males hunting less than 300 feet apart. This too was a departure from typical behavior and led us to explore why great grays have so little interest in defending their hunting grounds.

We found that one reason may be the relative abundance and accessibility of the primary prey in the areas we had under study. Our analysis of pellets regurgitated by nesting owlets indicated that the great gray owl diet consisted of 67 percent pocket gophers and 27 percent voles. Pocket gophers dig burrows and tunnels, and we noted that they were often caught
Perched in a cottonwood, an adult preens, left. Owlets typically exit the nest by falling, and two weeks may elapse before they learn to fly. In the interim, they crawl up leaning trees or deadfall and are often exposed to the elements, as was the rain-drenched chick below.

Jeff Foott

as they traveled through or excavated tunnels just below the surface of the ground. Great grays are probably attuned to the sounds the gophers make as they excavate these pathways. Voles, another major food item, spend most of their time under logs or in grass. Neither voles nor pocket gophers are likely to detect the approach of an owl on the hunt and are not likely to alter their behavior in response to one or several owls. Birds and such larger mammals as squirrels and rabbits, on the other hand, are aware of predators and react to them by hiding, mobbing, giving alarm calls, or running or flying to safety. And these creatures are more often prey items for the great horned, barred, and spotted owls. Since birds and larger mammals respond to an increase of predators by becoming more evasive, their predators do well to maintain individual hunting grounds. But the presence of more than one hunting male is no threat to the overall food supply of great grays. We therefore hypothesize that maintaining exclusive territories would be a pointless drain on a great gray owl’s time and energy. Voles and pocket gophers are no less accessible when the number of owls increases, and so as long as the great gray owl is able to move to sites where prey is available, nests do not necessarily have to be situated within the confines of prime hunting ground.

Availability of nest sites may be another factor in great gray sociability. Great gray owls do not build their own nests but depend on existing ones, such as the large stick nests built by other raptors, and on snags of dead trees. Because such platforms are often found clustered in nature and great gray owls defend only their immediate nesting area, several owl pairs can benefit from occupying a ready-made neighborhood. Large, territorial owls usually use only one site in a territory that may be as large as 1,500 acres.

Another advantage of defending only the nest precincts becomes a factor only after the young have fledged. The female remains near the fledged young for about three weeks, rarely catching food for them, but defending them with a vigor that discourages most would-be predators, such as red-tailed hawks, common ravens, great horned owls, and northern goshawks. After that, females usually leave the area, and the male is left to care for the chicks alone for the next nine or ten weeks. On the surface, this single-parent arrangement—which is not the pattern among other large owls—seems to offer little benefit. Without the mother’s vigilance, great horned owls take a heavy toll on the fledged young in some years. Females, however, are often in poor physical condition by the time the owlets fledge, and after guarding the young for several weeks, may desperately need to replenish their body reserves. In addition, with the female gone, all the food brought by the male goes to the incessantly demanding
Great grays are believed to live at least ten years; in Oregon, pairs do not attempt to breed until they are between two and four years old. Males court females with offerings of food. A male, right, offers a pocket gopher to a prospective mate. A courting pair, below, sit in a lodgepole pine.

Both photographs by Michael Quinton

young. But what if the single male is killed? Are the chicks doomed also?

We believe this question was partly answered by a serendipitous observation. In July of 1984, a juvenile great gray owl, out of the nest for only about two weeks, was found in the woods about a hundred miles away from our study area and delivered to us. Returning the owlet to its birthplace was out of the question because the adults were no longer in the vicinity. What could we do with an owlet unable to hunt for itself? Would one of the males in our study area adopt it? We decided to find out. We chose a male we called Bearpaw, which had recently lost two of his three offspring to a great horned owl, as a potential surrogate father. The orphan was released at night near Bearpaw’s single surviving offspring. Upon hearing the other owlet calling, the orphan began a cacophony of shrieks. No further introduction was necessary, and Bearpaw eventually fed the orphan.

Other researchers that have worked with great gray owls have had similar experiences. Heimo Mikkola, a Finnish ornithologist, observed great gray owls adopt two orphans. In Canada, Robert Nero and Jim Duncan of Manitoba’s Department of Natural Resources observed two different males feeding the same female and offspring. And we have seen four family groups mix on several occasions in eastern Oregon. Such observations make us think it is probable that if a male is killed, another parent male in the vicinity will adopt the orphaned young.

Thus, the great gray owl habit of residing in neighborhoods may increase to some degree the likelihood of offspring surviving in the event of a male parent’s death.

We can postulate at least one theory about why a male great gray owl might adopt offspring not his own: there is a decidedly greater than random chance that adults breeding in neighborhoods are related. We know, for instance, that when three great gray owls we banded as fledglings ultimately nested, two returned to the same neighborhood (within one and four miles, respectively, of the nests from which they fledged), whereas the third nested thirty miles away. It is therefore possible that adopting may not be entirely altruistic since any offspring a male might adopt may be related to him and carrying some of his own genes.

We suggest that nesting in neighborhoods ultimately improves the chance of great gray owlet survival. Such behavior would prove a successful reproductive strategy only if a species is nonterritorial or defends only a very small territory around the nest, is potentially limited by good nesting sites, can travel relatively long distances to forage, and can exploit dense populations of small mammals. We think that great gray owls have evolved just such a set of behavioral characteristics and are unique in their sociability among the North American owls.
Osorno Volcano (which Charles Darwin saw erupt in 1835) looms above the Chilean rain forest about fifty miles north of Puerto Montt. Crowns of coigue, a species of southern beech, can be seen emerging above the rest of the forest canopy.
Trees of the Trembling Earth

When earthquakes shake mountainous Chile, giant trees find their place in the sun

by Thomas T. Veblen

Under the volcanoes, beside the snow-capped mountains, among the huge lakes, the fragrant, the silent, the tangled Chilean forest. . . . My feet sink down into the dead leaves, a fragile twig crackles, the giant rauli trees rise in all their bristling height, a bird from the cold jungle passes over, flaps its wings, and stops in the sunless branches. . . . The wild scent of the laurel, the dark scent of the boldo herb, enter my nostrils and flood my whole being. . . . I pass through a forest of ferns much taller than I am: from their cold green eyes sixty tears splash down on my face and, behind me, their fans go on quivering for a long time. . . . Farther along, each tree stands away from its fellows. . . . They soar up over the carpet of the secretive forest, and the foliage of each has its own style, linear, bristling, ramulose, lanceolate, as if cut by shears moving in infinite ways. . . .

The lake district of the southern Chilean Andes is a land of rain and luxuriant vegetation. In the forests surrounding glacially scoured lakes, the trees are festooned with epiphytes and tangles of thick, wiry vines. The trunks of the many broad-leaved evergreens are carpeted with filmy ferns, mosses, and liverworts. Bamboos proliferate in the understory of these temperate rain forests. But in the midst of this vigorous growth, one group of trees stands out: species of the genus Nothofagus, or the southern beeches, close relatives of the beeches of the Northern Hemisphere. In mature forests, southern beeches are typically scattered giants several feet in diameter and more than 150 feet tall. Their great height takes them 30 to 60 feet above the rest of the forest canopy, and there, reaching for the sun, they spread their crowns, often 60 feet or more.

Within the lake district, four common species of beech, known locally as coigue, coigue de Chiloé, roble, and rauli, dominate mature forests from the lowlands up to approximately 3,000 feet. The two evergreen coigues are most common where conditions are moistest, while the deciduous roble and rauli prevail under slightly warmer and less-saturated conditions. Curiously, in forests unaltered by human activities, these trees are generally found only in two extreme sizes: as huge trees or as seedlings less than six inches tall; intermediate sizes are exceedingly rare. The many other trees of these mixed forests grow abundantly in all sizes, from seedlings to mature trees.

The lack of intermediate-sized beeches might lead one to speculate that these trees are failing to regenerate and that they will ultimately be replaced by species that are reproducing more successfully. There is no current evidence for this scenario, however, and every extensive forest stand in the Andes still has southern beech trees. Thus, puzzling questions persist: if the dominant beeches are not gradually disappearing, why are young beeches so rare in the forests? And under what conditions do these trees regenerate?

To answer these questions, I have spent much time over the last decade in the lake district, an area that extends from thirty-eight to forty-two degrees south latitude. The Andes here consist of old granitic rocks overlain by volcanic deposits laid down over the last 65 million years. Currently or recently active volcanoes are aligned on a north–south axis just to the west of the still-uplifting Andean summits. The Andes extend forty to sixty miles east to west and have been dissected into a labyrinth of steep valleys by Ice Age glaciers. Many of these valleys are now occupied by huge, crystal blue lakes. The glaciated slopes are typically blanketed by thick layers of pale orange to reddish brown volcanic ash. Cool, moist Pacific air masses forced upward over the Andes release copious precipitation—150 to 200 inches per year—on the western flanks of the Cordilleras. Although 40 to 50 percent of the rain falls during the austral winter of June through August, four to eight inches of rain falls in each of the “dry” summer months of January through March. With the Pacific Ocean so near, temperatures are relatively mild, somewhat like those of the Pacific Northwest of the United States.

Important clues to solving the mystery of the curious structure of southern beech forests were provided by an earthquake

that severely shook southern Chile in 1960. On a Sunday afternoon in May, 60 percent of the buildings in the coastal city of Valdivia were destroyed or seriously damaged by an earthquake measuring 8.7 on the Richter scale. This was one of a series of eleven shocks of an earthquake swarm that, over a four-day period, rocked much of southern Chile, including the lake district. Along with the earthquakes, tidal waves swamped settlements along the Chilean coast, as well as coastal sites in the western Pacific. Toward the northern edge of the lake district, the coastline was uplifted nearly six feet; to the south, it sank five feet. As a result, seawater inundated approximately 99,000 acres, much of it prime agricultural land. Volcanoes in the Andes erupted in May and June, depositing ash throughout the lake district and in the adjacent sector of Argentina. The seismic activity also triggered thousands of landslides in the Andes, where whole hillsides collapsed over a north-south distance of several hundred miles. Everything on these hillsides, including the majestic beeches, was demolished.

In the scientific inquest following the disastrous events of 1960, the profound long-term effects of earthquake-triggered landslides on landscapes and soils were quickly recognized. Many of the lake district’s valley bottoms, for example, are peppered with large boulders, and in the past, scientists assumed that glaciers had carried them there. Now we believe that many of these rocks were carried by earthquake-triggered debris flows. Similarly, soils formerly at the surface were found buried by several yards of debris from much older landslides. Surprisingly, however, no one was looking at the long-term effects of the quakes on vegetation.

In 1975, I arrived for a four-year stay in southern Chile to study the regeneration ecology of the southern beech. This was my first visit to the Andes, and I was impressed by how severely the 1960 landslides had scarred the landscape. In some valleys, more than 30 percent of the surface area had slid, and some mudflows were nearly a mile long. And as I inspected sites denuded by landslides, I observed a remarkable thing: seedlings and, significantly, the small beech trees so conspicuously absent in the mature forests were everywhere in evidence.

I began to wonder whether the beeches somehow depended on large-scale natural disturbances for regeneration. Perhaps the trees were not adapted to reproducing in the limited light beneath the closed canopy of a mature forest. If this was the case, then when there was no large-scale disturbance, the number of beeches would gradually decline, while more shade-tolerant trees would invade and reproduce. Gradually, a forest dominated by shade-tolerant species and free of beeches would develop. Given how long the beeches can live—about four or five centuries—this successional replacement would require many centuries, possibly more than a millennium. Since field reconnaissance and a perusal of timber inventories turned up no such beechless forests, I reasoned that the last major disturbance must have been too recent for this hypothesized succession to have taken place.

But any hypothesis is only as good as the evidence raised in its support. I felt I was on the right track, but now came the hard work of proving my theory. I set out to answer three questions, hoping my findings would tell me whether these magnificent beeches, seemingly so everlasting, owe their dominance to upheaval and change. First, I needed to determine the ratio of beeches to other trees on sites affected by large-scale natural disturbances. Second, I had to find out whether such disturbances were frequent enough in the past to account for the present numbers of beech trees in the mature forests.
Third, I needed to know whether the beeches were totally dependent on large-scale disturbance or whether enough trees regenerated within the mature forests to replace old giants as they died.

In the austral summer of 1976, I set out to answer the first question with the enthusiastic collaboration of David Ashton, an Australian botanist. We sampled numerous sites hit by the landslides of 1960. Nearly everywhere we went, the landslides had exposed deep and well-weathered volcanic ash layers. These volcanic deposits proved surprisingly favorable for plant growth, generally supporting dense mixtures of herbs, shrubs, and small trees. When volcanic ash is fresh, it contains little nitrogen, but among the herbs and shrubs were some that formed symbiotic associations with microorganisms and nitrogen-fixing blue-green algae, thus enhancing the site for the growth of other plants. The ages of the small trees (determined by counting the annual rings of wood samples obtained by coring) indicated that they began growing at most sites within two years after a landslide.

How many plants, and of which species, colonized a particular site was influenced by the nature of the volcanic substratum exposed by the landslide. Generally, shrubs and trees grew densest and fastest when the ash layer was the most thoroughly weathered and when the ash particles were smallest. At the few sites dominated by granite bedrock or rocky rubble, the plant cover was relatively sparse and tree growth slow. But most important, we found that southern beech seedlings and small trees were among the most abundant woody plants. Their light, winged seeds, produced in copious quantities in most years, allow them to disperse to sites 300 feet or more from parent trees. At the sites with the most favorable substratum and within a few hundred feet of seed sources, pure, dense stands of beech trees had grown to twenty feet and more. In contrast, the shade-tolerant tree species, such as tepa, trevo, and mañío, so common in the midelevation mature forests, were absent or extremely rare.

Landslides are apparently not the only large-scale disturbances favorable to the southern beeches. We observed young beech trees growing wherever suitably large, open areas had been created. After intensive logging and burning of mature forests, for example, beeches regenerate much more abundantly than shade-loving species. Likewise, beech seedlings often appear en masse after avalanches and windstorms, when winds in excess of 100 miles per hour may fell whole stands of trees in the mature forests. Natural fires, too, occasionally create conditions favorable for beeches. In 1979, for instance, a volcanic eruption ignited forests in the lake district. Generally humid, the region sometimes suffers from drought; at such times, fires can rage out of control for weeks. These fires may be fueled by the bamboos that are ubiquitous in the forest understory; at intervals of several decades or more, a large proportion of the bamboos flower at the same time and then die, leaving a huge accumulation of dry fuel.

But unquestionably, the landslides, floods, and ash deposits that accompany quakes and eruptions provide the beeches with their most spectacular opportunities. Southern Chile is one of the most seismically active regions of the world. From 1520 to 1946, the area was rocked by forty-seven notable earthquakes, seven of which were roughly comparable in magnitude and effects with that of 1960. Quakes partly destroyed Valdivia in 1575, 1737, 1837, and 1907. And as in 1960, collapsing slopes and numerous landslides were associated with these earthquakes. During the 1575 quake, a huge mudflow blocked the egress of water from Lake Rihuhe, into which flows one of the Andes’ major rivers. Four and a half months later, the lake breached the blockage, and catastrophic floods wiped out Valdivia. The same sequence of events nearly recurred in 1960, but the excavation of artificial channels through the mudflow dam prevented flooding.

Catastrophic volcanism has been a force in the region for many millions of years. During historical times, a great many volcanoes in the lake district have been active, Villarrica Volcano alone has experienced nine notable eruptions in the past two centuries. A rather mild eruption of ash from this volcano in 1972 gives a hint of the potential ecological effect of ash falls: fifteen miles from the source of the ash, box traps, which had been set out to measure seed and litter fall in a mature forest, accumulated the equivalent of nearly six tons of ash per acre over a period of a few days. Similarly, during the 1960 eruption of Puyehue Volcano, a 54,000-acre area was blanketed with two
inches—more in some places—of pumice, sand, and gravel.

From 1976 to 1979, we located many sites that had been devastated by landslides, floods, and ash deposition in the past. By analyzing forest stands of various ages, we were able to reconstruct general patterns of forest stand development. Our findings confirmed those of my initial survey in the summer of 1976. Bare sites lack seedlings of shade-tolerant species, despite the presence of seed-producing trees in nearby mature forests. The shrubs and herbs that do manage to colonize the sites gradually decline in number, and the beeches—with few competitors and plenty of the strong sun they thrive on—develop into dense thickets of small trees.

For the next hundred years or so, these sites may be dominated by nearly pure populations of beech. But as the beech trees grow taller and cast more shade, seedlings of tepe, trevo, and manio begin to sprout in the forest understory. At the same time, individual beeches compete with one another for survival, and small openings in the canopy are created as smaller trees die and fall. Meanwhile, the seedlings of the shade-tolerant species have been, in a sense, bidding their time in the understory. Now, in response to the increased light, they shoot upward. Eventually, they grow to full size, although they never reach the stature of the beeches. As the beeches continue to thin out, they create more gaps and more opportunities for the trees below them. After three hundred years or more, the typical structure of a mature forest is attained—a sparse population of giant beeches reaching thirty or more feet above a dense main canopy formed by shade-tolerant trees. Inspection of the trees' annual growth rings reveals patterns of growth consistent with our observations: initially rapid and then steadily declining growth rates for the beeches, compared with slow growth in the early years and then one or more bursts of accelerated growth for the other trees.

Large-scale disturbances are thus both highly favorable to the southern beeches and frequent enough to influence forest composition and structure. But what about our third question—how dependent is the southern beech on large-scale disturbance? Although infrequent, was there perhaps sufficient regeneration in the mature stands to maintain the present relatively sparse populations of the big beech trees? After all, when great beeches die and fall, the gaps they leave in the canopy average 4,000 square feet. An absolutely certain answer to this question requires monitoring changes in the forests over several decades. To this end, we installed permanent plots in 1977, but we also employed techniques that would give us tentative answers in the short run. We recorded the ages and sizes of individual trees and where they are in relation to one another, and we are monitoring seedlings under experimental conditions. We also located study sites where the forests were in the most advanced stage of successional development, unaffected by any large-scale disturbances for at least several hundred years.

Once again, we found no intermediate-sized beeches and plenty of shade-tolerant trees of all ages and sizes. Observation of permanent plots over a three-year period indicated that beech seedlings survived in the understory for only two years. And nowhere in an extensive 1983–84 survey did we find evidence of beeches taking advantage of tree-fall gaps. As we had come to expect, the gaps were occupied by the shade-tolerant trees and bamboos. Bamboos are common even beneath closed canopies, but it is in canopy openings that they really come into their own, forming nearly impenetrable patches. Following the fall of a tree, they produce new shoots and spread by vegetative reproduction. Individual shoots reach heights of eighteen to thirty feet during a single growing season.

Between the fast-growing bamboos and the shade-tolerant trees, the little beech seedlings don't have a chance. For them, more is required than the space provided by a fallen comrade; they need disturbance on a grand scale. But as we have learned, this they are assured of in Chile's lake district, a land where dramatic change and earth-shaking instability are the norm.
In a lowland evergreen forest near Puyehue, a coigue (right of center) is covered with epiphytic mosses and girdled by a hydrangea vine.

J.A. Fernandez, INIAFO
...
Shaker Village Views

The gift of being simple doesn’t destroy the gift of being artistic

by Robert P. Emlen

In the spring of 1780, I heard of a strange people living above Albany, who said they served God night and day and did not commit sin . . . . I went to see these remarkable strangers.

Thankful Barce, 1824

In the fall of 1776, eight English immigrants established a religious community at Niskayuna, New York, a few miles north of Albany. Fueled by their faith and the religious prophecies of their visionary leader, Mother Ann Lee, they founded a Millennial Church, which came to be called The United Society of Believers in Christ’s Second Appearing, and which, in the next fifty years, would establish twenty more settlements ranging from Maine to Kentucky. The Believers tried to lead a simple, righteous life, practicing pacifism and confession of sins and recognizing the equality of all humankind. Because their religious worship was expressed in ecstatic movement and inspired dance, their neighbors called them, erroneously, Shaking Quakers, and soon they came to be known, even among themselves, simply as Shakers.

The first Shakers congregated in small, informal communities of friends, neighbors, and families, where they concentrated on attaining spiritual grace and attempted to create their heaven in the lives they led on earth. As their religious precepts were developed and clarified, the practical applications of their faith became defined in more specific terms. For the Shakers, leaving behind the sins of avarice and pride meant relinquishing the private ownership of their earthly goods. Freedom from jealousy and lust meant separating the sexes and practicing sexual abstinence. To resist the temptation of these worldly evils, the Shakers needed more than the occasional company of kindred spirits. They needed each other’s constant support, encouragement, and admonition. And so, beginning in the late 1780s, they began to dissolve their natural families and to consecrate their property to the common good. They organized themselves into Shaker families and lived and worked in communal villages removed from the rest of the world.

During the years in which their society grew to be the largest and most successful communal religious group in America, Shaker artists drew elaborate pictures of the villages in which they worked and worshiped. Gathered together in these communities, Shakers attempted to shield themselves from the worldly distractions of nineteenth-century America. Not only were most of the early Shaker artists unfamiliar with the “correct” rules of drawing, they were also generally unconcerned with popularly acceptable styles of art. As a result, they pictured their homes in original and unconventional ways.

Other pictorial sources—surveyors’ plans, architects’ drawings, or illustrated periodicals—found their way into Shaker villages and did influence these self-taught artists. But while they borrowed from these sources, they did not feel confined by them. As Shakers they were part of a new social order whose purpose was to search, to innovate and refine, and to strive constantly for a more perfect life. The Shakers’ villages reflect this originality, both in the way communities were organized and in the way the artists chose to depict them. Shaker artists customarily

shared their drawings with one another, and the drawings developed not in isolated instances but as a society-wide phenomenon. Thus, their illustrated maps and landscaping views form a distinct artistic genre with no exact equivalent in the history of American art.

Shaker village views were created in various forms over the years, from simple notebook sketches to elaborate scrolls composed of several individual drawings. Depending on an artist's inclination, they could measure anywhere from eight or ten inches in the largest dimension to six or seven feet or more in length. They were rudimentary outlines of farmlands or they were complex portraits of densely grouped buildings. They could be staid, monochromatic diagrams or expressive, colorful illustrations. Over the course of the nineteenth century, they reflected the progress of the Shaker experience as it evolved from mainstream American culture, growing into a separate society and then back again closer to the mainstream of late-nineteenth-century life. But despite their varied appearances, the Shaker village views maintained their distinctive function; they were created to be used not as decoration but as documents of the Shaker way of life.

Shaker values shaped the landscape and the design of the settlements. A Shaker community differed from a neighboring farm in several ways. Shaker communities were usually much larger, encompassing the pooled resources of all their members and serving the needs of everyone in the Society. At their peak, several Shaker settlements were the size of small towns, including hundreds of members and covering thousands of acres. Unified by a single purpose and coordinated under a central leadership, the Believers also used the land differently. With individual pieces of property combined under Shaker ownership, a continuous stretch of fertile land did not need to be arbitrarily interrupted by walls and fences marking the boundaries set by the former private landholders. By using cooperative labor, the Shakers could develop and maintain their properties at a higher standard than their neighbors and at no greater cost.

Another consideration that determined the appearance of the Shaker landscape was religion. Order, neatness, and cleanliness were all-important in daily life. It was, therefore, more than just a nicety that the Shakers constantly mended their fences, trimmed their fields, filled and leveled their roads, and maintained their wood lots. For them, neatness was an article of faith.

Shaker villages were also distinct in the style and arrangements of their buildings. Like other settlers, the Shakers located their buildings on the best sites to receive the sun's warmth, to command a view, to catch a breeze, or to be sheltered from the wind. They made them from the same materials and in the same tradition as did the people in the communities from which the Shakers had withdrawn. As their pat-
patterns of communal living developed, however, they began to devise new kinds of structures and to place them in relation to one another in ways that responded to their own needs—arrangements that would have been irrelevant in the world outside their communities.

One obvious example was the way they built their meetinghouses. Because the Shakers practiced celibacy, and because they believed in the equality of the sexes, they built their churches with double doors, so that the brethren and the sisters might enter simultaneously, separate but equal. Because their religious worship took the form of fervent dance, they built their churches without interior partitions or supporting posts that would divide the space and interfere with the freedom of movement. This posed a structural problem, which the Shakers in eastern New York State resolved by adopting a local Dutch style of gambrel-roofed buildings. In these New York Shaker meetinghouses, interior trusses carried ceiling joists that spanned the width of the building without interruption, allowing for unimpeded movement within. So satisfactory was this distinctive construction that it was reproduced by Shaker builders in every Shaker village in New England and became one of the villages' most recognizable features. Large communal dwellings, also with double doorways, which housed as many as one hundred Believers, had rooms for food preparation, dining, religious meetings, and—up separate, matching flights of stairs—sleeping or "retiring" rooms.

Although other buildings were less elaborate, they, too, were created in response to the particular needs of a communal society. The Shakers cared for their sick in communal infirmaries called nurse shops, where those who were ill could be isolated from the rest of the community. Wood ash from the Shakers' stoves was dumped in special ash houses to cool and was later collected to fertilize gardens or to make lye.

Buildings were grouped together by function—the church next to the dwelling, the laundry near the well house, the barns near the workshops—and for the sake of efficiency in communication, tended to be set much closer together than buildings in neighboring villages, whose occupants sought privacy and prized the buffering space around them.

Shaker buildings were colorful, with their exteriors painted in whites, reds, grays, yellows, or browns. Although certain colors held a spiritual significance for the Shakers—white stood for purity, for instance, and green for increase—the way they were used around the village was also a matter of practicality. Since darker pigments were the least expensive, they were applied to common farm buildings such as sheds and barns. Workshops and dwellings, which lined the road and were more prominent, were painted yellow. White paint, the most expensive of all, was usually reserved for the community's meetinghouse. Not only was this combination of colored buildings distinctive to the Shaker village, but like the appearance of the village's lands or architectural plan, it tended to be consistent from community to community.

The outward appearance of a Shaker village—regular, efficient, and simple—was a good indication of the rest of the Shakers' material creations. Artisans were urged to temper their creative spirits with a sense of reserve and humility. They were admonished not to feel pride in their work or indulge themselves in displays of virtuosity and to make choices in harmony.
Shakers changed the appearance of their landscape, and in so doing they created a need for a different kind of map. Their new drawings would have to represent the structures of the built environment. This they did by sketching elevations of the buildings in combination with a plan of the site. Although they seem to contain inherent visual contradiction—the simultaneous representation of two- and three-dimensional features—these drawings had precedents in the techniques commonly employed to map the villages of colonial America. Like the Shakers, many of these early cartographers conceived of their maps experientially rather than diagrammatically and thought it only reasonable to represent both the structures and the landscape they knew.

Throughout the first two decades of the nineteenth century, while professional surveyors and illustrators refined their techniques, Shaker cartographers continued to record their own villages in this old-fashioned style. But in time, as the unusual needs of a Shaker community be-
came clear, and as creative and innovative solutions to communal problems began to emerge, the Shakers’ village maps began to be drawn in styles that clearly had branched off and away from the mainstream.

Why did the Shakers stop making surveyors’ plans and go on to draw large, elaborate, colorful pictures of their villages? Their reasons apparently seemed too obvious to them to mention, for no explanations have ever been found in their writings. As was the case with so much of their material expression, their drawings may have been in part a response to a parallel phenomenon in the mainstream of American culture. The flourishing of Shaker village views in the 1830s coincides with the availability of popular engravings of urban American views. Unlike their worldly neighbors, who furnished their homes with prints of landscape scenes, the Shakers did not intend their drawings as decoration. Like the surveyors’ plans from which they evolved, their purpose was to record and illustrate the physical aspects of Shaker villages.

This was a particularly important function in communal societies in general, both for practical and for personal reasons. Village plans helped members to visually organize and comprehend a large and complex property and served as a communal memory and a unifying force among the members. The Shaker village views functioned in both these ways. They served internal needs, assisting in the organization and management of the Society. Shaker law required that records be kept of the temporal progress of each family, and many of the village views made for this purpose stayed at the community in which they were made, apparently for use by the trustees as part of the Society’s land evidence and architectural inventories. They also served external needs: drawings, often copies of originals, were sent to New Lebanon, New York, to inform the parent ministry about the appearance of an individual community, or were shared with other, kindred Shaker societies, in order to maintain a bond of kinship across long distances and to help promote the sense of uniformity and continuity so valued by Believers.

Who made these Shaker village views? It seems to have been the brethren’s job. Of the eleven cartographers or landscape artists who signed the drawings or whose names can be associated with them, all are men. This stands to reason: whether the drawing was specifically concerned with architecture, horticulture, mill complexes, granite working, or boundary lines, an artist needed detailed knowledge of the building or of farm trades, which Shaker women would not have had.

But most of the men who drew these village views also shared another common experience—they had taught in the Shaker schools. They were at least nominally familiar with geography and architecture, and they had practiced the mensuration and penmanship skills needed to draw a village map. In 1849, Br. Peter Foster wrote:

The Artist who drew this Diagram, not being acquainted with any rules of drawing, hopes it will be sufficient apology for the imperfections which may be found.

Any “imperfections” that Peter Foster perceived in his 1849 plan of Canterbury would not have resulted from a lack of technical skill. Shaker schools taught young Believers penmanship and calligraphy. Nor was Brother Peter apologizing for any inaccuracies in his representations. Shaker craftsmen and craftswomen felt a moral obligation to produce their work at the highest possible standard, and Brother Peter apparently felt no qualms about the quality of his delineations. Instead, what he seemed to have sensed were his own artistic limitations and his inability to represent realistically on paper what he saw before him in the community. In fact, his drawing was no less accomplished than those of the Shaker artists who preceded him. But the apology with which he prefaced his plan reveals his awareness that his drawing, and by implication the other Shaker drawings he had seen, looked different from the maps and
Joshua Bussell continued to illustrate his maps with cartoon figures, as in his 1848 view of the Alfred community, below. A Shaker brother on horseback guides a chained team of oxen pulling a cartload of poles while another brother, in traditional Shaker smock and hat, urges the oxen on with a goad. A freight wagon, bottom, leaves a Shaker office with labeled boxes of merchandise. Bussell’s 1850 drawing of the Shaker community at Poland Hill, Maine, right, reflects a new step in Shaker map making. Although the buildings are still numbered as in a surveyor’s plan, this is the first picture with a horizon and an attempt at landscape perspective.

Both photographs from the Museum of Fine Arts, Boston.

pictures drawn by professional artists, and that there might be some more sophisticated and conventional way of presenting that information that would serve his purpose better.

Brother Peter may have come to this realization by having encountered commercial landscape views by artists who successfully represented three-dimensional subjects on a two-dimensional surface to create the illusion of space. By the standard of these professional village views, the village maps and landscape views by Shaker artists were indeed unconventional, both in style and in content.

Since naïve artistic styles were not unique to Shaker artists, what was so distinctive about their drawings? From the 1830s through the 1850s, most Shaker village views were drawn in a manner combining three stylistic elements to produce an effect not ordinarily found in worldly drawings. To begin with, they were extremely precise and literal. In the manner of other self-taught painters, Shaker artists sought to define individual details—each tree in an orchard, each stone in a wall—reflecting both the didactic uses of the paintings and their makers’ lack of sophistication in visual representations. In the last quarter of the nineteenth century, Shaker artists moved beyond this limnerlike attention to specific detail to represent their villages in a more generalized manner.

The second typical feature of Shaker sketches was the three-dimensional structure standing on the two-dimensional plane of a village plan. By recording stand-
ing features as elevations and land divisions as plans, the artists were able to identify each of those elements the most clearly. Nonetheless, by representing them simultaneously, they created a scene with inherent visual contradictions. Although, like Peter Foster, they might have seen pictures drawn in more convincing ways, Shaker artists were not schooled in the artifice of perspective construction and were left to their own devices for representing a depth of field. Generally, the artist drew the structures as he saw them from his vantage point in the middle of the village. As he turned to sketch different buildings, he turned his map as well. This had the effect of placing the artist in the middle of his own picture. The buildings seemed to lie down flat on the plan, variously facing the nearest road. No one side of the drawing was consistently oriented to the top. Although these topless drawings are confusing to the twentieth-century viewer, the audience for whom they were originally intended was probably unaware of the inherent contradiction in perspective. Like the artists, not being prejudiced toward any particular technique of graphic representation, the Shakers found that the stylized clarity of these drawings served their purposes well.

Shaker drawings abound with explanatory comments. This combination of words and pictures is a third characteristic that typifies Shaker village views. Given that these drawings were documents, the insertion of written comments seems natural enough. Often these annotations took the form of labels on individual buildings.
In his 1880 view of the Alfred church community, Bussell achieves a unified perspective view of buildings and landscape, right. The road that divides the village runs to a vanishing point. Brother Joshua had been influenced by more worldly landscape artists, and the result was designed to be hung rather than read on a table. For pictorial purposes, Bussell then subdivided maps into sections representing the buildings of the individual Shaker “families,” below. Producing compact drawings that could be hung meant sacrificing a maplike representation of the total community.


or numbers that referred to a descriptive key, which would be drawn on an available spot in a pasture or pictured floating in the sky above the horizon.

Shaker artists also used directional arrows in their drawings. These elaborate symbols became prominent features and, like the explanatory keys, were plotted in open spaces in the fields or suspended in the skies over a road leading north. Only occasionally did these arrows orient the viewer to the top of the page; the convention of placing north at the top seemed to have been an unnecessary one for the Shakers, whose cartographic orientation was dictated instead by the lay of the land.

How were the Shaker village views used in a society that would not allow them to be displayed? It appears that the drawings were folded or rolled up and stored away until they were needed, at which point they were laid flat upon tabletops and read as if they were maps or charts—which, during the first half of the nineteenth century, they actually were. The most practical way of using a map with no “right” side was to lay it flat, where each feature could be seen by turning it around or, if it were too large, by walking around it. It was not until midcentury that Shaker drawings outgrew their cartographic orientation and were conceived with the landscape in perspective and a sky above the horizon. These pictures were designed to be seen vertically.

The idea of displaying the maps seems to have become acceptable by the last third of the nineteenth century, when Shaker custom had relaxed sufficiently to permit picture frames to be used. Although as late as 1860 an English visitor described a Shaker village that had “no flowers, no pictures, no music...” it was just thirteen years later that while on a visit to the U.S. Armory in Springfield, Massachusetts, Elder Henry Blinn admired the “beautifully framed pictures hung from the walls.” From this point on, Shaker village views were designed to be hung in the Shakers’ rooms.

The Shaker village views, which had grown out of a need for planning, remained vital as long as the society continued to grow. Although the advent of photography overlapped with the last of these drawings, it was not the camera that brought this artistic phenomenon to an end. By then the fortunes of the Society had changed, and the camera merely recorded them in decline. The best and most intimate picture we have of life in Shaker villages in the years of growth, promise, and success are the drawings made by the Shakers themselves.
Wafer-thin strips of daikon, the Japanese white radish; daikon can also be grated to adorn sashimi dishes.

All photographs by Reinhardt Wolf from Japan: The Beauty of Food. Rizzoli International Publications.
These Japanese works of art end, ultimately, in the stomach

To say that we Westerners are full-blown, if unreflecting, sensualists, while the Japanese sift everything through their eyes and turn it into art would be a crude oversimplification. But anyone who has eaten even a routine Japanese meal knows about the Japanese emphasis on the visual. And the higher one rises in the gastronomic pecking order, the more the art component of Japanese cuisine takes over, until one reaches the acme of the whole beauty-based business, the *kaiseki* banquet. At these ultra-refined affairs, with their astronomical prices and Zen spareness, a few hard green noodles will portray pine needles in a cluster. The conceit is itself beautiful, but it is a contrivance that reminds us of simplicity; the artificiality leads the mind back to nature, to the natural loveliness of a tree.

To this already estheticized concept of eating, the German photographer Reinhart Wolf has added another layer of sensitive vision. With much help from the Zagreb-born art director and stylist Vilim Vasata, and with the cooperation of many restaurateurs in Japan, he has pointed his Hasselblad (mounted with a Planar 3.5/100-mm or Planar 4/120-mm lens system) at some especially exquisite Japanese food objects and come away with the arresting pictures you see. These images and many others like them are displayed in his forthcoming book, *Japan: The Beauty of Food* (Rizzoli International Publications, $50).

Wolf did not achieve such splendor just with random snapping. He does confess in a terse technical paragraph that he loaded his camera with 6/6-cm Kodak Ektachrome Professional film and lit the food with "diffuse flash from a soft box plus, in some cases, direct underlight through a pane of opal glass." But this conceals much expert fussing and striving.

In any case, these are not neutral journalistic simulacrums of fish and rice cakes and fancy lunch boxes. Wolf's photographs add their own elegant, low-gloss esthetic layer to the original substrate of Japanese prettiness. Some folks would call this painting the lily. To me, the Wolf pictures are an eloquent attempt to express the Western reaction to Japanese culture as one encounters it at table. And Wolf, as a photographer who did his work in Japan with Japanese help, comes far closer to rendering the food itself than the high-flying French chefs who have claimed Japanese authority for painting with food on plates in the *nouvelle cuisine*.

When those Frenchmen decided to emphasize the visual aspect of food *à la japonaise*, they did so in a culturally revealing (which is to say a French) manner. They did not retool and shape food to make it look like pine cones or remind diners of the season of the year in a direct pictorial way. French chefs painted largely abstract pictures, and even their representational efforts tended to lead the diner's mind back to the food itself.

I recall vividly one May some years ago when white asparagus had just come into season in France. At one three-star restaurant, they served extremely tiny asparagus concealed in a puff pastry box. At another place, the chef also put asparagus in a puff pastry box, but his asparagus were full size and hung out past the lid and over the edge of the box. These competitive arrangements ultimately were showcases for asparagus and for the chef's skill.

In Japan, as the pictures and commentary in this book show, the food serves the picture. Taste is secondary to the feasting of the eye. Take the clear soup called *o-sumachi*. It has "virtually no taste of its own." One famous chef is said to prepare it by infusing a few pieces of seaweed in hot water. Wolf shows a bowl garnished with a mussel, a slice of radish, and citron rind. Evidently this revered soup is like an aquarium for its garnishes. To complete the staging of the soup it is served in lacquered bowls (never porcelain) to appear warmer to the eye.

With *shio-katsu*, we enter further into the world of food as symbol, food as nonfood. If you are like me, when you see dried bonito stuffed with straw you speculate in your Western way that the straw in the mouth is some sort of statement about eating, stuffing oneself; perhaps the point is that overindulgence makes food unappealing and tasteless, like straw. The nose around the fish's throat could signify dependence on appetite.

But in Japan no one sees it that way. Dried bonito carries a double seasonal message and much else. This revered, sacred fish is a harbinger of summer, appearing in May. Traditionally, the shogun got the year's first bonito, the *hatsu-gatsu*. By midseason, fish that couldn't be eaten fresh were salted down and packed in straw, a Shinto symbol of purification. At the New Year, moreover, rice-straw garlands hang over doors to ward off evil spirits. So the dried bonito with his straw-filled gorge is a summer fish that is prized as a winter gift. The text that accompanies the Wolf photographs does not trouble itself to mention the taste or any gastronomic use of dried bonito. How culture-bound of me to wonder about such peripheral matters!

The same kind of question is raised, for me, by Wolf's graceful bandolier of dried flying fish strung together with rice straw. Yes, I admire the mock simplicity of the very artful tying and weaving of fish and rope. I like what Wolf has done with them too, adding a nonlinear arrangement to
the traditional line. But is this as frugal and plain a dish as it looks—air-dried fish on a rope? They are surely more sumptuous than the wooden fish indigent samurai supposedly pushed around on their plates so as not to seem poor.

Much easier to grasp are all the implications of daikon, the white radish Wolf shot shredded and also as a razor-thin Mobius strip. But even whole daikon has a snowy appeal to it. You might guess that this was a Japanese vegetable, so pretty and so bland for a radish, with nothing there to distract you from the look of it—unless a sushi chef is on hand to dazzle you with the way he cuts one root into one single slice with a rotation of hand and knife that put me in mind of a magician when I saw it done once in New York.

This is a stunt as visually dramatic as its result. But the same mentality is at work in the far simpler idea of dwarf bamboo leaves packed with sushi rice and given as gifts by one urban gourmet to another. These chimaki are handsome and, even when they conceal eels as well as rice, are too cute to tear open and consume. That's the Western view again, I guess. Probably Kyoto epicures like nothing better than to gobble chimaki after a hard day. For them there is no conflict between concept and consumption, whereas in this part of the world the principal objection usually raised against treating food as art is that food goes down the hatch no matter how supernal. The gut transmogrifies even the finest foie gras into waste.

Not every Occidental feels that way, and there is even a branch of culinary art in this culture that approaches the Japanese in its intricacy of means and distance from normal concerns of taste and feeding—sugar sculpture. This is an honorable sideline of pastry work performed with very hot, molten sugar that can be pulled into every shape in the universe. A French
Kabayaki, grilled pieces of eel that are served on a bed of rice

Flowering shiso, which has a peppermint-like taste, packed in a wooden box

Fresh mushrooms, sticks of red-bean paste confection, and five eggs in rice straw
Dried bonito that has been stuffed with straw is a common New Year's gift.

Spongy tofu filled with carrots, beans, and sea grass, wrapped in nori (algae)

Rice and eels packed into dwarf bamboo leaves form little packets called chimaki.
I once interviewed a patissier who was very proud of his three-dimensional reproduction of a Utrillo street scene in pulled sugar. My first reaction was that he had committed kitsch. Now I think that he was applying enormous skill to an art activity that lies at the margins of respectability here but which might easily find a place in the bosom of Japan if it could be connected with Japanese traditions.

The Japanese have been adept at assimilating what they wanted to from us and other cultures. You can see a small example of this, perhaps, in Wolf’s picture of tofu stuffed with carrots, beans, and sea grass. The basic ingredient is soybean curd, long ago an import from China to Japan but now a central item in the Japanese diet and “typically” Japanese both in its lack of strong taste and its purity of appearance. The actual tofu that Wolf has photographed is an entirely naturalized variety that was invented 500 years ago by the bonzes of the Koya Temple near Osaka. They left tofu on the roof one night, according to legend; the tofu froze and then, after defrosting in water, turned spongy.

Wolf’s spongy tofu starts, then, as a special piece of Japanese tradition. But its shape has been distorted by the insertion of stuffing that makes it bulge and also gives each slice a Cyclopean air. Is this abstract design the result of the influence of French nouvelle cuisine in Japan? Or is the studied display specially concocted for this photograph by its creators’ Western sensibility? Or is this purely Japanese?

Wolf has not insisted on portraying only such heights of decorative artificiality. He returns, for instance, to the daily reality of eating with his shot of kabayaki, or grilled eel, emblematic fish of the Japanese autumn, eaten in special eel restaurants. Today, eels are aquacultured efficiently in evenly warm and humid artificial ponds.
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The book also takes the reader on an armchair tour of the labs, storerooms, vaults, and attics of the Museum and the remarkable “hidden” collections they contain—the mumified Copper Man, the tusk vault, the great dinosaur bone storeroom, the gem vault, the carnivorous beetles, and much more. A wonderful book for anyone interested in exploration, discovery, and the history of science.

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The Reckless Advance of the Modern World

by Theodore Rosengarten

Until recently, the Sea Islands of South Carolina and Georgia were basking in obscurity. Home to the descendants of plantation slaves and a smattering of white people, the warm, sandy islands attracted anthropologists, folklorists, linguists, and historians who came to study the Gullah-speaking natives. Outsiders would be sure to finish their business by sundown. There were no hotels or guesthouses, few bridges or paved roads, and the darkness belonged to the hants, hags, and other spirits who brought trouble and protection to the islanders sealed in their houses for the night.

All this has changed. Places once remote and behind the times have leaped onto tourist itineraries. Developers, catering to a mania for waterfront property, have bought up the shorelines, turned ancestral farms into real estate, and built a wall of affluent homes and accommodations broken only by the bays, sounds, and firths that separate the islands. On island after island in this great archipelago, a pattern has emerged: white people occupy the waterfront and marsh edge, and black people live in the interior. This arrangement facilitates the flow of labor to and from the new clubs, inns, and private residences. Promoters boast that eighty million people live within a day's drive of the Sea Islands. Roads have been widened and bridges built to handle the projected human tide. Like sea turtles disoriented by headlights on our coastal highways, the hant or hag who ventures from the pine woods into this altered environment risks bewilderment at the strange lights and sounds or, worse, impalement on the hood ornament of a speeding Mercedes.

This is not the first time that the Sea Islands have been discovered. They became remote and hard to get to only when they lost their economic importance after the Civil War. By 1870, most Sea Island landowners were black, and the small family farm had replaced the plantation as the characteristic unit of agriculture. No one challenged the blacks' hold on the land for nearly a century. Year after year, the islanders extracted a living from the earth and the sea. Measured by income levels in other parts of the country, they were miserably poor. Yet they found sustenance and pleasures outside the cash economy. Changes on the mainland passed them by, and merely by clinging to their cultural norms and practices they became more different, their lives more divergent, from the American standard. Living apart from the institutions and technologies that were molding modern society and personality, the islanders relied instead on old-time communal responsibilities. Extended families sheltered the young and the old, dictated the layout of houses around a common yard, enforced the sharing of skills and resources, and transmitted styles of worship, dance, food preparation, and speech.

Yet these life-giving ways have proved a poor defense against developers armed with money, blueprints, and faith in their civilizing mission. In fact, as Patricia Jones-Jackson observes in her elegiac essay, the very traditions that have sustained the Sea Islanders have "robbed them of the ability to respond to the intrusion with equal and opposite force." Not that the inherited culture is enervating or ineffectual. It simply works only within a closed world. Once the insularity of that world is broken, the culture cannot compete—it loses face among the young people who are supposed to carry it forward. What are they to think? Their culture teaches quietude and conciliation, while developers roll over anyone in the way. Their culture suppresses personal cravings and elevates spiritual involvement over the irrelevant circumstances of life, while county schools promote the values of the outsiders.

When Roots Die documents the endangered traditions of the Sea Islands. With clarity and color, Jones-Jackson describes "the often reckless advances" of modernization and the futile resistance put up by the people. Resistance, to have any hope of success, would have to be political and politics has never been the islanders' strong suit. Their strength lies in their personal expressiveness, in the beauty and vitality of their prayers, stories, and conversations.

Gullah, the only surviving creolized form of English spoken in the United States, is at the heart of this book. As the first language of the Sea Islands, Gullah is the medium of cultural transmission and a chief target of the current assault on the Sea Island way of life. Take what happens in school, for example. Not all changes have to be bad, and the advent of modern public schools on the Sea Islands was greeted with hope. But the first thing Sea Island children are taught is that their language is inadequate. "Substandard" is the operative term. Not simply that Gullah isn't the language of the rest of the country, but that it is a dialect born of laziness and superstition. Rather than be-
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Most Sea Island black women continue to wear head wraps.

ing taught to respect their language, Gullah-speaking children are taught to despise it.

Following in the path of Lorenzo Turner, who demonstrated the profound African influence on the phonology, structure, and vocabulary of Gullah, Patricia Jones-Jackson went to the Sea Islands in search of African retentions. The Sea Islands are a logical place to look. In antebellum days, the white owners spent up to six months a year away from their plantations. The blacks, working under an arrangement called the task system, which minimized the need for direct supervision, felt little pressure to adopt white culture. Far outnumbering whites during and after slavery, and living with minimal disruption in the same communities for upward of two hundred years, black Sea Islanders were free to fall back on their own cultural resources. Just what did they bring with them from Africa? What values and time-honored practices endured the trials of slavery?

These questions have been hotly debated for sixty years. Historical wisdom formerly held that Africans arrived in America culturally denuded, that their sensibilities and folkways did not survive the ordeal of middle passage, and that their only meaningful history began with the Emancipation Proclamation in 1863. Although eroded by the findings of archaeology, ethnography, and linguistics, and by a reconsideration of the inner
strengths that contributed to the Africans’ highly successful adaptation to the plantation regime, this viewpoint dies hard.

Jones-Jackson does not cite the controversy. She does not doubt that many Sea Island cultural practices, from netmaking to hair wrapping, from alligator hunting to storytelling, originated in Africa. Her method is to apply the rule laid down by the great Africanist Melville Herskovits, in the 1930s, and revitalized by the historian and folklorist Charles Joyner, in the 1980s: when looking for antecedents to cultural forms in Afro-American life, look first to Africa. If, for instance, the Sea Island concept of a tripartite body, soul, and spirit once occurred in Scotland or Wales but also occurred in West Africa, then West Africa is its likely source. A good, reasonable rule. The danger is that the rule discourages testing. Like a big broom it sweeps up coincidences, parallel developments, and genuine antecedents all in a heap. Jones-Jackson is less aggressive than Herskovits, and less comprehensive than Joyner, in assigning African roots to Afro-American cultural phenomena. Still, she can be faulted for not being cautious enough, for relying too heavily on anecdotal evidence, and for using rather narrow bases of comparison.

Jones-Jackson calls the extended family “an African-like social tradition on the Sea Islands.” In a different context, the use of like would imply mere similarity. But coming in a catalog of African retentions and derivations, like discourages probes in other directions. How can we know if the Sea Island tradition is derived from the African? Have the Sea Islanders always lived in extended families? Is this a modern development, perhaps, or a return to an abandoned tradition? And what of the Africans with whom they are being compared? What sorts of families were they plucked from two hundred and fifty years ago, at the peak of the slave trade?

The history of family life in the Sea Islands and in the slave-generating regions of Africa suggests that the extended family Jones-Jackson found is a recent growth, a nearly simultaneous response on two continents to comparable kinds of stress. In the Sea Islands, the extended family may have developed after the betrayal of Reconstruction and the collapse of the staple crop economy. In short, many men left home for part of every year to find work. The families they left behind had to reorganize themselves to cope. Something similar happened in central and southern Africa in the early part of this century, when colonial policies compelled men to look for work far from their homes.

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found today in the Sea Islands and West Africa may express something other than tradition or preference. They may be recent innovations forged by a common need to maintain family ties as a resource against social and economic dislocations. The assertion that the Sea Island extended family is African-like may prove to be true, but it has not been thoroughly tested.

If the results of applying theory to the question of African retentions are not always satisfying, Jones-Jackson's sketches of her Wadmalaw Island friends and informants are uniformly rewarding. In a series of gilt-edged portraits, she introduces us to Gullah-speaking men and women whom the twentieth century is crowding out. We meet Mr. Ted Williams, a landowner and philosopher, who tells his stories standing up, with every part of his body in motion, especially his eyes and nose; Mr. Ozzie Rivers, born with a caul over his face that gave him the gift of "special sight," enabling him to see hants and hags and "to know things that other people are not privileged to know"; Ida Mae, four times a grandmother by age thirty-nine, a smoker and drinker who "has given up trying to be respectable." Not renowned as a storyteller herself, her presence at social gatherings is a powerful catalyst for other tellers.

Jones-Jackson has recorded some of their tales, prayers, and sermons. She groups the tales according to those that exemplify audience participation and those with African parallels. Written out, Gullah tales may seem sparse, lacking in detail, and limited by repetition and a small lexicon. Yet, Jones-Jackson's transcriptions are emotionally full. By recording audience responses—the laughing, clapping, whining, and shaking—she wraps the tales in pleasure, thus completing a loving act of preservation. Tales and other utterances that were music to her ears now glow on the page.

At the end of this short book, the reader wishes there were more. More tales from the lips—with the help of the lungs and other organs of mimicry and modulation—of Ted Williams; more sermons from the allusive genius of the Reverend Renty Pinkney, who has memorized the Bible; more interviews with fishermen like Daniel Dent, who can call the porpoises for miles around.

Gullah will survive for another generation or two. Once people stop speaking it, it will be dead. Nothing will revive it because as a written language Gullah has no utility. Jones-Jackson's heroic effort to render its aesthetic delights cannot change that.
Scholars will continue stalking the Sea Islands until the last condominium has blocked the view to the sea or for as long as the area remains a laboratory of social and cultural change. For the newcomers, the change is an opportunity to buy happiness and status. For the native islanders, the change is a devastating problem. To Jones-Jackson, the change meant the death of Africa in America, the passing of an Africa more African possibly than the Dark Continent today.

I speak of her in the past tense because on June 29, 1986, Patricia Jones-Jackson died from injuries suffered in an automobile accident the day before, on Johns Island, South Carolina, while on assignment for National Geographic Magazine. Her death was a terrible loss to humane studies and an unspeakable tragedy to her family and friends. I was due to meet her soon for the first time. Her reputation as a tireless fieldworker and a complete scholar preceded and smoothed the way for her. But it was her excellence as a person, her outpouring of love and kindness, that won her a name.

Six years ago, Wadmalaw resident Thomas Mack, Sr., had heard that she was writing a book and offered a prayer for her success. Jones-Jackson included the prayer in the Gullah texts. As if informed by some "special sight," Mr. Mack composed a eulogy. Death is the subject of the first eight lines, a warning that "death will soon rob [us] all of what we here possess/This evening." Almost in passing, the prayer mentions Jones-Jackson's task. "Help her to write her book/This evening, O God/That some might understand..." Abruptly, and with a strange incandescence, the foreboding returns, as the prayer calls on Jesus to remember her parents and

Help them up on every leaning side
This evening, Jesus
Build them up
Where torn down
This evening, O God!
Brace they back
Against the wall of Zion
And turn they head
Toward heaven side
If only you so please
This evening, Jesus.

Rudderless now, Gullah's ability to navigate the straits of the majority culture is sadly impaired.

Writer Theodore Rosengarten lives in McClellanville, South Carolina. He is the author of All God's Dangers: The Life of Nate Shaw and Tombee: Portrait of a Cotton Planter.
Guest Stars Are Always Welcome

Through the ages, stellar explosions have turned sky watchers on

by F. Richard Stephenson

The recent explosion of a star in the Large Magellanic Cloud, a satellite galaxy of our Milky Way, is a reminder that the seemingly orderly universe can at times be very violent. Situated so far from the earth that the light from the explosion took about 170,000 years to reach us, the star became clearly visible to the unaided eye in the Southern Hemisphere for several weeks following its discovery on February 23. At maximum brilliance, it was radiating 100 million times as much energy as the sun.

Stellar explosions on a scale this great are known as supernovae. They have catastrophic consequences for the star involved. In what is known as a Type I explosion, the entire star is blown apart. The current supernova is a Type II—the spontaneous collapse of a fairly massive star at the end of its active life, when all the hydrogen in its core has been transformed into helium and heavier elements and the nuclear reactions in its core have ceased. The outer layers of the star are then blown off into space and the core collapses into a superdense neutron star, composed primarily of neutrons—atomic particles that have no charge.

Supernovae are rare. The Milky Way contains about 100,000 million stars, yet a huge stellar explosion typically occurs only three or four times a century in our galaxy. They are observed even less frequently because clouds of galactic dust tend to obscure them. Thus we usually don’t notice a supernova unless it is relatively near the earth. Although the supernova in the Large Magellanic Cloud is outside of our galaxy, it was readily seen, since its light path avoided much of the obscuring dust in the Milky Way.

As the result of careful telescopic searches, several new supernovae are detected every year in distant galaxies. But the last such event known to have been seen in our galaxy occurred in 1604, five years before the advent of telescopic astronomy. For descriptions of supernovae that occurred in our neighborhood we therefore have to rely on observations made with the unaided eye. Nevertheless, the remnants of those explosions can now be detected with radio telescopes and X-ray satellites hundreds or even thousands of years after the original outburst. Historical detective work, especially in Oriental chronicles, can confirm the original appearance of supernovae whose aftereffects are now detectable with modern instruments.

From at least as early as 200 B.C., Chinese emperors employed official astronomers to keep a regular watch of the sky, both night and day, and to interpret any unusual celestial omens. Although the main motive for observation was astrological, the stargazers of ancient and medieval China have left many useful records of comets, supernovae, and other rare phenomena. Summaries of the reports of the Chinese astronomers are readily available today in the officially compiled dynastic histories that cover the entire period between 200 B.C. and the seventeenth century. By about A.D. 1000, Korean and Japanese astronomers maintained a watch of the sky following the pattern adopted in China. From then on it is not unusual to find two or even three independent descriptions of the same phenomenon.

Chinese astronomers had a special term for comets with evident tails, hui-hsing (broom star). A comet with a less obvious tail was usually described as a po-hsing (bushy star), while an unusual starlike object was customarily termed k’o-hsing (guest star). The modern astronomer-detector cannot assume, however, that all guest stars were supernovae. The term guest star was usually applied to stellar explosions, but comets and supernovae were sometimes mistaken for each other, although comets move across the sky.

And even if we can be sure that a guest star did not move, it might have been a "mere" nova—that is, the sudden, irregular brightening of a binary star. Although not in the same league as a supernova, a nova explosion is still on a vast scale compared with the light output of a normal star. At peak brilliance, the output may exceed 100,000 suns for several days.

A major difference between the two types of exploding stars lies in the intensity of the radiation emitted by their remnants after the outburst itself has subsided. The remains of supernovae are among the most powerful sources of radio waves and X-rays in the sky and remain active for many thousands of years. By comparison, the remains of novae are very feeble radiation emitters and are barely detectable even with modern instruments. The true nature of a supernova can be readily recognized by the character of the radiation it emits. Supernova remnants have very strong magnetic fields and behave like giant particle accelerators, producing nonthermal radiation.

Potential supernovae can also be identified in early records by how long they were visible. Modern observations of supernovae appearing in galaxies outside the Milky Way show that they fade very slowly after attaining peak brightness. This was an obvious characteristic of the recent outburst in the Large Magellanic Cloud. Hence we would expect a supernova in our own galaxy that was bright enough to be seen by the unaided eye to remain visible for many months or even...
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years. Ordinary novae, on the other hand, tend to wane rapidly after maximum, and furthermore, the greater the real brightness of the star, the faster it declines. For these reasons, studies of historical supernovae are best restricted to those guest stars that remained visible for more than about six months.

Historical records, mainly from the Orient, reveal that over the past 2,000 years, as many as eight stellar outbursts have remained visible to the unaided eye for at least six months. Seven of these appeared either within or close to the track of the Milky Way and thus rate as good supernova candidates. They appeared in A.D. 185 (in Centaurus), 393 (in Scorpius), 1006 (in Lupus), 1054 (in Taurus), 1181 (in Cassiopeia), 1572 (also in Cassiopeia), and 1604 (in Ophiuchus). In the case of the two earliest guest stars, only a single report of each is available and celestial locations are rather vague. For the five stars seen since A.D. 1000, however, several independent records still survive. These give sufficiently precise positions to enable us to establish a link with a present-day supernova remnant in every case.

On the evening of April 30, 1006 (on the Julian calendar), the brightest supernova on record shone forth. Discovered by astronomers in Egypt, the star was detected the following night in both China and Japan and was also seen in various parts of Europe. One of the most careful Chinese accounts is contained in the astronomical treatise of the official history of the Sung dynasty (960–1279).

Arab and European records testify to the extreme brilliance of the star. A Baghdad observer wrote that “its rays on the earth were like the rays of the moon,” while in Egypt it was said that “the sky was shining because of its light; the intensity was a little more than a quarter of that of moonlight.” Lupus is a southern constellation, and the star would not have been visible in the more northerly parts of Europe. Yet in Switzerland, where the supernova barely skimmed the southern horizon, it was described as “glittering in aspect and dazzling the eyes.” From these various descriptions, it would seem that at maximum brilliance, the star was about as bright as the half moon. It was thus vastly more luminous than Venus, which often dominates the evening or morning skies.

Combining individual estimates of position gives a location for the supernova near the star Beta Lupus. Only two known supernova remnants lie anywhere near this site. One of these is the Lupus Loop, a very old remnant that must have been expanding for up to about 100,000 years to reach its present extensive size. The other remnant is much more compact and about 1,000 years old. It was discovered in 1965 with the 210-foot-diameter radio-telescope at Parkes in New South Wales. That remnant, known as PKS 1459-41, has since been detected in both X-rays and visible light. Its distance from us is estimated at only about 3,000 light-years, and there is little absorption of light by galactic dust clouds in its direction. This same condition would account for the great brilliance of the supernova of 1006.

A guest star that appeared in 1054 must surely be known to everyone with an interest in astronomy. Although much fainter than its predecessor in 1006, its remnant—the Crab nebula—is one of the strongest sources of radio waves and X-rays in the sky. The original outburst was noticed in Constantinople (Istanbul), but the only useful observations were made by the astronomers of China and Japan. The following three extracts from Chinese histories during the Sung dynasty contain the main details (I have converted the dates to the Julian calendar):

July 4, 1054: “A guest star appeared approximately several inches [a fraction of a degree] to the southeast of T’ien-kuan. After more than a year it gradually vanished.”

August 27, 1054: “Earlier, in July, the guest star appeared in the morning at the east, guarding T’ien-kuan. It was visible in the day, like Venus. It had pointed rays on all sides and its color was pink. Altogether it was visible [in daylight] for 23 days.”

April 6, 1056: “The Director of the Astronomical Bureau reported that since July in 1054 a guest star had appeared in the morning at the east, guarding T’ien-kuan and now it has vanished.”

In order to be visible in daylight, the guest star must have been about as bright as Venus—as the second text states. There are, however, no indications of extreme brilliance, unlike the outburst in 1006. The position of the guest star is carefully described, for T’ien-kuan was equivalent to the rather isolated star Zeta in Taurus. Japanese observers also stated that the guest star “flared up at T’ien-kuan.” There is nothing to suggest any movement of the star during the twenty-one months of visibility, so a comet can be ruled out. By the same token, such a long duration is much more characteristic of a supernova than a nova.

The Crab nebula is the only supernova remnant found in the vicinity of Zeta Tauri. A faint patch of light a little to the northwest (not southeast) of Zeta Tauri, the Crab nebula was discovered by the English astronomer William Bevis in
1731. But it was not until 1928 that Edwin Hubble, the American astronomer, first linked that object with the stellar outburst of 1054. Interest in the Crab nebula (so named by the nineteenth-century British observer Lord Rosse) was heightened by the discovery of radio emission from it in 1948. It is now known to contain a pulsar (a rapidly rotating neutron star that emits flashes of radiation), the product of a Type II supernova, and to emit vast quantities of radiation at all wavelengths, from short gamma rays to longer radio waves. Its total power output, about 100,000 times that of the sun, is mostly produced by the pulsar, which rotates thirty times every second (a normal star rotates once every few days).

Photographs taken a few decades apart reveal the rapid expansion of the Crab nebula and indicate that the initial explosion occurred about 900 years ago. The only evidence that seems to contradict the identification of the nebula as the remnant of the supernova of 1054 is its location, about one degree northwest of Zeta Tauri. This conflicts with the most careful Chinese description of the position of the guest star. Possibly an error in direction was made when the original reports of the imperial astronomers were condensed for inclusion in the official history of the time. Certainly Oriental records give no reason for suspecting there was another supernova in this vicinity during the last two millennia.

A third medieval supernova was observed by Chinese and Japanese astronomers in 1181. This was only visible for six months and may have been considerably fainter than its two predecessors. The star appeared in the constellation Cassiopeia, and independent descriptions of its position by astronomers in South China, North China, and Japan all agree on a location near Epsilon in Cassiopeia.

In order to deduce the most accurate position from the various texts, which mention several stars in Cassiopeia, I undertook careful studies of medieval Chinese star maps. Only a single supernova remnant lies near the site of the outburst, and this fits the observed location very well. The remnant is known as 3C 58 (number 58 in the third Cambridge catalog of cosmic radio sources). Although a much fainter emitter of both radio waves and X-rays than the Crab nebula, 3C 58 bears many similarities to the nebula, suggesting that 3C 58 was probably produced by a supernova of Type II. The remnant may thus contain a pulsar that has not yet been discovered.

After 1181, nearly four centuries elapsed before the appearance of the next...
supernova—in 1572. In the interim, the traditional astronomy of China was surpassed by the new astronomy of Renaissance Europe. Without doubt the best observations of the 1572 supernova, which was as bright as Venus and remained visible for fifteen months, were made by European astronomers—notably the Danish astronomer Tycho Brahe. The position of the star, measured to within a small fraction of a degree, was very close to Kappa in Cassiopeia. Careful notes were kept of its changing brightness by comparing it with other stars. The position as measured by Brahe was so accurate that it actually lies inside the compact radio and X-ray source that is now recognized as the remnant of the supernova. Further, Brahe’s brightness estimates show that the supernova was of Type I. The star is thus the earliest supernova whose type can be established from the historical data alone. The type is in fact confirmed by modern observations of the remnant, which does not contain a pulsar.

The most detailed Chinese description is worth quoting for its historical interest but it will be seen that this is far from precise. It is contained in a detailed chronicle of the Ming dynasty (1368–1644) dated November 8, 1572:

At night a guest star was seen at the northeast; it was like a crossbow pellet. It appeared beside Ko-tao [in Cassiopeia] in the degrees of Tung-pi lunar mansion. It gradually became fainter. It emitted light in the form of pointed rays. After November 24 at night the same star was orange in color. It was as large as a lamp and the pointed rays of light came out in all directions. It was seen before sunset. At the time, the Emperor noticed it from his palace. He was alarmed and at night he prayed in the open air on the Vermillion Steps.

Finally, only thirty-two years later, in 1604, we come to the most recent galactic supernova on record. Once again, European astronomers supplied most of the scientific data regarding an accurate position (in the constellation Ophiuchus) and the changing brightness of the star. At peak brightness, this supernova was probably not as bright as Venus, and the duration of its visibility—twelve months—was shorter than that of the supernova in 1572. The position measured by the German astronomer Johannes Kepler and other Europeans was even more accurate than that of Tycho Brahe, and long before radio waves from it were detected, the faint optical remnant was discovered. The changing pattern of brightness deduced from the estimates of Kepler resembles a Type I supernova, although the rate of decline was unusually rapid. The remnant, which is similar to that of the 1572 supernova, reveals no trace of a pulsar.

Chinese observations of the supernova in 1604 were very poor, but the Korean astronomers made a remarkable series of observations of it—although these were rather crude by the European standards. On almost every clear night for nearly six months, the Koreans measured the guest star’s position to the nearest degree and reported on its brightness. The Koreans also regularly recorded when thick clouds blanketed the sky or if bright moonlight made observation difficult. The brightness comparisons, first with the planets Venus and Jupiter and later with Antares (the very red star in Scorpius) and other fainter stars, accord well with European estimates. The late sixteenth century was a time of remarkable achievement by the official astronomers of Korea, as demonstrated in 1592 when they made careful observations of a nova in Cetus over a fifteen-month period. This star was not noticed in China or even in Europe.

Supernovae are of special interest in astronomy today. They are recognized as intense sources of cosmic rays—high energy subatomic particles that continually enter the earth’s atmosphere and can penetrate far below ground level. A relatively close supernova—say within about fifty light-years of the solar system—would have serious consequences for life on Earth. The earth would be showered with cosmic rays and very shortwave radiation such as gamma rays and X-rays. One of the effects would be to destroy the upper atmosphere’s ozone layer, which protects us from incoming solar ultraviolet radiation; another effect would be the production of genetic mutations.

The occurrence of five bright supernovae in the last thousand years leads us to speculate about future events. Almost certainly, the light from other nearby supernovae is on its way to us, but because of the vast distances involved, it may take many hundreds of years to reach the earth. What is sure is that we are better able today to study a supernova outburst than ever before. Nothing, however, can diminish the importance of the contribution made by our stargazing predecessors—especially the sky watchers of the Orient. Without their efforts, we would have no direct knowledge of the occurrence of any supernova in our galaxy. Present-day astronomers have good reason to be grateful to them.

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Equinox May Be a Misnomer

by Thomas D. Nicholson

In June I wrote about why the earliest sunrise and latest sunset do not occur exactly on the dates of the solstices, the times of the year when the sun appears at its most northerly and most southerly positions. The reason for that apparent aberration in celestial reckoning has to do with how we measure time.

The equinoxes also present a puzzle. As the name implies, those are the two times of the year when the sun crosses the equator and day and night are presumed to be of equal duration. They are (in a technical sense) and they are not (in a practical sense). The inequality appears in the times of sunrise and sunset. At the equinoxes, sunrise does not occur at 6:00 A.M., sunset does not occur at 6:00 P.M., and the difference between them is not exactly twelve hours. They are off by just a little bit, but they are off.

Why should we expect day and night to be equal at the equinoxes? Because the sun is then on the celestial equator (a circle in the sky directly over the earth's equator), and the celestial horizon (another circle where the horizon meets the sky) divides the celestial equator exactly, one half above the horizon, and the other below. When the sun is on the equator, it must spend equal time above and below the horizon everywhere on the earth.

Two culprits cause discrepancies in the times of sunrise and sunset and the length of the day and night at the equinoxes: the refraction, or bending, of sunlight by the earth's atmosphere and the way we measure the instant of sunrise and sunset.

Unlike other stars (which seem to us only points of light), the sun has a distinct size, about 32 minutes of arc, about half a degree. So we must specify exactly what point on the sun we mean when we say the sun is on the equator or on the horizon. At the equinoxes, the center of the sun is on the equator. But we mark sunrise and sunset in terms of the appearance and disappearance of the upper edge of the sun. The sun's center (the point exactly on the equator) is half a diameter below the horizon at sunrise and sunset. This lengthens the day by twice the time it takes the sun to move half a diameter relative to the horizon.

In addition, refraction by the earth's atmosphere causes the sun to appear higher in the sky than it actually is. Refraction is greatest when the sun is at the horizon, where it appears raised about 35 minutes of arc, more than its own diameter. When you see the sun with its lower edge touching the horizon, the sun itself is actually below the horizon. This adds about two minutes to the length of the day at each end of the sun's daily arc.

Taken together, these factors lengthen the apparent day by six minutes or more (depending on latitude). That's why the day is about 12 hours and 9 minutes long on September 23 (the fall equinox), for middle northern latitudes, rather than exactly 12 hours. The apparent length of day and night are equal (12 hours each) on September 26. Equal days and nights always occur a few days earlier than the spring equinox and a few days later than the fall equinox, in both hemispheres.

Events in the calendar below are given in local time unless otherwise indicated.

September 1: After dusk tonight, the slightly gibbous moon, with Antares to its right, forms the base of an equilateral triangle with Saturn as the apex.

September 2: The moon is in Sagittarius, surrounded by the stars of the Archer's "teapot."

September 5: The perigee moon (nearest the earth) is in Capricornus. Look to its right for the constellation's dim bikinilike arrangement of stars.

September 7: Full moon is at 1:13 P.M., EST, near the border of Aquarius with Pisces.

September 10: The moon crawls slowly past Jupiter when they rise after sundown, having passed the planet at about 7:00 P.M., EST, before they came up.

September 12: The hazy group of stars rising with the gibbous moon late at night is Taurus's Pleiades cluster. Bright Aldebaran is to their left.

September 14: Last-quarter moon (at 6:44 P.M., EST) is still in Taurus. It rises after 11:00 P.M., close to El Nath, at the end of the Bull's right horn.

September 17-20: The morining crescent moon, on the part of the ecliptic (the sun's annual path on the celestial sphere) that keeps it high during twilight, will be a predawn attraction from the 17th, when it is near Pollux and Castor, through the 20th, when it is near Regulus. Apogee moon (farthest from the earth) is on the 17th.

September 22: The new moon at 10:08 P.M., EST, will be accompanied by an annular solar eclipse, not visible from North America, of course, where the alignment of sun and moon occurs in the middle of the night. Partial phases cover just about all of Asia and the Pacific Ocean, including Hawaii.

September 23: The sun arrives at the autumnal equinox at 8:45 A.M., EST; summer ends and fall begins in the Northern Hemisphere.

September 24-25: The evening crescent moon may not be seen until the 25th, after it has passed (and occulted) Spica and Mercury on the 24th.

September 28-29: The moon is in conjunction with the star Antares and the planets Saturn, Venus, and Ceres (the last is only a minor planet), all within a day, and it occults Antares and Ceres, which are below our horizon at the time. On the 28th, the crescent moon, Antares, and Saturn duplicate their show from early this month. On the 29th, the others will be farther to the moon's right, while the crescent itself decorates the "spout" of Sagittarius's teapot.

September 30: First-quarter moon in the teapot's handle is at 5:39 A.M., EST.

Editor's Note: The Sky Map in the July issue shows the evening constellations and stars for this month and gives the times and dates for use.
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AMNH/ANTARCTICA!
Suburban "Hotbeds of Sexual Diversity"

We are up to our knees in poison ivy, in brambles up to our chests—a party of four stalking along a power cut last fall in suburban Farmington, Connecticut. Michael Klemens, a senior scientific assistant in herpetology at the American Museum of Natural History, leads, unfazed by the underbrush. Suddenly he raises his hand. Hank Gruner from the Science Museum of Connecticut and Julie Victoria, a wildlife biologist with the state of Connecticut, have been out with Klemens before. They stand stock still. The next second Klemens either dives or falls, but somehow goes crashing down into the underbrush, out of sight, scuffing along the ground on his knees. When he comes up, his face is flushed, his eyes glisten, and in his hands he holds the tail of a black snake, its head still down in the thicket at his feet.

"Grab his head!" Klemens yells. But there are no takers. Nobody moves. Klemens, like a man hauling an unyielding anchor line, grunts an exaggerated plea for another hand. Just then the snake rears from the brush and swirls wildly in the air. "Somebody grab his head!" Klemens shouts.

Gruner is grinning from ear to ear. "Once in Middletown," he tells us, as Klemens holds a writhing three or four feet of black snake at arm's length, "Michael stood with a hognose in one hand and a black racer in the other just looking for someone to help out and refusing to put either of the snakes down." His point made, he steps forward, makes a grab for the snake, and gets nipped on the hand.

Klemens, out of patience, puts the snake's head down, while Gruner, now a little bloodied and out of humor, holds the snake to the ground with the long metal crook he carries for just this purpose. Klemens gets both head and tail in hand and lifts the tensed snake into the air.

"Racer," he notes for the record. "Coluber constrictor. Among low shrubs and tall herbaceous." The snake is as big around as a cable and a gleaming black in the bright sun.

"He was sneaking away. He was making the noise of a big snake sneaking away. And I heard him," Klemens puts his face right up to the snake's tense belly to admire the lay of its scales and the musk of its anger. Then he lowers it into a white pillowcase, which he knots closed.

This was the first big find after a morning of traipsing through muddholes, debris piles, and stony, treeless slopes on the edge of abandoned rock quarries. These landscapes, which seem dismal to me, fire Klemens's enthusiasm. He slogs on, amidst old tires, discarded appliances, and shards of glass. In a muddhole where murky water pools around discarded metal drums, Klemens comes up with a bullfrog under an old refrigerator door, a red-backed salamander under a rotted log, and three white-bellied pickerel frogs. He bags all but two of the pickerel frogs.

"Once, going after painted turtles in a muddhole like this," he says, as his sneakers suck in mud, "I sank in up to my waist, consumed by my own greed."

We are hunting microhabitats, he explains, places where animals survive and carry on as best they can under very limiting conditions. A muddhole is more than just a muddhole. "These are islands of diversity in urban seas. Look, raccoon tracks. Heron tracks. Regurgitated newt."

Newts secrete a toxin through their skins that makes them unpalatable to herons, but Klemens deduces that this newt, lying out on the surface and made torpid by the long, cold night, must have looked too good to the heron to pass up.

While many biologists succumb to the call of the exotic, Klemens claims the long-neglected New England archipelagoes as his rain forest. Not that he doesn't travel. His forays and herpetologic surveys for Connecticut, Massachusetts, and the Nature Conservancy take him some eight thousand miles a year. In the last eight years, Klemens has added more than 5,000 specimens to the collections at the American Museum.

"On expeditions into the rain forest you may get to see only a few of the hundreds of species that make up the system. Only when you begin to find animals with some frequency can you start to draw ecological conclusions from what you've seen."

For instance, although an animal may
be found throughout a great geographical range—the shaded areas on the maps in many field guides—the chance of running into that animal in most places in its range is small. This “illusion of ubiquitous distribution,” as Klemens calls it, “gives you the feeling that an animal is everywhere, when in fact, it is not.” It may only exist (and often in great numbers) in isolated plots. Mapping the plots and seeing what they have in common, in terms of geology, vegetation, temperature, and moisture, can tell much about the animal, its history, and its needs. Save the right plots and the animal may be able to survive the tide of development rising around it.

Klemens's censuses of New York's Central Park, for example, show that garter and brown snakes, once common, disappeared within the last twenty years. The snapping turtle—aquatic, nocturnal, and cantankerous (“tough and mean,” Klemens says, “the ultimate urban turtle”)—is king of Central Park's ponds. Last year, when workers discovered a clutch of two dozen snapper eggs nestled in the dirt near the Seventy-second Street boathouse, Klemens took the eggs, incubated them throughout the summer, and in the fall, under the watchful eyes of two Mountie-hatted, side-armed conservation officers, released the dark-shelled, speckle-bellied hatchlings, four of which could fit in an outstretched hand, back into the lake.

The distribution of a species, Klemens says, can be a beautiful, fine, and fascinating pattern woven out of history and ecology. The eastern box turtle, for instance, with its brown-yellow dome—and, in the male, red eyes—ranges from Georgia into southern New England. Like many other reptiles and amphibians, it Near the northern extent of its range in New York State. Farther north, winters are too cold and long; summers too short. What the distribution of this turtle shows is that by sticking to the warmer, coastal lowlands and river valleys—the Hudson in New York, the Connecticut and Farmington in Connecticut—box turtles have colonized more northerly climes. This same pattern of following the river valleys north is found in spotted turtles, Fowler's toads, spadefoot toads, marble salamanders, and copperhead and black rat snakes.

The central Connecticut lowland is a glacial basin. Ten thousand years ago, reptiles and amphibians would have found cold comfort on these new-wooded plains. The ice sheet reached as far south as Long Island. When the ice began to recede, ocean waters to the east rose, and prehistoric coastlines were inundated. Displaced reptiles and amphibians moved west, where receding ice exposed new land. As temperatures rose, forests grew, fresh water pooled, and cold tundra turned inviting habitat.

To introduce his salamander finds, Klemens likes to narrate the end of the last glaciation in newswel style: “Salamanders on the march! Ice pack melts! Waters rise! Blue-spotted salamanders move west before sinking late Pleistocene coastline! Meanwhile, from the Midwest and the southern Appalachians, where Jefferson's salamanders were long bottled up by the ice, the word went out, 'There is new territory to settle, go east—and north—young salamander!'”

Salamanders now make up more of the biomass in the northern woods than any other vertebrate. The tale of their rush to colonize newfound land is told in the diverse makeup of the survivors. Klemens, along with James Bogart of the University of Guelph in Ontario, Canada, finds that these New England lowlands have become, in Klemens's words, “hotbeds of sexual diversity” over the last four thousand years. When blue-spots met Jefferson's in the temperate New England corridors, the species mated with some abandon, creating populations of unusual genetic distinction: hybrids with two, three, and four sets of chromosomes and populations with few males or perhaps none at all.

The Housatonic River valley west of the Connecticut lowland is the zone of greatest hybridization. In Klemens's notations, where L stands for a set of blue-spot (Ambystoma laterale) chromosomes, and J stands for a set of Jefferson's (A. jeffersonianum), salamanders may be JJ, LL, LJ, JLL, JLL, and JLIJ. To
the east, a population in Harvard, Massachusetts, contains only LJ, LL, or LLJ salamanders, which look and breed most like blue-spots: they are four to six inches long with distinct blue flecks, breed in swamps, and release single eggs. To the west, populations of Jefferson-like salamanders predominate. In Clinton Hollow in Dutchess County, New York, LJ, LJJ, and LIJJ’s are five to seven inches long, breed in vernal pools, and produce long clumps of eggs. LJ’s in Clinton and Harvard have identical sets of chromosomes but behave like the other salamanders among which they live.

With few males in any of the populations, Klemens and Bogart have only been able to guess at the methods of reproduction. Gynogenesis, in which sperm is necessary to activate the egg but there is no fusion of sperm and egg, has been suggested but never proved.

“Normal” sex among salamanders does occur—but not in Connecticut. Like clans long out of touch with the postglacial world, relict populations of pure blue-spotted salamanders—LL’s, male and female—still exist. Klemens and Bogart have found two such populations: one at Montauk on the easternmost end of Long Island and another on Prince Edward Island in Canada. This coincidence bears out Klemens’s Ice Age footage: both islands were isolated from the mainland by rising waters as the ice sheet receded and before Jefferson’s salamanders moving north and east were able to invade.

The preservation of the Montauk blues, threatened by development, is important to Klemens. It is a little battle he wagers even with some conservationists. “Conservationists tend only to look at these things on a species level: ‘a blue-spot is a blue-spot is a blue-spot.’ But this is the way we lose genetic diversity.” The pure blue-spots, Klemens believes, deserve to be preserved as if they were a distinct species.

As we drive past Danbury on Interstate 84, where it crosses (shamefully, in Klemens’s view) a herpetologically valuable limestone swamp, more questions of preservation arise. Suburbs sprawl north along the Connecticut River corridor. Sandy soils from glacial lakes made good farmland, but now the farms are giving way to housing developments and shopping centers. The sprawl cuts across lowland habitats, making patterns of distribution difficult to recognize, creating more islands of diversity. Without a record of where species exist, there is no way to know which habitats require saving.

The search for verifiable finds drives Klemens. Atop Cook’s Gap, on a ridge of traprock above an abandoned quarry, he turns and replaces chunks of talus on the chance of turning up a copperhead. This is one of a range of basalt ridges, three hundred to six hundred feet high, that run like a chain of volcanic islands from New Haven north into Massachusetts, through the center of the lowlands. Consisting of hardened extrusions of volcanic rock, these steep, rugged cliffs defy development and thus offer the only uncorrupted habitat above the suburban sea. From the plains, they rise steeply, impressive red-orange cliffs with names like Sleeping Giant, Hanging Hills, and Lamentation Mountain. The Dutch name for New Haven was Rodenburg, after the red faces of the nearby hills.

The west-facing slopes of these ridges are very dry. They heat up quickly and hold the heat well, making them unbearably hot even on early fall afternoons. As the slopes warm, air rises up the face. Cool air is drawn in below. At the bottom of the cliffs the air is very cold; hiking in is like
walking into a refrigerator. There, the plant life is more like that of Vermont. At the same time, the ridgetops are scrubby, like grussy prairies, with frequent prairie-like fires. The conditions are desertlike, perfect for snakes, especially for those at the northermost limits of their range. This holds for some plants as well. We find several prickly pear cactuses bearing full, red fruits, but no copperheads.

Klemens is not discouraged. His perseverance over the last few years has resulted in finding sizable populations of four-toed salamanders, red-bellied snakes, and smooth green snakes, all three once thought to be rare in Connecticut ("just secretive"). At the same time Klemens has found that while the leopard frog and dusky salamander are thought to be widespread, they are not. His work has led to the establishment of several sanctuaries where threatened species are protected.

The day's fieldwork turns up more snakes, more toads, frogs, salamanders. With Gruner and Victoria, we walk for miles. By midafternoon all of us, whether we're wearing boots or sneakers, are soaked from slogging through streams. As rain begins, Klemens leads us up Lantern Hill near North Stonington. He notes and bags the finds: ring-necked snake under rock on moist stream bank in deciduous woods; spring peeper on talus slope; wood frog under stone, among scattered forest-floor plants; American toad under maple at wetland with salamanders.

"Beautiful, beautiful," Klemens chants as he charges over the rocks at the summit of the hill, where as the fog lifts, the view of green hills extends for fifty miles. "You see that rock below with lichen on it? That's where the sun hits. That's where the copperheads are, even if we don't find them today."

That night, in a makeshift lab in the basement of Klemens's house, we preserve the specimens, preparing them for the Museum's collection, recording their vital statistics. "I have a matrix of twenty-five parameters on my computer from geological to vegetational, so I not only know what is there but why it's there. Had this information been collected fifty years ago, it would have been invaluable. The real value of what I'm collecting won't be realized until long after I'm gone."

So Klemens returns to his sites; rainy night road running for migrating blue-spotted salamanders, wading vernal pools in hip boots and headlamp while stalking egg-laying Jefferson's, gathering spotted salamanders in minnow traps, log rolling, woodpile thrashing, rock turning—all kinds of island hopping.

Bruce Stutz

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At the American Museum

Margaret Mead Film Festival
The American Museum of Natural History's eleventh annual Margaret Mead Film Festival will run from Monday, September 14, through Thursday, September 17. The festival's fifty-one documentaries will explore major issues that affect the world in which we live. Among them are: Classified People, which explores emotional scars of apartheid on a South African family; Born Again, a film that looks at lust, love, and leadership in a Moral Majority community; and Threat, which follows the fallout from the Chernobyl nuclear accident to northern Sweden, where nuclear contamination nearly caused the destruction of the Lapp (Sami) culture.

Forty-four of the films will have their New York premieres at the festival. Screenings start at 6:30 p.m. and continue to 10:30 p.m. in four Museum theaters: the Main Auditorium, Kaufmann Theater, Linder Theater, and People Center. Admission is $5 per evening; $4 for members. Tickets, which will be sold at Museum entrances at 5:00 p.m. each day, are for general admission (not for particular films). Seating is on a first-come, first-served basis. For a free program listing, call (212) 769-5305 on weekdays, 9:30 a.m. to 4:30 p.m.

Project Snow Leopard
From base camps at altitudes of 10,000 feet or more, wildlife biologist Rodney Jackson and his field associates tracked the snow leopard through the Himalayas of western Nepal in the most comprehensive study of this animal ever undertaken. In this presentation of slides and commentary, Jackson discusses this rare cat's solitary nature, its elaborate scent-marking and ground-scraping system, and its staggered use of shared territory. This program takes place Tuesday, September 29, at 7:30 p.m. in the Main Auditorium. Tickets are $4 for members, $8 for non-members. For further information call (212) 769-5600.

At the Planetarium
Premiering Thursday, September 10, at 1:30 p.m., Cosmic Illusions, the Planetarium's newest Sky Show, simulates nature performing some of its best optical illusions. Stars change color, the sun seems to appear when it's not really there, and blue moons rise. For information call (212) 769-5920.

Library Hours Extended
The Museum's library has extended its hours on Wednesdays to 8:30 p.m. On all other weekdays, the library, which opens to the public at 11:00 A.M., will close at 4:00 P.M. A research facility for scholars and the public at large, the Museum library is one of the world's largest on natural history subjects.

People Center
The Leonhardt People Center will remain closed for the month of September.
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Une Liaison Dangereuse

Juvenile fish in the open sea are drawn toward almost anything that floats, such as weedlines and drifting debris, which trap small crustaceans and also offer the young fish a measure of protection. Some juveniles, like these jacks photographed in the Coral Sea off Australia's Great Barrier Reef, find both prey and safe passage among the entangling tentacles of jellyfish. With no known immunity from the paralyzing stings of their host, the jacks must be nimble enough to dodge the medusa's battery of nematocysts. When they grow too large to remain sheltered behind the protective curtain provided by the jellyfish, these pelagic fish—whose main protection is their speed—swim out into the open ocean.—B.D.S.

Photograph by
Chris Newbert
The Natural Moment
Curator of North American archeology at the Smithsonian Institution, Dennis Stanford (page 10) has been intrigued by New World origins since he was an undergraduate. This September 26 he will speak on “Readaptation: Life without Mammoths” as part of a symposium, “Americans before Columbus: Ice Age Origins,” at the Smithsonian’s National Museum of Natural History. Stanford’s projects include excavating a hematite mine in Wyoming that dates back to late Ice Age time. It was used as a source of raw material by hunters who made Clovis-type spearpoints, the earliest generally accepted artifacts in the Americas. For additional details on the Colorado sites he describes in this issue, see his chapter “Pre-Clovis Occupation South of the Ice Sheets” in Early Man in the New World, edited by Richard Shutler, Jr. (Beverly Hills: Sage Publications, 1983). How animal remains get buried is covered in Bones: Ancient Man and Modern Myth, by Lewis R. Binford (Orlando: Academic Press, 1981), and Fossils in the Making: Vertebrate Taphonomy and Paleoecology, edited by Anna K. Behrensmeyer and Andrew P. Hill (Chicago: University of Chicago Press, 1980). Natural processes that have an effect on animal bones are described by A. Coneyeare and Gary Haynes in Quaternary Research, vol. 22, 1984, pp. 189–200.

During her twelve years as a research biologist for the U.S. Forest Service, Evelyn Bull (page 32) has become closely acquainted with the wildlife of Pacific Northwest forests. Her article in this issue grew out of her extensive fieldwork on the hunting, feeding, and nesting habits of forest-dwelling owls, including the great gray, the biggest owl in North America. “In 1981, I became interested in this large, spectacular owl because it inhabited forests in the Pacific Northwest and because intensified timber management was likely to affect it,” says Bull. “Almost nothing was known of the species, and I wanted to determine its habitat requirements, so they could be maintained to insure continued occupancy by the owls after logging.” Coauthor Mark Henjum, a regional nongame biologist and Pacific Northwest native, joined the great gray study in 1984. As the owls became increasingly wary and difficult to radio tag, Henjum worked out new capture techniques. He is also studying other nongame birds, such as the upland sandpiper, long-eared and saw whet owls, and peregrine falcons. Both Henjum and Bull plan future work with goshawks. Two books of interest for owl fans are Robert Nero’s The Great Gray Owl: Phantom of the Northern Forest (Washington: Smithsonian Institution Press, 1980) and Heimo Mikola’s Owls of Europe (Vermilion: Buteo Books, 1983).
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"The first Shaker village view I ever saw was a midnineteenth-century drawing of the community at Poland Hill, Maine," says Robert Emlen (page 48). "It was unlike anything I’d ever seen before. I wanted to know what sort of person would create a picture that looked like that—and why, and how such a thing could be permitted in a society that discouraged art." This started Emlen on a quest that led him to identify and personally examine every known example of Shaker views in libraries, museums, and private collections across the country and to personally visit the sites each drawing depicts. Emlen is executive director of the John Nicholas Brown Center for the Study of American Civilization in Providence, Rhode Island, an adjunct lecturer at Brown University, and also teaches at the Rhode Island School of Design. For those who want to pursue the subject, Emlen suggests Priscilla Brewer’s Shaker Communities, Shaker Lives (Hanover: The University Press of New England, 1986).

Remote Coral Sea reefs off the coast of Australia cater to Chris Newbert’s fascination with the organisms of the open ocean (page 88). Where the water depth drops sharply from just a few to thousands of feet, deep-sea creatures and inshore inhabitants meet. He was in shallow water when he looked up to see the jellyfish and noticed the jacks swimming among its tentacles. He took this month’s “Natural Moment” closeup using a Canon F1 fitted with a 24-mm lens. Newbert’s subjects are not always so approachable. His diving and photography careers began some twenty years ago in Hawaii (after he gave up the idea of teaching history), and his specialty has been photographs of whales and dolphins. Newbert’s book of marine life photographs, Within A Rainbowed Sea, published by Beyond Words Publishing in 1975 (and reviewed in Natural History, March 1985), was recently named by the White House as the presidential gift of state.
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To mark Audubon's bicentennial, the Museum has decided to issue a new edition of six prints struck from these original double-elephant sized plates, last used in the early 19th century.

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The six prints in the new edition are: the Wild Turkey, Male; the Female Turkey and Young; the Snowy Owl; the Mallard Duck; the Canada Goose; and the Great White Heron.

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What may surprise many who appreciate Audubon's work is that the artist, although delighted with the superb quality of the original engravings, was terribly disappointed with the coloring of many of the prints.

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"These recent proofs are no more like my drawings than a chimney sweep is to your beautiful wife."

The Museum and Alecto therefore went back to Audubon's original watercolors, notes, letters and even bird specimens to produce this edition.

The results have not only surpassed our expectations but have also met with outstanding recognition among curators, art historians and Audubon experts.

The well known British naturalist David Attenborough wrote; "These new impressions of the 150-year-old plates could well be judged to be a finer representation of Audubon's intentions than any produced during the artist's lifetime."

"Living Bird Quarterly", a scholarly journal published by Cornell University commented; "Many experts are judging the new edition to be superior to Havell's original prints."

A very limited edition.

Because of the extremely high value of the original plates and the possibility of stress to them, the Museum is limiting the edition to just 125 sets worldwide.

The plates will then be retired for at least half a century.

The set of six prints cost $36,000. (A 19th century set from the same plates fetched over $145,000 at auction at Sotheby's in 1983.)

Already most of the edition has been claimed, the majority of the sets going to important collections in North America including the Library of Congress, the Boston Public Library, the McIlhenny Collection and the National Library of Canada.

Some sets have also been purchased by major corporations, including Dow Jones and the Southland Corporation.

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If you would like to receive a prospectus, please write to the Museum at the address below or call Sherry Goodman on (212) 245 5753.

The prints will be available for private viewing in major cities throughout the country during the next three months.

The plates will be coming back to the Museum where they will remain untouched for at least 50 years.

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NEW YORK

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Cover: The blue dragon, a sea slug found off the southeastern Australian coast, lives on the nutrients produced by algae within its body. Photograph by William B. Rudman. Story on page 50.
Return of the Western Wolf

Exterminated in the western United States more than fifty years ago, the gray wolf made an unexpected start at a comeback when a twelve-member pack moved from British Columbia, Canada, into Montana's Glacier National Park in the fall of 1985 (see Natural History, May 1986). The group was dubbed the Magic Pack for its mysterious appearances and disappearances. Its members were radio collared and have been tracked on the ground and from the air for two years by the Wolf Ecology Project, directed by Robert Ream, a biologist at the University of Montana's School of Forestry.

Whether the Magic Pack would stay south of the border and reproduce were subjects of conjecture when Natural History first published the story. Ream now reports that the original dominant female of the Magic Pack had five pups in the first spring after the pack left Canada, making Glacier National Park the first U.S. location west of the Mississippi to have a breeding pack of gray wolves.

The succeeding year was a time of change. The first female to breed apparently lost her dominant status, left the Magic Pack in January, and was later found alone in British Columbia. A subordinate female that left the pack in late December of 1986, was lost to researchers until she was found, shot, in Alberta, 550 miles north of her starting point. Another female assumed dominance of the Magic Pack and produced a litter of six pups fourteen miles south of the pack’s first home in the park. Then, in spring and early summer, four adult or subadult Magic Pack wolves drifted northward to join the original dominant female—presumably their mother—to form a new pack of five in Canada; four new pups have been born in this group. Researchers can’t decide whether to call this new pack the Magic Pack, so they’ve now named the pack north of the border the Sage Pack and the one in the park the Camas Pack. In addition to tracking the Magic Pack, Ream and his group have also been following a lone male. In the winter of 1986–87 this solitary male was joined by a female that may have been a Magic Pack member. The pair produced a litter in British Columbia. Other wolves have gained a toehold east of the Continental Divide, on the Blackfeet Indian Reservation east of Glacier National Park.

Dispersal and the kind of pack splitting observed during the past year are the mechanisms that will make wolf recovery succeed, says Ream. The population in Ream’s study area in and around Glacier National Park increased from about fifteen or twenty wolves to thirty to thirty-five in the summer of 1987, all but nine of them in Canada. Ream says that wildlife officials in southeastern British Columbia, fearing a rapid increase in the wolf population, have initiated a wolf hunting and trapping season to run from mid-September to early December. The take is limited to one wolf per hunter and officials declare they will monitor the season closely and abolish it if too many wolves are taken.

Despite the obstacles to wolf recovery, Ream is optimistic. Seventy percent of the people interviewed in his study area want the wolf supported, not eliminated. With three to four active packs in 1987, and the probability that more wolves will disperse and find mates the next year, there should be enough new wolves to offset those that may be taken by humans.

Sudden Refugee Death

In "Why Has Death Stalked the Refugees?" (see Natural History, November 1983), Jacques Lemoine and Christine Mougeon probed the mystery of sudden, unexplained death that had claimed more than sixty Laotian Hmong and other Southeast Asians who had recently settled in the United States. The victims—generally young men—died in their sleep, their hearts apparently locked in ventricular fibrillation, a rapid and uncoordinated series of contractions that result in an ineffective heartbeat. Sometimes family members saw the victims move and make gasping or gurgling sounds, but they could not be wakened. Standard autopsies revealed no underlying cause of death, such as coronary artery disease, which might have caused a heart attack, although pathologists were investigating possible defects in the conduction system, the heart’s natural pacemaker. Whether the deaths were precipitated by stress, terrifying nightmares, or other triggers was a matter of speculation.

Soon thereafter, in the Journal of the American Medical Association, Dr. Roy C. Baron and others at the Centers for Disease Control issued the results of their study of fifty-one deaths from 1977 to 1982. No suspect factors, such as exposure to chemical or biological agents of warfare in Southeast Asia, turned up in a review of the case histories. And only minor differences were found when the first twenty-six cases among Laotian refugees were compared with a matched control group. For example, the victims tended to have been separated from their homelands and living in the United States for less time than the controls. This and other observations suggested that the stresses of dislocation and resettlement might have contributed to provoking a fatal arrhythmia (abnormal heart rhythm) in certain predisposed individuals, but there was no clue as to why the deaths were nocturnal and nearly always involved men.

Continued tabulation of cases (now totaling more than 100) has added fuel to the argument that those at greatest risk are the more recently arrived refugees. In a report to be issued soon, Dr. Gib Parrish, a medical epidemiologist at the Centers for Disease Control, documents a decline
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in deaths each year, following a peak in 1981 and 1982. The decline seems related to a fall in the number of refugees being admitted to the United States since 1980, the height of the influx. While the total refugee population continues to rise (it is now about 800,000), the number of those who have lived in the United States only a short time has declined. Parrish concludes that the events of moving and resettling are important factors, but whether the key is emotional stress, a change in life-style habits (such as diet and medication), or some other condition of the transitional period cannot be determined from the statistics alone.

Ronald Munger, an epidemiologist at the University of Minnesota School of Public Health, is investigating the possibility that an element of the Southeast Asian environment may be implicated. He has found that these deaths strike at a higher rate in the refugee camps in Thailand, especially in December and January. He has also examined trends in the Philippines and Japan, where similar deaths are recognized under the traditional names bangungut and pokkuri. According to Munger, an environmental, perhaps nutritional, factor may be shared by certain groups of Asians, including the impoverished refugees in the Thai camps. They are therefore at a high level of risk when they arrive in the United States.

In the meantime, details of pathological studies of eighteen victims’ hearts appeared in a November 1986 article in the Journal of the American Medical Association, written by Robert H. Kirschner, Friedrich A.O. Eckner, and Roy C. Baron. Fourteen of the hearts showed slight to significant enlargement, characteristic of an increased workload. In addition, one or more abnormalities of the conduction system were present in all but one of the hearts. The conduction system consists of specialized heart muscle cells that create and conduct the electrical impulses that coordinate the contractions of heart muscle tissue; the system also adjusts the heartbeat in response to regulating impulses received from the autonomic nervous system. Microscopic examination of several hundred sections taken from each of the affected hearts revealed extra connections in this system, in many cases representing the persistence of fetal structures that, in the course of development, normally disappear by age two.

The authors of the pathology study point out that it is inconclusive because an appropriate control group is lacking. They propose, however, that irregularities in the conduction system may have provided an anatomical basis for the formation or conduction of electrical impulses that interfered with the victims’ normal heart contractions. Despite these clues, the monitoring of several near-victims, who were resuscitated by emergency medical intervention, revealed no arrhythmias following their brush with death. “Thus,” the researchers conclude, “the underlying condition in this syndrome is, for the most part, clinically silent, and fatal or near-fatal episodes probably occur in response to rare cardiac electrical accidents.”

When recently contacted, Kirschner, of the Office of the Medical Examiner of Cook County, Illinois, confirmed that the trigger remains a mystery. He did not exclude the possibility, however, that nerve impulses resulting from a nightmare could set off the arrhythmia.

Such a triggering mechanism makes sense to Dr. Michael A. Brodsky, assistant professor of medicine at the University of California at Irvine and director of the university medical center’s Cardiac Arrhythmia Service, who approaches the problem as a clinician, rather than as a medical examiner. Working in Orange County, where many of the Southeast Asian refugees have settled temporarily or permanently, he sees a steady stream of patients who have suffered cardiac arrest, ventricular tachycardia (a racing heartbeat, indicative of cardiac irritability, that in some cases can suddenly lead to ventricular fibrillation), fainting, or other symptoms suggestive of heart disorder. Frequently these patients can be diagnosed as having an underlying heart disease, but a significant number appear to have normal hearts. Many in this group are Southeast Asians, often women.

Brodsky and his colleagues describe six female patients—including one from Cambodia, one from Vietnam, and one from Korea—in an April 1987 article in the Journal of the American Medical Association. All of the women had episodes of ventricular tachycardia. Five were depressed, anxious, or otherwise psychologically distressed, and each of these had arrhythmias associated with changes in the activity of the nervous system. For these five, drugs called beta-blockers were prescribed. These drugs specifically block the sympathetic branch of the autonomic nervous system, whose arousal is associated with psychological stress. In each case, the treatment reduced the occurrence of ventricular tachycardia.

These clinical findings do not answer the question of why in some individuals (particularly males) stress may result in ventricular fibrillation and death. Brodsky is reluctant to attach importance to the pathological findings concerning the conduction system. From a practical point of view, however, he believes that the standard medical treatment to control ventricular tachycardia could effectively preserve the lives of many otherwise destined for sudden, unexplained death.

He recommends that all Southeast Asian refugee men between the ages of 20 and 45—especially those who have recently resettled in the United States—have some appropriate medical evaluation, and that any refugee, male or female, who actually suffers from palpitations, fainting spells, nightmares, emotional distress, or other relevant symptoms have a thorough examination by a specialist. By interviewing the patient and using noninvasive instruments (notably the electrocardiograph), a cardiologist can evaluate the risk and, where indicated, prescribe medications, including perhaps beta-blockers.

While they look to the American medical establishment for a definitive solution, the refugees themselves continue to entertain various explanations of sudden, unexplained death. Some blame exposure to chemical or biological agents of warfare in Southeast Asia or ingestion of food additives in the United States. Others maintain that the neglect of traditional religious practices has resulted in loss of protection by their ancestors’ spirits. More are aware of the fearful prospects of autopsy—a practice they usually oppose—than of the scientific findings.

Attempting to bridge the gap is the Asian Sudden Death Information Center, opened in February 1986 at the Saint Paul–Ramsey Medical Center. The center’s program, now being taken over by the American Refugee Committee in Minneapolis, has been to collect and disseminate basic knowledge about sudden, unexplained death, as well as new developments, to a nationwide network of medical and public health authorities, social service and health-care providers, teachers of English as a second language, scientific researchers, and refugee organizations. Practical advice offered to the families of potential victims includes when and how to use 911 or similar emergency telephone numbers and the value of learning cardiopulmonary resuscitation (CPR).

If pursued, the detective work on sudden, unexplained deaths could have many general medical implications. Ironically, the welcome fall in deaths in the United States threatens to undercut research efforts vital to incoming Southeast Asian refugees. Also liable to be forgotten are the more than 100,000 refugees still waiting in Thailand camps, where death continues to stalk unhindered.
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Clovisia the Beautiful!

If humans lived in the New World more than 12,000 years ago, there’d be no secret about it

by Paul S. Martin

During the Pleistocene—the last Ice Age, 1.8 million to 10,000 years ago—elk, moose, musk oxen, mountain goats, buffalo, mountain sheep, Dall’s sheep, pronghorns, caribou, white-tailed deer, mule deer, grizzly bears, black bears, wolves, and cougars were not the only large animals living in North America. Mammoths, mastodons, native camels and llamas, native horses, ground sloths, armadillo-like glyptodonts, tapirs, giant peccaries, mountain deer, giant beavers, four-legged antelopes, and various species of woodland musk oxen and other bovids also roamed the continent. In addition to these now-extinct herbivores, the land harbored such predators and scavengers as dire wolves, native American lions, saber-toothed cats, and scavenging birds.

If, as I believe, the first Americans were foragers who mainly hunted game, they would have been drawn to the habitats of these animals—to grasslands or woodlands adjoining flood plains, to mineral springs, lake shores, and coastal marshes. Large herbivores frequented these places because they provided edible foliage, fruits, seeds, roots, and tubers. If the first Americans also relied on plant foods, the same habitats would have been equally attractive to them. Today, the ancient flood plains, mineral springs, lake shores, and adjacent caves and sinkholes are all good places to hunt fossils.

Among North American vertebrate paleontologists, some of the sites famous for their late Pleistocene bones are such freshwater and mineral springs as Hot Springs, South Dakota; Boney Springs, Missouri; Saltville, Virginia and Big Bone Lick, Kentucky; certain coastal deposits such as Seminole Field, Florida; numerous alluvial deposits such as Murray Springs, Arizona; various damp caves in the eastern United States, including Big Bone Cave, Tennessee; and an assortment of dry caves and sinkholes in the western United States, notably Gypsum Cave, Nevada, and Natural Trap, Wyoming. In addition, a vast number of bones of large animals have been excavated at Rancho la Brea and various other tar seeps in California. Yet at none of these sites do human remains or artifacts turn up until after 12,000 years ago.

Of the more than seventy species of large mammals that once lived together in North America, only fifteen survive. In deposits reliably dated by the radiocarbon method, the remains of the extinct animals, whether found in flood plains or in dry caves, turn out to be at least 10,000 years old. In contrast, carefully dated archeological sites rich in cultural remains are all less than 12,000 years old. Only in a relatively few deposits of intermediate age can one actually find evidence of human hunters together with fossils of extinct species. Clovis points (named for discoveries made near Clovis, New Mexico) and other stone and bone tools are found with bones of mammoth and bison. More rarely, mastodon or other species are associated with these implements. For the western United States, C. Vance Haynes of the University of Arizona and his associates have established a remarkably narrow time range for the encounter between Clovis hunters and the extinct fauna: just between 11,500 and 11,000 years ago.

The search for evidence yields a consistent pattern. When bones of extinct mammals are found in natural deposits 12,000 years old or older, human artifacts are absent. When prehistoric stone or bone tools (and, under favorable conditions in dry caves, even sandals, matting, and other perishable remains) are found in archeological sites of the last 10,000 years, fossils of the extinct large animals are absent. While in exceptional cases, accidents of redeposition have allowed older material to intrude into younger deposits, or vice versa, only between 12,000 and 10,000 years ago do extinct Pleistocene animal remains and human artifacts clearly coexist. Even these cases are few, and at least locally, the overlap appears to have lasted much less than two millennia.

By 10,000 years ago, when the extinctions had run their course, human artifacts regularly appear in the same types of sediments and deposits that formerly received bones of the extinct fauna. The contents of some dry caves in Arizona, New Mexico, and Utah occasionally reveal the switch: the bones and even the preserved dung of extinct large animals lie directly beneath traces of prehistoric people who consumed small game and plants. Setting aside the lively controversy of whether human hunters brought about the extinctions (see Donald Grayson’s article in the May issue of Natural History), these observations raise doubts about the likelihood of a human presence in the New World before 12,000 years ago.

Those hunting for “early early” humans in America are not, after all, seeking a rare, forest-dwelling primate, like the gorilla or chimpanzee, that foraged mainly on plants. If restricted in range to a moist forest environment, where acid soils prevent ready fossilization, such a creature might indeed have left very few bones or other traces of its existence. Pleistocene fossils of African gorillas, for example, have yet to be discovered. But humans did not prefer a forest habitat.

Besides, evidence of human occupation includes the tool kits and debris of master flint knappers, whose individual output
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consisted of countless blades, knives, scrapers, drills, awls, and piles of waste flakes. Ivory spearpoints, bone needles, and bone shaft straighteners also may be expected. Ice Age people used these stone and bone tools to hunt, butcher, and process a variety of large mammals from a variety of habitats: forest, woodland, grassland, and desert. The difference between the Old World and the New in the quantity of such artifacts discovered before 12,000 years ago is amazing. For Japan, for example, an island smaller than California with an archaeological record extending back continuously at least 30,000 or 35,000 years, Shizuo Oda and Charles T. Keally report several thousand Late Pleistocene archeological sites, of which at least 500 can be ranked as important, each yielding more than a thousand artifacts, including knife-shaped stone tools, small blades, and flake tools. Another measure of the difference is seen in the Stone Age trophics and art treasures of Europe and Asia. The exhibition Dark Caves, Bright Visions, which was presented a year ago at the American Museum of Natural History, provided a sample of this heritage. From western Europe came carved figurines of human and animal forms, many more than 20,000 years old; ivory beads; and carved shaft straighteners 10,000 to more than 30,000 years old. A full-size model re-created an elaborate hut abandoned 16,000 years ago in the Ukraine: it was made of mammoths’ jaws and other bones and was entered through an archway of ivory tusks. Knives, scrapers, and drills of flint and chert typified Old World sites where large animals were butchered and processed. If Paleolithic hunters entered America long before 12,000 years ago, why didn’t they leave us some similar trophies of equivalent age?

The fossil record of Stone Age people in Asia reveals tens of thousands of years of hunting and gathering, with large animals as a major source of food. The bands that ultimately entered America were not primitive. Anatomically, the first Americans were not much different from ourselves, and they were far more skillful at outdoor life than even present-day “survivists” might imagine. They wore sewn clothing and were adept at starting and maintaining fires. They were superb trackers, killers, and butchers of large animals, perhaps aided in the hunt by opportunistic packs of wolves.

These hardy pioneers (like Columbus thousands of years later) found the New World rich in resources. But unlike seventeenth-century European colonists, who had to master new agricultural conditions while disputing turf with Native Americans, the earlier pioneers from Asia faced no major environmental or cultural obstacles once they left the arctic tundra. They were not exposed to many, if any, new illnesses, and in their passage through the natural quarantine of cold regions (where tropical and many temperate parasites cannot thrive) they shed such deadly or debilitating diseases as sleeping sickness, malaria, and hookworm.

Perhaps these explorers were surprised when they first saw tall trees and awed when they entered a forest. Nevertheless, they were guided to water, to salt licks, and to the natural haunts of their quarry by prints, trails, dung, chewed or bent twigs, shed hair, and other, more subtle clues that are of such keen interest to contemporary hunters tracking inside or outside a forest. My estimate, based on data from Africa, is that there were at least 50 to 10 million large animals in North America north of Mexico. Many species—woolly mammoth, horse, caribou, camel, and bison—were similar to, if not identical with, prey species long hunted in Europe and Asia. Others such as the slow-moving glyptoc-
dents and ground sloths must have been absurdly easy to dispatch. For that matter, big game in general was probably unwary of the few two-legged predators and (at least initially) easily subdued.

Given easy hunting and the absence of disease, human population growth was most likely rapid. Growth rates of 2 to more than 3 percent, with a doubling in numbers every twenty to thirty years, commonly reported by demographers for present-day populations, were feasible. Increasing at this rate, 100 human colonists could have severely depleted the large animal resources in an area the size of the United States in 300 years or less. The abundant food sources would have drawn them to the High Plains, to Mexico, and inevitably to the forest primeval of South America.

To be sure, there is no direct way to prove there weren't at least a few people in the New World before 12,000 years ago. The likelihood of a population explosion once successful entry was achieved, however, underlines the absence of human remains at sites rich in the bones of Pleistocene animals. Thus, on environmental as well as paleontological grounds, the possibility of a human society inhabiting America much before 12,000 years ago ranks as highly improbable.

While a number of sites described as older than 12,000 years have been presented in this series, I and many others view the latest finds as less than conclusive. The reason is our sense of dejà vu. In the last thirty years, various discoveries have been reported to be 15,000, 30,000, or even 200,000 years old. One after another of these once-popular claims, however, have crumbled when subjected to modern techniques of geological and archaeological analyses. For example, the Koch mastodon site in Missouri; Sandia points from Sandia Cave in New Mexico; the Holly Oak pendant from Delaware; Tule Springs, Nevada; Smith Creek Cave, Nevada; Lewisville, Texas; and Gypsum Cave, Nevada—all once widely touted—have been re-investigated by a new generation of scientists. The results have not yielded any confirmations.

We may look back just ten years for another example, when human bones from a variety of sites in California (including Del Mar, Sunnyvale, La Jolla, and Laguna Beach) were dated by an experimental technique called aspartic acid racemization. An age of 70,000 years for these finds was announced in the prestigious journal Science. Recently, the organic residues were analyzed using a particle accelerator, a major innovation in the radiocarbon method that is especially suitable for dating small bone samples. The new measurements indicated that the human bones, supposedly up to 60,000 years older than Clovis, were instead all younger. The sample used to calibrate the original results was found to be the source of the error. The new accelerator dating method has also dealt severely with other pre-12,000-year-old claims, such as the caribou flesher from Old Crow in the Yukon, the Taber child from Canada, and Yuha man in California. These were much younger than originally claimed, and in no case as old as Clovis.

The publicity surrounding a fresh find invariably galvanizes attention and overshadows the short shelf life of previous claims, but by now we should have learned to be cautious. I think we should wait a generation or at least a decade before giving much credence to any newly minted claim. Let the inevitable burst of hype dissipate while the evidence is reviewed calmly, preferably in place, and ideally by skeptics. Meanwhile I persist in believing that the first people to colonize the New World were the Clovis hunters or their immediate ancestors, who followed game east, across a cold, dry plain linking Asia with North America, to enter a forager's paradise, a Garden of Eden. Perhaps we should rename the New World in honor of these unwitting explorers—Clovisia, Clovisia the Beautiful!
Justice Scalia's Misunderstanding

What good to science is a lovely idea that cannot, as a matter of principle, ever be affirmed or denied?

by Stephen Jay Gould

Charles Lyell, defending both his version of geology and his designation of James Hutton as its intellectual father, described Richard Kirwan as a man "who possessed much greater authority in the scientific world than he was entitled by his talents to enjoy."

Kirwan, chemist, mineralogist, and president of the Royal Academy of Dublin, did not incur Lyell's wrath for a mere scientific disagreement, but for saddling Hutton with the most serious indictment of all—atheism and impiety. Kirwan based his accusations on the unlikely charge that Hutton had placed the earth's origin beyond the domain of what science could consider or (in a stronger claim) had even denied that a point of origin could be inferred at all. Kirwan wrote in 1799:

Recent experience has shown that the obscurity in which the philosophical knowledge of this [original] state has hitherto been involved, has proved too favorable to the structure of various systems of atheism or infidelity, as these have been in their turn to turbulence and immorality, not to endeavor to dispel it by all the lights which modern geological researches have struck out. Thus it will be found that geology naturally ripens ... into religion, as this does into morality.

In our more secular age, we may fail to grasp the incendiary character of such a charge at the end of the eighteenth century, when intellectual respectability in Britain absolutely demanded an affirmation of religious reality, and when fear of spreading revolution from France and America equated any departure from orthodoxy with encouragement of social anarchy. Calling someone an atheist in those best and worst of all times invited the same predictable reaction as asking Cyrano how many sparrows had perched up there or standing up in a Boston bar and announcing that DiMaggio was a better hitter than Williams.

Thus, Hutton's champions leaped to his defense, first his contemporary and Boswell, John Playfair, who wrote (in 1802) that

such poisoned weapons as he [Kirwan] was preparing to use, are hardly ever allowable in scientific contest, as having a less direct tendency to overthrow the system, than to hurt the person of an adversary, and to wound, perhaps incurably, his mind, his reputation, or his peace.

Thirty years later, Charles Lyell was still fuming:

We cannot estimate the malevolence of such a persecution, by the pain which similar insinuations might now inflict; for although charges of infidelity and atheism must always be odious, they were injurious in the extreme at that moment of political excitement [Principles of Geology, 1830].

(Indeed, Kirwan noted that his book had been ready for the printers in 1798 but had been delayed for a year by "the confusion arising from the rebellion then raging in Ireland"—the great Irish peasant revolt of 1798, quelled by Viscount Castlereagh, uncle of Darwin's Captain FitzRoy.)

Kirwan's accusation centered upon the last sentence of Hutton's Theory of the Earth (original version of 1788)—the most famous words ever written by a geologist (quoted in all textbooks, and often emblazoned on the coffee mugs and T-shirts of my colleagues).

The result, therefore, of our present enquiry is, that we find no vestige of a beginning—no prospect of an end.

Kirwan interpreted both this motto, and Hutton's entire argument, as a claim for the earth's eternity (or at least as a statement of necessary agnosticism about the nature of its origin). But if the earth be eternal, then God did not make it. And if we need no God to fashion our planet, then do we need him at all? Even the weaker version of Hutton as agnostic about the earth's origin supported a charge of atheism in Kirwan's view—for if we cannot know that God made the earth at a certain time, then biblical authority is dethroned, and we must wallow in uncertainty about the one matter that demands our total confidence.

It is, I suppose, a testimony to human carelessness and to our tendency to substitute quips for analysis that so many key phrases, the mottoes of our social mythology, have standard interpretations quite contrary to their intended meanings. Kirwan's reading has prevailed. Most geologists still think that Hutton was advocating an earth of unlimited duration—though we now view such a claim as heroic rather than impious.

Yet Kirwan's charge was more than merely vicious—it was dead wrong. Moreover, in understanding why Kirwan erred (and why we still do), and in recovering what Hutton really meant, we illustrate perhaps the most important principle that
we can state about science as a way of
knowing. Our failure to grasp the prin-
ciple underlies much public mispercep-
tion about science. In particular, Justice
Scalia's recent dissent in the Louisiana
"creation science" case rests upon this er-
ror when it discusses the character of evolu-
tionary arguments. We all rejoiced
when the Supreme Court ended a long
episode in American history and voided
the last law that would have forced teach-
ers to "balance" instruction in evolution
with fundamentalist biblical literalism
masquerading under the oxymoron cre-
ation science. I now add a tiny hurrah in
postscript by pointing out that the dissent-
ing argument rests, in large part, upon
a misunderstanding of science.

Hutton replied to Kirwan's original at-
tack by expanding his 1788 treatise into a
cumberous work, The Theory of the
Earth (1795). With its forty-page quota-
tions in French and its repetitive, involuted
justifications, Hutton's new work con-
demned his theory to unreadability. Fortu-
nately, his friend John Playfair, a math-
ematician and outstanding prose stylist,
composed the most elegant pony ever writ-
ten and published his Illustrations of the
Huttonian Theory of the Earth in 1802.
Playfair presents a two-part refutation for
Kirwan's charge of atheism.

1. Hutton neither argued that the earth
was eternal nor even claimed that we
could say nothing about its origin. In his
greatest contribution, Hutton tried to
develop a cyclical theory for the history of
the earth's surface, a notion to match the
Newtonian vision of continuous planetary
revolution about the sun. The materials of
the earth's surface, he argued, passed
through a cycle of perfect repetition in the
large. Consider the three major stages.
First, mountains erode and their products
are accumulated as thick sequences of
layered sediments in the ocean. Second,
sediments consolidate and their weight
melts the lower layers, forming magmas.
Third, the pressure of these magmas
forces the sediments up to form new
mountains (with solidified magmas at
their core), while the old, eroded contin-
tents become new ocean basins. The cycle
then starts again as mountains (at the site
of old oceans) shed their sediments into
ocean basins (at the site of old continents).
Land and sea change positions in an end-
less dance, but the earth itself remains
fundamentally the same. Playfair writes:

We can easily grasp the revolutionary
nature of this theory for concepts of time.
Most previous geologies had envisioned an
earth of short duration, moving in a single
irreversible direction, as its original moun-
tains eroded into the sea. By supplying a
"concept of repair" in his view of magmas
as uplifting forces, Hutton burst the stric-
tures of time. No more did continents
erode once into oblivion; they could form
anew from the products of their own de-
cay and the earth could cycle on and on.

This cyclical theory has engendered the
false view that Hutton considered the
earth eternal. True, the mechanics of the
cycle provide no insight into beginnings or
ends, for laws of the cycle can only pro-
duce a continuous repetition and therefore
contain no notion of birth, death, or even
of aging. But this conclusion only specifies
that laws of the present order of nature
cannot specify beginnings or ends. Begin-
nings and ends may exist—in fact, Hutton
considered a concept of starts and stops
absolutely essential for any rational under-
standing—but we cannot learn anything
about this vital subject from nature's pres-
tent laws. Hutton, who was a devoted
theist despite Kirwan's charge, argued that
God had made a beginning, and
would ordain an end, by summoning
forces outside the current order of nature.
For the stable period between, he had or-
dained laws that impat no directionality
and therefore permit no insight into these
beginnings and ends.

Note how carefully Hutton chose the
words of his celebrated motto. "No vestige
of a beginning" because the earth has
been through so many cycles since then
that all traces of its original state have
vanished. But an original state it certainly
had. "No prospect of an end" because the
current laws of nature provide no insight
into a termination that must surely occur.
Playfair describes Hutton's view of God:

He may put an end, as he no doubt gave
a beginning, to the present system, at some
determinate period; but we may safely con-
clude, that this great catastrophe will not be
brought about by any of the laws now exist-
ing, and that it is not indicated by any thing
which we perceive.

2. Hutton did not view our inability to
specify beginnings and ends as a baleful
limitation of science but as a powerful
affirmation of proper scientific method-
ology. Let theory deal with ultimate ori-
gins, and let science be the art of the
empirically soluble.

The British tradition of speculative ge-
ology—from Burnet, Whiston, and Wood-
ward in the late seventeenth century to
Kirwan himself at the tail end of the eight-

enth—had focused upon reconstructions
of the earth's origin, primarily to justify
the Mosaic narrative as scientifically plau-
sible. Hutton argued that such attempts
could not qualify as proper science, for
they could only produce speculations
about a distant past devoid of evidence to
test any assertion (no vestige of a begin-
ning). The subject of origins may be vital
and fascinating, far more compelling than
the humdrum of quotidian forces that
drive the present cycle of uplift, erosion,
deposition, and consolidation. But science
is not speculation about unattainable ulti-
mates; it is a way of knowing based upon
laws now in operation and results subject
to observation and inference. We ac-
knowledge limits in order to proceed with
power and confidence.

Hutton therefore attacked the old tradi-
tion of speculation about the earth's origin
as an exercise in futile unprovability. Bet-
ter to focus upon what we can know and
test, leaving aside what the methods of
science cannot touch, however fascinating
the subject. Playfair stresses this theme
more forcefully (and more often) than any
other in his exposition of Hutton's theory.
He regards Hutton's treatise as, above all,
an elegant statement of proper scientific
methodology—and he locates Hutton's
wisdom primarily in his friend's decision
to eschew the subject of ultimate origins
and to focus on the earth's present opera-
tion. Playfair begins by criticizing the old
manner of theorizing:

The sole object of such theories has hitherto
been, to explain the manner in which the
present laws of the mineral kingdom were
first established, or began to exist, without
treating of the manner in which they now
proceed.

He then evaluates this puerile strategy
in one of his best prose flourishes:

The absurdity of such an undertaking ad-
mits of no apology; and the smile which it
might excite, if addressed merely to the
fancy, gives place to indignation when it
assumes the air of philosophic investiga-
tion.

Hutton, on the other hand, established
the basis of a proper geological science by
avoiding subjects "altogether beyond the
limits of philosophical investigation." Hutton's
explorations "never extended to the
first origin of substances, but were
confined entirely to their changes." Playfair
elaborated:

He has indeed no where treated of the first
origin of any of the earths, or of any sub-
stance whatsoever, but only of the transfor-
mations which bodies have undergone since
the present laws of nature were established.
He considered this last as all that a science,
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built on experiment and observation, can possibly extend to; and willingly left, to more presumptuous inquirers, the task of carrying their reasonings beyond the boundaries of nature.

Finally, to Kirwan's charge that Hutton had limited science by his "evasion" of origins, Playfair responded that his friend had strengthened science by his positive program of studying what could be resolved:

Instead of an evasion, therefore, any one who considers the subject fairly, will see, in Dr. Hutton's reasoning, nothing but the caution of a philosopher, who wisely confines his theory within the same limits by which nature has confined his experience and observation.

This all happened a long time ago and in a context foreign to our concerns. But Hutton's methodological wisdom, and Playfair's eloquent warning, could not be more relevant today—for basic principles of empirical science do have an underlying generality that can transcend time. Practicing scientists have largely (but not always) imbibed Hutton's wisdom about restricting inquiry to questions that can be answered. But Kirwan's error of equating the best in science with the biggest questions about ultimate things continues to be the most common of popular misunderstandings.

I have often mentioned that fifteen years of monthly columns have brought me an enormous correspondence from nonprofessionals about all aspects of science. From sheer volume, I obtain a pretty good sense of strengths and weaknesses in public perceptions. I have found that one common misconception surpasses all others. People will write, telling me that they have developed a revolutionary theory, one that will expand the boundaries of science. These theories, usually described in several pages of single-spaced typescript, are speculations about the deepest ultimate questions we can ask—what is the nature of life? the origin of the universe? the beginning of time?

But thoughts are cheap. Any person of intelligence can devise his half dozen before breakfast. Scientists can also spin out ideas about ultimates. We don't (or, rather, we confine them to our private thoughts) because we cannot devise ways to test them, to decide whether they are right or wrong. What good to science is a lovely idea that cannot, as a matter of principle, ever be affirmed or denied?

The following homily may seem paradoxical but it embodies Hutton's wisdom: the best science often proceeds by putting aside the overarching generality and focusing instead on a smaller question that can be reliably answered. In so doing, scientists show their intuitive feel for the fruitful, not their narrowness or paltriness of spirit. In this way we sneak up on big questions that only repel us if we try to engulf them in one fell speculation. Newton could not discover the nature of gravity, but he could devise a mathematics that unified the motion of a carriage with the revolution of the moon. Darwin never tried to grasp the meaning of life (or even the manner of its origin on our planet), but he did develop a powerful theory to explain its manner of change through time. Hutton did not discover how our earth originated, but he developed some powerful and testable ideas about how it ticked. You might almost define a good scientist as a person with the horse sense to discern the largest answerable question—and to shun useless issues that sound bigger.

Hutton's positive principle of restriction to the doable also defines the domain and procedures of evolutionary biology, my own discipline. Evolution is not the study of life's ultimate origin as a path toward discerning its deepest meaning. Evolution, in fact, is not the study of origins at all. Even the more restricted (and scientifically permissible) question of life's origin on our earth lies outside its domain. (This interesting problem, I suspect, falls primarily within the purview of chemistry and the physics of self-organizing systems.) Evolution studies the pathways and mechanisms of organic change following the origin of life. Not exactly a shabby subject either—what with such resolvable questions as "how, when, and where did humans evolve?"; "how do mass extinction, continental drift, competition among species, climatic change, and inherited constraints of form and development interact to influence the manner and rate of evolutionary change?"; "how do the branches of life's tree fit together?" to mention just a few among thousands equally exciting.

In their recently aborted struggle to inject Genesis literalism into science classrooms, fundamentalist groups followed their usual opportunistic strategy of arguing two contradictory sides of a question when a supposed rhetorical advantage could be extracted from each. Their main pseudoargument held that Genesis literalism is not religion at all, but really an alternative form of science (creation science) not acknowledged by professional biologists too hidebound and dogmatic to appreciate the cutting edge of their own discipline. When we successfully pointed out that creation science—as an untestable set of dogmatic proposals—could not qualify as science by any standard definition, they turned around and shamelessly argued the other side. (They actually pulled off the neater trick of holding both positions simultaneously.) Now they argued that, yes indeed, creation science is religion, but evolution is equally religious.

To support this dubious claim, they tumbled (as a conscious trick of rhetoric, I suspect) right into Kirwan's error. They ignored what evolutionists actually do and misrepresented our science as the study of life's ultimate origin. They then pointed out, as Hutton had, that questions of ultimate origins are not resolvable by science. Thus, they claimed, creation science and evolution science are symmetrical—that is, equally religious. Creation science isn't science because it rests upon the untestable fashioning of life ex nihilo by God. Evolution science isn't science because it tries, as its major aim, to resolve the unresolvable and ultimate origin of life. But we do no such thing. We understand Hutton's wisdom—"he has nowhere treated of the first origin . . . of any substance . . . but only of the transformations which bodies have undergone . . . ."

Our legal battle with creationists started in the 1920s and reached an early climax with the conviction of John Scopes in 1925. After some quiescence, it began in earnest again during the 1970s and has haunted us ever since. (I have written more than half a dozen essays, most in this series, on the resurgence of creation science.) Finally, in June 1987, the Supreme Court ended this major chapter in American history with a decisive 7-2 vote, striking down the last creationist statute, the Louisiana equal time act, as a ruse to inject religion into science classrooms in violation of first amendment guarantees for separation of church and state.

I don't mean to appear ungrateful, but we fallible humans are always seeking perfection in others. I couldn't help wondering how two justices could have ruled the other way. I may not be politically astute, but I am not totally naive either. I have read Justice Scalia's long dissent carefully, and I recognize that its main thrust lies in legal issues supporting the extreme judicial conservatism espoused by Scalia and the other dissenter, Chief Justice Rehnquist. Nonetheless, though it may form only part of his rationale, Scalia's argument relies crucially upon a false concept of science—Kirwan's error again. I regret to say that Justice Scalia does not understand the subject matter of evolutionary biology. He has simply adopted the creationists' definition and thereby repeated their willful mistake.

Justice Scalia writes, in his key statement on scientific evidence:
You're invited to embark on a prehistoric journey millions of years back in time. Beware of the murderously equipped predator, Tyrannosaurus rex, who hurl's its five ton body after prey at speeds up to forty miles per hour. Not to mention the 75-foot, 40-ton upland dweller, the Brontosaurus, who muches nonchalantly from the tallest treetops.

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The people of Louisiana, including those who are Christian fundamentalists, are quite entitled, as a secular matter, to have whatever scientific evidence there may be against evolution presented in their schools.

I simply don't see the point of this statement. Of course they are so entitled, and absolutely nothing prevents such a presentation, if evidence there be. The equal time law forces teaching of creation science, but nothing prevented it before, and nothing prevents it now. Teachers were, and still are, free to teach creation science. They don't because they know that it is a ruse and a sham.

Scalia does acknowledge that the law would be unconstitutional if creation science is free of evidence—as it is—and if it merely restates the Book of Genesis—as it does:

Perhaps what the Louisiana Legislature has done is unconstitutional if creation science is free of evidence—as it is—and if it merely restates the Book of Genesis.

Scalia therefore admits that the issue is not merely legal and does hinge on a question of scientific fact. He then buys the creationist argument and denies that we have sufficient evidence to render this judgment of unconstitutionality. Continuing directly from the last statement, he writes:

But we cannot say that on the evidence before us . . . . Infinitely less can we say (or should we say) that the scientific evidence for evolution is so conclusive that no one would be gullible enough to believe that there is any real scientific evidence to the contrary.

But this is exactly what I, and all scientists, do say. We are not blessed with absolute certainty about any fact of nature, but evolution is as well confirmed as anything we know—surely as well as the earth's shape and position (and we don't require equal time for flat earthers and those who believe that our planet resides at the center of the universe). We have oodles to learn about how evolution happened, but we have adequate proof that living forms are connected by bonds of genealogical descent.

So I asked myself, how could Justice Scalia be so uninformed about the state of our basic knowledge? And then I remembered something peculiar that bothered me, but did not quite register, when I first read his dissent. I went back to his characterization of evolution and what did I find (repeated, by the way, more than a dozen times, so we know that it represents no one-time slip of his pen, but a consistent definition).

Justice Scalia has defined evolution as the search for life's origin—and nothing more. He keeps speaking about "the current state of scientific evidence about the origin of life" when he means to designate evolution. He writes that "the legislature wanted to ensure that students would be free to decide for themselves how life began based upon a fair and balanced presentation of the scientific evidence." Never does he even hint that evolution might be the study of how life changes after it originates—the entire panoply of transformation from simple molecules to all modern, multicellular complexity.

Moreover, to make matters worse, Scalia doesn't even acknowledge the scientific side of the origin of life on earth. He argues that a creationist law might have a secular purpose so long as we can envisage a concept of creation not involving a personal God "who is the object of religious veneration." He then points out that many such concepts exist, stretching back to Aristotle's notion of an unmo
mover. In the oral argument before the Court, which I attended on December 10, 1986, Scalia pressed this point even more forcefully with counsel for our side. He spurred:

What about Aristotle's view of a first cause, an unmoved mover? Would that be a creationist view? I don't think Aristotle considered himself as a theologian as opposed to a philosopher.

In fact, he probably considered himself a scientist: . . . Well, then, you could believe in a first cause, an unmoved mover, that may be impersonal, and has no obligation of obedience or veneration from men, and in fact, doesn't care what's happening to mankind. And believe in creation. [From the official transcript, and omitting the responses of our lawyer.]

Following this theme, Scalia presents his most confused statement in the written dissent:

Creation science, its proponents insist, no more must explain whence life came than evolution must explain whence came the inanimate materials from which it says life evolved. But even if that were not so, to posit a past creator is not to posit the eternal and personal God who is the object of religious veneration.

True indeed; one might be a creationist in some vernacular sense by maintaining a highly abstract and impersonal view of the creator. But Aristotle's unmoved mover is no more part of science than the Lord of Genesis. Science does not deal with questions of ultimate origins. We would object just as strongly if the Aristotelophile of Delaware forced a law through the state legislature requiring that creation of each species ex nihilo by an unmoved mover be presented every time evolution is discussed in class. The difference is only historical circumstance, not the logic of argument. The unmoved mover doesn't pack much political punch; fundamentalism ranks among our most potent irrationalisms.

Consider also, indeed especially, Scalia's false concept of science. He equates creation and evolution while evolutionists can't resolve the ultimate origin of the inorganic components that later aggregated to life. But this inability is the very heart of creationist logic and the central reason why their doctrine is not science, while science's inability to specify the ultimate origin of matter is irrelevant because we are not trying to do any such thing. We know that we can't, and we do not even consider such a question as part of science.

We understand Hutton's wisdom. We do not search for unattainable ultimates.

We define evolution, using Darwin's phrase, as "descent with modification" from prior living things. Our documentation of life's evolutionary tree records one of science's greatest triumphs, a profoundly liberating discovery on the oldest maxim that truth can make us free. We have made this discovery by recognizing what can be answered and what must be left alone. If Justice Scalia heeded our definitions and our practices, he would understand why creationism cannot qualify as science. He would also, by the way, sense the excitement of evolution and its evidence; no person of substance could be unmoved by something so interesting. Only Aristotle's creator may be so impassive.

Don Quixote recognized "no limits but the sky," but became thereby the literary embodiment of unattainable reverie. G.K. Chesterton understood that any discipline must define its borders of fruitfulness. He spoke for painting, but you may substitute any creative enterprise: "Art is limitation: the essence of every picture is the frame."

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.
The Four-Year Itch

Do divorce patterns reflect our evolutionary heritage?

by Helen E. Fisher

Samuel Johnson defined remarriage as the triumph of hope over experience. Anthropologists call this human habit “serial monogamy.” Americans joke about the “seven-year itch.” Call it what you will, the human penchant for divorce and remarriage is worldwide.

Among the !Kung Bushmen of southern Africa’s Kalahari Desert, for example, men and women often marry more than once. Although the !Kung are rapidly adopting Western values and twentieth-century technology, divorce is not a new development. The traditional !Kung, who were studied by anthropologists, lived in semi-permanent groups. During the rainy season, ten to thirty individuals—including couples, their children, and other kin—interacted daily. Friends and relatives traveled between communities, connecting a fluid network of several hundred people. Every two or three days some of the women of a band went collecting. They returned from their expeditions with roots, melons, nuts, berries, honey, and occasionally, small mammals, insects, and birds’ eggs. !Kung men went hunting about three days a week. Often they came home with meat: sometimes just a hare; sometimes an antelope large enough to be divided among all community members.

Sixty to 80 percent of the daily staples were provided by women; women shared the rights to waterholes in the desert, too. During their reproductive years, women held high status, and older women had an important say in community affairs. When a woman found herself in a desperate marriage, she often assembled her few belongings and departed for another camp nearby.

Sometimes !Kung couples argued for months before splitting up. Neighbors also got involved. But eventually, many unhappy marriages ended; either the man or the woman walked out. Perhaps they could do so because both partners were relatively self-sufficient. Of the 331 marriages reported by !Kung women to sociologist Nancy Howell, 134 ended in divorce. Some men and women had more than four consecutive spouses.

Divorce is also common in other societies where men and women are relatively economically independent. Among the Yoruba of West Africa, where women traditionally control the complex marketing system, as much as 46 percent of all marriages end in divorce. In highland Nepal, the Tamang give little girls a chicken or other livestock, corn, or a small amount of money and encourage them to increase this wealth. By their late teens, Tamang women often own substantial movable property and the right to distribute it. When she first marries, a young woman rarely transfers all of her livestock or other wealth to her husband’s farmland. If the marriage goes poorly, she just walks home. The divorce rate among the Tamang is also high.

The Hadza live in the rocky grasslands of Tanzania. During the dry season, men hunt impala, buffalo, and other large game, but meat is a luxury. Both men and women collect vegetable foods, which are never in short supply. Among the Hadza, marriage is a casual affair; divorce occurs when a couple cease to live together for more than a few days. Anthropologist Ernestine Friedl, reporting on research done in the 1960s, says that divorce rates are “roughly five times as high as in the United States.”

Divorce is less common where women and men are economically dependent on one another—most notably in societies that use the plow for agriculture. In such societies, spouses need each other to make ends meet. Examples are India and China and, in the past, preindustrial Europe and America. For example, in 1700 a woman living on a small farm in Massachusetts depended on her husband to move the rocks, fell the trees, and plow the land. He depended on her to sow, weed, pick, prepare, and store the vegetables. Together they worked the farm. More important, whoever elected to leave the marriage left empty-handed; neither spouse could dig up half the land and relocate. Farming women and men were tied to the land, to one another, and to a network of stationary kin. Under these ecological circumstances, divorce was not a practical alternative, and cultural mores made marital separation very difficult.

The Industrial Revolution changed this relationship between the sexes. When factories began to appear beyond the barns of agricultural America, men and women began to leave home for the workplace, bringing back money—movable, divisible property. During much of the 1800s, middle-class women still ran the home. But in the early decades of the twentieth century, American women began to join the labor force in greater numbers. With time, the steady influx of women into the job market began to give them economic autonomy; not coincidentally, the American divorce rate began a slow but steady rise. For an unhappy man will leave a wife who brings home an income long before he will desert a woman who depends on to weed his garden. And a woman with a salary may be less tolerant of marital despair than one dependent on her spouse to provide the evening meal. Since 1960, the number of women in the job market has doubled. The American annual divorce rate has doubled too. Many demographers identify
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women's employment as a prime factor in this rising frequency of divorce.

The relationship between rising divorce rates and female—male economic autonomy has been seen before in Western culture. Shortly after the Romans conquered Carthage in the third century B.C., an urban upper class emerged. Wealthy Roman patricians were apparently no longer willing to let massive dowries pass into the hands of potentially errant sons-in-law, as was customary under the traditional religious marriage forms. Instead, they married off their daughters in civil unions, and the women themselves were able to control their fortunes. As a class of economically self-sufficient women emerged in ancient Rome, the divorce rate soared.

Since 1947, census takers in places as culturally dissimilar as South Africa, Morocco, Japan, the Soviet Union, Greece, El Salvador, and the United States have periodically asked about divorce. Among their survey questions are: How many years were you married at the time of your divorce? How old were you when you divorced? How many children did you have when you divorced? These data, compiled every decade by the Statistical Office of the United Nations, present a surprisingly consistent global picture.

Most striking, in a sample of fifty-eight populations where data are complete, there are three divorce peaks—among couples married for four years, among people between the ages of 25 and 29, and among couples with no children or one dependent child. Although the data are not sufficient to show the relationship between these three peaks, the relatively high frequency of divorce after about four years of marriage probably accounts in large part for the divorce peak among couples with one or no children. The risk of divorce for men and women in their late twenties is always high, however, regardless of where the divorce peak falls with respect to numbers of years married.

The three-peak pattern appears unrelated to high or low divorce rates. Finland is a typical example. In the 1950s, the divorce rate was relatively low; it has risen steadily since. But the "profile" of divorce has remained almost the same. In 1950, divorces peaked among couples married four years and among women aged 25 to 29 and men aged 35 to 39. Seventy-one percent of divorces involved couples with one dependent child. In 1966, divorce peaked after the third year of marriage, then shifted back to the four-year peak in 1974 and 1981; for these years, the peak for men and women was in the 25 to 29 age group. The overall pattern remained remarkably similar in all four decades, despite a doubling of divorces. With some variation, this pattern is seen around the world. Across the United Nations sample, an average of 48 percent of the divorces occur within seven years of marriage; they cluster around the four-year peak. So divorce commonly occurs early in marriage, among couples at the height of their reproductive and parenting years.

A comparable statistical breakdown of divorce practices is not available for most so-called primitive cultures. But anthropologist Napoleon Chagnon recently
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began studying the “decay rate” of the nuclear family in thirteen Yanomamö villages along the upper Orinoco River in Venezuela. He reported that among these hunters and gardeners, nearly all children younger than five lived with their natural mother; the majority had their biological father living with them too. But the cohabitation of biological parents declined sharply among children older than five.

This divorce pattern among the Yanomamö is consistent with the United Nations data on fifty-eight industrial and agricultural peoples. And it is difficult to attribute this pattern to the forces of society. These peoples vary widely in religion, social structure, economy, political views, and per capita income. Why are their divorce profiles similar?

There is a possibility that the common pattern is a result of brain physiology. Psychiatrists divide the love between a man and woman into two fundamental stages: the “attraction phase” and the “attachment phase.” During the attraction phase, infatuation engulfs lovers with giddiness, euphoria, optimism, and energy. Michael Liebowitz, a psychiatrist at the New York State Psychiatric Institute, thinks these feelings may be caused by increased activity in the brain of phenylethylamine or other natural brain stimulants. John Money, a sexologist from Johns Hopkins University, suggests that among lovers who see each other regularly, this stage of intense emotion can last only about two or three years—long enough, however, to foster pregnancy.

Liebowitz theorizes that the brain’s tolerance for these natural aphrodisiacs grows, eventually dulling the sensation of intense infatuation. Now stage two, the attachment stage, sets in. This is the stage of peaceful, secure, comfortable love that so many couples report. Liebowitz suspects that the attachment stage is associated with a different set of brain chemicals, the endorphins—the opiates of the mind: “Biologically, it appears that we have evolved two distinct chemical systems for romance; one basically serves to bring people together and the other to keep them together.” He attributes these systems to our evolutionary heritage.

But Liebowitz cautions that even with this brain circuitry, “if you want a situation where you and your long-term partner can still get very excited about each other—you have to work on it. In some ways you are bucking a biological tide.”

Nature seems quite determined that we fall in love; she has dedicated less evolutionary energy to maintaining that state. Anthropologists have, in fact, argued about the essence of the human pair bond for decades. Some think it does not exist. They will tell you that less than one-fifth of human cultures practice monogamy, while more than four-fifths permit men to have several wives simultaneously. But in the vast majority of these polygynous cultures, only about 10 percent of men actually have more than a single wife at one time; moreover, women in polygynous households marry only one man at a time. So monogamy—a mating and marriage system in which an individual forms a social, economic, and sexual union with a single member of the opposite sex at one time—is pretty standard for the human species.

This is not to say that spouses are necessarily faithful to each other; monogamy does not imply fidelity. In the late 1940s and early 1950s, Alfred Kinsey and his colleagues estimated that, based on their sample, about one-third of all American married men and about one-fourth of American married women were sexually unfaithful to their spouses. Since then these statistics have gone up. And American patterns of adultery are not unusual; extramarital affairs are reported in many cultures, even where participants are punished with death. But records taken by the United Nations show that an average of 93 percent of women and 92 percent of men in industrial and agricultural societies marry. The ethnographic literature confirms that marriage is nearly universal in traditional societies.

And in cultures where divorce is common, so too is remarriage. The U.S. National Center for Health Statistics has projected that, if current trends continue, 47.4 percent of all first marriages that were contracted in 1974 will end in divorce. But Andrew Cherlin, a sociologist at Johns Hopkins University, reports that about five out of six men and about three out of four women who divorce remarry, half the time within three years. Statistics on marriage and divorce recorded in other countries, as well as anthropological data on traditional societies, indicate that remarriage among couples of reproductive age occurs regularly.

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Monogamous species practice this reductive strategy for several reasons. Gibbons, primate relatives of ours, probably originally evolved monogamy for an ecological reason. In the jungles of Indonesia the resources are so scattered that two females cannot raise their young in the same home range; therefore they must spread out. A male and female pair up shortly after puberty and establish a permanent territory containing fresh water and a few dispersed but continually renewing fruit trees. Here they mate for life, raising their young and defending their small home range. In a fundamental respect, a man and woman living on a small farm in Massachusetts in 1700 displayed the same mating strategy—marrying for life and raising their children on a small plot of land with a continually renewing food supply.

Monogamy is also common in species where more than one parent, the female, may be needed to rear the young successfully. Females of some species bear many infants at once or bear young that are altricial (relatively undeveloped). The female red fox, for example, may deliver too many pups to raise by herself. The male and female form a pair bond in winter and raise a litter together during the spring and summer months. But as autumn leaves pile up around the den, and the young begin to wander, the parents split up to forage independently. The bond only functions to raise the young.

The formation of bonds in association with a breeding season is also common among birds. Most birds bear altricial young and form pair bonds to raise them. Half of this group, like the robin, form a pair bond that lasts only through the breeding season. Some pairs stay together and raise more than one brood in the same season. But after the last fledglings leave the nest, the parents split up. And they do not always mate with the same partner the following year.

Human beings have some things in common with robins and foxes. Human females bear altricial babies and need help in caring for them. Moreover, they do not necessarily mate for life. In societies where men and women are not economically dependent on one another, some bond serially—typically dissolving their marriages after about four years.

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often, passing the critical trait to bear highly immature infants across the eons to women around the world today.

Exactly when this occurred has still to be settled. Recent comparisons of growth patterns in the teeth of modern humans with those of fossil hominids suggest that it was one and a half million years ago or even more recently. But other data on dental growth support the conclusion that females bore babies in the human pattern by two million years ago. In either case, along with this fundamental change in female reproductive physiology must come some modern human mating patterns. Why? Because small groups of these early females, encumbered with infants, were walking through the dangerous grasslands of Africa, from nut grove to berry thicket to fishing pond. They must have begun to need a mate to help feed and protect the helpless babies, and pairing between male and female was the solution. The brain physiology of infatuation and attachment—all of the mechanisms that initiate and maintain a bond today—must have evolved with monogamy.

But I see no reason why these early human pair bonds always needed to be permanent. Once a child had been weaned, it could join play groups or become the responsibility of several community members. Why should a couple necessarily remain together unless a second infant was conceived? While there may have been strong evolutionary selection for couples to remain together at least long enough to raise a single baby through infancy, there may have been no stringent selection for permanent monogamy during the reproductive years.

Americans idealize lifelong marriage; they equate divorce with failure. But among our ancestors, there may even have been biological advantages to changing mates during the reproductive years. For instance, a prehistoric male who “divorced” his partner after seeing one offspring through infancy would have had the opportunity to pick a younger “spouse” more capable of bearing and raising babies. A female might leave one mate to “marry” a better provider for her and her forthcoming children. More significant, a male or female who changed mates during his or her reproductive years would have produced genetically more varied young, probably enhancing the likelihood that his or her lineage would survive in fluctuating environments.

There may have been cultural advantages to divorce and remarriage, too. Edward Tylor, one of the founding fathers of anthropology, observed in 1889 that “among tribes of low culture there is but
one means known of keeping up alliances, and that means is inter-marriage." More recently, Ernestine Friedl of Duke University noted that in horticultural societies, where men and women garden without the plow, divorce is extremely high, particularly for first marriages arranged by the kin of the married couple. She reports that, nevertheless, there are few permanent negative consequences of divorce for the couple involved or their kin. If this is the case, why not marry more than once and create associations with two or more neighbors?

Similarly, for early human groups, serial monogamy, as opposed to lifelong bonding, would have extended ties. Contemporary observers have commented on the growing role of the "new" extended family, which includes stepparents and other steprelatives. Given the hypothesis that serial pair bonding evolved on the grasslands of Africa two million years ago, these multiconnected households are not new at all.

I am not suggesting that ancestral couples consciously engaged in serial monogamy to further their genetic lines. They probably fell in and out of love for many of the same psychological reasons we do today. But those who did change mates bore genetically more varied children that grew up in environments of extended cultural resources. These young survived disproportionately, passing to modern humankind our nagging restlessness during long relationships, our penchant for divorce, and our perennial optimism about our next relationship.

I also do not wish to suggest that lifelong monogamy was an inferior reproductive strategy. Permanent relationships between compatible partners, in the right ecological circumstances, must have had genetic and cultural payoffs too. Today, about half of American marriages last for life, and about half the spouses are faithful to their partners. Human beings are certainly capable of enduring relationships, particularly as they age. In fact, other things being equal, the statistics bode well for the American family. America is getting older. Our huge baby boom generation is in its late thirties and early forties, past the age of highest divorce risk. As this large group moves beyond its reproductive years, we may experience a few decades of relative family stability.

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It's Worth Investigating.
At the American Museum

Ancient Eskimo Ivories of the Bering Strait

Ancient Bering Sea Eskimos developed a sophisticated maritime society that flourished from the third century B.C. to A.D. 1200. The artistic tradition that this culture created along the shores of the Bering Strait is the focus of an exhibition at the American Museum of Natural History organized by the American Federation of Arts. The exhibition, made possible by a grant from the Exxon Corporation with additional assistance from the National Endowment for the Arts, will be at the Naturemax Gallery from Friday, October 9, to Sunday, January 3. The ivories on display are from collections in England, Denmark, France, and the United States, including some from the Museum’s own collection. Some of the human and animal figures may have been used for ceremonial purposes and have motifs that reflect shamanic beliefs. Other objects are tools, such as harpoon fittings. Three distinct Old Bering Sea periods will be represented, as well as the Ipiutak and Punuk styles.

Africa Month

October is Africa Month at the Leonhardt People Center. Each weekend will celebrate the cultural achievements of African countries. Among the programs will be dances of the Mandinka, Ghanaian highlife music, West African sign painting, and a marionette display. Lectures will cover such topics as the African marketplace, apartheid in South Africa and its effect on neighboring countries, African family life, and the role of women in African societies. Demonstrations and performances will be repeated several times during Saturday and Sunday afternoons. Programs are free to the public and seating is on a first-come, first-served basis.

The African Revue, which showcases ancient and modern aspects of Africa’s diverse ethnic groups, will be presented on Wednesday, October 28, at 7:30 P.M. in the Main Auditorium.

A three-part program exploring African art and its influence on twentieth-century art in the Americas will take place Wednesday, October 7; Wednesday, October 14; and Wednesday, October 21, at 7:00 P.M. in the Kaufmann Theater. For a complete schedule of events call (212) 769-5315.

The Rainbow Road Dancers

With a dazzling display of music, costumes, and special effects, The Rainbow Road Dancers will perform on Sunday, October 18, at 1:00 and 3:00 P.M. in the Kaufmann Theater. This program for children ages 5 to 12 features a combination of modern dance and theater pieces. "Origins," a dance inspired by exhibits at the American Museum, portrays the evolution of life on our planet, from sea-dwelling invertebrates to humans. "Colors," featuring jazz music and prose recitations, explores rainbows, the color spectrum, and the relationship between color and mood. The 45-minute program encourages audience participation. Tickets are $2.50 for members and $5 for nonmembers. For further information call (212) 769-5600.

Ghost Stories

Storyteller Laura Simms returns to the Museum with an all new program about restless spirits, magic, and witchcraft. Friday, October 30, at 7:30 P.M. in the Kaufmann Theater, a program for adults features a Tibetan tale of a talking corpse, which was told to Simms by a lama; a Russian fairy tale about the mother of death; and a North African epic of a buffalo panther woman. A special program for children, from age six up, takes place Saturday, October 31, at 1:00 and 3:00 P.M. in the Kaufmann Theater. A Hallowe'en tradition at the Museum, Simms’s programs have enthralled sold-out audiences for the past six years. Tickets are $3 for members and $5 for nonmembers. For further information call (212) 769-5600.

At the Planetarium

Parisian Michel Deneuve will perform works by Mozart, J.S. Bach, and Erik Satie on a glass instrument called La Crystal. At the touch of moistened fingers, La Crystal sounds similar to a violin. Deneuve, who has performed in European planetariums, marks his New York planetarium debut with this concert on Tuesday, October 20, at 7:00 p.m. in the Planetarium Sky Theater. Visuals, including a live television projection of the musician performing against the starry sky, will accompany the music. Tickets are $5 for members, $8 for nonmembers.

Dinosaurs Past and Present

By drawing inferences from fossil data and making analogies with modern animals, paleontologists have speculated that dinosaurs were active, care-giving animals. Dinosaurs Past and Present, an exhibition of dinosaur paintings, illustrations, sculptures, and models, will be in the Museum’s Gallery 1, October 9 through January 3. Realistic portrayals of dinosaurs in their natural habitat (by Charles Knight and Benjamin Waterhouse, among others) will be on display.
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Devils Hopyard, New Hampshire

by Robert H. Mohlenbrock

Having driven to the northern tip of New Hampshire's White Mountain National Forest, I stopped at South Ponds, only thirty miles from the Canadian border. A sign that pointed down an inviting trail to the "Devils Hopyard" immediately intrigued me. Following a ravine forested with American beeches, sugar maples, and other hardwood trees, and a sprinkling of hemlocks, red spruces, and balsam firs, I walked for half a mile, occasionally crossing a meandering rivulet on slippery submerged stones. Then unexpectedly happened: around a sharp curve, the slope on either side abruptly narrowed the trail, narrowing the canyon floor to only seventy-five feet. Scattered across the canyon floor were countless boulders left by Ice Age glaciers. Some were feet high, others smaller, and each covered by the most prolific growth of mosses I had ever encountered outside the tropical rain forest. The lower part of the tree trunks in the canyon were also covered by mosses.

Thriving moss was a rather large species, *Plococinium splendens*, whose segments were arranged in flattened sprays above the other. Howard Crum and Langdon, in their encyclopedic work *Mosses of the United States*, proposed "step moss" as the common name for this species. Each spray represents one moss. Unlike most mosses, step moss can grow ramified if conditions are favorable; in the forests of Sweden, it often forms dense carpets.

Like other plants, mosses manufacture food through photosynthesis in their roots and a vascular system of each moss plant, called rhizoids, more than hairlike tubes, or chlorophyll cells, that anchor the plant to the substratum. All photographs by James Jonn.
Devils Hopyard

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moss to whatever it is growing on. There is little evidence that these rhizoids are responsible for the mosses’ intake of water and dissolved minerals. Instead, this function is left to the mosses’ “leaves” (technically termed microphylls), which are mostly only one cell thick.

Because moss leaves lack the waxy cuticle that covers the leaves of most other plants, they are able to absorb even tiny amounts of moisture, such as a drop of dew. But without the protection of a cuticle, they are also in constant danger of drying out. Most mosses thus do best in moist, shaded areas. The arrangement of their leaves maximizes their ability to capture moisture as well as the light needed to carry out photosynthesis.

A moist habitat is also vital for reproduction in mosses, which form swimming sperm cells. Usually a drop of dew is all that is required for the sperm to reach the egg, since both are formed at the base of the uppermost leaves of the plant. Like ferns, mosses alternate between a sexual generation, which reproduces through male and female gametes, and an asexual generation, which reproduces via spores. The familiar, conspicuous ferns belong to the asexual generation, and the sexual plants are tiny and inconspicuous. Among mosses, however, the familiar plants are usually reduced to a stalk and a spore-bearing capsule that protrudes from the top of the plant.

Plants with vascular tissues are able to conduct water and minerals for considerable distances—more than 300 feet in the case of the tallest redwood trees. Since mosses lack these special conducting tissues, they can transport materials only very short distances. Consequently they can attain only a “Lilliputian form of growth,” as described by John Bland in his popular book Forests of Lilliput: The Realm of Mosses and Lichens. Entire moss plants may range from only one sixteenth of an inch to just a few inches in height. Little wonder that they rarely dominate natural habitats.

The unusual abundance of mosses at Devils Hopyard may be due to a number of favorable conditions. Nancy Slack of Russell Sage College, studying mosses in similar habitats in the Adirondack Mountains of New York, discovered that mosses tend to do well on acidic substrates where there is much shade, late snow cover, and high humidity. At Devils Hopyard, the needles that drop from the red spruce, balsam fir, and hemlock trees provide an acidic environment, and the density of the trees in the narrow ravine provides the deep shade required for lush growth.

Snow, which often blankets the area until late spring, increases the humidity. Finally, the far end of Devils Hopyard closed by ever larger and more numerous boulders, forming a box canyon. With its ravine closed in on three sides, high moisture is maintained throughout the year.

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Seals Under the Sun

Most of the time, a Galápagos fur seal mother manages to care for herself and her young, but occasionally she finds herself in hot water

by Fritz Trillmich

Gliding in through the crest of a wave, a Galápagos fur seal mother lands on a rock just as an incoming breaker touches the lava shore. She swirls around to meet the following roller head-on, then climbs a few steps higher onto the next boulder. There, out of the surf’s reach, she sits and grooms for a while before uttering a highly distinctive, drawn-out call. Over the last ten years, I have tape-recorded and listened to these calls innumerable times, even coming to recognize a few females by their voices. The call begins with a low sound and ends in a high-pitched scream that penetrates the noise of the waves crashing around her. She is calling her pup, which she left ashore some forty-eight hours ago.

The pup has spent its time alone playing and resting near the spot on shore where it last was with its mother. Now, if not asleep, it will respond with an equally distinctive call of its own. Calling repeatedly, mother and pup move toward each other. It is no easy task for a little pup to pass through rugged terrain strewn with lava boulders, many the size of a human head, some as big as a cottage. Many a crevasse has to be crossed, and unfriendly adults may threaten as the pup tries to approach its mother.

When the two finally meet, the mother sniffs the pup to make sure it is really her own. Satisfied, she settles down and allows it to nurse. No stranger is allowed to take the precious fat-rich milk. Seal milk ranks among the most nutritious of mammalian milks. Cow’s milk, with 3.7 percent fat and 3.2 percent protein, seems weak indeed when compared with milk of the Galápagos fur seal, which consists of a remarkable 25 percent fat and 12 percent protein. And even this pales next to milk of the northern fur seal, which weighs in at 42 percent fat and 14 percent protein.

Mother and pup find themselves in an inhospitable environment for marine mammals. Farther south, fur seals of subpolar seas only rarely see the sun. There, overcast skies, sheets of rain, and howling winds are commonplace, and the thick fur coat and heavy blubber layer typical of marine mammals are a boon. But in the Galápagos, where the strong equatorial sun beats down on a hot lava desert, fur and blubber become a tremendous burden, at least as long as the animals are ashore. Mornings—the usual time for mothers and pups to get together—may start out cool enough, but both fur seals and rocks heat up rapidly. The seals soon move off to find wet rocks or a shady site, often under a cliff overhang or between huge boulders. Only then can the pup feed on the several hundred grams of milk that its mother has produced during her foraging trip. Because other females may be attracted to the same sites, disturbances are frequent.

Newborns have an even harder time resting peacefully with their mothers. When their pups are very young, mothers do not stay close to the water’s edge for any length of time, for there a newborn may cool down fast and is also in constant danger of being washed away. At this stage, mothers and pups shuttle back and forth between wet, cool rocks close to the waves and dry, hot lava where the pup is safer. For the mother, resting near the water is most comfortable, but the pup is frightened there; high up on land the pup can find little holes for shade, but its mother cannot tolerate the heat for long. Often the conflict between the mother’s and the pup’s thermoregulatory demands is resolved when the pup disappears into a little hole that provides just enough shade for it. There it goes to sleep, refusing to respond to its mother’s calls. The mother then leaves and cools off by swimming for a short while in front of the colony, but she returns regularly to check on her pup’s well-being. Only in the evening, when temperatures drop off rapidly, will mother and pup be able to nurse and rest without having to move or suffer interruptions.

For fur seals of the Galápagos archipelago the water is not nearly so stressful as the land. Although the islands straddle the equator, the ocean around them is relatively cool—not even warm enough for coral reefs to grow—thanks to trade winds from the southeast that drive cool water masses, known as the Humboldt, or Peru, current toward the archipelago. This shallow current, along with an upwelling of cold water around the western side of the islands, produces a climate that is almost
Responding to its mother’s call, a Galápagos fur seal pup cries out in its own distinctive voice. To identify a pup as her own, a female relies on both sound and scent.

Fritz Trilloch
temperate during the June-to-December cool season. From December to June, however, trade winds slacken, local upwellings decrease, and much less cold water comes into the archipelago. During this warm season, sea-surface temperatures increase and the productivity of the ocean falls, resulting in much less plant and animal life. Production drops for two main reasons. With less upwelling, fewer plant nutrients rise up from the rich depths of the sea. And as the season progresses, local warming thickens the warm surface layer of the sea, and the fishes and squid on which the seals feed are more dispersed, thus becoming harder for the fur seals to catch.

Galápagos fur seals reproduce during the cool season, when the young and their mothers are least apt to suffer from the heat. And perhaps more important to a mother seal, needing both to recover from giving birth and to begin producing copious quantities of milk, food is most plentiful then.

Its rugged habitat made the Galápagos fur seal's recovery from nineteenth-century sealing so inconspicuous that the scientific community did not know much about the species until recently. Indeed, when I arrived in 1976, I was not sure whether enough animals were left to make a study of their behavioral ecology worthwhile. Fortunately, I was told by people from the Charles Darwin Research Station, and soon found out for myself, that the animals were abundant, particularly along the western coasts of the archipelago. My good luck continued as I found the ideal study site: Cape Hammond, on Fernandina Island. This proved to be the only place in the Galápagos where a camp could be built on sand (preferable, by far, to rock-hard, jagged lava) and right behind a dense fur seal colony.

The colony is dense only by Galápagos standards. Six to ten adult females may populate a 1,000-square-foot section of coast, a mere sprinkling in comparison with the crowded colonies of subpolar fur seals, which may be ten times as crowded. Other warm-climate species—the Guadalupe, Juan Fernandez fur seals, and the Peruvian population of the South American fur seal, for example—are not very numerous either. And neither is the Galápagos sea lion, the archipelago's other pinniped, although it may seem more numerous to tourists. (Sea lions are found throughout the Galápagos and because
Lava heats up rapidly under the equatorial sun, and after a brief cool period in the morning, mother and pup, left, move off to a wet or shady spot to nurse. Peace is hard to find, however. Often two generations of siblings try to nurse at the same time, below, and even though the mother intervenes repeatedly, the youngest born, unable to compete, often starves.

Both photographs by Fritz Tönnies

...they prefer flat, sandy or rocky beaches, they are far more conspicuous. These animals have found an elegant solution to the problem of heat stress: they simply stay close to water at places where even small pups can enter without being endangered by heavy surf. The males defend territories from the water along the shorelines where mothers give birth. This keeps them from overheating even when fighting or copulating.)

The sparsity of pinnipeds living in warmer waters is probably related to their food supply, which is never as rich as that of the subpolar seas and is sometimes dramatically unreliable. This idea was brought home to me in a most forceful manner during the 1982–83 warm season. In some years, toward the end of December—as the cool Humboldt current is already slackening—warm water known as El Niño flows into the coastal and equatorial oceans off Peru and Ecuador. The 1982–83 El Niño was particularly strong, and surface temperatures of the water warmed up to 88°F—from a norm of 63°F. When the water is this warm, the food supply plummets, and Galápagos fur seal mothers may be away for ten days or more. The desperate young soon begin to look like bags of bones and try to steal milk from other mothers. I once observed one of these skinny little creatures sneak up to a strange female, sitting still when she raised her head and inching forward again as she rested. When the pup finally reached the teat and began to suck, the female woke up snarling. The pup, weakened by hunger, was bitten before it could reach safety.

During the nine-month-long 1982–83 El Niño, pups, one- and two-year-olds alike, soon succumbed to the lack of food, and one-third of the adult animals also died of starvation. Recurrent El Niño events—although usually not as strong as the 1982–83 catastrophe—may well keep the population at a low level.

All eared seals (the fur seals and sea lions) bear their pups ashore. For the first week, a mother is with her pup constantly. Then, one evening, she quietly slips away, often when the pup is sleeping. While the well-fed pup sleeps off its bellyful of milk, the mother swims out to sea and forages. How she manages to catch fish and squid at night in the open ocean is not entirely clear, but apparently her large eyes and the sensitive, whiskerlike hairs around her mouth enable her to see and catch these organisms even in almost complete darkness. When she returns to the pup the next morning, she looks a bit rounded out.

As the pup grows older, the mother falls into a routine of one to three nights hunting away from the pup and then a day or two with it, nursing and resting. Subpolar fur seal species tend to spend more time away from their pups, about a week. They make up for their reduced time with their young by providing them with a milk much richer in fat content.

Not all seal mothers have to shuttle between land and sea to replenish their body stores while nursing. Elephant seals and other phocid (true) seals gather a huge store of fat reserves before they come ashore to give birth. This store pro-
vides both fuel for their metabolic needs and raw material for milk production so that they can stay on land, continually lactating, for a few weeks. When the reserves are spent, the pup is weaned rather abruptly and the mother leaves to restore her reserves.

Among fur seals, the Galápagos species takes the most time to wean its young. South African and New Zealand fur seals have been observed nursing yearling offspring, but in most species, the nursing period is much shorter. Subpolar fur seal pups often wean themselves at about four months of age, when they leave the breeding beaches on their own. Mothers may return once or twice, looking for their young. At any rate, the mother–pup bond is dissolved by summer’s end, for these seals—unlike the Galápagos fur seals—are migratory. They spend the next eight months swimming about in the open sea. The northern fur seals migrate as far south as California, feeding on small schooling fish and squid. Antarctic fur seals live on krill, small shrimplike organisms plentiful enough to feed even the whole blue whale population in its heyday.

All fur seals, regardless of weaning time, maintain a regular yearly cycle of reproduction. They copulate about one week after giving birth, but implantation of the fertilized egg is delayed three to four months, at which time embryonic development begins. Gestation is roughly eight months, so sibling pups are born about one year apart. When I first began to study the Galápagos animals, I observed that very big juvenile animals regularly met their mothers and nursed. Marking of pups and yearlings soon proved that many juveniles accompanied their mothers for two or three years. Apparently, weaning age increases as latitude decreases, from four months in the subpolar fur seals, to eight to twelve months in fur seals of temperate areas, and then to the record of twelve to thirty-six months in the Galápagos, right on the equator.

Sometimes, Galápagos fur seal pups of two different years try to nurse at the same time. In 1977, I camped for the first time on Fernandina during the fur seals’ reproductive season. One night I was wakened by the incessant calls of a young and its mother, intermingled with the almost continuous bleating of a very young pup. The next morning, I found a mother with a newborn accompanied by her yearling. The yearling was fighting for access to its mother’s teats, while the mother was trying to keep it away and nurse the newborn. The yearling screamed again and attempted to move around to its mother’s teats (there are four) or to reach over her and bite the newborn. Although the mother often tried to place herself between her two young to protect her younger pup, the older sibling often succeeded in displacing the baby at her teats.

Older pups soon learn that mothers allow them to nurse as long as the newborn is quiet or not within reach. Often, the older sibling then becomes even more aggressive. The tough little pup tries time and again to get back to its mother and nurse, but the struggle takes its toll. Slowly, the younger seal weakens, and eventually dies from sun exposure or starvation. Over the years, I witnessed one young fur seal outcompete two of its later-born siblings, first when it was a yearling and then when two years old. Only in the third year was its mother able to raise another pup without interference by her previous young.

To learn why fur seal young take so long to become independent in the Galápagos, I obviously needed a better understanding of the ecology of the species. As a first step, I investigated the fur seals’ diving habits. Since I could not follow them out to sea at night, I asked Gerald Kooyman of the Scripps Institution of Oceanography for his help. He has developed a mar-
Unlike the phocid, or true, seals, Galápagos fur seals have external ears, relatively flexible necks, and powerful front flippers capable of supporting the weight of the body and moving it up jagged lava slopes, left. Below: Life in the harsh Galápagos land environment is not without its diversions. This fur seal pup entertains itself by harassing a marine iguana.

Fred Brummer

The velous little instrument, called the time–depth recorder, which when put on a fur seal’s back, continuously records the time and depth of the animal’s dives for ten to fourteen days. Before Kooyman came to my aid, I had thought that the fur seals might be deep divers. I based my speculation on the animals’ limited distribution: they establish colonies only along coasts where deep water, 200 fathoms or more, is nearby. Maybe they were hunting deep down below the thermocline (the layer of water separating the warmer, surface zone from the colder, deep-water zone). But when Gerry arrived in the Galápagos and placed the first few time–depth recorders on females, we found out that my speculation had been wrong. A single recorded dive to 345 feet proved that the fur seals were capable of very deep dives; most of the time, however, they were diving no more than 30 to 120 feet. Interestingly, while almost all the seal dives took place at night, the sea lions quite sensibly left their home beaches when it got hot and did most of their diving during the day. Apparently, some kinds of food are accessible during the day but are not taken by fur seals.

What then were the fur seals feeding on? We speculated that organisms from what is known as the deep scattering layer might contribute most of their food. When sonar from echo-sounding equipment hits the sea floor, the sound waves scatter. Frequently, echo soundings show a “false bottom,” which fishermen know is composed of squid and schools of fish that spend the day at that depth—presumably to avoid predators that hunt by sight—and migrate toward the surface during the night to feed on plankton. If fishermen know this, I figured, seals most likely do too. To find out, Thomas Dellinger, of the Max-Planck Institute, joined me in an analysis of the hard remains in fur seal scats. We soon confirmed my suspicions: the seals were eating such exotic species as lanternfish and deep sea stints (bathylagid fish), which are known to live in the deep scattering layer.

Complementary evidence has come from studies of Antarctic fur seals, in which scientists have observed how the distribution of prey influenced predators. The seals matched the depths of their dives to the movements of the krill, which rise toward the surface at night. They dived deep toward the rising krill in the evening, were working almost at the surface by midnight, and dived deeper again shortly before sunrise, following the krill as they sank to safer depths.

How can this knowledge help us understand the unusually long time it takes Galápagos fur seals to wean their pups? I think the January-to-June warm season plays a crucial role in keeping young fur seals dependent for so long. Imagine the following sequence of events over the fur seal year. A pup is born in October. Mother finds plentiful food nearby in the cold, upwelled waters and returns to her pup every two to three days to nurse. The little pup grows rapidly, gaining perhaps two ounces a day. This growth rate is similar to that of subpolar fur seals and, if sustained, should lead to early weaning.
A fur seal, below, uses its long front flippers to propel itself through the water, seemingly without effort. Right: The islands’ other pinniped, the sea lion, is also most at home in the water. In fact, unlike young fur seals, this pup (left) and the yearling inspecting it (right) seldom stray far inland, remaining in the water or close to the edge at all times.

C. Lockwood; Bruce Coleman Inc.

But as we have seen, with the beginning of the warm season in December, the mother seal often must forage farther for less food. Moreover, the quality of the fish she catches is inferior, containing less fat and protein than do cold-season fish.

The mothers respond almost as if the warm season were a mini-El Niño, staying away from their pups for four to six days and then returning to shore for just a day before leaving again. At these times, the colonies can seem almost deserted much of the time. With their food supply so diminished, the five- to six-month-old pups—which by now weigh seventeen to twenty-two pounds—hardly grow at all. They spend all their time near the colony, apparently making no effort to feed themselves. A fur seal pup, unable to hold its breath for more than a minute or two, is a much poorer diver than its sixty-five-pound mother and would likely use up more energy hunting for food than it would derive from anything it might catch. Left on its own at this time, the young seal would perish, so the mother continues to slave for her big pup.

Her efforts are costly. Not only may older pups outcompete younger ones, but they may also keep the mother from reproducing that year. The energetic expenditure of hunting under adverse food conditions for both themselves and large, hungry juveniles is apparently so stressful to many females that they do not manage to implant or develop a fetus while lactating. They thus lose the opportunity to reproduce in the cool season. This same sequence of events can occur the following year, too. Now nearly a year and a half old, the juvenile will be hunting on its own by then but may still have a difficult time finding enough food during the warm season. If its mother has to contribute further milk to sustain the juvenile during this stressful period, she may again fail to reproduce.

Surviving a normal warm season with dependent young is difficult enough, but on top of this, Galápagos fur seal mothers are periodically faced with the severe warm season effects of an El Niño year. On average, El Niño comes along every three years, but the exact time is almost as unpredictable as an earthquake. And when El Niño does happen, its strength varies tremendously from one occurrence to the next. Thus, mother fur seals can do no better than be prepared for both the worst and the best. Maternal behavior that is flexible enough to carry young through tough times but wean them when food is abundant would produce the most surviving young. This is apparently what female Galápagos fur seals do.

In my ten years of study, I have witnessed both the best and the worst, from a seal mother’s perspective. In 1982–83,
during the strongest El Niño of this century, all pups, yearlings, and two-year-olds starved in a sea as warm as bath water. In striking contrast, 1985 was a very good year. It was a cold, windy year with a warm season much cooler than usual. The low temperatures, combined with a lack of rain that led to the death of many cattle in the dried-out highlands, caused many of the Galápagos people to complain, but the seals fared unusually well. Almost all the yearlings were weaned before the next generation of pups was born; the mothers therefore had the luxury of nursing their newborns without interference from the older young.

Years like 1985 may make up for the hard times and may help explain why the Galápagos fur seal has retained the typical annual reproductive cycle of other fur seals, rather than evolve a two-year cycle. For these seals, the opportunity to wean their pups before the next are born may not arise very often, but cold, food-rich years do occur, however occasionally, and when they do, the seals are ready to take advantage of them. Since her reproductive life span may be no more than ten years, the female Galápagos fur seal cannot afford to sit idly by.
Solar-powered Animals

Some nudibranchs raise plants inside their bodies and live off the harvest

by William B. Rudman

One of the most intimate relationships between an animal and a plant developed in the shallow, sunlit seas of the tropics. There, reef-building corals (and some other coelenterate animals) evolved symbiotic associations with zooxanthellae, single-celled algae that drift in the upper layers of the ocean. The corals grow the algae within their bodies, living off of the sugars and other nutrients that their algal tenants produce during photosynthesis. Without the extra energy supplied by their "guest workers," the tiny coral animals would not be able to build the massive coral reefs of the tropics.

Some years ago, while doing fieldwork along the coast of East Africa, I discovered a number of coral predators, nudibranchs that had also evolved a form of self-contained agriculture and were also growing zooxanthellae in their bodies. Nudibranchs—also known by the less flattering name of sea slugs—are essentially shell-less snails that feed on corals and other coelenterates, such as hydroids and sea anemones.

The species I discovered were aeolids, a nudibranch suborder whose members have elongated bodies with tubular outgrowths, called cerata, along their sides. The blood-filled cerata act as gills and also contain a long branch of gut. Recent discoveries in Australia show that several other aeolid nudibranchs have independently evolved the ability to grow zooxanthellae within themselves.

The blue dragon, Pteraeolidia ianthina, is a well-studied aeolid commonly found just below the tidal zone off the coast of southeastern Australia. Local divers named it because of its blue stripes and its resemblance to the sinuous dragons of Chinese festivals.

The blue dragon starts life as a small white slug living on or near the hydroids it eats. At an early stage, it consumes a hydroid polyp containing a few zooxanthellae, then stimulates them to grow rapidly and multiply. The blue dragon gradually darkens as it develops a brown layer of plants just beneath its skin. At this stage the nudibranch moves away from its hydroid

Before ingesting its first algae-bearing polyp, the juvenile nudibranch known as the blue dragon, above, is completely white. Later, the rapid growth of symbiotic algae in the gut produces a dark layer just beneath the surface of the skin, right.

All photographs by William B. Rudman
food and seldom if ever returns, seemingly able to live on the nutrients milked from the photosynthesizing zooxanthellae in its tissues.

To accommodate large numbers of plants in its body, the blue dragon evolved a greatly modified gut, adding fine, plant-filled branches throughout its body just below the skin. Nudibranchs also adapt to zooxanthellae symbiosis by greatly increasing their surface area. The blue dragon is quite long, with fanlike clusters of cerata that do not shade each other.

The cerata of another large tropical aeolid, *Phyllodesmium longicirra*, have evolved into huge, flattened paddles. Discovered in Indonesia, this nudibranch is more than six inches long with brown rings all over its body. It was first described at the turn of the century by the Swedish naturalist Rudolph Bergh, who received an illustration and specimen of the creature and thought it so unusual in shape and size that he created a new genus and family for it.

Recently rediscovered specimens of the same species from the Great Barrier Reef show that the gut has developed great branches throughout the body wall and extending into the cerata. The distinctive brown rings are gardens of zooxanthellae specially arranged to achieve the greatest possible amount of sunlight. In the vocabulary of the current age, the great, rounded, flattened cerata of this species are truly solar panels. Like the blue dragon, this Great Barrier Reef nudibranch is seldom found near its food. Although we do not yet have direct laboratory evidence that this species also grows its own food through zooxanthellae symbiosis, its remarkable shape and behavioral traits strongly suggest that it does.

The widespread phenomenon of symbiosis between zooxanthellae and tropical nudibranchs has only recently been recognized. These mutualisms have evolved independently at least eight times and exist among aeolids feeding on soft corals, reef-forming corals, colonial and solitary sea anemones, hydroids, and hydrozoan corals. This year I discovered a similar symbiosis in *Tritonia*, a nudibranch of a different suborder, and diligent searching will surely turn up more.

How do such complex symbioses evolve and why have nudibranchs been so successful at developing them? The nudibranchs' first advantage is that the food they eat already contains symbiotic algae. Nudibranchs have few restraints on shape, the loss of the shell having freed them for many adventures into bizarre body forms. And their translucent skin is no barrier to light. These traits, along with the blood-filled cerata, meet the physiological requirements of the zooxanthellae, which like most plants, require light, a ready supply of oxygen and nutrients, and a system to remove gas and other wastes produced during photosynthesis and respiration.

While a fully developed plant–animal symbiosis has advantages for at least the nudibranch partner, what possible advantages did such a symbiosis offer in the early stages of its development? One possible scenario is illustrated by the coral-eating nudibranch *Phestilla lugubris*, which has a greatly branched gut usually packed full of zooxanthellae. Yet this species has no physiological need for the zooxanthellae since it continues to forage for corals. The advantage to the animal is camouflage. In its flattened body, the nudibranch harbors zooxanthellae identical in color to the coral colony on which it feeds. This makes the animal almost invisible to predators.

Zooxanthellae range in color from yellow to dark brown and are often the sole source of coloration for the corals in which they live. For a nudibranch living permanently on coelenterates, coloration similar to that of its food source would be a great advantage. The complex system of internal agriculture of the blue dragon and other solar-powered nudibranchs probably began as a simple and effective means of camouflage.

*William B. Rudman is a senior research scientist in the Division of Invertebrate Zoology at the Australian Museum in Sydney.*
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DIVISION OF CHRYSLER MOTORS

BUCKLE UP FOR SAFETY.
A rematista moves a bag of toronjas (a citrus fruit) from a passenger ship into his own boat. Scrambling aboard the larger vessels, rematistas aggressively compete for any agricultural products passengers may be carrying. The toronjas, along with the plantains already in the boat, will end up in the Iquitos market.

Ruth photographs by Allen Rokach, The New York Botanical Garden
Risky Business

Courage and energy are essential for the small wholesaler in the Peruvian Amazon

by Christine Padoch

As the Jorge Carlos rounds a meander of the Amazon River and the Peruvian city of Iquitos comes into view, three large, motor-powered dugouts approach the vessel. In each of the dugouts a half dozen men and women are standing or crouching, ready to board the ship. The Jorge Carlos doesn’t stop. The dugouts’ passengers grasp the railing to haul themselves aboard; a few of the more corpulent women are dragged onto the ship by their companions. Their unsteady craft bob in the waves made by the larger vessel.

These are not boarding parties of river pirates, although some on the Jorge Carlos regard them as no better. The invaders are rematistas, small wholesalers operating out of the markets of Iquitos. The risk of a dunking in the muddy waters does not deter them from trying to be the first to bargain for any produce carried on the Docking space is in short supply, so eager wholesalers must jump from boat to boat seeking produce to buy.
ship. They are the vanguard of a horde of at least a hundred buyers that will virtually attack the ship as it draws into port. And the farmers, small shopkeepers, and government functionaries who are arriving on the *Jorge Carlos* will have to keep their wits about them in the face of this onslaught. Those with products to sell will need to think fast and hold their ground courageously to get a good price for their goods. Those who merely want to disembark will have to fight their way off the ship, clutching tightly any agricultural products they may be carrying with them. *Rematistas* typically grab the product first and then ask whether it’s for sale.

I have arrived many times in Iquitos on the *Jorge Carlos* and other motor launches serving the rural communities of the Peruvian Amazon. Each time I am filled with admiration for the courage of the *rematistas*. They fling themselves from rafts, boats, or the shore onto the lurching and rocking vessels maneuvering to a berth. I am awed by their energy at five o’clock in the morning and by their good humor when they fall off a ramp and lift themselves from the mud laughing. I am also appalled when one of them tries to wrestle away the scrawny chicken I hold in my hand (it is a gift that I have no intention of selling). After more than two years of research in the markets and hamlets of the Amazon, I know how the farmers fear and distrust the *rematistas*. I also know what daily risks the *rematistas* face trying to make a modest living in this city that is sharing the hard times of most of tropical America.

The lowland Peruvian Amazon is an enormous area with few people. Its population density is fewer than four people per square mile. Almost half of Peru’s lowland Amazonians live in the city of Iquitos. The rest inhabit a few small towns and many hamlets linked only by long, meandering rivers. The rural folk consume most of what they produce, but almost all of them exchange some portion of their harvest for the sugar, soap, kerosene, fabrics, notebooks, and medicines that have now become necessities. And almost all such commerce begins or ends in Iquitos. With a quarter of a million residents, Iquitos, built largely by the great rubber boom at the turn of the century, is the single significant market of the region. Like most Amazonian towns, it has survived a series of sharp economic ups and downs. Currently in a deep slump, it still serves as the place to buy and sell almost all that is produced and collected in the fields and forests of the great lowland valley.
Iquitos has six markets, of which the Mercado Belén is by far the most important. In addition to the two-story covered market built and managed by the municipal government, Belén's stalls sprawl over twenty-six city blocks. The retail vendors of food products and herbal medicines alone number almost 6,000. More difficult to count, but without doubt numbering in the hundreds, are the various wholesalers through whose hands pass the products that eventually appear in the stalls of Belén.

In studying the marketing networks of the Peruvian Amazon, I have become particularly intrigued by the strategies used by the rematistas and other middlemen plying their trade in Iquitos. There are many different ways to minimize risks and maximize profits among market intermediaries. Figuring them out has not been an easy task, primarily because middlemen are such a varied, as well as variable, lot.

The most storied and romantic among the Amazon's middlemen are the regatones—long-distance buyers and sellers. In the days of steamboats and boats paddled many days from village to village, regatones constituted a large percentage of the region's traders. Transforming their small boats into floating general stores, these adventurous men, often accompanied by their wives, brought market goods to the most remote human settlements. They exchanged sugar, salt, fabrics, and pots for the products of the forest, field, and river—wild rubber, jaguar skins, manioc meal, plantains, and salt fish. These long-distance traders are the subjects of many stories. Like the peddlers of the North American West, regatones are said to bring isolated hamlets their only tastes of the sophistication of the metropolis, to charm the farmer's wife and run off with his daughter, to swindle the uncautious and cheat the native, whom they first get drunk on the cheapest alcohol. But they also endure storms and are attacked by river pirates and enormous anacondas. And when their boats, with all their worldly possessions aboard, succumb to the river's whirlpools, currents, or other dangers, they dry themselves off and start all over again.

Since motor-powered boats have become more common and market goods more available to rural residents, the sphere of the true regatones has become restricted to the farthest villages. Despite faster transport, most regatones make trips that last at least a month. As a group, they have long been accused of being shady businessmen. Taking advantage of their distance from the city, some regatones do sell worthless but flashy merchandise at very high prices, falsify contracts and receipts, and engage in other dishonest practices. Many, however, benefit the otherwise isolated rural communities that they visit. They provide the inhabitants, often members of tribal groups, with news from their relatives in the city, useful goods from the nearly inaccessible market, and the only opportunity to sell local products.

The regatón represents one way of dealing with the grave marketing problems along the Amazon—problems that reflect the small and scattered population, the
The interior of a river bus, a boat that makes short, local trips, below, is crowded with villagers bringing avocados, peppers, uvila fruit (hanging in rear), and live chickens to Iquitos to sell. Cargo boats line up at the garbage-strewn docks of Belén, right, the local commercial port in Iquitos. The plantains in the foreground will be carried up to the main market for retail sale.

Tom Taylor

Typical low levels of agricultural production and the general poverty of most consumers. Almost everyone wants to sell something, but few have much to sell. And only Iquitos has a large and relatively affluent consumer population.

Every marketer in the world deals with risk and uncertainty. What products are available in the rural area and at what price? What products can be sold in the city and at what profit? When will the goods arrive? In what condition? Such questions make any wholesaler nervous. In the Peruvian Amazon, marketing is an especially risky undertaking because the necessary information is practically impossible to get. Communication and transportation facilities are still poorly developed. Only the city is served by regular mail delivery, and only a handful of towns outside of Iquitos have any telephone service. Roads are limited to a few miles close to the city. River transport is slow, often unreliable, and hazardous.

The regaño, therefore, generally restricts his purchases to products that do not perish quickly. Dried corn, processed manioc meal, unripe plantains, and live pigs and chickens are usually salable even after a trip of a week or more. But the long journeys of regaños prevent them from keeping abreast of changes in market prices. And in Iquitos, which lies many days away from any other city, prices fluctuate wildly. In one week in August 1984, the price of aguaje, a palm fruit, went up fourfold. Prices of plantains, a food staple, can change by 100 percent from day to day, depending on supply. The regaño must rely on his ability to pay so low a price for agricultural products that no matter what happens in the Iquitos market, he will realize some profit. And the agriculturist must accept a low price since he has few other opportunities to sell and little way of knowing what the price in the Iquitos market really is.

One solution to the regaño’s communication problem is to somehow get information on market conditions. He might do that by engaging a partner who stays close to the market, following price changes. To pass that information to the regaño, a week’s journey away, only one medium is available: radio. Of course, broadcasting information on the airwaves makes it public, giving the regaño no edge over his competitors and relaying the same information to the farmer, who may then demand a fairer price. In response to this predicament, a system of coded radio messages has developed. A local station, Radio Atlántida, nightly carries communications for people in rural areas. Many of these messages are encoded directives to buyers in remote places.

A message to cousin Humberto in Pucabarranca on the Napo River to “bring the little piglet down to Iquitos,” probably means, “Buy all the green plantains you can find, the price is high”; and “Tell Uncle Miguel to start planting more corn,” may well mean, “Beans are selling well, buy 100 kilos.” The use of such coded messages is well known throughout the area. When agencies hoping to aid small farmers broadcast market price information, even their broadcasts are treated with caution. All but the most
gullible regard information on the radio with considerable skepticism.

By traveling far and buying cheap, the regaton also largely avoids the fierce competition that plagues rematistas. But to reach areas where other marketers seldom go, regatones have to brave the dangers of rivers and storms. All regatones can tell stories of foundering, fires, and pirates. My close friend, Don Andres Panduro, lost a boat, a new motor, and most of his life's savings when his vessel, the Concordia, caught fire on the lower Maranon River. He survived but lost his money when he dived into the muddy, swirling waters in the dead of night, clutching an attache case full of bills. He now laughs when he recalls how the current ripped the bag from his hand. But he has never really recovered financially or psychologically; two of his friends who were with him on that boat died. One stormy night, his competitor's boat hit a half-submerged log and splintered; 200 plantains stalks went to the bottom of the Urituyacu River along with the boat. Many regatones operating today have lost boats and restarted their businesses from scratch two or three times.

The small wholesalers who stay close to the market face other dangers, and their businesses are often even shakier. The great majority of rematistas have very little operating capital. Fifty dollars is not considered too little to get some foothold in the wholesale market. That small amount of capital must, however, be accompanied by a strong competitive spirit and lots of good luck and hard work. Most rematistas work with a partner; one takes care of selling the merchandise while the other constantly cruises the port or market checking products and prices and anticipating sudden changes. Iquitos lies near the confluence of three of the world's largest rivers: the Ucayali draining the southeastern slopes of the Peruvian Andes, the Maranon draining the northeastern slopes, and the Napo coming down from Ecuador. With varying flooding regimes and agricultural potentials and different natural resources to exploit, villagers along these rivers produce and sell products throughout the year. A successful rematista must not only know what products are apt to arrive in Iquitos but also on which boat and on which day.

Don Segundo Tapullima, a rematista with twenty years of experience in the Belen market, has frequently recited to me the names of dozens of cargo boats that will arrive in Iquitos in any week. He knows where zapote fruits are ripening, the quality of sachamangua fruits that
should be coming in any day from the Itaya River, and whether the Ucayali River is apt to flood the plantain fields around Flor de Punga this week or next. This information is gathered without any modern means of communication. Being in the market is his only aid—listening to and evaluating the gossip and carefully watching everything that goes on.

Last August Don Abelardo Mori decided to take a risk. The price of plantains was extremely high, and every rematista in Iquitos was scrambling to find a stalk or two and make a killing. Don Abelardo took about two hours to make his purchase and haul the plantains to the Belén market. During that time two large launches arrived from the Ucayali bringing 400 stalks. The price went down by half and Don Abelardo lost a day's profits. Another, more marginal rematista might have lost his shirt.

Apart from having good information in hand, a great middleman must be endowed with "manera." Rematistas are noted for their aggressive manner. The most successful, however, talk not only fast but sweet. And a reputation for trustworthiness is important. Most agreements in Belén are made without signatures, collateral, or lawyers, and are impossible to enforce. Belén's old rematistas have told me many times that they survived in the business, and in some cases prospered, because they were noted for their prompt payment for goods delivered and for the quality of the produce they marketed. Having a large family to work for you—children who will watch your inventory while you're off buying more, a wife who may retail a few of the very best fruits at a nice profit on a street corner, a brother-in-law who will sell your produce when you are sick and not cheat you on the returns—is helpful too.

Farmers along the rivers are deeply convinced that rematistas are in league with one another, fixing prices and blackballing recalcitrant producers who hold out for better prices. Among themselves, rematistas complain of the tremendous competition and the lack of professional ethics—many rematistas will steal purchases from under the nose of another who is already handing over his money. Some will offer a higher price to a farmer who weeks before agreed to sell his produce to another buyer. The problem, say the experienced, is that an enormous number of small wholesalers have entered the market in recent years.

The growth of the middleman population reflects several economic facts in the Peruvian Amazon. Perhaps the most important is the recent decline in employment. Most of Iquitos's plywood factories have closed, the petroleum industry employs few workers, and manufacturing is almost nil. Recent high floods on the Amazon have wiped out many farmers who then decided to seek their fortune in the city. And as always, the provision of services—education, medical care, communication—to rural areas has lagged behind the growing expectations and needs of the population. Therefore many in Iquitos turn to marketing to make or to supplement their income.

Another set of factors that explains the boom in wholesalers has to do with the money that Iquitos earned previously in the petroleum industry. The late seventies saw considerable oil exploration in the Amazon and the building of a pipeline to the Pacific. These tasks employed many young men who earned more than they ever had before. Although petroleum extraction continues, few workers are now hired. As a result, considerable numbers of young men with a taste for consumer goods have found themselves unemployed in recent years. Many of them are now found among Belén's rematistas.

The newcomers are often weeded out of the business within the first few weeks. But those who can learn the trade, who
Vendor in the Iquitos market sells ungurahui (a palm fruit) from a large red pot at her side. The smaller bucket contains the mashed fruit. Lined up on her low table are (from left) plastic bags of camu-camu fruit; masato, a fermented manioc paste (neatly packaged in green leaves) that is used to make an alcoholic drink; and small plastic bags of mashed ungurahui.

manage, in Don Abclardo’s words, to **agarrar la onda** (catch the wave) of wheeling and dealing in Belén, survive and sometimes prosper. Often they learn by first working as a minor partner to an experienced dealer. Few ever become rich. Don José Ríos laments that after forty years as a rematista he barely survives and cannot bankroll any of his sons into the business. A few rematistas experience greater success.

Reputedly, there are nine large wholesale- ers in the city of Iquitos. These middle- men deal in tens of thousands of dollars in capital; most have boats and warehouses. All are targets of gossip alleging that their money was made by deals in illicit pro- ducts or using questionable methods. A few other people have made their fortunes as rematistas and then left the market. Among them is Doña Rosalbina, now the owner of a fleet of gasoline distribution trucks and of one of Iquitos’s few gas stations. A woman of about fifty, Doña Rosalbina lives in a splendid southern California-style house and is active in the evangelical church.

A monument to the Protestant work ethic, she began as a small rematista specializing in **aguaje**, a palm fruit that is somewhat of an obsession with Iquiteños. Learning much of the business from her mother, a street corner retailer of **aguaje**, Doña Rosalbina went into business in the fifties with a male partner. In addition to purchasing **aguaje** fruits when they arrived in Belén’s ports, she contracted with dozens of extractors of the fruit, which is not cultivated but grows naturally in immense swamps. At the height of her trading career, Doña Rosalbina would buy up to ten tons of **aguaje** in one day and manage a wide-ranging commercial network of subcontractors, boat owners, and palm-fruit gatherers on several rivers. She did all this without mail service, a telephone, or a telex. She did have, however, a set of strong nerves, a capacity for hard work, considerable luck, and a sound business code. She paid a fair price for all the fruit her contractors brought in, no matter how low the market price fell. She recalls times when she was down to her last coin and drowning in **aguaje** that was spoiling fast and had to be dumped. Her willingness to occasionally take a loss and benefit the people in the field, however, assured her of faithful contractors and a good supply when the fruit was scarce and prices high.

At times, Doña Rosalbina had twenty subcontractors working for her; few other rematistas manage that many. Contracting for agricultural and forest products is another way that Belén’s wholesalers attempt to keep the uncertainties of the trade down. Money or materials are often advanced to insure that a producer will market a quantity of goods to a particular buyer. Again the peculiar characteristics of the Peruvian Amazon—the distances, the floods, the lack of communication—make this kind of dealing less than a sure thing. Even if the producer brings in the product as promised, one of the rematistas who board boats before they reach port may persuade him or her to sell at a slightly higher price.

Most of the successful wholesalers actually deal simultaneously or serially in sev-
Market vendor, below, sells a drink made from aguaje (a palm fruit), a favorite among Iquiteños. Spread out before a young vendor, right, are her few articles for sale: (from left) peppers, coconas (a tomatolike fruit), and huitos (a fruit).

Both photographs by Allen Rokach, The New York Botanical Garden

eral trading strategies. Some who have boats may make trips as regatones. Others occasionally rent boats and make shorter trips to nearby villages where competition may be greater but other risks are lessened. Some occasionally turn to retailing. Even the most specialized will change. No wholesaler survives long if he or she is unwilling to be flexible and take risks.

Wholesaling in Iquitos is regarded both officially and by the person on the street with distaste and perhaps a bit of envy. It is commonly said that wholesalers daily line their pockets with excess profits while hardly working at all. Politicians suggest that both the rich and the poor would be better off without them. “From the farm to the pot,” “from the producer to the consumer,” are slogans heard in almost every society where wholesalers operate. But the vast majority of them are poor. As long as few other opportunities are offered, the poor will turn to small wholesaling as a way to make ends meet. The risks are considerable for the regatón, the rematista, the contractor, and the numerous other varieties of wholesalers who work in Belén. Although the rewards can be great, riches come to very few.
Batmom's Daily Nightmare

How can she find her offspring among millions of squealing pups?

by Gary F. McCracken and Mary K. Gustin

We tape our shirtsleeves tightly around our wrists, pull on high-top Wellington boots, put on hard hats, adjust our respirators so that they don't leak around the nose, and muse as to why presumably intelligent, normally clean people would do what we are doing. We are about to enter a Mexican free-tailed bat maternity roost, one of the largest, densest mammal colonies in the world. Our clothing will protect us from the feces and urine that rain down from the several million bats roosting on the cave's walls and ceilings. It will also help keep off the dermestid beetles that live in bat guano and the mites that live on the bats. The respirators will protect our lungs from the high ammonia concentrations and from infection by the fungal spores floating in the cave atmosphere. We doubt, however, that these devices will filter out the tiny rabies viruses that may also circulate in the cave air, so we've received immunizations.

Mexican free-tailed bats spend winters in caves and old buildings in northern and central Mexico. In spring, after mating, pregnant females migrate as far as 800 miles into the southwestern United States, where they form enormous roosting colonies in caves. There they give birth to and nurse their pups. Some males also migrate north, forming perhaps 5 percent of the maternity colonies, but most remain in Mexico throughout the year. Bracken Cave, just north of San Antonio, Texas,
The entrance to Bracken Cave, right, where some 20 million Mexican free-tailed bats roost each spring. Bats roost in caves throughout the Southwest, with many colonies located within a 100-mile radius of San Antonio, Texas. They leave the caves at dusk to feed. The bats from Bracken Cave consume about 150 tons of insects each night.

Bracken

over the last twenty-five years, however, our understanding of evolutionary processes has changed. We now know that if individuals act in ways that benefit others at a cost to themselves, the cost must be recouped. Studies of mammalian physiology show that the energy used to produce milk is often several times that expended during gestation. Since nursing pups other than her own means a cost to the female, how does she recoup the expense? If nursing really were indiscriminate, natural selection should favor the female that placed her pup in the crèche for others to nurse and then shirked all nursing duties herself. This female would save herself the substantial energy of milk production and, at the same time, would not jeopardize her own pup's chance of survival any more than that of any other pup in the population.

Between dawn and dusk, the gray-furred adults—as many as 1,800 per square yard—cling to the cave ceiling and

rich food source during the energy-demanding period when females give birth and care for their young. In the Texas colonies where we have been working, the birth of bat pups—one per female—begins during the first two weeks of June and ends late in the month. Immediately after giving birth, the mother bat nurses her newborn and deposits it in a mass, or crèche, with other pups. She then moves off to roost in another part of the cave, returning to the crèche to nurse at least twice each day, usually in the afternoon before she leaves the cave and in the morning after she returns from foraging. Pups are weaned when about five weeks old.

For many years, little was known about the relationship between females and pups. The most widely held idea was that the bond between the female and her newborn ceased to exist after the initial milk meal and placement of the offspring in the crèche. Females returning to the massed pups supposedly nursed indiscriminately, giving milk to the first pups attached to their teats. This conclusion was widely accepted and repeated frequently. The proponents of this view argued that indiscriminate nursing assured that the most aggressive, largest, and presumably most robust pups were more likely to survive and that this benefited the population.

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houses an estimated twenty million free-tailed bats and is currently the largest known colony of the species. There are also at least a dozen other such nurseries, scattered throughout much of the American Southwest, each with summertime populations exceeding one million. The two caves in which we've conducted most of our research on mother-pup interactions are in central Texas. An estimated four to five million mothers and babies roost in each of these caves.

On summer evenings before dusk, adults leave the roost to forage for food. What look like thick columns of black smoke emanating from the mouths of these caves are millions of bats. The exodus from Bracken Cave can take as long as four hours. Each night, each bat will consume about half its own body weight in insects, mostly small moths for which the bats forage at altitudes often higher than 900 feet. Given an average body weight of half an ounce per bat, a colony like Bracken Cave, with twenty million individuals, might consume 150 tons of insects each night. Since moths develop from caterpillars, and caterpillars eat plants, these bats affect the ecology and benefit the agriculture of the Southwest.

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wall. Crèches can cover hundreds of square yards; each packed with as many as 5,000 pink, unfurred pups. Their high-pitched calls can be heard even from outside the roost. The constant swirl of adults flying within can be made out in the twilight of the cave entrance. The heat within is oppressive. The millions of small, warm bodies and their decomposing guano bring the temperature up to a hundred degrees, making a natural incubator for the bat pups. As we enter with our lights, the pups’ squeals increase and thousands of adults take flight, some colliding with us or one another. If pups lose their grip on the walls in the confusion and fall, they face almost certain death. Along with the sick and injured adults, they will be devoured by the dermestid beetles that live in the thick guano on the cave floor.

Because of the immense size and extreme density of these roosts, direct observation of the nursing relationships between marked females and pups is an enormous logistic problem. To date, we have found direct observations physically impossible. Therefore, we assessed nursing affiliations indirectly by comparing the genotypes of female–pup nursing pairs. To do so, we entered a maternity roost during nursing periods and picked pairs—females and the pups they were nursing—from the cave ceiling. We then took a small blood sample and a muscle tissue sample from each bat. Using the technique of gel electrophoresis we were able to assay for differences in the structure of proteins that we extracted from these samples. Our purpose was to identify the genotypes of each individual at the genetic loci that are responsible for the structure of these proteins. By sampling a large number of female–pup nursing pairs (we examined a total of 167 pairs), and by examining several protein-encoding genetic loci, we were able to examine nursing affiliations in relation to nursing female–pup genotypes.

The results of our tests were unequivocal. Females usually find and nurse their own pup. But on occasion (in 7 cases out of the 167 we examined) they nurse pups that are not their own. Whose pups are these females nursing? Are they random pups? Are they the pups of the female’s relatives? In among the masses of pups do they simply mistake another pup for their own? Or is there shared nursing responsibility among some groups? How do females find and nurse particular pups or particular sets of pups within these enormous colonies?

Ideally, studies by direct observation would provide answers to all of these questions. Pairs would be marked when the pup is born. Unfortunately, although mother–newborn pup pairs can be captured and easily marked, the enormous number and density of bats in these roosts, the unpredictability of when a particular female will return to the crèche to nurse, and the bats’ sensitivity to light and the
presence of an observer, all hampered our ability to make these observations.

Using a low-light sensitive infrared video system to observe the behavior of unmarked females and pups, we learned that nonparental nursing occurs when pups steal milk from females that are searching for their offspring. This milk stealing appears to occur among unrelated individuals that are unlikely to have had any prior experience with one another.

Our genetic studies indicated that adults and pups roost randomly without regard to their blood relationships. To test whether the bats had any kind of stable roosting relationships, we entered caves at night after the adults had departed for foraging, and marked the heads of pups with fluorescent paint. These paint marks are easily seen when we flood the crèche area with long wavelength (black) light. When each pup was marked, we recorded its exact roosting location. We then returned to the crèche at 24-hour intervals to relocate them and record their subsequent roosting spots. Pups do not roost in the same spot night after night. Instead, they move over short distances and in apparently random directions. On average, the marked pups moved eighteen inches a night. We also found that pups roosting next to one another on one night move independently and are not adjacent on subsequent nights.

We have watched unmarked females from the time they landed on the crèche until they found and nursed a pup or until they abandoned their search and flew from the crèche. Typically, a female emits calls for several seconds after landing on the crèche and then begins to crawl over and through the massed pups. After moving about an inch or two she stops again, calls, and then continues her apparent search. While she searches, pups in her vicinity orient themselves in her direction and often attempt to gain access to her teats. Occasionally a "milk thief" succeeds in its evident intention, and we have observed as many as four different pups attach briefly to the teats of a single female before she located and accepted a fifth pup (presumably her own) for nursing. We have even observed other adults attach briefly to the teats of female searchers, demonstrating that not only pups steal milk. Females guard their teats with their folded wings, but when pups or adults attempt to attach to the teats of a female searching the crèche, she vigorously repels the attacker by scratching it with her hind feet, biting it, and beating it with her wings.

Some two-thirds of the searches we observed ended when the female flew from the crèche without finding and nursing a pup. Often the female abandons the search after being incessantly harassed by hungry pups. In the remaining third of the
When a mother bat returns to the cave she lands near the crèche, left, in which her pup hangs. She smells and calls and usually ends up nursing her own pup, although on occasion an unrelated pup will steal a meal. A Mexican free-tailed bat, below, with longer and thinner wings than most bats, can fly thirty miles a night, often at altitudes higher than 900 feet.

Both photographs by Merlin D. Tuttle

searches, however, the female eventually showed interest in a particular pup, touching noses with it, smelling it, and exchanging vocalizations. These exchanges typically last for seconds, but may persist for a minute or more, before the female raises her folded wing and nudges the pup toward one of her teats. While she nurses the chosen pup on one teat, other pups will attempt to sneak under her other wing for access to the other teat. A typical meal lasts five minutes. The female shuttles the pup from the first teat to the second, and then, perhaps, back to the first.

In these searches, the distance from the female’s landing point to the accepted pup averaged sixteen inches. Since pup movements between meals are generally limited to a foot or two, a female might easily remember her pup’s location. But with the density of pups on the crèche, we estimate that she still must screen some 1,500 pups before she finds her own. This is a large number, but much less than the several million pups in a typical roost.

Even before we did our video studies, we were virtually certain that mothers and pups communicated vocally. Bats are renowned for their sophisticated abilities to emit and receive acoustic signals, and studies of other species found that mothers and pups communicate vocally and recognize each other’s calls. In many species, hungry or lost pups call out and their mothers respond, keeping up the duets until they are reunited. Some studies even suggest that each pup’s call is unique and thus recognizable by its parents.

In a Mexican free-tailed bat roost, a visitor immediately notices the noise. Although bat echolocation calls are generally above the frequencies that humans can hear, both adults and pups often emit calls that, although high-pitched, are partially audible to humans. These sounds travel longer distances than high-frequency sounds and, as a rule, are better adapted for communication than for echolocation. To investigate whether the calls of Mexican free-tailed bat pups could communicate individual identity, Deborah Gelfand, a graduate student working with us, compared the calls of different pups. She collected twenty female–pup nursing pairs, separated the females from the pups, and recorded the isolation calls of each pup. She then measured several features in the structure of more than 300 calls. She found each pup’s call differed in duration, time between calls, maximum frequencies, and the amount of sound energy at different frequencies. A mother bat, with more sensitivity than these electronic instruments, would probably have little difficulty recognizing the call of her own pup.

Video observations also suggested that odor may be important for mother–pup recognition. Odor as a factor in individual recognition has not been well studied in bats, but it has been documented in many other mammal species, particularly in rodents, ungulates, and primates, including humans. We investigated the possibility of olfactory recognition by allowing the female bat to tell us whether she could discriminate among the odors of various pups. For these studies we captured nursing pairs, separated each female and pup, and collected odor from pups by rubbing their skin with clean cotton swabs. Females were then allowed to choose between a swab taken from the pup she was nursing versus a swab taken from a randomly selected pup. Swabs were placed in opposite “arms” of a plexiglass Y maze. Females introduced to the maze generally moved quickly to one of the swabs, sniffed it, and settled quietly next to it. In several tests the female placed her wing over one of the swabs, as if to nurse it. Females
A mother bat shelters a pup, below, in a crevice away from the crèche. The crèche, right, is a mass of young pink bats, up to 5,000 per square yard, clinging to the cave surface, all jostling each other for space and squealing for their mothers and a meal.

Both photographs by Merlin D. Tuttle

most often chose the swab that was rubbed on the pup they were nursing when they were captured. Mexican free-tailed bats have many actively secreting sebaceous glands on their muzzles as well as elsewhere on their skin. We are not yet certain if females mark pups with these odors or if pups produce their own odors. However, in other odor-choice tests using similar procedures, female bats tended to move toward the scent taken from their own muzzle glands versus odors taken from another lactating female.

We hypothesize that a bat remembers the approximate area in which she left her pup after the previous nursing. We believe that after returning to this area of a crèche, the mother uses sounds and scents to find her pup. While she is searching, other pups, as well as adults, attempt to and occasionally succeed in stealing milk from her. Amidst conditions we humans find chaotic, a bat follows clues to find and care for her young.
The Biggest Chill

When ocean currents shifted, Europe suddenly got cold. Could it happen again?

by Wallace S. Broecker

We, the inhabitants of planet Earth, are performing a gigantic climate experiment. Begun by our grandparents, its results will be recorded by our grandchildren. The experiment involves the production and release into the atmosphere of gaseous molecules made up of three or more atoms; the most important of these are carbon dioxide (CO₂), methane (CH₄), and the freons (CF₂Cl₂ and CF₂Cl). Unlike the two-atom molecules, oxygen (O₂) and nitrogen (N₂), which make up 99 percent of our atmosphere, these multiatom molecules have the capacity to capture packets of outgoing radiation from the earth. Just as a blanket helps retain our body heat, these gases retain the earth’s heat. Hence, the result of our experiment will be to make the surface of our planet warmer.

Unfortunately, our knowledge of the earth’s climate system is still not good enough to reliably predict the effects of this heating on wildlife, agriculture, and a host of other matters important to humans. We will only know the results of the buildup of these “greenhouse” gases if our learning rate greatly accelerates.

In the face of such uncertainty, one might ask why the experiment is not declared dangerous to the well-being of the planet and abandoned. The reason is that the generation of greenhouse gases is not an enterprise designed by scientists. Rather, it is an inescapable byproduct of our civilization. Carbon dioxide is produced when coal, oil, and natural gas are burned. When carbon atoms, which make up the bulk of these fuels, combine with oxygen molecules from the atmosphere, an amount of CO₂, weighing roughly three times more than the fuel burned is generated. There is no feasible way to prevent this CO₂ from escaping into the atmosphere. Methane is produced by living organisms. The metabolic systems of steers and the bacteria in the mud of rice paddies are methane producers. Hence, some methane will be added to the atmosphere for each hamburger or bowl of rice we eat. Freons are manufactured by industry as foaming agents, refrigerants, and propellants. Except for the freons, the greenhouse gases are products of activities essential to human survival. If five or so billion people are to be maintained on our planet, we must continue the greenhouse experiment. We are hooked.

Scientists struggle to increase our understanding of how the earth’s environmental system operates in the hope that we will be able to predict at least some of the coming consequences. If so, we can
develop strategies to cope with the “bad” and take advantage of the “good” results of this experiment.

These inquiries have recently revealed a piece of disquieting information. Geological studies suggest the Earth’s climate system resists change until pushed beyond some threshold; then it leaps into a new mode of operation. The situation is akin to that of a radio with automatic frequency control. When the dial on such a radio is turned, instead of one station fading out and the next one fading in, the radio remains locked on one station until a threshold is crossed, at which point it suddenly jumps to another station. The implication of this finding for future climates is clear: the effects of the greenhouse gas buildup may come in sudden jumps, rather than gradually. Such jumps would pose great threats to humans and wildlife.

Our suspicion that the Earth’s climate changes in leaps comes from the evidence recorded in deep-sea sediments and in ice. The most studied of these records is the amount of heavy oxygen found in the preserved shells of microscopic animals on the ocean floor. The heavy form of oxygen in water vapor tends to be lost as atmospheric moisture is transported to the icecaps. The larger the icecap, the more heavy oxygen remains behind in the seawater. Thus, in eras when the icecaps were large, shelled organisms contained more heavy oxygen than they did when the icecaps were small; the shells therefore contain a history of the ice ages.

The oxygen isotope record tells us that over the last million years the polar icecaps have changed in a cyclic fashion, going from the rather small size of the current warm period to the very large size...
at the maximum of the last glaciation. More important, these fluctuations in ice volume have been shown to be in tune with periodic changes in the earth’s orbit around the sun, generated by gravitational interactions among the objects making up our solar system. Because the timing of the oxygen isotope changes (as determined by age measurements on deep-sea sediment cores) matches what would be expected if the changes were driven by the earth’s changing orbit, scientists are reasonably certain of the cause-and-effect relationship.

Why do changes in the characteristics of the earth’s orbit have anything to do with climate? The answer is that these changes alter the earth’s seasons. The relative amounts of each year’s sunlight received during the winter months, as opposed to the summer months, changes in accordance with the changing orbit. Exactly how changes in the strength of the seasons drive the expansion and contraction of the earth’s polar icecaps remains a matter of debate.

While the oxygen isotope record in the deep-sea sediments provided evidence pointing to the earth’s orbital cycles as the pacemaker of glaciation, it also tended to lull scientists into concluding that the earth’s climate responds gradually when pushed. This conclusion was drawn despite the realization that the response of polar icecaps to changing climate would have to be so sluggish that a smooth oxygen isotope record would be expected no matter how abrupt the changes in environmental conditions might be. So lulled were we that other clues in paleoclimatic records that pointed to abrupt response were largely disregarded.

The awakening came in the early 1980s when Hans Oeschger and his group at the university in Bern, Switzerland, carried out detailed measurements of the CO₂ content of air trapped in the ice from a deep boring made at a site in southern Greenland. These measurements concentrated on a section of the core on which earlier studies made by the Danish group of Willi Dansgaard had shown repeated leaps in Greenland’s air temperature. To everyone’s surprise, each of Dansgaard’s jumps was accompanied by a 20 percent change in the CO₂ content of the air trapped in bubbles in the ice (and hence in the CO₂ content of air above Greenland at the time the ice formed).

Eyebrows were raised by Oeschger’s CO₂ jumps because while the temperature jumps could be written off as a curiosity of Greenland, the CO₂ changes could not. The atmosphere’s CO₂ is well mixed with its other gases, hence a measurement in Greenland typifies the entire globe. Furthermore, the changes in CO₂ content found by the Oeschger group occurred in times as short as a few hundred years. To bring about these changes in CO₂ requires some extraordinary change in the earth’s chemical cycles, particularly those operating in the ocean. Scientists were therefore forced to the realization that the leaps in Greenland’s climate were far-reaching, involving the workings of the ocean as well as those of the atmosphere.

The new look at the ocean triggered by the finding of the Oeschger group brought to the fore the potential importance of a curious tie that exists between the functioning of today’s ocean and today’s atmosphere. This tie results in a globe-straddling ocean current that keeps north-
ern Europe unusually warm. Paris lies almost a full ten degrees farther north than New York, yet its mean annual temperature is similar to that of New York.

The extra heat received by northern Europe is carried by a conveyor-belt-like ocean current. The part of the conveyor closer to the surface moves to the north; the conveyor's deeper part moves to the south. The important point is that the water of the upper part is warm, while that of the lower part is cold. The temperature change occurs at the northern limit of the belt (in the region around Iceland). Here, during the winter months, water warmed during its passage through the tropical and temperate Atlantic meets air cooled during its passage over frigid Canada. The meeting results in the transfer of heat from the sea to the air. The amount of heat is staggering, measuring about 30 percent of that received by the surface of the North Atlantic from the sun. The result of this transfer is twofold. First, the sting of the cold Canadian air masses is removed before the air hits northern Europe. Second, the waters are cooled and consequently made more dense. The extra density allows the water to sink to the abyss and feeds the lower part of the conveyor. Thus the ocean current acts as a pump, extracting heat from low-latitude air and transferring it to high-latitude air.

The water that sinks to the bottom of the northern Atlantic flows down the full length of the Atlantic, around Africa, through the southern Indian Ocean, and finally up the Pacific Ocean. This deep current carries twenty times more water than the combined world rivers.

There is also an ocean conveyor belt in the North Pacific but it runs the opposite way around. Deep waters move toward the north and upwell to the surface. From there they move toward the equator in the upper ocean. So in today's world, the Atlantic Ocean conveyor belt carries tropical heat for delivery to the atmosphere at high northern latitudes, while the Pacific conveyor belt carries cold surface waters southward, pushing the invading warm waters back toward the equator. Today's major ocean current system thus heats the lands adjacent to the northern Atlantic.

While we don't have the complete answer to why our ocean operates in this fashion, we do have the first principles. The pattern of circulation is governed by the sea's salt. To understand this we must consider the transport of water through the atmosphere. The water that evaporates from the ocean falls eventually as rain or snow. Some of this precipitation reaches the land and some reaches the sea. Some precipitation that falls on land evaporates and returns to the ocean. The water cycle thus balances the transport of water between the atmosphere and the ocean.

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orates (mainly from plants) and some runs down the rivers and back to the sea. This cycle must exactly balance: for each molecule that evaporates from the sea, one molecule must return to it either by precipitation on its surface or from the mouth of a river. While this is true for the ocean as a whole, it need not be true for each part of the ocean. In fact, in today's world, an imbalance exists between the Atlantic and the Pacific. The Atlantic loses more water by means of evaporation than it gains by precipitation and continental runoff. The situation is reversed in the Pacific, which receives more water as rain and runoff than it loses by evaporation. While this imbalance is compensated for by a net flow of seawater from the Pacific to the Atlantic, it leaves a mark on the ocean's salt budget. Salt does not evaporate. Thus, the transport of water vapor from the Atlantic to the Pacific enriches the waters of the North Atlantic in salt content. The enrichment in salt must be compensated for by a flow of more salty water from the Atlantic to the Pacific. This is accomplished by the great conveyor belt: the water sinking to the abyss in the northern Atlantic carries excess salt.

The ocean conveyor system maintains higher surface water temperatures in the northern Atlantic than in the northern Pacific. Warmer waters have a higher vapor pressure and lose more water to the air by evaporation. Thus the rate of evaporation from the Atlantic is higher than that from the Pacific. This creates a global "still": water is extracted from the warm Atlantic and transferred through the atmosphere to the cool Pacific.

The phenomenon that maintains this situation is a devilish one; the circulation pattern is self-reinforcing and hence self-stabilizing. The deep current is driven by the extra density supplied to the waters of the northern Atlantic through the enrichment of salt. The enrichment of salt is driven by the heat carried by the water that flows northward in the upper Atlantic. Thus we have a classic chicken and egg situation; excess evaporation causes the deep current and the deep current causes excess evaporation.

The self-stabilization of this great conveyor belt is like the radio automatic frequency control already mentioned. And like that control, the mode of operation of the joint ocean–atmosphere operation will jump if pushed too far. The evidence contained in paleoclimatic records seems to be telling us that the conveyor of today's ocean did not function during the glacial time. Hence it is tempting to conjecture that the turning on and off of the conveyor constitutes an important link between the
earth’s orbits and our climate. When the belt in operation, the warmth it delivers prevents ice from accumulating on the lands surrounding the northern Atlantic; when the conveyor is not in operation, these lands are sufficiently cold to permit their glaciation. If this is indeed the case, then the orbitally induced changes in seasonality must somehow alter the extent to which the water evaporating from the Atlantic Ocean escapes removal by the precipitation that falls on continental areas whose drainage is back into the Atlantic. Salt buildup is caused only by that fraction of the water evaporating from the Atlantic that escapes these basins and falls as rain in the Pacific or on continental drainage basins feeding the Pacific.

As we do not yet understand enough about the rules controlling the transport of water vapor through the atmosphere, we cannot say why changes in seasonality cause changes in the transport of water vapor from one ocean basin to another. We can only say that compelling evidence exists in the marine-sediment record for a fluctuating on and off of the ocean conveyor belt. Since the most vulnerable attribute of the conveyor is water-vapor transport from the Atlantic to the Pacific, some link between this transport and seasonality seems logical.

Evidence for rapid jumps in climate on the land surrounding the northern Atlantic was discovered many decades ago by scientists studying pollen grains preserved in sediments. The record from bogs created during the early phases of the retreat of the icecap that covered Scandinavia and the British Isles during the last glaciation (20,000 to 14,000 years ago) shows a transition from the herbaceous shrubs of the cold period back to the forests of a warmer period. Those early postglacial forests persisted for about 2,000 years and then were suddenly replaced by shrubs akin to those of glacial time. This intense cold snap lasted about 700 years and then just as suddenly came to an end, permitting the forests to return. This brief reversion to cold conditions, which punctuated the period of deglaciation, was named the Younger Dryas (dryas is one of the herbaceous plants that clothed the landscape during the glacial time).

Like other signs pointing to rapid climate change, this rather extraordinary and relatively short-lived return to cold conditions was not given very high billing until Oeschger’s group found the rapid CO₂ changes. It then became the focus of attention because detailed records for many localities on the earth’s surface were available for the time interval when the earth emerged from its last episode of
must have averaged about half the current discharge of the Northern Hemisphere's combined rivers. Where it went would therefore have an important impact on the ocean's salt cycle.

Geologists studying the deposits left behind during the retreat of the largest of the glacial icecaps, the one that covered Canada from the Rocky Mountains to the Atlantic Ocean, have reconstructed the routes taken by the meltwater released from its southern margin. Their studies reveal that during the initial phases of melting, all routes converged on the Mississippi River and hence all the meltwater flowed into the Gulf of Mexico. However, starting about 11,800 years ago, those routes were captured one after another by eastward-leading channels that progressively opened as the ice front retreated to the north. First, the water entering the basins of what are now Lakes Erie and Ontario was diverted to the sea through the Hudson River valley. Then the water entering the basins of what are present-day Lakes Huron and Michigan was diverted to the Saint Lawrence River valley through a channel in the glacially de-pressed landscape north of Lake Erie. Finally, the biggest and most important of these diversions occurred when a lobe of ice blocking off the eastern end of what is now Lake Superior melted, allowing water to flow into Lake Huron and from there to the Saint Lawrence. At this point all the water melting from the southern margin of the Laurentide ice sheet was flowing eastward into the Atlantic. Nearly all of this water reached the Atlantic via the Saint Lawrence River. While the diversion of the meltwater from the Mississippi to the Saint Lawrence occurred in

Fluctuations in the earth's orbit, affecting how much summer sunlight the earth receives (top graph), have expanded and contracted the polar icecap, driving the Northern Hemisphere in and out of glacial (Ice Age) episodes. Although the volume of the ice changes sluggishly and gradually (bottom graph), an abrupt global warming has marked the end of each glacial period, indicating that ocean–atmosphere operation can change suddenly (middle). The Younger Dryas event, a 700-year return to glacial conditions that interrupted the present warm episode, is thought to have been caused by a sudden diversion of melting Canadian ice sheet waters from the Mississippi to the Saint Lawrence River.
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several discrete steps over a period of about 800 years, the largest of these diversions was the last, involving the meltwater released from about 60 percent of the southern perimeter of the Laurentide ice sheet. As dated by the radiocarbon method, it occurred about 11,000 years ago. Within the margin of error of such age determinations, this corresponds to the time the Younger Dryas began.

Scientists understand why the sudden diversion of a large meltwater flow from the Mississippi River to the Saint Lawrence would affect the ocean conveyor. As stated above, an essential feature of this system is the densification through cooling of high salt content water in the northern Atlantic. Today, the sinking of this water feeds a globe-encircling deep current. The sudden influx directly into the northern Atlantic of an amount of water equivalent to that carried by the Amazon River would almost certainly diminish the salinity of surface waters in the northern Atlantic enough to disrupt the deep-water formation process. One might say that the Younger Dryas was not only a warning about the manner in which climate reacts when pushed but also clearly showed that the coupling between the transport of fresh water across the earth's surface and the transport of salt within the sea is a critical element in the earth's response to climate change.

If this reading of the paleoclimatic record is correct, then we must face up to the reality that our climatic system does not operate in an orderly manner. As the greenhouse gases we produce build up, the ocean–atmosphere system may leap to yet another mode of operation. Unfortu-

nately, the paleoclimatic record provides no clues as to how the earth's climate system responds when warmed beyond its prevailing state. Over the period for which our paleoenvironmental records are sufficiently detailed to permit such reconstructions, climate has not been significantly warmer than today's. So we are pushing the earth into an unknown realm. We have no way to predict how the great ocean conveyor will respond, nor can we be sure of other important elements of the system, which are subject to dramatic change.

The computer simulations that have greatly improved our ability to predict weather have also told us some important things about the possible response to the greenhouse buildup. But because of their basic design, these computer models cannot tell us anything about the ocean–atmosphere system and leaping climates. At present no one knows how to incorporate the oceans into these simulations. Decades may pass before this can be done. Even then I doubt if computer simulations will offer much insight into the changes in climate that might be triggered by the greenhouse buildup.

The upshot is that we must take our greenhouse experiment more seriously. Rather than treating it as a cocktail hour curiosity, we must view it as a threat to human beings and wildlife that can be resolved only by serious study over many decades. We must expand our efforts to understand the operation of each of the units of the earth's climate system and how they interact. Only in this way will our grandchildren be able to prepare wisely for the changes that are bound to be wrought by our great experiment.
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The discovery nearly half a century ago of the Lascaux cave in southwestern France is one of the world's great adventure stories. Four boys with a homemade oil lamp and time on their hands set out to explore "a fairly deep hole" in a wooded hillside and found treasures beyond expectation: incredibly rich galleries of magnificent prehistoric figures painted some 17,000 years ago.

A great deal has happened since then. A compact cave, consisting of a main entrance hall and two branches ending in cramped, dead-end spaces, Lascaux ranks as the most spectacular of the 200-odd art caves discovered to date in western Europe. It is also the most intensively studied. Simply taking an inventory of the art has been a formidable task, and no one claims that the current count of more than 80 paintings and some 1,500 engravings represents a complete list.

Nearly ten years ago France's Ministry of Culture commissioned the late Mario Ruspoli, a skilled movie-maker who had filmed Etruscan tombs and other underground sites, to create a documentary of the Lascaux art. In the course of shooting 150 reels over a three-year period, Ruspoli became so entranced with what he was seeing and learning that he decided to produce a written, as well as a cinematic, record of his experiences. The Cave of Lascaux, a beautifully illustrated, up-to-date account of the site and the times when the earliest fine art flourished, is the result of his decision.

Prehistoric artists planned a special frieze in the main hall, a sweeping panorama of animals painted high on the chamber's curving limestone walls. More than two dozen figures make up this breathtaking display: seven bulls (including one eighteen feet long, the largest known cave painting), some twelve horses, six deer, and an enigmatic animal with two prominent horns, which guides and archeologists persist in calling a "unicorn." The passage from this gallery to the

An aurochs, ancestor of the domestic ox, facing a small red horse

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left-hand branch leads through a keyhole-shaped opening into a corridor containing, among other paintings, an arched ceiling composition of three red cows and a delicately drawn Chinese-style horse.

The author, like others before him, felt the "occult power" of Lascaux's most secret place, or inner sanctum, located at the bottom of a 26-foot-deep pit off the right-hand branch of the cave. Known as the Shaft of the Dead Man, it includes a famous painting—a stick-figure man falling backward before a wounded bison with horns lowered. The man has a bird's head, and just below him is a pole with a bird on top. The meaning of this scene remains elusive, but Ruspoli suggests that it represents a myth, perhaps part of a prehistoric epic recorded visually millennia before the invention of writing. Incidentally, he complains about the "excessive administrative restrictions" that limited his filming time in the shaft to fifteen minutes.

The shaft has yielded other archeological treasures. Excavators found more than sixty stone lamps in deposits at the bottom of the pit, slabs with hollowed-out portions to hold fuels. One of them, spoon shaped and made of highly polished sandstone, still contained charcoal remains of juniper wicks saturated with animal fat. Experimental replicas of these lamps indicated that, placed at strategic points near cave walls, they burned five or more hours and provided ample illumination for the artists. Also in the same deposits were traces of red ocher and the natural black pigment manganese dioxide. (Deposits in other parts of the cave yielded a rich variety of pigments in shades of yellow, orange, and brown as well as black and red.)

One of the most important finds, made not far from the edge of the pit, has nothing to do with art or artists. In fact, it would have been missed by anyone but an experienced archeologist who looks everywhere and is always ready for the unexpected. About forty years ago excavators working at night, when there were no tourists about, accidentally bumped into a wall and knocked off a piece of clay that broke in two, revealing in one half a cylindrical section of decomposed plant fiber, and in the other half the imprint of a braided rope. As emphasized by archeologist Randall White of New York University, this single item implies a whole technology—the ability to make nets, fishing lines, snares, thread, and perhaps woven goods and baskets.

Lascaux soon became big business. More than two million paying customers were ushered through the main hall and adjacent galleries, but with financial success came deep trouble. Paintings miraculously preserved in brilliant colors for thousands of years began deteriorating within a generation after the discovery. The first signs, detected in 1960, were patches of green algae, presumably brought in by visitors, starting to spread over some of the paintings. Three years later the so-called green leprosy had progressed so far that the cave was closed to the public. Although antibiotics and rigid temperature and humidity controls have helped restore the paintings, the cave remains closed.

But a special alternative is now available to tourists. In one of their major contributions to Ruspoli's book, Brigitte and Guy Delluc, dedicated experts on cave
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art, describe the construction of a man-made Lascaux II—"an enormous concrete blockhouse buried in a disused open quarry...about 200 yards from the original cave." Engineers have re-created the main hall and the right-hand branch, which contains most of the paintings, duplicating wall contours to within an accuracy of a few inches. And the artist Monique Peytral used natural pigments (many from sites in the region) to produce striking copies of the paintings, which attract some 300,000 visitors a year.

The Cave of Lascaux discusses current efforts to account for the phenomenon of prehistoric art and draws heavily on the research and insights of the late André Leroi-Gourhan. What demands explaining is the sudden emergence of art in a grand creative explosion during the upper paleolithic period 35,000 to 10,000 years ago, after two million completely artless years of human evolution. Leroi-Gourhan believed that ceremonies were conducted in the painted caves, perhaps initiations and puberty rites, since out of the thousand or so footprints preserved on the clay floors, the majority are those of children.

The mystery deepens with this plausible speculation. If the burst of art represents a burst of ceremony, that also calls for explanation. Everything seems to have exploded during the upper paleolithic, which saw the appearance of big-game hunting on a regular mass-killing basis; of potent new weapons, including harpoons, spear-throwers, and possibly the bow and arrow; of necklaces and other body ornaments; long-distance trade; needles and "tailored" clothing; burials with grave goods, indicating people of status; and very probably basic changes in the nature of language itself.

Although the Ruspoli book is mainly descriptive, it hints at these developments and their significance in relation to the cave art. Also, it includes a reference to Lascaux Inconnu (The Unknown Lascaux), by Arlette Leroi-Gourhan and J. Allain, which I recommend as a companion volume, among other reasons for its reproductions of finely executed engravings that were too difficult to photograph within Ruspoli's time limits. We are fortunate to have these records of a great tradition that lasted more than twenty millennia but that is covered sketchily, if at all, in practically all books and courses on art history.

John E. Pfeiffer has visited Lascaux and many other art caves on numerous occasions. His book, The Creative Explosion (Harper and Row), discusses the origins of art and religion.
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Lunar Coverups

by Thomas D. Nicholson

Depending on how one counts them, there may be from none to as many as three lunar eclipses per year. The ordinary rules count only umbral eclipses, either total or partial, making nice, clean, easy-to-see earth shadows on the moon’s surface. Some years there aren’t any umbral eclipses at all.

There is, however, another kind of lunar eclipse that can occur up to three times a year. In these penumbral eclipses, the earth’s shadow doesn’t fall anywhere on the moon, but the moon skirts close enough as it goes past the earth’s shadow to receive somewhat diminished sunlight.

We can think of lunar eclipses as solar eclipses taking place on the moon. If the earth hides all of the sun from all or part of the moon’s surface, we see an umbral eclipse of the moon. But if the earth hides only part of the sun from the moon’s surface, we see a penumbral lunar eclipse.

The penumbral eclipse early in October offers something interesting. The moon comes about as close as possible to the edge of the earth’s shadow without actually touching it. At mid-eclipse, shortly after 11:00 p.m., EST, on the 6th, the moon’s southern edge passes only 8 seconds of arc—only 0.2 percent of a degree—from the northern edge of the earth’s shadow; that is, less than 1 percent of the moon’s diameter, almost a “grazing,” partial umbral eclipse.

This time, because the moon’s edge is so close to the earth’s shadow, a darkening along the lower edge of the moon should be easily discernible. But there will be no clear line of shadow because a small sliver of the sun will still be shining, even at the extreme southern edge of the moon, peeking around the earth’s edge as seen from the moon’s surface. The brightness at the bottom edge of the moon will be no more than we would see around us on the earth during the last seconds of a total solar eclipse when the sun is about to disappear, and that’s pretty dark. From the bottom of the moon upward, more of the sun’s light will be visible, and on the moon’s upper edge, almost the entire sun will be shining.

The penumbral eclipse begins at 8:53 p.m., EST, on the 6th and ends at 1:10 A.M., EST, on the 7th, but these times may be relatively meaningless for viewers because no visible events take place to mark them. At about 10:45 p.m., the darkness on the moon’s edge should begin to be obvious. The darkening will begin before that, but only gradually, melding into the unchanged brightness on other parts of the moon. The lower edge of the moon will be darkest at about 11:01 P.M., EST, and will brighten slowly thereafter.

Remember that Eastern Standard Time must be adjusted for daylight-saving time and for other time zones. Similar adjustments must be made for the data in the calendar below, where times are expressed in EST.

October 1: The moon, well up in the south at dusk and just a day past first quarter, sits almost exactly on the border between Sagittarius and Capricornus.

October 2: Find Capricornus’s bikini-shaped star group on either side of the moon tonight. With a gibbous moon nearby, the constellation’s dim stars need a clear night to be seen.

October 3–4: Perigee moon (nearest the earth) is on the 3d. Mercury is at its greatest distance to the sun’s left on the 4th, but the shallow tilt of the ecliptic (the path of the sun on the celestial sphere) on the western horizon spoils the viewing advantage of elongation. The same is true for brilliant Venus, also in the west near Virgo’s brightest star Spica.

October 5: Look toward the moon after twilight ends. Pegasus’s Great Square is above it near the top of the sky, while Diphda (Cetus’s brightest star) and Fomalhaut (in Piscis Austrinus) are below, left and right, respectively.

October 6–7: The full moon (at 11:12
Celestial Events

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P.M., EST, on the 6th) is the harvest moon, rising in twilight and hanging low and large in the early evening for several more nights. A penumbral lunar eclipse, visible throughout the Americas, begins on the 6th and ends on the 7th (EST).

October 8: Jupiter is probably the only object visible in the brightly lighted sky near the moon.

October 9: Look toward the rising moon in the east after dark. The hazy outline of the Pleiades, Taurus’s faint star cluster, appears near it. The Bull’s reddish star Aldebaran, just below the Pleiades, and Auriga’s star Capella, to the right, are harbinger of the winter sky. They rise before the moon on subsequent nights.

October 12: Tonight’s rising moon (at about 9:00 P.M.) is almost exactly above the summer solstice, near the border between Taurus and Gemini. A few hours later, the brightest stars of the two constellations, Taurus’s Aldebaran, above, and Gemini’s Pollux and Castor, below, bracket the moon.

October 14: The moon, after reaching last-quarter phase at 1:06 P.M., EST, makes a threesome with Pollux and Castor at about midnight.

October 15: Apogee moon (farthest from the earth) is in Cancer.

October 16: Mercury begins retrograde (westerly) motion as its poor evening performance approaches an end.

October 18: Jupiter, at opposition from the sun, becomes an evening star. The brilliant late-night planet offers a better view this year than last, but it will be even better next year.

October 19–22: The last days for the morning crescent moon—the 19th through the 21st—should be good since the late moon rises steeply above the horizon each morning. The conjunction of Mercury and Venus, both poor evening stars, will go unnoticed on the 19th, but we should see Mars as a morning star near the moon on the 21st, shortly after their con-

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junction. New moon is at 12:28 p.m., EST, on the 22d, which should please meteor watchers looking for the Orionids during morning hours before and after the shower's maximum on the 21st.

October 25: The young crescent moon is near Saturn in late evening twilight. You may also see reddish Antares (in Scorpius) below the moon, forming a triangle with it and the planet. The moon occulted Antares earlier today as seen from the Southern Hemisphere.

October 26-28: The crescent moon slides gracefully through Sagittarius's stars, separating nightly from Saturn below it. Mercury moves into the morning sky at its inferior conjunction on the 28th.

October 29: First-quarter moon is at 12:10 p.m., EST, in Capricornus. Perigee moon occurs again later in the day.

October 31: The waxing gibbous moon ends the month among the dim stars of Aquarius.

The fall Sky Map shows the constellations and stars for October, November, and December from 40° north latitude at the hours given below. To use the map, hold it vertically with south (S) at the bottom and match the lower half of the map with the stars you see when you face south. As you face other directions, turn the map to bring the corresponding compass direction to the bottom of the map. The stars move west continuously during the night. By morning (before dawn), stars on the western half of the sky will have set, those on the eastern half will have moved into the west, and new stars (those of the spring evenings) will have risen in the east. The map shows the sky at about 2:00 a.m. on October 1; 1:00 a.m. on October 15; midnight on October 31; 11:00 p.m. on November 15; 10:00 p.m. on November 30; 9:00 p.m. on December 15; and 8:00 p.m. on December 31. The map can be used for an hour or more before and after the times given.
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Spanish Short Subjects

Tapas, the hors d’oeuvres of Spain, are more like miniature meals

by Raymond Sokolov

Returning from Spain this spring, I happened to overhear a young American woman athlete on my flight complaining that “it was impossible to stay in training. I could never get dinner before eight.” I didn’t have the heart to tell her how lucky she was to find a place willing to serve her the evening meal before nine or ten. You only see foreigners in Spanish restaurants at eight, angry that they have to wait even that long to find anyone ready to cook.

There are many reasons for the late Spanish dinner hour. The warm climate and the late sunset are the main objective ones. But I am more inclined to believe that long ago, for obscure cultural reasons, the Spaniards adopted the late-rising, late-retiring night-owl schedule that still shapes their day. Much more formally regulated than ours, their schedule starts later and has more punctuations.

Getting up early in Spain is a waste of time. Even newstands in major centers don’t really open until eight. The same is true for breakfast shops or cafes, with their coffee, chocolate, and pastries, including the fluted, deep-fried fingers of dough called churros. Lunch tends to begin about three. This gives working people time to get home after the two o’clock shop closing and get settled with food in front of the television to watch the news, strategically scheduled at three o’clock. By four, most places of business have reopened, and for many the business day won’t end until eight.

Into this thoroughly sensible if rigid framework fits another one designed to accommodate people who are hungry between meals, as it were. I am speaking, of course, of tapas, those mixed appetizers, or hors d’oeuvres (English and French are hopelessly inadequate to describe this full-blown food institution), available at bars everywhere in Spain.

Tapas bars double as pastry bars but never simultaneously. In the morning, pastries of many shapes and descriptions, usually too sweet for the North American palate, cover the bar. At noon, they vanish and out comes a profusion of plates filled with everything from olives and almonds to the fabulous cured ham (jamón serrano) of Jabugo and other mountain villages to cold omelets called tortillas to snacks to hot dishes of serious sophistication. The variety is practically infinite, but the portions are a largish nibble (except when you order a ración, which is a plateful of a particular item). The American food writer Penelope Casas wrote a whole book devoted to the subject (Tapas: The Little Dishes of Spain, Knopf, 1985).

In her travels all over Spain, Casas uncovered seafood tapas, regional tapas in Galicia and Catalonia, even nouvelle cuisine tapas. She also encourages Americans to make whole meals at home out of selections of tapas, which is what Americans out of sync with the restaurant-dining schedule in Spain should definitely try doing, thereby turning the tapas ritual to their own advantage.

In Spain, the tapas plates that come out at noon are put away about three and out come the pastries again. At eight the tapas return. This alternation of sweet and savory foods coincides with the presumed desires of customers dropping in at different hours of the day. During the elongated Spanish morning, the pastries serve as breakfast or coffee-break food. At noon tapas are sold to people leaving work and heading toward home for lunch. The afternoon pastries are a form of dessert. The 8:00 p.m. tapas accompany the evening’s aperitif or stave off the hunger pangs of those who are having a drink after work on their way to their evening meal. The tapas—pastry ritual fits the needs of a culture almost constantly on the move because of four rush hours and what used to be a traditional devotion to the public stroll, or paseo.

I cannot say whether the paseo has vanished completely in the new and up-to-date Spain that has emerged since the death of Franco just over a decade ago. But in two recent visits that covered most of the country except the northern coast, I did not once encounter the dancelike paseos I remember seeing regularly in Spain outside Madrid in the early sixties. Then, even if you didn’t know the word paseo, you knew something special was going on when you saw one. A paseo was not just a crowd of people milling around outdoors. In my experience it took place in the central square, the plaza mayor, of a town. People in small groups, families, bevies of
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Kenya Safari
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This spring I returned to Spain for what may be the peak of the tapas year in the capital of tapas. During Holy Week in Seville, the entire population of the city and its sprawling environs, not to mention every outsider who can beg or force his way into a Sevillian hotel, joins in the city's amazingly elaborate schedule of Eastern tide street processions. Cofradias, or brotherhoods, march in hooded robes carrying pasos (floats) with statues representing scenes from the Passion, the last suffering of Jesus. The processions go on day and night, a continuous quintessence of the paseo for which Seville's numerous tapas bars are ready and waiting.

I did not, unfortunately, bring along Casas's handy list of recommended tapas bars in Seville but I had no trouble finding excellent examples of deep-fried squid, octopus in vinaigrette, or smelts. Anyway, it seems to me not in the spirit of this week-long super paseo to carry a guidebook. The natural and easy thing is to drop in wherever you are when hunger strikes or when the price of a tapa can bring you a curb side seat for a procession.

The processions and tapas go together so well that you might easily conclude they both go back to the beginnings of religious life in Spain. In fact, the processions date primarily from the populist, propagandizing days of the Counter Reformation in the sixteenth century. Tapas came much later, in the nineteenth century, apparently, and in Andalusia, Seville's region. Some genius of a publican took to draping ham or perching a slice of chorizo (sau- sade) on the top of a wineglass. A tapa is a lid or cover. The etymology is obvious.

Tapas have now spread to New York, where they fit into the grating yuppie culture quite well, even if their original role in a coherent dietary schedule has been lost. But I do not want to overemphasize this ritual aspect of tapas. They are not, after all, a very old ritual, and their gastronomic significance goes well beyond their role as preprandial snacks. They present, in miniature, much of the historical and regional food of Spain, including sauces. It is as if someone wanted to display as many typical dishes as possible all at once without
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the formality and pressure of a proper meal. *Tapas* are like a sampler of traditional Spanish cuisine, of dishes much older than the institution of *tapas* itself.

This impulse to serve a great variety of important foods all at once is a quite unusual and specifically Spanish thing. Other cultures tend to mark off their snack food or their street food or other forms of informal feeding from the rest of their cuisine. But very few of the *tapas* recipes in Casas’s book would seem strange if served as a full-blown course in full portions at a regular sit-down meal.

What we get at a *tapas* bar is a convenient, quick taste of foods that in most cases would have been available to Cumbus in Spain. But this diverse menu suffered a sea change when it was carried to the New World. The tortilla changed from an omelet to a flat corn bread. The *empanada* remained a stuffed turnover, but it took on local color in Argentina or Chile or wherever it resettled. Real Spanish *tapas* did not cross the Atlantic until practically yesterday, by which time we already had our own Hispanic smorgas-

### Pork Ribs in Paprika Sauce
(Slightly adapted from *Tapas: The Little Dishes of Spain*, by Penelope Casas, Knopf, 1985)

1. Melt the lard or heat the oil in a deep caserole. Add the ribs and sprinkle with salt, oregano, paprika, and flour. Stir to coat the meat.
2. Add the bay leaf and white wine and bring to a boil. Cover and simmer very slowly for one hour.
3. Uncover and boil the liquid down to half. Skim off any excess fat before serving. (May be prepared ahead.)

Yield: 4 servings

### Bacalao Posmodernizado
(Pan-Hispanic Dried Cod Fritters)

1/4 pound skinned and dried salt cod
2 tablespoons olive oil
4 cloves garlic, peeled
1/4 cup flour
bord, a heritage of Spanish colonialism, the cuchifrito stand.

There is an ocean of difference between the deep-fried pork oddments of the typical Caribbean cuchifrito joint and the refined cornucopia of the tapas bars of Spain. But the contrast says much about Spanish America and how it continues to reflect the Columbian legacy. I will return to this subject soon. In the meantime, I append two recipes. One is an authentic tapas dish that might be thought of as a refined precursor of the barbecue ribs sold in New York's Spanish Harlem. The cod fritters on the other hand, are an improvisation in a New World vein on an idea from Spain and an ingredient (salt cod) shared by the whole Hispanic world. Wine and paprika may define the ribs as Spanish but cayenne pepper gives the fritters a New World tinge. To anyone who has eaten on both sides of the Atlantic, the culinary bloodlines are clear.

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

1½ teaspoons baking powder
Pinch of salt
Cayenne pepper
¼ cup milk
Oil for deep frying

1. Set cod in cold water to cover and let it sit at room temperature for a day or two, changing water every few hours. This is to remove excess salt and to reconstitute the cod. After the first day, taste the fish. If it isn’t too salty, proceed with the rest of the recipe. Otherwise wait overnight and taste again. Thirty-six hours of soaking should be sufficient.

2. Put the olive oil and the garlic cloves in a small pan and cook over low heat 20 minutes or until garlic softens. Remove garlic from oil with a slotted spoon. Mash in a bowl. Reserve cooking oil separately.

3. To the mashed garlic, add flour, baking powder, salt, cayenne pepper, milk, and three tablespoons of the garlic cooking oil (add extra oil if there isn’t enough cooking oil). Mix well.

4. Drain the cod. Pull it into flakes and shreds with your hands, removing and discarding any skin or bones. Stir into the batter from step 3.

5. Heat vegetable oil (to a depth of ½ inch in a skillet or to the required depth in a deep fryer) to 380 degrees. With two serving spoons, form dumplings out of the cod mixture and drop them carefully, a few at a time, into the oil. Fry until golden brown. Drain on paper and serve.

Yield: 4 servings

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In the Pink

From a cliff about one hundred feet above Lake Nakuru, Kenya, it's impossible to pick a face out of this crowd of flamingos. Besides, most of their faces are buried in the water because the birds are avidly feeding.

On October days, when the short rainy season begins in East Africa, as many as one million lesser and greater flamingos gather at Nakuru. Situated in a volcanic basin, the lake — in the first African national park designated for birds — is highly alkaline and replete with algae and plankton that give the waters a rich, soupy consistency.

An impressionistic study in pink in the setting sun, two species of flamingos are seen here enjoying a late afternoon meal. The lesser flamingo feeds directly on the blue-green algae, while the greater flamingo dines on the small crustaceans that live in the lake. Combined, the two species at Nakuru consume about 200 tons of food a day.

While neither species has been seen nesting on the lake in recent years, biologists speculate that the lesser flamingo uses Nakuru as a display, as well as a feeding, ground. But as photographer Robert Caputo jokes to friends more accustomed to plastic than to feathered flamingos, Nakuru also looks like the place flamingos stay while waiting for their lawn assignments.

Shari Rudavsky
A professor of geosciences at the University of Arizona, where he has taught since receiving his doctorate in zoology from the University of Michigan, Paul S. Martin (page 10) has been concerned with the origin of North America's early big-game hunters for more than twenty years. His model of a "blitzkrieg," which maintains that these hunters caused the extinction of many Ice Age species, has become a benchmark in paleoecological debates. Martin's research also extends to the timing, intensity, and pattern of late Quaternary extinctions elsewhere in the world. For additional reading he recommends "The American Blitzkrieg: A Mammoth Undertaking," by Jared Diamond (Discover, June 1987, pp. 82–88); "Were Clovis Progenitors in Beringia?" by C. Vance Haynes, in Paleoeocology of Beringia, edited by David M. Hopkins et al. (Orlando: Academic Press, 1982); and "The Americas: The Case Against an Ice-Age Human Population," by Roger C. Owen, in The Origins of Modern Humans: A World Survey of the Fossil Evidence, edited by Fred H. Smith and Frank Spencer (New York: Alan R. Liss, 1984).
In 1981, Christine Padoch (page 56) began studying indigenous agroforestry systems in the Iquitos area of Peru. “Any visitor to the city will immediately realize that Iquitos is a great commercial center and Belén a great regional market,” says Padoch (below left). “The apparent chaos of the market tempted me to try to figure out just how the marketing system works.” In cooperation with Peru’s Instituto de Investigaciones de la Amazonía Peruana and the Centro Amazonico de Antropología and Aplicación Práctica, Padoch is currently participating in an interdisciplinary study of native fruits of the Peruvian Amazon. The project’s goal is to identify, develop, and promote little-known but economically promising fruits. For further reading, Padoch, an associate scientist at the Institute of Economic Botany at the New York Botanical Garden, suggests Mario Hiraoka’s article, “Zonation of Mestizo Riverine Farming Systems in Northeastern Peru” (National Geographic Research, vol. 2, no. 3, pp. 354–371, 1986).
Wallace S. Broecker (page 74) is a true-blue Columbia University loyalist. He attended Columbia as an undergraduate and earned his doctorate in geology there as well. Broecker has spent thirty-five years, his entire working life, at the university, mostly at the Lamont-Doherty Geological Observatory. He is now the Newberry Professor of Geology. In June 1986, he testified before the Senate Subcommittee on Environmental Pollution. This November he will share the prestigious Vetlesen Award for oceanographic studies with Harmon Craig of the Scripps Institute of Oceanography. Under his own imprint, Broecker has published *Tracers in the Sea* (1982) and *How to Build a Habitable Sea* (1987). Further information about oceans and climate can be gleaned from *Ice Age: Solving the Mystery*, by John Imbrie and Katherine P. Imbrie (Hillside: Enslow Publishers, 1979).

Photographer Robert Caputo (page 104), shown above with a group of Masai, wanted to take an overhead picture of the flamingo flocks at Lake Nakuru in Kenya, but feared that the standard method—flying above the birds in an airplane—would disturb their pattern. So he found a quieter vantage point on a cliff. After waiting a day for the clouds to clear, Caputo, using his 600-mm lens, captured the image for this month’s “Natural Moment.” A few months later, the photograph won first prize in the science and natural history category of the National Press Photographer’s Association Picture of the Year Competition. Caputo, who has been a wildlife photographer in Africa for more than ten years, started his career as a cinematographer for Jane Goodall and has also worked for Time-Life Books, Inc., and *National Geographic*. He has a graduate degree in film and has written and illustrated two children’s books. Caputo is currently working on a picture book about the Nile River.

Gary F. McCracken (page 66) studied the population genetics of snails for his doctorate from Cornell University, but after working on a genetic study of bats, he became devoted to studying bat behavior. Now an associate professor of zoology at the University of Tennessee, McCracken spends most of his summers working in the bat caves of Texas. Coauthor Mary K. Gustin has spent summers since 1981 assisting McCracken. Gustin is a senior research assistant in environmental sciences at the Oak Ridge National Laboratories in Tennessee. She has begun to study the migration of the free-tailed bats and how they choose their caves, while McCracken continues his studies on social behavior and mating. For further reading on bats, the authors recommend *Bats: A Natural History*, by John E. Hill and James D. Smith (Austin: University of Texas Press, 1984), and *Just Bats*, by N. Brockfenton (Toronto: University of Toronto Press, 1983).
How nuclear energy can help defuse the next oil crisis

Nuclear-generated electricity, still the fastest-growing major energy source in America, may be our best defense against another oil crisis.

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The 1987 special report on U.S. energy security, ordered by the President and prepared by the U.S. Department of Energy, states that without electricity from nuclear energy, the United States "would be using more oil, paying more for each barrel of it, and feeling much less secure about its energy outlook."

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With over a hundred operating plants in the U.S., nuclear energy is now our second leading source of electricity. But in spite of all that we have accomplished, the threat of foreign oil dependence remains. Difficult choices still need to be made, but one fact is clear: the more we develop our own energy sources, the more we can control our own destiny.

For a free booklet on energy independence, write to the U.S. Council for Energy Awareness, P.O. Box 1537 (FQ21), Ridgely, MD 21661. Please allow 4-6 weeks for delivery.

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Old Grand-Dad
HEAD OF THE BOURBON FAMILY

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Cover: The palm viper of Central America adjusts its blood pressure to suit its posture. Photograph by Michael Fogden, Oxford Scientific Films. Story on page 38.
Mulberry Impatience

How unfair of you to publish Raymond Sokolov's "Here We Go Round the Mulberry Bush" in the October 1986 issue. After ten long months of impatient waiting for the New York City Central Park mulberries to ripen, I was finally able to try my hand at the recipe for murrey. The results, as based on the reactions of my dinner guests, were wonderful. Following the first attempt, I returned to Central Park for a thirty-five-pound harvest—this time shaking the laden branches so the berries fell on a twelve-by-fifteen-foot dropcloth.

For major mulberry harvesters I submit the following recipe for cold mulberry soup as an alternative to the murrey:

2 cups mulberries
½ cup sugar
½ cup sour cream
1 ½ cups ice water
½ cup red wine


Yield: 4–5 servings

Herb Schon
New York, New York

From Surtsey to the Moon

Your commemorative of my March 1967 article, "Birth of an Island" ("Postscripts" August 1987), evoked memories and musings: memories of how lucky I was that no large-scale pyroclastic blast occurred as our little plane flitted back and forth over the active volcano as a moth might fly about a flickering flame; musings on how the sight of red, meandering lava streams coursing down Surtsey's cold, black flanks eventually led to a theory of how the moon's maria (smooth low-lying areas) were formed.

NASA pictures of the moon taken by Ranger and lunar orbiter spacecraft in the early and mid-1960s showed sinuous valleys in the smooth mare depressions that looked remarkably similar to the meandering lava streams I had observed on Surtsey. These valleys, or rills, were considered by scientists in the pre-Apollo 1960s to be dried-up river valleys formed by ancient lunar waters that had since evaporated into space. I, however, with the help of several groups of high school students in the 1960s, espoused an igneous origin for the rills and other lunar features.

In the October 1967 issue of the Science Teacher, we identified volcanoes, lava fields, and other igneous features and suggested that ancient lunar volcanism could be confirmed by "future lunar orbiting vehicles" able to detect huge igneous rock intrusions (subvolcanic plutons) via gravity measurements.

Unbeknown to us, in 1956 Nobelist Harold Urey had predicted the existence of massive objects under the maria. He postulated that they were asteroids that had excavated the mare depressions on impact and had then been buried under the fragments that fell back into the maria. In 1968, Muller and Sjögren, by analyzing lunar satellite orbital variations caused by gravity anomalies, discovered mascons (mass concentrations) under the maria. They considered the mascons to be Urey's asteroids. Other theories on the mascons included Baldwin's dense lavas, which caused mare collapse after extrusion onto the lunar surface (1968), and Gilvarry's dense sediments deposited in desiccated lunar ocean basins (1969). My students and I postulated dense, extinct plutons underlying huge mare calderas (volcanic depressions) that had collapsed onto the once-molten plutons (Nature, October 11, 1969).

Despite the evidence of ancient lunar volcanic activity derived from the Apollo missions, the pluton explanation of mascons did not gain widespread acceptance until the mid-1970s.

Julian Kane
Garden City Senior High School
Garden City, New York

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Debris Danger Zone

The littering of the earth's orbital space is a byproduct of the space age. When astrophysicist Donald J. Kessler wrote about the problem for Natural History (March 1982), the North American Air Defense Command (NORAD), responsible for detecting and identifying orbiting junk with radar, was tracking about 5,000 objects. In the last five years the number of radar-detected objects has risen to about 7,000. A piece of orbiting trash can be as large as a spacecraft or as small as a grain of salt, but NORAD only follows objects about four or more inches in diameter. Most of the tracked material consists of small fragments of rocket bodies that exploded accidentally or pieces of payloads that were deliberately destroyed. A different kind of debris is tiny aluminum oxide particles that come from the firing of solid-fueled rocket motors.

The altitude of the debris ranges from about 200 to 700 miles—the zone of greatest danger for space collisions. Spacecraft, satellites, and rockets are seldom put into higher altitudes, but above 700 miles, objects may stay in space for hundreds or even thousands of years. Consequently, if they should collide with each other at those higher altitudes, their fragments would remain up there and pose no immediate threat. Below the danger zone, objects tend to enter the earth's atmosphere, burning up in the process.

Scientists estimate that about 35,000 other objects, too small for NORAD to detect with radar but detectable with powerful earth-based telescopes, are also circling in the danger zone. This debris poses little danger to us on the earth, but since it is traveling at average relative speeds of six miles per second, it can severely damage expensive equipment in a collision. This threat was dramatized by a cavity one-eighth of an inch in diameter created in a window of the Challenger shuttle on a mission in 1983. The pit was determined to have been caused by a collision with a speck of paint traveling at a speed of about two to four miles per second. The window had to be replaced.

One year later, the Solar Maximum satellite, launched in 1980 to monitor the sun during periods of maximum solar activity, was repaired while in its 350-mile-high orbit after its guidance system had stopped functioning. At that time, about ten square feet of its aluminum louvers and fifteen square feet of its thermal insulating blanket were replaced and the original materials were returned to Earth for examination. Both were found to be pitted with pin-sized holes. Although some of the holes were made by meteoroid fragments, most were deemed to have been caused by man-made debris. These findings have caused concern among astronomers about the fate of the $1 billion Hubble Space Telescope, to be launched in 1988.

As more and more nations put satellites into space, the risk of collision can only increase. The solution is prevention, says Kessler, who is responsible for research on controlling the growth of orbital debris at the Space Environment Office of the Johnson Space Center in Houston. The United States has always required its astronauts to bag their wastes and return them to Earth. The U.S. Air Force has agreed to conduct low-altitude rather than high-altitude tests of objects it puts into space so debris from tests will reenter the earth's atmosphere and burn up. Extra shielding will also reduce the risk. For example, 2,000 pounds of additional shielding is being considered for each of six space station crew modules. Further, the European Space Agency, an international consortium, is also looking into preventive measures.

Additional actions, Kessler says, would be to control discarded rocket stages so they reenter the earth's atmosphere and land deep in the ocean. They are made of metal, are not radioactive, and should not harm the ocean any more than sunken ships do. Unused fuel on spent rockets should also be dumped in space to keep the rockets from exploding. This dumped liquid will eventually evaporate, adding only gases to the upper atmosphere. Although he believes the situation will probably get worse before it gets better, Kessler says, "things will not be as bad as they would be if nobody were doing anything and if nothing were being planned."
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“Friend by Day, Enemy by Night”

In one generation, blood feuds have taken over a Pakistani village

by R. Lincoln Keiser

The long bus ride from the Pakistani village of Thull to Dir town is a torment, made worse by dust and a rutted dirt track that passes for a road. Passengers who cannot cram onto the seats either hang precariously off the back or climb on top, crowding within the intricate metal rack that surrounds the roof. Adorned with garish scenes of speeding streamliners and modern F-15 fighter planes, the bus agonizes over the boulders and ditches in its path. Thus, whenever I made my biweekly grocery run by Jeep to the market in Dir town, friends and acquaintances begged to come along. Through various contortions most of the would-be riders somehow jammed into the back seat.

One trip was particularly memorable. I had agreed to take along Anwar, who was both my good friend and one of my principal sources of ethnographic information. For three years he had sought vengeance for his brother’s murder, carefully hoarding his money until he had finally accumulated enough to buy the rifle that would permit him to kill his enemy. In Dir town he planned to catch a bus to Bajour, where local gun shops sold good firearms. I had also promised a place in the Jeep to Mir Said, who each night slept outside my door with his weapons at his side, guarding my safety.

Moments before we left, Mir Said’s brother-in-law Hazrat Gul sauntered up to the Jeep to ask for a ride, his Russian-made automatic rifle slung across his shoulder. As he crowded in, tension filled the vehicle: Anwar’s close friendship with Gholam Sarwar, one of Hazrat Gul’s enemies, caused the problem. Anwar and Hazrat Gul were not themselves feuding, but the potential for violence between them was clear to all in the community. Most of the time the two men avoided each other with studied carelessness.

Much to my surprise the tension quickly dissipated. Throughout the five-hour trip to Dir town, Hazrat Gul and Anwar laughed, joked, and gossiped together. They even swore everlasting friendship, referring to each other as “brothers.” Later I asked Anwar if he and Hazrat Gul really were as friendly as they seemed. Anwar thought for a minute and answered, “Doske dos, radke dashman” (“friend by day, enemy by night”), a proverb that captures one of the basic realities of life in Thull.

A community of roughly 6,000 Moslems, Thull consists of a series of settlements scattered along a six-mile stretch of the upper Panjkora valley, in Pakistan’s Northwest Frontier Province. Ethnically these people are Kohistanis, distinct from their better-known neighbors, the Pathans. When I first arrived there in 1984, I was surprised by the intensity of blood feuds (mar dashman, literally “death enmity”). Earlier reports by anthropologists had led me to believe that the Kohistanis generally settled internal disputes without bloodshed. The obsession with mar dashman had in fact developed only in the previous fifteen years. Before then there had been fights, usually expressing opposition between the three major local patrilineal clans or their subdivisions, but they

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did not involve deadly weapons, since most people in Thull feared death enmity between clans would destroy the community. Today, the majority of conflicts do not involve clans but instead oppose individual male antagonists, alone or supported by various categories of allies. Killing the enemy in retaliation for some personal injury is the goal, and no rules limit the use of weapons.

An enemy (dushman) is a person with whom one has bad relations and toward whom one feels enmity (dushmani) and distrust. Exchanging bullets and blows (with fist, ax, knife, or club) whenever possible and refusing either to give or to accept food and drink demonstrate mar dushmani. In contrast, allies are those with whom one has good relations and toward whom one feels amity and trust. Sharing personal possessions, giving and accepting food and drink, and exchanging labor typify behavior between allies.

The potential for change in relationships of alliance and enmity always exists. Moreover, most men in Thull are neither allies nor enemies although they may unexpectedly become so. Therefore neither trust nor distrust but guarded suspicion governs behavior between most men in Thull. As my friend Anwar explained, smiling words express normal good manners, but only fools trust those who speak them. The men of Thull are masters of deceit, and except for one’s allies, those who give smiles during the day may well give bullets at night.

To make his point clear, Anwar told me how his brother Said Omar was killed. Said Omar lived in an outlying area where houses were scattered among fields and pastures. One day Said Omar heard via village gossip that his neighbor Diliwar Khan had no food. Although Said Omar did not have a close relationship with Diliwar Khan, he gathered together a basket of bread and cheese, went to Diliwar Khan’s house, about 100 yards away, and knocked on the door. When it opened, Diliwar Khan stood in the doorway, his rifle at his shoulder. He fired immediately, the bullet going straight through Said Omar’s heart and killing him instantly. To add insult to murder, Diliwar Khan unleashed his attack dogs when Said Omar’s young son attempted to retrieve his father’s body.

““But why,” I asked, “would a man kill a neighbor who was only trying to help him?”


I heard similar explanations from other men as well. One evening Gholam Sarwar invited his friend Fakir to share a meal at his house. At about nine o’clock, after a pleasant evening of good food and gossip, Fakir left to return home. As far as anyone knew, Fakir had no enemies, yet about ten minutes later an ambush was sprung, and Fakir lay dead, shot in the head. The next morning five men, neighbors of the slain man, left Thull for the high mountain pastures. This was generally interpreted as a sign of their guilt, yet they never publicly admitted the murder or revealed any motive they might have had. Gholam Sarwar explained it simply: “The night killed him.” He too swore vengeance, and soon thereafter purchased a Russian AK-47 assault rifle.

Fakir actually was murdered at night, but to say that “the night killed him” is a metaphor meaning that the real reason is hidden, or secret. No one kills without cause. As a general principle, retaliation is owed whenever a man is wronged by another, but the act of revenge itself should not exceed the original wrong; a blow should answer a blow; a death answer a death. In the first case, antagonists share anger (roshagat), and the aggrieved tries to injure his opponent. In the second, foes share death enmity, and the aggrieved tries to kill his enemy. Men prefer to avenge themselves on the actual murderer, but a father, adult brother, or adult son is a permissible substitute. Killing any other kinsman is inappropriate, while killing women and children is unheard of.

Wrong committed against men through wives, sisters, and daughters are a special case: whatever the transgression, the most appropriate response is to kill the offending person. For example, staring at a man’s wife or his daughter or sister (if she is of marriageable age) demands deadly retaliation. Thus, according to some in Thull, Diliwar Khan killed Said Omar because Said Omar had come to Diliwar Khan’s door not to bring food, but rather to catch a glimpse of Diliwar Khan’s attractive young wife.

Except for attacks through women, taking revenge is not always required. In cases of physical injury and murder, the wronged party can choose to settle the case peacefully by accepting compensation. If a man defending himself against vengeance is desperate enough (usually for fear of being killed), he can try to enter his enemy’s house with a piece of white cloth tied to his dagger. If he gets inside without being shot, he will crawl under a string bed and say to his dushman, “Kill me! I am at your mercy.” The process is a way of formally asking an enemy to accept compensation in lieu of revenge. The enemy cannot kill the supplicant while he is in his house, but he is not obligated to abandon vengeance. He may instead stand out of his house, find a close relative, and say to him, “A dog is in my house! Make him leave!”

I was told that supplication is common, and that no one criticizes those who ask for mercy. Yet no one settled mar dushmani by supplication while I was in Thull. The more normal method seems to be that at a meeting of all men in the community, important individuals unrelated to either side entreat the vengeance seeker to accept compensation. He will most likely acquiesce if those of high standing among his allies pressure him to do so.

Compensation for murder is usually paid in money, normally a sum of four to six thousand dollars. Sometimes land is given; more rarely, women are given in marriage as well. After the opposing sides agree to the compensation, the former enemies sit down to a shared ritual meal of rice and meat. At its conclusion a mullah (Moslem priest) intones a special prayer, and the bad relationship between the two dushman theoretically ends. The murdered man’s father, sons, and brothers usually divide the compensation.

Payign compensation does not always terminate mar dushmani. Vengeance often involves the opposition of many people, and not all allies share the compensation. A friend or distant relative who feels aggrieved by a murder sometimes takes it upon himself to seek vengeance in spite of the peaceful settlement. Moreover, vengeance seekers sometimes agree to peace as a ploy to trick enemies into lowering their guard, making them easier to kill. To take revenge by that tactic seriously violates community morality, but those who do so usually find some way to make their deed an open secret, to demonstrate their character.

The rise of mar dushmani in Thull can be traced to events since 1965, when the government of Pakistan asserted control over the region and embarked on an ambitious program of social and economic development. The most important external change was the construction of a road and the establishment of regular bus service linking Thull with the rest of Pakistan. As a result, an ever increasing number of priests from Thull traveled to Mardan and Peshawar to study in centers of Islamic learning with noted scholars and teachers, bringing back an ethically Pathan vision of Islam that, at the risk of oversimplifying, could be termed fundamentalist.

Whereas saint cults had until then been an important part of Islamic beliefs and practices in Thull, this fundamentalist ide-
ology denied the existence of any humans with special access to God. Priests returned to Thull to campaign against such beliefs, and shrines to saints no longer exist in the community. As part of this Islamic purification movement, the priests also preached against music and dancing (especially at weddings) and for the seclusion of women.

The issue of excluding women was especially important in the development of mar dushmani, couched as it was in terms of the Pathan notion of ghrairat, or "honor" (in the sense of personal worth, integrity, or character). As men in Thull explain, ghrairat is natural, a gift from God (in fact, God's most valuable gift). Every Moslem is born with ghrairat, and although the actions of others can pollute it, a man only loses his ghrairat by failing to protect it.

Protecting ghrairat depends on following a clearly defined code of conduct. A man must provide his wife (or wives) and daughters with appropriate food and clothing to the degree his wealth allows; he must never permit his wife or daughters to speak to men who are not closely related; he must never eat or exchange friendly conversation with the enemy of a close paternal kinsman; and he must always be ready to strike at those who sully his ghrairat. Having sexual relations with a man's wife or unmarried daughter, proposing intimacy with her, or attempting to flee the community her, sullies the man's ghrairat. So does staring at such a woman, reflecting light from a snuff box mirror on her, or looking at her through a camera. The murder of a close paternal kinsman, verbal abuse, theft, and assault also pollute ghrairat and similarly demand vengeance.

Because ghrairat is rooted in Islam, attacks on a man's identity as a Moslem call for strong emotions. Men often cast aspersions on their opponents in terms of the distinction between Moslems and kafirs (infidels), each accusing the other of kafir kar karant (making kafir work, that is, acting like a kafir). Such accusations are dangerous, however, often leading to violence and even murder. During Ramadan, the Moslem month of fasting, for example, accusations of breaking the fast have led to serious injury and loss of life.

The construction of the road brought about economic changes within Thull that also contributed to the growth of mar dushmani. Formerly, subsistence was based on a balance between herding and agriculture. During the winter, herd owners kept their goats and cattle in special quarters in or near permanent settlements, and in the summer they took their herds into the mountains to graze on the rich grass found in high alpine meadows. Men generally did the herding work, while women cultivated maize in the fields near the permanent settlements. Herding also provided the only cash income in the community, the men carrying cheese and butter down from the mountains to sell in surrounding market centers.

The economic importance of herding was instrumental in keeping peace. Summer pastureland was divided into named parcels, each consisting of two clearly demarcated pastures (one for early summer, one for late summer). An annual lottery allocated these pasture parcels to groups, called lud, composed of segments from different clans. As a result, the people who herded together, who had common rights to pastures and a common interest in protecting these rights, were often the very people who might oppose one another in political disputes or battles between clans. The crosscutting allegiances encouraged the peaceful settlement of disputes.

The construction of the road changed all this. By allowing relatively rapid and inexpensive trucking of produce to market centers throughout Pakistan, it made potatoes (which grow particularly well at high elevations) a viable cash crop. The road also permitted farmers to bring more land under cultivation. Previously, the number of livestock in the community limited the amount of land that could be cultivated, because manure from animals furnished the sole source of fertilizer. Now farmers could import artificial fertilizer. As a result, the economic base in Thull shifted from a system balanced between herding and cultivation to one weighted in favor of the cultivation of potatoes as a cash crop. As the proportion of men actively involved in herding diminished, cross-clan ties created by the lud diminished as well. Although the lottery system of pasture distribution continued virtually unchanged, it no longer had the same moderating influence over disputes.

In addition, the supply of cash in the community increased following the development of large-scale timber operations (for which purpose the government originally constructed the road). Timber contractors hired local men as wage laborers, and the government paid an annual royalty to the community as a whole. In 1984, timber royalties alone came to about $1,000 per family. With increased cash from potatoes and timber came an explosion in the number of firearms owned by members of the community; even poor men could buy rifles. Acting out emotions framed by ghrairat, they turned the newly purchased rifles on their neighbors. Bogart's quip in The Big Sleep, "Such a lot of guns around town and so few brains," seems appropriate.

The men of Thull are always vigilant in defense of their self-respect. At the same time, they are repeatedly thrown into situations where, unknowingly, they might pollute another's ghrairat. Each man is thus in the center of a sea of potential enemies, and tension has become so pervasive in male social relationships that acid digestion is now a common medical complaint. The rules are such that whole sequences of reciprocal murders may be created. For example, if a man kills another for shining a light on his wife, the killing cleanses his ghrairat but just as significantly pollutes the ghrairat of the murdered man's close paternal kin, re-
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quiring them to kill in return. As a result, relationships of mar dushmani develop easily and often, and once developed they are difficult to end.

Organized violence may evolve gradually over a long period of time, changing focus and intensity. One sequence began quite innocently in the summer of 1979. Mamad Said, Ramadin, and Amin were lazing about on one of the high mountain pastures, laughing, gossiping, and in general having a good time. Ramadin joked about Amin’s prowess as a hunter, and in playful retaliation Amin shoved Ramadin. Mamad Said, getting into the spirit of things, picked up a stick and swung it at Amin in mock seriousness, fully intending to miss. Unfortunately, at that precise moment Amin turned toward Mamad Said, catching the blow directly across the face. Blood began to flow, and the afternoon turned ugly.

Amin staggered to a lean-to in a nearby pasture where his maternal uncle Shah Hajji Khan and a number of maternal cousins were herding their goats. Shah Hajji Khan and Mamad Said were paternal relatives, thus members of the same clan, while Amin was in a different clan. Yet the tie between a man and his maternal relatives is particularly strong in Thull; Shah Hajji Khan sided with Amin, his sister’s son.

The next day Amin, his uncle, and his cousins attacked Mamad Said’s lean-to, hoping to catch him unawares and inflict on him an injury similar to the one Amin had suffered. But Mamad Said cried for help, and a number of his paternal cousins camped nearby rushed to the scene, bringing axes, spades, and fighting clubs. The melee left many seriously wounded, but Amin and his supporters had by far the worst of the fight. Shah Hajji Khan’s own son suffered broken bones and an ax blow to the head that almost ended his life. As a result of the two incidents, Shah Hajji Khan and Mamad Said became formal opponents. Because no one had died, anger, rather than death enmity, defined the nature of their opposition.

To gain vengeance for the wounds suffered by his son, Shah Hajji Khan asked for help from Khan Akbar, an uninvolved third person, offering in return to join Khan Akbar’s political party. In the spring of 1982 the two finally hatched a plot to ambush Mamad Said. Mamad Said escaped injury, however, by hiding in an irrigation ditch. A few months later he died of tuberculosis. No one blamed his death on the failed ambush—except Mamad Said’s brother Hazrat Gul.

Hazrat Gul stands out in a crowd. He had had a bad reputation as a teen-ager, many in Thull calling him a badmash (looter, or outlaw). Although he later outgrew stealing, he remained proud of his notoriety: the swagger in his walk, the hat cocked low over one eye, the twirling of his long luxuriant moustache, the casual but practiced handling of his Kalashnikov assault rifle all convey the image of a dangerous man. Many men in Thull find him abrasive.

In his heart Hazrat Gul never accepted that tuberculosis was the cause of his brother’s death. Instead he believed that it was brought about by the cold water of the irrigation ditch in which his brother hid to escape the ambush. His opportunity to avenge Mamad Said’s death came the following year when Khan Akbar sent his grown son Sakhi to the high mountain pastures to spend a few days watching over the family’s numerous goats and cattle. After dark one evening, while Sakhi hunted for a secluded spot to urinate, a hidden assailant cut him down in a hail of automatic rifle fire. Hazrat Gul dropped from sight for a week. No one actually saw him pull the trigger, but because he did not deny killing Sakhi, and because he disappeared immediately after the murder, people in Thull assumed he was the assassin. Hazrat Gul’s actions were more than enough proof for Khan Akbar, who immediately began planning revenge.

Khan Akbar made his move a few months later. Hazrat Gul and his friend Gul Mir secretly planned a trip to the bazaar in a neighboring community. Through his spies, Khan Akbar discovered the plans in time to lay an ambush along the road. When the pair returned to Thull, a volley of bullets cut down Gul Mir; miraculously the real target, Hazrat Gul, walked into the village unscathed.

The murder of Gul Mir ordinarily would have drawn his close relatives into the feud. But Gul Mir’s kinsmen were both poor and few in number; they publicly abrogated their responsibility, declaring Hazrat Gul himself should decide whether to seek revenge.

Now both Hazrat Gul and Khan Akbar owed the other murder. Khan Akbar acted first. One morning in the summer of 1984, Hazrat Gul left my house after exchanging gossip and requesting medicine for his wife’s illness. When he reached the road, rifle shots rang out from Khan Akbar’s property located on the high mesa dominating the road. Although the bullets hit close to his feet, Hazrat Gul sauntered down the road with his usual swagger, not even looking in the direction from which the shots came.

Six days later he was not so lucky. At about 7:15 in the evening rifle bullets struck Hazrat Gul in the arm and stomach as he left his house. Although badly wounded, he somehow managed to crawl back through his front door and return fire with his Kalashnikov machine gun. His close paternal kin who lived nearby quickly opened fire on the attackers. The battle raged for about thirty minutes before third-party elders intervened to stop the fighting. Hazrat Gul was taken to a government hospital in Peshawar where major surgery saved his life.

Serious fighting broke out again two weeks later. A member of Khan Akbar’s faction hid in a tree close to Hazrat Gul’s house in hopes of gathering some useful intelligence. But one of Hazrat Gul’s cousins discovered the intruder’s presence and began blazing away with his rifle. The bullets missed, allowing the spy to scramble down the tree and sprint to his uncle’s house a few hundred yards away. A furious battle then broke out. Khan Akbar heard the shooting in his house two miles away and, gathering his allies, hurried to the scene of battle. In a surprise move Gholam Sarwar and his close paternal kin joined the fighting on the side of Khan Akbar. Later I learned that Gholam Sarwar had met secretly with Khan Akbar a few days earlier and had agreed to become his ally, partly because Khan Akbar promised to help in Gholam Sarwar’s mar dushmani with the killers of Fakir. Gholam Sarwar had always disliked Hazrat Gul anyway.

The fire fight lasted for about three hours, with tracers lighting the sky until well after dark. Although outnumbered, Hazrat Gul’s forces successfully stood off the attack, because they possessed greater fire power. Finally, onlookers had had enough. Several prominent leaders representing powerful groups of allies walked between the warring parties, forcing them to stop fighting. Miraculously no one was killed or wounded, whether by design or poor marksmanship I will never know.

The intensity of the fighting and the number of people involved on each side worried many people in Thull. Hazrat Gul’s mar dushmani with Khan Akbar appeared to be out of control, threatening many uninvolved members of the community. The same leaders who had intervened to stop the battle called a meeting of all the adult men in the community to cajole the opposing sides into making peace. Hazrat Gul refused to attend, so the attempt fizzled. But the leaders had made their point: for the time being, at least, both sides refrained from further violence. Still, when I left Thull, real peace between Hazrat Gul and Khan Akbar seemed only a distant possibility.
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William Jennings Bryan's Last Campaign

Scientists and their acolytes are partly to blame for the lengthy and bitter struggle against creationism

by Stephen Jay Gould

I have several reasons for choosing to celebrate our legal victory over "creation science" by trying to understand with sympathy the man who forged this long and painful episode in American history—William Jennings Bryan. In June 1987, the Supreme Court voided the last creationist statute by a decisive 7–2 vote, and then wrote their decision in a manner so clear, so strong, and so general that even the most ardent fundamentalists must admit the defeat of their legislative strategy against evolution. In so doing, the Court ended William Jennings Bryan's last campaign, the cause that he began just after World War I as his final legacy, and the battle that took both his glory and his life in Dayton, Tennessee, when, humiliated by Clarence Darrow, he died just a few days after the Scopes trial in 1925.

My reasons range across the domain of Bryan's own character. I could invoke rhetorical and epigrammatic expressions, the kind that Bryan, as America's greatest orator, laced so abundantly into his speeches—Churchill's motto for World War II, for example: "In victory: Magnanimity." But I know that my main reason is personal, even folksy, the kind of one-to-one motivation that Bryan, in his persona as the Great Commoner, would have applauded. Two years ago, a colleague sent me an ancient tape of Bryan's voice. I expected to hear the pious and polished shoutings of an old stump master, all snake oil and orotund sophistry. Instead, I heard the most uncanny and friendly sweetness, high pitched, direct, and apparently sincere. Surely this man was more than what H.L. Mencken, reporting the Scopes trial for the Baltimore Sun, called "a tinpot Pope in the Coca Cola belt."

I wanted to understand a man who could speak with such warmth, yet talk such Yahoo nonsense about evolution. I wanted, above all, to resolve a paradox that has always cried out for some answer rooted in Bryan's psyche. How could this man, America's greatest populist reformer, become, late in life, her arch reactionary?

For it was Bryan who, just one year beyond the minimum age of thirty-five, won the Democratic presidential nomination in 1896 with his populist rallying cry for abolition of the gold standard: "You shall not press down upon the brow of labor this crown of thorns. You shall not crucify mankind upon a cross of gold." Bryan who ran twice more, and lost in noble campaigns for reform, particularly for Philippine independence and against American imperialism in the election of 1900. Bryan, the pacifist who resigned Wilson's secretary of state because he sought a more rigid neutrality in the First World War. Bryan who stood at the forefront of most progressive victories in his time: woman suffrage, the direct election of senators, the graduated income tax (no one loves it, but can you think of a fairer way?). How could this man have then joined forces with the cult of biblical literalism in an effort to purge religion of all liberality, and to stifle the same free thought that he had advocated in so many other contexts?

This paradox still intrudes upon us because Bryan forged a living legacy, not merely an issue for the mists and niceties of history. For without Bryan, there never would have been antievolution laws, never a Scopes trial, never a resurgence in our day, never a decade of frustration and essays for yours truly, never a Supreme Court decision to end it all. Every one of Bryan's progressive triumphs would have occurred without him. He fought mightily and helped powerfully, but women would be voting today and we would be paying income tax if he had never been born. But the legislative attempt to curb evolution was his baby, and he pursued it with all his legendary demoniac fury. No one else in the ill-organized fundamentalist movement had the inclination, and surely no one else had the legal skill or political clout. Ironically, fundamentalist legislation against evolution is the only truly distinctive and enduring brand that Bryan placed upon American history. It was Bryan's movement that finally went down in flames last June in Washington.

The paradox of shifting allegiance is a recurring theme in literature about Bryan. His biography in the Encyclopaedia Britannica holds that the Scopes trial "proved to be inconsistent with many progressive causes he had championed for so long." One prominent biographer located his own motivation in trying to discover "what had transformed Bryan from a crusader for social and economic reform to a champion of anachronistic rural evangelism, cheap moral panaceas, and Florida real estate" (L.W. Levine, Defender of the Faith: William Jennings Bryan, The Last Decade, New York: Oxford University Press, 1965).

Two major resolutions have been proposed. The first, clearly the majority view, holds that Bryan's last battle was inconsistent with, even a nullification of, all the populist campaigning that had gone before. Who ever said that a man must maintain an unchanging ideology throughout adulthood; and what tale of human psychology is more familiar than the transition from crusading firebrand to diehard reactionary. Most biographies treat the Scopes trial as an inconsistent embarrass-
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ment, a sad and unsettling end. The title to the last chapter of almost every book about Bryan features the word "retreat" or "decline."

The minority view, gaining ground in recent biographies and clearly correct in my judgment, holds that Bryan never transformed or retreated, and that he viewed his last battle against evolution as an extension of the populist thinking that had inspired his life’s work (in addition to Levine, cited previously, see Paolo E. Coletta, William Jennings Bryan, vol. 3, Political Puritan, University of Nebraska Press, 1969; and W.H. Smith, The Social and Religious Thought of William Jennings Bryan, Coronado Press, 1975).

Bryan always insisted that his campaign against evolution meshed with his other struggles. I believe that we should take him at his word. He once told a cartoonist how to depict the harmony of his life’s work: “If you would be entirely accurate you should represent me as using a double-barreled shotgun, firing one barrel at the elephant as he tries to enter the treasury and another at Darwinism—the monkey—as he tries to enter the schoolroom.” And he said to the Presbyterian General Assembly in 1923: “There has not been a reform for 25 years that I did not support. And I am now engaged in the biggest reform of my life. I am trying to save the Christian Church from those who are trying to destroy her faith.”

But how can a move to ban the teaching of evolution in public schools be deemed progressive? How did Bryan link his previous efforts to this new strategy? The answers lie in the history of Bryan’s changing attitudes toward evolution.

Bryan had passed through a period of skepticism in college. (According to one story, more than slightly embroidered no doubt, he wrote to Robert G. Ingersoll for ammunition but, upon receiving only a pat reply from his secretary, reverted immediately to orthodoxy.) Still, though he never supported evolution, he did not place opposition high on his agenda; in fact, he evinced a positive generosity and pluralism toward Darwin. In “The Prince of Peace,” a speech that ranked second only to the “Cross of Gold” for popularity and frequency of repetition, Bryan said:

I do not carry the doctrine of evolution as far as some do; I am not yet convinced that man is a lineal descendant of the lower animals. I do not mean to find fault with you if you want to accept the theory. . . . While I do not accept the Darwinian theory I shall not quarrel with you about it.

(Bryan, who certainly got around, first delivered this speech in 1904, and described it in his collected writings as “a lecture delivered at many Chautauqua and religious gatherings in America, also in Canada, Mexico, Tokyo, Manila, Bombay, Cairo, and Jerusalem.”)

He persisted in this attitude of laissez faire until World War I, when a series of events and conclusions prompted his transition from toleration to a burning zeal for expurgation. His arguments did not form a logical sequence, and were dead wrong in key particulars; but who can doubt the passion of his feelings?

We must acknowledge, before explicating the reasons for Bryan’s shift, that he was no intellectual. Please don’t misconstrue this statement. I am not trying to snipe from the depth of Harvard elitism, but to understand. Bryan’s closest friends said as much. Bryan used his first-rate mind in ways that are intensely puzzling to trained scholars—and we cannot grasp his reasons without mentioning this point. The “Prince of Peace” displays a profound ignorance in places, as when Bryan defended the idea of miracles by stating that we continually break the law of gravity: “Do we not suspend or overcome the law of gravitation every day? Every time we move a foot or lift a weight we temporarily overcome one of the most universal of natural laws and yet the world is not disturbed.” (Since Bryan gave this address hundreds of times, I assume that people tried to explain to him the difference between laws and events or reminded him that without gravity, our raised foot would go off into space. I must conclude that he didn’t care because the line had a certain rhetorical oomph.) He also explicitly defended the suppression of understanding in the service of moral good:

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live up to what we do understand, we will be kept so busy doing good that we will not have time to worry about the passages which we do not understand.

This attitude continually puzzled his friends and provided fodder for his enemies. One detractor wrote: “By much talking and little thinking his mentality ran dry.” To the same effect, but with kindness, a friend and supporter wrote that Bryan was “almost unable to think in the sense in which you and I use that word. Vague ideas floated through his mind but did not unite to form any system or crystallize into a definite practical position.”

Bryan’s longstanding approach to evolution rested upon a threefold error. First, he made the common mistake of confusing the fact of evolution with the Darwinian explanation of its mechanism. He then misinterpreted natural selection as a mar- 
tial theory of survival by battle and destruction of enemies. Finally, he made the logical error of arguing that Darwinism implied the moral virtuousness of such deathly struggle. He wrote in the Prince of Peace (1904):

The Darwinian theory represents man as reaching his present perfection by the operation of the law of hate—the merciless law by which the strong crowd out and kill off the weak. If this is the law of our development then, if there is any logic that can bind the human mind, we shall turn backward toward the beast in proportion as we substitute the law of love. I prefer to believe that love rather than hatred is the law of development.

And to the sociologist E.A. Ross, he said in 1906 that “such a conception of man’s origin would weaken the cause of democracy and strengthen class pride and the power of wealth.” He persisted in this un- easiness until World War I, when two events galvanized him into frenzied action. First, he learned that the martial view of Darwinism had been invoked by most German intellectuals and military leaders as a justification for war and future domination. Second, he feared the growth of skepticism at home, particularly as a source of possible moral weakness in the face of German militarism.

Bryan united his previous doubts with these new fears into a campaign against evolution in the classroom. We may question the quality of his argument, but we cannot deny that he rooted his own justifications in his lifelong zeal for progressive causes. In this crucial sense, his last hurrah does not nullify, but rather continues, all the applause that came before. Consider the three principal foci of his campaign, and their links to his populist past:

1. For peace and compassion against militarism and murder. “I learned,” Bryan wrote, “that it was Darwinism that was at the basis of that damnable doctrine that might make right that had spread over Germany.”

2. For fairness and justice toward farmers and workers and against exploitation for monopoly and profit. Darwinism, Bryan argued, had convinced so many entre- preneurs about the virtue of personal gain that government now had to protect the weak and poor from an explosion of anti-Christian moral decay: “In the United States,” he wrote, pure-food laws have become necessary to keep manufacturers from poisoning their customers; child labor laws have become necessary to keep employers from dwarfing the bodies, minds and souls of children; anti-trust laws have become necessary to keep overgrown corporations from strangling smaller competitors, and we are still in a death grapple with profiteers and gamblers in farm products.

3. For absolute rule of majority opinion against imposing elites. Christian belief still enjoyed widespread majority support in America, but college education was eroding a consensus that once insured compassion within democracy. Bryan cited studies showing that only 15 percent of college male freshmen harbored doubts about God, but that 40 percent of gradu- ates had become skeptics. Darwinism, and its immoral principle of domination by a selfish elite, had fueled this skepticism. Bryan railed against this insidious undermin- ing of morality by a minority of intellectuals, and he vowed to fight fire with fire. If they worked through the class- room, he would respond in kind and ban their doctrine from the public schools.

The majority of Americans did not accept human evolution, and had a democratic right to proscribe its teaching.

Let me pass on this third point. Bryan’s contention strikes at the heart of academic freedom, and I have often treated this subject in previous essays. Scientific ques- tions cannot be decided by majority vote. I merely record that Bryan embedded his curious argument in his own concept of populism. “The taxpayers,” he wrote, have a right to say what shall be taught . . . to direct or dismiss those whom they employ as teachers and school authorities. . . . The hand that writes the paycheck rules the school, and a teacher has no right to teach that which his employers object to.

But what of Bryan’s first two arguments about the influence of Darwinism on mili- tarism and domestic exploitation? We de- tect the touch of the Philistine in Bryan’s claims, but I think we must also admit that he located something deeply trou- bling—and that the fault does lie partly with scientists and their acolytes.

Bryan often stated that two books had fueled his transition from laissez faire to vigorous action: Headquarters Nights, by Vernon L. Kellogg (1917), and The Sci- ence of Power, by Benjamin Kidd (1918). I fault Harvard University for many things, but it has one great glory—its unparalleled resources. Half an hour after I needed these obscure books if I ever hoped to hold the key to Bryan’s activities, I had extracted them from the depths of Widener Library. I found them every bit as riveting as Bryan had, and I came to under- stand his fears, even to agree in part (though not, of course, with his analysis or his remedies).

Vernon Kellogg was an entomologist and perhaps the leading teacher of evolu- tion in America (he was a professor at Stanford and wrote a major textbook, Evolution and Animal Life, with his mentor and Darwin’s leading disciple in Amer- ica, David Starr Jordan, ichthyologist and president of Stanford University). During the First World War, while America maintained official neutrality, Kellogg be- came a high official in the international, non-partisan effort for Belgian relief, a cause officially “tolerated” by Germany. In this capacity, he was posted at the headquarters of the German General Staff, the only American on the premises. Night after night, he listened to dinner discussions and arguments, sometimes in the presence of the Kaiser him- self, among Germany’s highest military officers. Headquarters Nights is Kel- logg’s account of these exchanges. He ar- rived in Europe as a pacifist, but left com- mitted to the destruction of German militarism by force.

Kellogg was appalled, above all, at the justification for war and German supremacy advanced by these officers, many of whom had been university professors be- fore the war. They not only proposed an evolutionary rationale but advocated a particularly crude form of natural selection, defined as inexorable, bloody battle: Professor von Flussen is Neo-Darwinian, as are most German biologists and natural philosophers. The creed of the Allmacht ("all might" or omnipotence) of a natural selection based on violent and competitive struggle is the gospel of the German intel- lectuals; all else is illusion and anathema. . . . This struggle not only must go on, for that is the natural law, but it should go on, so that this natural law may work out in its cruel, inevitable way the salvation of the human species . . . That human group which is in the most advanced evolutionary stage . . . should win in the struggle for exis-
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Darwin's striking idealism—its *Kultur*—on the others, or, alternatively, to destroy and replace them. This is the disheartening kind of argument that I faced at Headquarters... Add the additional assumption that the Germans are the chosen race, and that German social and political organization the chosen type of human community life, and you have a wall of logic and conviction that you can break your head against but can never shatter—by headwork. You long for the muscles of Samson.

Kellogg, of course, found in this argument only "horrible academic casuistry and... conviction that the individual is nothing, the state everything." Bryan conflated a perverse interpretation with the thing itself and affirmed his worst fears about the polluting power of evolution.

Benjamin Kidd was an English commentator highly respected in both academic and lay circles. His book *Social Evolution* (1894) was translated into a dozen languages and as widely read as anything ever published on the implications of evolution. In *The Science of Power* (1918), his posthumous work, Kidd constructs a curious argument that, in a very different way from Kellogg's, also fueled Bryan's dread. Kidd was a philosophical idealist who believed that life must move toward progress by rejecting material struggle and individual benefit. Like the German militarists, but to exorcise rather than to praise, Kidd identified Darwinism with these impediments to progress. In a chapter entitled "The Great Pagan Retrospection," Kidd presented a summary of his entire thesis:

1. Darwin's doctrine of force rekindled the most dangerous of human tendencies—our pagan soul, previously (but imperfectly) suppressed for centuries by Christianity and its doctrines of love and renunciation.

   The holde which the theories of the *Origin of Species* obtained on the popular mind in the West is one of the most remarkable incidents in the history of human thought... Everywhere throughout civilization an almost inconceivable influence was given to the doctrine of force as the basis of legal authority... For centuries the Western pagan had struggled with the ideals of a religion of subordination and renunciation coming to him from the past. For centuries he had been bored almost beyond endurance with ideas of the world presented to him by the Churches of Christendom... But here was a conception of life which stirred to its depths the inheritance in him from past epochs of time... This was the world which the masters of force comprehended. The pagan heart of the West sang within itself again in atavistic joy.

2. In England and America, Darwinism's worst influence lay in its justification for industrial exploitation as an expression of natural selection ("social Darwinism" in its pure form):

   The prevailing social system, born as it had been in struggle, and resting as it did in the last resort on war and on the soil of an excluded proletariat, appeared to have become clothed with a new and final kind of authority.

3. In Germany, Darwin's doctrine became a justification for war:

   Darwin's theories came to be openly set out in political and military textbooks as the full justification for war and highly organized schemes of national policy in which the doctrine of force became the doctrine of Right.

4. Civilization can only advance by integration: the essence of Darwinism is division by force for individual advantage. Social progress demands the "subordination of the individual to the universal" via "the iron ethic of Renunciation."

5. Civilization can only be victorious by suppressing our pagan soul and its Darwinian justification:

   It is the psychic and spiritual forces governing the social integration in which the individual is being subordinated to the universal which have become the winning forces in evolution.

This characterization of evolution has been asserted in many contexts for nearly 150 years—by German militarists, by Kidd, by hosts of the vicious and the duped, the self-serving and the well-meaning. But it remains deeply and appallingly wrong for three basic reasons.

1. Evolution means only that all organisms are united by ties of genealogical descent. This definition says nothing about the mechanism of evolutionary change: in principle, externally directed upward striving might work as well as the caricatured straw man of bloody Darwinian battle to the death. The objections, then, are to Darwin's theory of natural selection, not to evolution itself.

2. Darwin's theory of natural selection is an abstract argument about a metaphorical "struggle" to leave more offspring in subsequent generations, not a statement about murder and mayhem. Direct elimination of competitors is one pathway to Darwinian advantage, but another might be cooperation through social ties within a species or by symbiosis between species. For every act of killing and division, natural selection can also favor cooperation and integration in other circumstances. Nineteenth-century interpreters did generally favor a martial view of selection, but for every militarist, there was a Prince Kropotkin, urging that the "real" Darwinism be recognized as a doctrine of integration and "mutual aid."

3. Whatever Darwinism represents on the playing fields of nature (and by representing both murder and cooperation at different times, it upholds neither as nature's principal way), Darwinism implies nothing about moral conduct. We do not find our moral values in the actions of nature. One might argue, as Thomas Henry Huxley did in his famous essay "Evolution and Ethics," that Darwinism is primarily a law of battle, and that human morality must be defined as the discovery of an opposite path. Or one might argue, as grandson Julian did, that Darwinism is a law of cooperation and that moral conduct should follow nature. I can only conclude that Darwinism offers no moral guidance.

But Bryan made this common threefold error and continually characterized evolution as a doctrine of battle and destruction of the weak, a dogma that undermined any decent morality and deserved banishment from the classroom. In a rhetorical flourish near the end of his "Last Evolution Argument," the final speech that he prepared with great energy, but never had the opportunity to present at the Scopes trial, Bryan proclaimed:

Again force and love meet face to face, and the question "What shall I do with Jesus?" must be answered. A bloody, brutal doctrine—Evolution—demands, as the rabble did nineteen hundred years ago, that He be crucified.

I wish I could stop here with a snide comment on Bryan as Yahoo and a ringing defense for science's proper interpretation of Darwinism. But I cannot, for Bryan was right in one crucial way. Lord only knows, he understood precious little about science, and he wins no medals for logic of argument. But when he said that Darwinism had been widely portrayed as a defense of war, domination, and domestic exploitation, he was right. Scientists would not be to blame for this if we had always maintained proper caution in interpretation and proper humility in resisting the extension of our findings into inappropriate domains. But many of these insidious and harmful misinterpretations had been promoted by scientists. Several of the German generals who traded arguments with Kellogg had been university professors of biology.

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source. In his "Last Evolution Argument," Bryan charged that evolutionists had misused science to present moral opinions about the social order as though they represented facts of nature.

By paralyzing the hope of reform, it discourages those who labor for the improvement of man's condition. . . . Its only program for man is scientific breeding, a system under which a few supposedly superior intellects, self-appointed, would direct the mating and the movements of the mass of mankind—an impossible system!

Bryan was quite correct here. One of the saddest chapters in all the history of science involves the extensive misuse of data to support biological determinism, the claim that social inequalities based on race, sex, or class cannot be altered because they reflect the innate and inferior genetic endowments of the disadvantaged (see my book *The Mismeasure of Man*). It is bad enough when scientists misidentify their own social preferences as facts of nature in their technical writings. It is especially unfortunate when writers of textbooks, particularly for elementary and high school students, promulgate these (or any) social doctrines as the objective findings of science.

Two years ago, I obtained a copy of the book that John Scopes used to teach evolution to the children of Dayton, Tennessee—*A Civic Biology*, by George William Hunter (New York: American Book Company, 1914). Many writers have looked into this book to read the section on evolution that Scopes taught and Bryan quoted. But I found something disturbing in another chapter that has eluded previous commentators—an egregious claim that science holds the moral answer to questions about mental retardation, or social poverty so misinterpreted. Hunter discusses the infamous Jukes and Kallikaks, the "classic," and false, cases once offered as canonical examples of how bad heredity runs in families. Under the heading "Parasitism and Its Cost to Society—the Remedy," he writes:

Hundreds of families such as those described above exist today, spreading disease, immorality and crime to all parts of this country. The cost to society of such families is very severe. Just as certain animals or plants become parasitic on other plants or animals, these families have become parasitic on society. They not only do harm to others by corrupting, stealing or spreading disease, but they are actually protected and cared for by the state out of public money. Largely for them the poorhouse and the asylum exist. They take from society, but they give nothing in return. They are true parasites.

If such people were lower animals, we would probably kill them off to prevent them from spreading. Humanity will not allow this, but we do have the remedy of separating the sexes in asylums or other places and in various ways preventing intermarriage and the possibilities of perpetuating such a low and degenerate race.

Bryan had the wrong solution, but he had correctly identified a problem!

Science is a discipline, and disciplines are exacting. All maintain rules of conduct and self-policing. All gain strength, respect, and acceptance by working honorably within their bounds and knowing when transgression upon other realms counts as hubris or folly. Science is a discipline dedicated to learning about the factual state of nature and trying to explain and coordinate these data into general theories. Science teaches us many wonderful and disturbing things—facts that need weighing when we try to develop standards of conduct and ponder the great questions of morals and aesthetics. But science cannot answer these questions alone and cannot dictate social policy.

Scientists have power by virtue of the respect commanded by the discipline. We may therefore be sorely tempted to misuse that power in furthering a personal prejudice or social goal—why not provide that extra oomph by extending the umbrella of science over a personal preference in ethics or politics? But we cannot, lest we lose the very respect that tempted us in the first place.

If this plea sounds like the conservative and pessimistic retrenching of a man on the verge of middle age, I reply that I advocate this care and restraint in order to demonstrate the enormous power of science. We live with poets and politicians, preachers and philosophers. All have their ways of knowing, and all are valid in their proper domains. The world is too complex and interesting for one way to have all the answers. Besides, highflalutin morality aside, if we continue to overextend the boundaries of science, folks like Bryan will nail us properly for their own insidious purposes.

We should give the last word to Vernon Kellogg, the great teacher who understood the principle of strength in limits, and who listened with horror to the ugliest misuses of Darwinism. Kellogg properly taught in his textbook (with David Starr Jordan) that Darwinism cannot provide moral answers:

Some men who call themselves pessimists because they cannot read good into the operations of nature forget that they cannot read evil. In morals the law of competition no more justifies personal, official, or national selfishness or brutality than the law of gravitation justifies the shooting of a bird.

Kellogg also possessed the cardinal trait lacked both by Bryan and by many of his evolutionary adversaries: humility in the face of our profound ignorance about nature's ways, combined with that greatest of all scientific privileges, the joy of the struggle to know. In his greatest book, *Darwinism Today* (1907), Kellogg wrote:

We are ignorant, terribly, immensely ignorant. And our work is, to learn. To observe, to experiment, to tabulate, to induce, to deduce. Biology was never a clearer or more inviting field for fascinating, joyful, hopeful work.

Amen, brother!

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

Postscript: As I was writing this essay, I learned of the untimely death from cancer (at age 47) of Federal Judge William R. Overton of Arkansas. Judge Overton presided and wrote the decision in *McLean v. Arkansas* (January 5, 1982), the key episode that led to our final victory in the Supreme Court last June. In this decision, he struck down the Arkansas law mandating small time for "creation science." This precedent encouraged Judge Duplantier to strike down the similar Louisiana law by summary judgment (without trial). It is this decision of summary judgment that the Supreme Court has now affirmed. (Since Arkansas and Louisiana had the only antievolution statutes in the country, these decisions close the issue.) Judge Overton's brilliant and beautifully crafted decision is the finest legal document ever written about this question—far surpassing anything that the Scopes trial generated, or any document arising from the two Supreme Court cases (*Epperson v. Arkansas* of 1968, striking down Scopes era laws that banned evolution outright, and last month's decision banning the "equal time" strategy). Judge Overton's definitions of science are so cogent and clearly expressed that we can use his words as a model for our own proceedings. *Science*, the leading journal of American professional science, published Judge Overton's decision verbatim as a major article.

I was a witness in *McLean v. Arkansas*. I never spoke to Judge Overton personally, and I spent only part of a day in his courtroom. Yet, when I fell ill with cancer the next year, I learned from several sources that Judge Overton had heard and had inquired about my health from mutual acquaintances, asking that his wishes be conveyed to me. I mourn the passing of this brilliant and compassionate man, and I dedicate this essay to his memory.
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by Philip G. Koehler and Richard S. Patterson

In early November of 1985, Ed Shower of MacArthur Pest Control was called back for the third time in as many weeks to spray for cockroaches at the house of one of his regular clients in Kathleen, Florida, not far from Lakeland. This time he decided to scout the area for anything that might explain the ineffectiveness of his pesticide. As he walked around the house, he noticed groups of insects either flying ahead of him or leaping across the lawn like grasshoppers. Running quickly to one, he trapped it against the ground, then held it up for a closer look.

It was a small brown cockroach about one-half inch long, with two stripes behind its head and wings extending beyond the last segment of the abdomen. Aside from its being outdoors, it appeared to be no different from the common household pest, the German cockroach. But Shower

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was curious and collected a few specimens. Bob Broyles, the owner of MacArthur Pest Control, put the cockroaches in a jelly jar and sent them to us at the Household Insect Research Project, a cooperative program of the University of Florida's Institute of Food and Agricultural Sciences and the U.S. Department of Agriculture's Agricultural Research Service.

Looking at the specimens under a dissecting microscope and examining the males' genitalia (a feature that often distinguishes one species of insect from another), we still found no evidence that the specimens were anything but German cockroaches. Specimens sent to another university expert for a second opinion (there are forty-nine species that look like German cockroaches) were declared definitely German.

We called Broyles and informed him that even though German cockroaches did not usually live outdoors, they were sometimes taken out with garbage and could live in protected areas for several weeks. Broyles said he sprayed the lawn in December and had not received any more complaints. But in early February, when two researchers from the laboratory accompanied Ed Shower on a return visit to the lawn at Kathleen, they again saw cockroaches, this time by the thousands. One family in the neighborhood said that when they sat down to watch television at night, the cockroaches landed on the television screen and the illuminated wall. Every morning they found 200 to 300 cockroaches under the doormat. They found them crawling through the leafy vegetables in the garden, and when they pulled turnips, cockroaches were hiding in the loose soil.

This was not German cockroach behavior, so we sought yet another identification. We sent specimens to Louis Roth at Harvard University, who in turn, sent specimens to Takayki Mizukubo in Japan. Both men had previously published work on cockroaches. By examining the genitalia, they determined that the cockroach infesting the town of Kathleen was a distinct species, first identified by Mizukubo as native to Southeast Asia, India, South China, and the Andaman Islands.

The Kathleen specimens were the first found and identified outside of the Far East. The Asian cockroach, as we called it, is only slightly smaller than the five-eighths-inch-long German cockroach and its wings are slightly longer and narrower. Both insects are pale brown, with two distinct, dark, parallel bands running the length of the pronotum, the shield behind the head.

How the Asian species had been introduced into Florida and how far it had spread was a mystery. By June of 1986, we believed the insect's range was limited to a six-square-mile area just north of Lakeeland. In July, however, Jemy Hinton, a county horticultural agent in Tampa, heard from a resident who said she had seen large numbers of cockroaches in her lawn, in trees, and in leaf litter. We found a massive infestation that covered an area of some 60 square miles. The cockroaches have since extended their range to cover some 500 to 600 square miles from Saint Petersburg to Lakeland. Because most in-
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fested sites are only two miles from the Port of Tampa, we think the cockroach was introduced there in shipments from the Orient.

This is a time-honored method of transport. The Asian and the German cockroach both originated in Asia. The German cockroach was brought to eastern Europe and Russia many centuries ago on infested Greek and Phoenician ships. The species became established in England at Leeds when soldiers returning from the Crimean War brought back cockroach-infested breadbaskets.

Of the 3,500 species of cockroaches, less than one percent are household pests. Hundreds of species inhabit the tropical rain forests, other species are semiaquatic, some burrow through the ground, a few, like termites, bore through and eat wood, and a few live in the burrows of rodents or the nests of ants, wasps, and termites. Some species live in caves in close association with bats and their droppings; others survive in the desert. They are an ancient group of insects. The oldest-known fossil cockroach is *Paleoblatta dowillei*, which was found in pre-Carboniferous remains from about 280 million years ago. Its preferred habitat was among ferns in low, moist areas along the banks of rivers and marshes.

These insects have changed little through time. They are oval shaped, with flat bodies that allow them to hide in crevices, where they spend 75 percent of their time at rest, with their long, whiplike antennae pointing forward and upward. When the harborage is satisfactory, that is, where there is enough food and water, they secrete chemicals, known as pheromones, that attract cockroaches of the same species. Water is the most vital component of cockroach habitat. Given a choice between food and water, field-collected cockroaches in a laboratory will always choose water.

Cockroaches have slender legs, which are depressed beneath their heavily spined bodies. Their legs are designed for running and most species have atrophied wing muscles that keep them from flying. German cockroaches can only glide short distances when disturbed. Asian cockroaches, however, take readily to the air. (They often fly straight out of greased laboratory jars that always confine German cockroaches.) We have seen them fly as far as 120 feet in a single flight; thus they can quickly infest yards and houses from wooded areas adjacent to suburban homes.

Cockroaches have two types of eyes: large, prominent compound eyes with many small facets; and ocelli, which are simple eyes located close to the base of the antennae. The eyes have two types of sensors. One type detects ultraviolet light and the other is capable of sensing blue-green light. Why Asian cockroaches are attracted to light, while the German species runs from ultraviolet but not from gold, yellow, or red light, is still not known. Recent studies indicate that cockroaches are also startled by minute air movements, which may alert them to a predator.

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and even in areas with intermittent snowfall. In Florida, it thrives in shaded areas of lawns, under ground cover, in citrus groves, in wooded areas, or in yards landscaped with mulch from deciduous trees. It is abundant in wild areas with ample leaf litter and shade, feeding on decaying plant matter instead of the household garbage that German cockroaches eat.

Asian cockroaches are most active from early evening until dawn. At sunset a frenzy of activity begins. If temperatures are above 70°F and winds are under ten miles per hour, the cockroaches crawl from the leaf litter to the tops of blades of grass, the ends of branches of shrubs, and the trunks of trees. The adults, both males and females, take flight, landing in illuminated areas and perching approximately two feet off the ground on lit walls or shrubbery. Some enter houses through cracks around doors and windows and sit on walls, tables, chairs, dishes, and any other objects that may be illuminated. Unlike cockroaches that shun light, the Asian cockroach will find and enter rooms where the lights are on.

About an hour after sunset the insects are less active, but at all stages of development they continue to move throughout the night. Adults perch on bushes and trees, often feeding on honeydew secreted by aphids. About ninety minutes before sunrise, the cockroaches descend from the grass, bushes, and trees to the lawn and leaf litter where they spend their days. When disturbed by someone walking across the lawn, they will climb to the tips of grass, fly short distances, usually less than six feet, and then return to the hatch.

Asian cockroaches mate several days after the last molt and may copulate repeatedly. Only one mating, however, is necessary to fertilize all the eggs a female will produce for the rest of her life. (The offsprings of a single female could produce some ten million cockroaches in a year.) The female’s abdomen swells and an ootheca, or egg capsule, is formed about two to four days after the first successful copulation. The ootheca remains attached to the female’s abdomen for seventeen to twenty days. The thirty to forty nymphs that emerge molt five to seven times before they become adults, and the average development time is six to seven weeks. Only the adults are winged and highly mobile.

The potential for the spread of this insect is great. Asian cockroaches flew into our vehicles at infested field sites. One landed on our windshield and was not dislodged by the wind until we reached a speed of forty-five miles per hour. We
found them in the engine compartments and under the molding around car doors. We have found Asian cockroaches in plant nurseries, warehouses, and food distribution centers. Many states already inspect trucks hauling vegetables, plants, and food from Florida in an attempt to intercept the insect's spread. We expect it to travel in the same way as the brown-banded cockroach, which along with the German and American cockroach, is among the most widespread of the country's insect pests. The brown-banded species was first identified in Florida at Miami and Key West in 1903. (The species originated in the tropics and subtropics of Africa and came to the West Indies on slave ships.) By 1937, traveling in the cars and luggage of Florida tourists, it had spread throughout the country. The only thing limiting the distribution of the Asian species is that it is primarily an outdoor species and will establish populations only where it can survive the winters: along the East Coast northward to Maryland, and along the West Coast as far north as Washington State. Where populations become established in greenhouses or other locations, they may migrate to lawns and wooded areas during the summer.

The Asian cockroach is now the predominant insect in the infested areas around Tampa and Lakeland, with populations of as many as 100,000 per acre. We are now surveying the species' populations in Asia to see if their numbers per unit area are similar to those in Florida. If there is something there holding their growth in check, what is it? Birds appear to have no taste for them, and although lizards and frogs eat them, not enough animals prey on them to control their spread. In our laboratory we have crossed Asian and German cockroaches. The hybrids fly, but we don't believe such hybridization would take place outside the laboratory. If it did, our greatest concern would be that insecticide resistance prevalent in the German cockroach would cross into the Asian cockroach with disastrous consequences.

High populations outdoors will inevitably affect the quality of life in infested areas. Camping on infested ground will be virtually impossible since the cockroaches are attracted to moisture and will crawl into damp towels and onto the faces of sleeping people throughout the night. The lights of outdoor patios will also attract the species. Residents in Florida are concerned that the infestation cannot be controlled, while the thirty-three million tourists who visit Florida each year might be concerned that they are returning home with unwanted guests.

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Travels of an Ancient Reef

The odyssey of a coral island is just part of the epic of continental drift

by George D. Stanley, Jr.

In 1985, a colleague from West Germany and I excavated the first fossils from a huge limestone outcrop in the Wallowa Mountains of northeastern Oregon. My fellow geologist, Baba Senowbari-Daryan of Erlangen-Nürnberg University, is an expert on the paleontology of fossil coral reefs in Austria and Germany. I recall his initial astonishment and then his excitement as we approached Summit Point in Wallowa-Whitman National Forest. Embedded in a massive outcrop of limestone some 6,000 feet above sea level, he saw old friends that he knew and loved—familiar fossil sponges, algae, mollusks, sea urchins, and most abundant, corals. Although we were standing in Oregon, we might just as well have been looking at a geologic formation in the Alps, more than 13,000 miles away.

The Wallowa fossils are the remains of a once tropical coral reef that thrived during the late Triassic period, some 218 to 210 million years ago, the first coral-dominated reef of this age ever found in North America or the whole of the eastern Pacific. The twenty or so coral species, sponges, and other invertebrate fossils we have identified so far are identical to specimens from alpine reef limestone. Rock characteristics, such as color, bedding, cavities, cements, and infilling reddish reef sediment, also show striking parallels to those of the Alps. How can we account for the appearance of identical fossil coral reefs at different ends of the earth? I believe the answer will be found in the global geography of Triassic times and the dynamic processes of plate tectonics.

The Triassic period, which lasted from about 250 to 205 million years ago, saw a major evolutionary event in the history of marine life. In the greatest of mass extinctions—which we use to mark the end of the Permian and beginning of the Triassic period—most genera and many families of plants and animals died out. Reefs were particularly hard hit. For five to ten million years, all reefs and most organisms inhabiting them disappeared. At least their fossils are not known from any rocks of this time period anywhere in the world—and paleontologists have done a lot of searching. In the mid-Triassic, reef...
The peaks of the Dachstein Reef Limestone of Austria contain rich remains of 210-million-year-old sponges, algae, mollusks, and corals.

Todd Powell
environments reappeared, and a dramatic adaptive radiation of a variety of new life began. It included some survivors of the Permian period and a new group, the hexacorals, ancestors of all of today's colorful reef-building corals. For a few million years, hexacorals took a back seat to other reef organisms, such as algae and calcareous sponges, but some 220 million years ago, corals began to increase rapidly in abundance and diversity and to take up more active roles as reef builders. Eventually they supplanted the calcareous sponges, algae, and other invertebrates that had reestablished a firm foothold on reefs during most of the earlier Triassic period. In the Jurassic period, from about 205 to 144 million years ago, corals became more diverse and firmly established their dominance on reefs—a dominance they have enjoyed, with only a few ups and downs, until today.

Much of our knowledge about Triassic reefs comes from the alpine regions of central Europe. Here enormous shallow platforms accumulated thousands of feet of limy sediment and reefs rimmed the Tethys Sea, a vast east-west trending, near-tropical body of water ancestral to the Mediterranean. This luxuriant, reef-lined seaway opened to the east upon the ancient Pacific Ocean, the Panthalassa. Following the Triassic period, the African and other southern continental plates pulled away, and subsequent earthquakes and tectonic forces caused the reefs to founder and collapse completely. Remnants of this great seaway are found today in the faulted and upthrust mountain ranges that form the backbone of Eurasia and extend from central Europe, through Turkey, Iran, and the Himalayas, to southern China and Indonesia.

One of the best-known geologic reef formations from the former Tethys Sea is the Dachstein Reef Limestone of Austria and Germany, in which rich corals, sponges, calcareous algae, and other reef-related species came together to produce reef complexes more than 4,000 feet thick. This region of the Alps, now famous for its ski slopes and hiking trails, once existed as reef-lined banks and shallow platforms bordering the western edge of the warm Tethys Sea. In 1981, I went there for a year as a visiting Fulbright scholar to explore and study firsthand the impressive fossil reefs that make up much of the towering limestone peaks.

Aside from the Eurasian mountain chains, a few Dachstein-type Triassic reefs are found on islands of the western Pacific, southward from Japan to the Moluccas and Timor. With the exception of some remnant reef corals reported from the Philippines, no other Triassic exam-
Gists

Ples are known farther east within the Pacific. Furthermore, all the sea floor in this region is relatively newly formed and shows evidence of tectonic rifting. This leads to several provocative questions. If alpine reefs bordered the whole Tethys, what happened to other reefs that must have existed to the east of this long-vanished inland sea? If the ancient Pacific was, as many scientists believe, strown with tropical and subtropical volcanic islands—a reconstruction that mirrors the present-day western Pacific—where are the remains of these islands today? Plate tectonics and the new concept of displaced terranes shed light on these problems.

Continental drift, the driving force of what is now understood as plate tectonics, was one of the most outrageous megatheories ever conceived. Initially dismissed as absurd but now accepted by most geologists as gospel, plate tectonics united many unrelated disciplines and marshaled compelling evidence for theories about the fragmentation and movement of former continents several hundred million years ago. Today the plates continue to move at rates measured by precision laser beams. Paleontology has been at the forefront of plate tectonic theory; for example, the undeniable similarity of fossils, particularly those from southern continents, such as Africa, South America, and Antarctica, helped scientists reconstruct the original position of the once great supercontinent of Pangaea.

A recent spinoff of plate tectonics has been the recognition of numerous, independent smaller fragments and slivers of land, some oceanic and some continental in origin, that resulted from the breakup of continental plates. Today, western North America is a conglomeration of these numerous slivers. Because of their exotic nature, these former islands and fragments of continents have become known as displaced terranes. According to the plate tectonic theory, they were moved along in conveyor-belt fashion by sea-floor spreading, some possibly traveling great distances across the former Pacific Ocean, and eventually docking with, and adding new land to, the western edge of the North American continent. More than 25 percent of North America is thought to consist of displaced terranes.

For some ten years now, I have focused much of my geologic research on the excavation and detailed study of rich Triassic invertebrate faunas and limestone rocks in displaced terranes from Alaska to Nevada. Scattered throughout the mountainous regions of western North America, these rocks are often associated with extensive, fiery episodes of sea-floor and island volcanism. Perched atop thick piles of lava flows and volcanic debris, the limestones have yielded many fossils, some coral rich. All of these fossil reef localities are situated within displaced terranes, so all are thought to have originated independently from North America. Except for the Wallowa example, however, corals are not the dominant organisms and massive reef complexes, like those of the Tethys region, are not present.

Because they require warm, uniform temperatures and well-lit water, reef corals and their associates are restricted to regions from 30° north latitude to 30° south latitude. The presence of reeflike limestone deposits at the high latitudes of Alaska and the Yukon gave impetus to the concept of displaced terranes. Beginning life as free-swimming microscopic larvae, reef-dwelling organisms such as sponges, corals, and clams are limited in the distances they can disperse; and some islands are beyond cruising range of the tiny larvae. In adulthood, as shallow-water, bottom-dwelling, and attached invertebrates, they are even more restricted to specific marine environments. Therefore, shelly animals such as clams, sponges, snails, and corals may be useful in distinguishing certain terranes, especially if the terranes were once isolated from one another. Both the unique magnetic signature of the high-latitude rocks and their marked difference from neighboring terranes support the theory that they originated separately in tropical latitudes, were conveyed northward, came to dock with North America, and over time, were shifted more than a thousand miles northward along major tectonic shear lines analogous to the present-day San Andreas fault.

One of the most extensive and best known of all of western North America’s many displaced terranes is found in Alaska and Canada and is known as Wrangelia. In parts of Wrangelia, vast outpourings of oceanic lava, perhaps the most extensive ever, produced a pile of volcanic rock up to five miles thick. Lava ultimately surpassed sea level and became huge volcanoes fringed by shallow-water limy sediments of late Triassic age. The whole succession is similar to that of subiding Pacific coral islands, such as Tonga and Fiji, or coral atolls whose origins upon a volcanic foundation were postulated by Darwin during the last century. In modern times, Darwin’s ideas of volcanic origin have been confirmed by deep drilling.

Displaced terranes account for 25 percent of the North American landmass. The distinctive species of fossilized corals and other reef inhabitants in the Wallowa-Seven Devils terrane reveal its Tethyan origin.
penetrating through miles of reef rock to uncover a volcanic base. Surprisingly, fossils inextricably linked with those of some North American displaced terranes can also be found in the South American Andes, as my three summers of fieldwork there have verified. In the Andes, as in Wrangellia, I found no evidence of reef building, and the deposits contrasted markedly with reefs of the same age in the Tethys region and in Oregon. The Wallowa Mountains, once thought to be an extension of Wrangellia, are now known as the Wallowa-Seven Devils terrane, one of many terranes added by accretion to form central and northeastern Oregon.

The Wallowa reef, I believe, developed in atoll fashion, along the edge of a shal-
Solitary fossil corals entombed in limestone from the Wallowa Mountains, left, and the Alps, left, bottom, are identical species. Organic microfossils that form a crust around the corals are also the same for the two distant regions, as are the colonial branching corals, below (top, from the Alps; bottom, from Wallowa). The Alpine colonial coral shows budding at coral tips where new individuals were starting to form.

Low, tropical, submerged platform. This platform grew directly upon a subsiding volcanic island after an episode of violent eruptions. The composition of the underlying basalts and volcanic rocks and the composition of the overlying fossil reef corals, however, suggest a setting different from Wrangellia. In the Wallowa Mountains, a series of patch reefs lined the edge of the shallow platform adjoining a deeper-water region known to geologists as an intra-arc basin. While upward growth of shelly organisms and the sediment they produced kept pace with rising sea level, steep, unstable slopes developed adjacent to the basin. Triggered by earthquakes, voluminous debris in broken reef rocks and fragments of fossils cascaded off the platform and down into the adjoining basin. The Triassic limestones in the Wallowa Mountains grade upward from shallow-water reef deposits to younger calcareous mudstone and slates of deepwater origin. These overlying rocks record, by the succeeding Jurassic period, the drowning and burial of the whole reef complex. Again, the general nature of the sequence conforms to that of sunken atolls and subsea volcanic plateaus that dot the present-day Pacific.

Where did the Wallowa terrane, a former volcanic island, come from and where could it have existed during reef growth in late Triassic time? It was clearly not part of western North America at that time. The nature of global ocean current patterns never allows reefs to flourish along the western margins of continents. Furthermore, rocks of Permian to Triassic age lying farther east in continental North America show no evidence whatsoever of layers of ash or the effects of volcanic activity. I therefore assume that, as palaeomagnetic evidence and characteristic fauna dictate, lost volcanic islands such as Wallowa existed at tropical latitudes somewhere in the ancient Pacific.

The Wallowa reef began to develop about 218 million years ago. It most likely grew on the eastern side of an island arc, exposed, like modern examples, to trade winds blowing toward the southwest. During its travels, from 166 to 159 million years ago, Wallowa collided with another Oregon volcanic island terrane, situated to the east. These terranes subsequently became amalgamated in the late Jurassic but did not dock with North America until about 100 million years ago—a date established by the intrusion of deep molten magmas. The time interval between reef formation and docking is thus some 118 million years. Assuming a very conservative rate of sea-floor spreading of 3 inches per year (the total range for the Pacific today is 1.5 to 7 inches per year), we can account over geologic time for 4,656 miles of movement—enough for our reef to travel from Japan to Oregon.

What was the effect of terrane movement on the living organisms inhabiting warm, shallow water around volcanic islands? Paleontologist Malcolm McKenna, of the American Museum of Natural Hist-
The Wallowa Mountains, a prominent feature of Oregon’s Eagle Cap Wilderness, were created by faulting and other forces after an exotic displaced terrane docked with North America about 100 million years ago.

Willard Clay

...has used the term Noah’s Ark to explain the wholesale transportation of island fauna by plate tectonic sea-floor spreading processes. The concept of an ark fits the case of the Oregon reef, the most Tethyan-type coral reef yet found. It not only explains the similarities of the Wallowa and Alpine fossils but also the characteristics of the enclosing rocks and sediments, all of which bear a Dachstein or Tethyan signature. The same signature, incidentally, also turns up in a deposit in Japan, about midway between the European and Oregon locales.

So where do we look for other roving volcanic islands that may have dotted the Triassic Pacific? The dynamics of sea-floor tectonics dictate that the islands’ ultimate fate will be destruction near the edge of the North American continent, either by being subducted (pulled down) under or obducted (pushed up) over the converging plate boundaries. We therefore should seek vestiges amid deformed and faulted terrane rocks along the continent. Here, sea-floor basalts and volcanic fragments have been scraped off, mashed up, and faulted to form some of our most spectacular mountain scenery. Considering their tortuous history, we are fortunate to find any traces at all of these lost islands and their tropical reef faunas.

When a given terrane drifted onto the shores of North America after its journey across the Pacific, it probably was carrying a precious cargo of already fossilized reef remains. The annals of human history record how, at death, venerated Viking kings and war heroes sometimes were placed in funeral ships, which were ceremoniously set afire and adrift across the dark, uncharted sea. Eventually, with favorable currents and wind, a few funeral ships and what was left of their cargo drifted ashore on distant, foreign lands. With this rite in mind, paleontologists are using the term beached Viking funeral ships to describe the analogous process in the fossil record. Today, using fossils and rather odd-sounding terms such as Noah’s Ark and Viking funeral ships, paleontologists are attempting to piece together some of the most fantastic parts of the plate tectonic puzzle.
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Elephants from two families greet each other, holding heads and ears high and uttering loud, throaty rumbles. The dark lines visible on the faces of some of the elephants are secretions from the temporal gland behind the eye. In females and young males, such secretions are watery and unrelated to sexual condition. But when mature males enter musth—a period of heightened sexual activity—the fluid becomes darker, sticky, and leaves a longer-lasting stain.
Elephants in Musth, Lust

As their sexual appetite rises, big bull elephants lower their voices

Text and photographs by Joyce H. Poole

Jessica rushed forward, flapped her large ears, and gave out an almost deafening rumble. Fluid streamed down the sides of her face. Turning to Aristotle, she stretched her trunk toward his genitals and again ear flapped and rumbled. Then she spun around and backed into him, her head and ears high. Seconds after the pair mated, the rest of Jessica’s family charged over from where they had been feeding fifty yards away. Jezebel, the matriarch of the family, led the way, followed closely by her sister Joyce. Their faces, too, were streaked by secretions from the temporal glands located behind their eyes. They, too, rapidly flapped their ears and rumbled. Jill, Joan, Jezebel’s pubertal daughter, Jolene, and all of the family’s calves joined in, trumpeting, roaring, and spinning around while urinating and defecating. Mating over, Aristotle stood resting with his head down and his ears flopped forward, seemingly oblivious to the females’ continuing commotion.

It was April 1985, the month of highest reproductive activity among the long-studied population of 680 elephants living in Kenya’s Amboseli National Park, and Jessica was in estrus. I recorded the date, April 1; the time, 12:53; the name of the male that mated with her, Aristotle; and the pair’s behavior before and after the mating. Had Aristotle vocalized before mating Jessica? Had Jessica vocalized afterward? How had the members of her family responded? All of these details were important pieces in the unsolved puzzles of elephant social and reproductive behavior. The Amboseli Elephant Project, started by Cynthia Moss, was in its third year. I had been studying the elephants’ reproductive behavior and vocal and olfactory communication since 1976.

Jessica continued her loud, modulated calls, repeatedly inspecting Aristotle and the spot where she had been mated. After several excited minutes, the other females, one by one, relaxed, wandered off, and returned to their rhythmic rip-ripping of trunkfuls of grass. Only Jessica remained next to Aristotle and continued to rumble, her calls becoming softer and more widely spaced.

Aristotle now guarded Jessica closely, aggressively keeping away the younger, smaller males. Jessica made his task easier. She was an experienced female. Over the years, she had learned that by keeping close to the highest-ranking male she could avoid the constant harassment of young males.

Jessica stayed near the large elephant for an additional reason. Aristotle, an old male in his late forties, was in musth, a period of heightened sexual and aggressive activity experienced once a year by males over thirty in peak condition. During musth, males call frequently, secrete from swollen temporal glands, and leave a continuous trail of strong-smelling urine. The duration of musth is age-related; males in their early thirties may only stay in musth for a week, while males in their late forties may be in musth for three or four months. Once in musth, a male’s rank and attractiveness to females increase dramatically. He dominates all nonmusth males, even those larger than himself, and although nonmusth males do mate, males in musth are more successful.

Each male comes into musth during a specific time of the year, which varies from male to male. For example, Bad Bull—one of Amboseli’s three highest-ranking males—has come into musth during June, July, and August for as long as I have known him. The park’s other two dominant males—Iain and Dionysus—have also entered musth at predictable times for the last eleven years. Taken together, the musth periods of these three elephants cover the eight months of the year when the majority of females conceive.

On this particular day, Bad Bull was not in musth, and Aristotle was outnumbered only by Dionysus and Iain. By selecting Aristotle, Jessica had chosen a large, healthy male who had survived to an old age. Perhaps her calf would also have a good chance of surviving to an old age and, in turn, producing many offspring.

I looked up from my note-taking and scanned the horizon. Over the years of elephant watching, I had noticed that elephants have an uncanny ability to locate other, distant groups of elephants: a behavior that hunters and game wardens
have often attributed to extrasensory perception. I had frequently observed males stop, their ears extended and their eyes cast down, as if listening, and then make a beeline for a group of elephants that was miles away.

To the east, a single elephant strode across the open plain toward our group at a steady pace. He was about a half mile away, but I knew by his walk, by the set of his tusks, who he was: Dionysus. My heart quickened. I was about to see one of the rare encounters between two musth males that make all the hours of heat and dust and bumping around bearable.

Even at a distance, I could tell—by his extended ears, by the rhythmic swinging of his head, and by the way he frantically searched the ground with his trunk for information—that Dionysus was in musth. From daily monitoring, I knew eight males were in musth, well above the average of three. In order of descending rank they were: Iain, Dionysus, Aristotle, Kioko, Alfred, David, Harmon, and Beachball. I did not need my binoculars to distinguish Dionysus’s beautiful, long wide-set tusks and an ear that had been damaged in a fight in 1982 and now flopped backward. Although I estimated Aristotle and Dionysus to be the same age (approximately forty-eight) and weight, Dionysus was slightly taller than Aristotle and had much bigger tusks. Normally the combination of two musth males close in size would have meant a battle. But in recent years Aristotle had gone into a decline; his musth periods were becoming shorter and more sporadic and he had lost several fights to younger, smaller males. I suspected that when he detected Dionysus, Aristotle would probably flee.

The wind was blowing from the east; Aristotle would soon pick up the strong odor of the fast-approaching musth male. But how had Dionysus—upwind of our group—located us? Had he heard Jessica’s series of postcopulatory calls from a mile or more away?

The gap closed to about 50 yards before Aristotle started and jerked his head and trunk up to face the other male. He smelled the air briefly, then turned and ran. Dionysus passed Jessica in pursuit of the fleeing male, but then he suddenly spun around and strode back to her. The younger, nonmusth males, who had taken advantage of the confusion to chase Jessica, lowered their heads and moved out of his way. As Dionysus walked toward Jessica, he waved and folded his ears and gave a barely audible, pulsed rumble, which was answered with loud throaty rumbles from all the females. He reached Jessica, stretched his trunk out to smell her genitals, and she backed into him, urinated, and again rumbled loudly, her mouth wide open.

Dionysus now began to guard Jessica, although not as closely as Aristotle had. Forty minutes later I again scanned the horizon. To the west I spotted another musth male moving steadily toward us. Although only his head and shoulders were visible above the tall grass, my immediate guess was that it was Iain.

In the thirteen years of the elephant study, Iain and Dionysus had been seen together only once although their musth periods overlapped (Dionysus’s from late January to mid-April; Iain’s from early March to mid-June) and each had been observed well over a hundred times. On that one occasion, Cynthia Moss had watched Dionysus chase Iain for more than a mile across Olonginya Swamp. If I had been given only one chance to see an interaction between musth males, I would have chosen these two elephants.

While in musth, males have extremely high levels of testosterone and are highly aggressive toward other males. Musth males of equal rank will fight if they meet, but fights are extremely rare, the males seeming to avoid one another. During all the years of the elephant study only thirty dangerous conflicts have been witnessed; twenty of them were between males in musth. Fighting males are often badly injured or killed; David died as a result of a wound received in a fight that he won; Harvey was killed by Bad Bull; Iain dropped out of musth after being tasked by RBG and didn’t come into musth again for two years; Alfred was blinded in one eye; and Sleepy was badly gored in the chest.

I lifted my binoculars to my eyes—there was the anvil-shaped notch on his upper left ear that had allowed me to identify Iain on an East African Wildlife Society picture postcard taken in 1963 and on a picture stuck on the large matchboxes for sale in Nairobi. A huge bull with heavy tusks, Iain was Amboseli’s oldest and highest-ranking male. Only in Amboseli, and in a few other isolated populations, are elephants protected well.
enough to allow what was about to happen. Elsewhere in Africa males with tusks that size would have been killed long ago by hunters or, more likely, by poachers. Ivory figurines to decorate the homes of wealthy Japanese and ivory bracelets to adorn the ladies of the world have meant that few males now live long enough to come into musth, let alone live as long as Iain and Dionysus. Only about 20 percent of the ivory traded is legal (tusks collected from natural deaths or from culling operations); the rest comes from elephants that have been slaughtered by well-armed gangs of poachers. Most of the remaining elephants in Africa are males under thirty years old and females under thirty-five, living in fragmented families, with shattered bonds and many, many orphans.

Iain was approximately five years older than Dionysus, slightly taller, and a bit heavier. In addition, Iain had been in musth for less than a month, while Dionysus was nearing the end of his musth period and had lost condition. Still, I knew they would fight. Iain was downwind of us. He would know that Dionysus was here and guarding an estrous female. Dionysus, meanwhile, was facing east, unaware of Iain's approach. The gap between them narrowed, each step bringing Iain more than a yard closer: thirty yards, twenty-five, twenty, and then suddenly Dionysus whirled around, his head and tusks high.

There were no preliminaries, no sizing-up of each other, even though the two males had spent almost no time together. They appeared to know each other's fighting abilities well, perhaps from their repeated calling and from the urine trails that each left during their constant searching for estrous females. For a moment, each tried to maneuver into a better position. Suddenly they rushed at each other, their trunks outstretched to reduce the blow, stopping only inches before their tusks made contact. Dust billowed upward, standing out sharply against the steel blue storm clouds gathered over Kilimanjaro. Jessica, long since forgotten, was being pursued in circles by several young, nonmusth males. Only twenty-year-old Jake, an independent male from the fam-
Some 250 elephants make their way across the plain led by two tuskless females—one, the matriarch of a family in the group; the other, her daughter. The head of a musth male, Iain, towers above them all.

ily, watched the fight. The two males backed off, ear waved, rumbled the deep, pulsating sound made only by males in musth, and then rushed at each other again. The loud clank of ivory against ivory rang out. They separated, danced around each other, and charged a third time. Although they matched blows, Dionysus began to back up, coming closer and closer to my car. Suddenly he spun around and fled with Iain in pursuit. As they avoided my car I was able to get a good look at their genitals: Dionysus’s urine dribbling had ceased but Iain continued to dribble urine profusely.

During the fight I hadn’t noticed that it had begun to rain. Now it came down in a torrent and Dionysus slipped and slid across the open pan as he fled from the bigger male. Iain pursued Dionysus for a couple of miles before abandoning the chase and returning to Jessica.

After the excitement, I stopped to reflect on the series of events. At 12:53 P.M., Jessica was mated by a musth male, Aristotle. She gave a series of loud, postcopulatory rumbles. Her family joined in rumbling, trumpeting, and screaming in what we have called a mating pandemonium. At 1:12, Dionysus was spotted upwind making a beeline for Jessica and Aristotle. At 1:20, Dionysus rumbled and was answered by the females with a loud chorus of rumbles and trumpets, a typical response to the arrival of a musth male. Half an hour later Iain was spotted approaching fast from the west. Two minutes later Amboseli’s highest-ranking males fought. The arrival of these two males was not a coincidence, and the evidence pointed strongly to some form of long-distance communication.

Although I knew that musth males used urine trails to monitor one another’s movements, this didn’t always explain their ability to avoid each other, over many miles, as they moved widely in search of estrous females. Nor did it explain how Dionysus and Iain, coming from opposite directions, met up that day.

The low-pitched vocalizations of musth males were, to my ears, barely audible. I often wondered why such large, aggressive animals made such quiet sounds. Or
were they? A 1980 study had shown that elephants hear frequencies well below the human range, and zoologist Judith Berg had suggested that some elephant vocalizations are very low in frequency. Were the sounds made by these large males actually loud but too low in frequency for human ears to detect? Were they using these low-pitched musth rumbles to monitor one another's movements?

In late 1984, during a visit to the Washington Park Zoo in Portland, Oregon, Katherine Payne (of Cornell's Laboratory of Ornithology) became aware of a throbbing sensation in the air as she sat quietly watching the elephants and guessed that they were making sounds below the range of human hearing. Together with her colleagues, William Langbauer and Elizabeth Thomas, Payne returned to the zoo with sensitive recording equipment. Soon afterward I received an excited phone call from her: the rumbles made by Asian elephants were full of infrasonic components. I invited her to join me and to record sounds from free-ranging African elephants. Two months later we were bouncing around Amboseli in a Land-Rover.

Over the years of the study, Cynthia Moss, biologist Phyllis Lee, and I had identified twenty-five different calls made by African elephants. Fifteen of these vocalizations were in the low-frequency group termed rumbles. Katy Payne and I concentrated on these low-frequency calls. While she ran the tape recorder and microphones in the back of my Jeep, I tried to identify the sender, the call type, and the social context of each call that I was able to hear. In the month that Katy was in Amboseli, we recorded hundreds of rumbles. Some of these sounds, such as the musth rumble, the estrous females' postcopulatory rumble, and the chorus of rumbles given by females to a musth male, contained infrasonic fundamental frequencies with upper harmonics that were audible to us. When analyzing our tapes, however, we found that we had recorded many other calls that we had been unaware of at the time.

While the discovery that free-ranging African elephants use infrasound was exciting, we were more impressed by the power of these seemingly soft calls. For example, we found that some of the musth rumbles had sound pressure levels of up to 105 decibels; the chorus of rumbles made by females in response to a musth male had sound-pressure levels of up to 99 deci-
A rare aggressive encounter between two of Amboseli’s dominant males in musth. Below left: Dionysus raises his trunk to smell Iain as each tries to maneuver into a good position from which to attack. Below: The two males rush at each other, trunks outstretched to reduce the blow, stopping only inches before making contact. Overleaf: The two collide, and the impact frees dust long trapped between deep wrinkles. Iain, the larger bull, lifts 12,000-pound Dionysus off the ground, forcing him backward. A subordinate male stands in the background, interested but with his head lowered in a submissive posture.

bells; the postcopulatory rumble was recorded with sound-pressure levels of up to 113 decibels. Very low frequency sounds are subject to much less environmental attenuation than are higher frequency sounds of the same intensity. Therefore, some of the elephants’ calls may be audible to other elephants several miles away.

The discovery that elephants use loud, very low frequency sounds to communicate may explain some of the remarkable flexibility of elephant social dynamics. Females and their calves live in a complex society of family units, bond groups, and clans. Family units are composed of several related females and their offspring. Strong, lifelong ties exist between related families. These families, known as bond groups, associate closely and greet one another with loud rumbles, trumpets, and screams after periods of separation. However, the physical proximity of family and bond-group members may change dramatically from day to day, and they may be separated by long distances. The occurrence of intense infrasonic calls may help explain the uncanny ability of cows and calves to coordinate their movements while miles apart.

Elephants probably also use loud, very low frequency calls as they search for mates. Male and female elephants live in separate but overlapping social and spatial spheres. Adult males move through the entire population in search of receptive females. At any particular time only one female in the population may be in estrus, and she is always guarded by a musth male during her peak two days of estrus. Musth males probably locate receptive females by listening for their loud, very low frequency estrous calls.

Equally remarkable is the ability of the aggressive musth males to avoid others in the same condition as they search for estrous females. In addition to tracking the urine trails of other males, they most likely monitor the intense, very low frequency rumbles to determine the movements of other musth males.

Elephants are highly intelligent, with rich and complex social lives. Each year, as we learn more about their behavior, Africa’s elephants decline by another 10 percent through demand for their tusks. As fifty-year-old bonds are shattered, families fragmented, and orphans left to mill helplessly around, the time has come to view elephants as something other than so many pounds of ivory.
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DIVISION OF CHRYSLER MOTORS

BUCKLE UP FOR SAFETY.
Snakes under Pressure

On land, in trees, and beneath the water, their circulatory system adapts to the demands of gravity

by Harvey B. Lillywhite

On the first Thursday of May, the townspeople of Cucullo, Italy, walk in procession behind a wooden statue of Saint Dominic, which they have adorned for the occasion with harmless rat snakes belonging to the genus *Elaphe*. These snakes have a natural inclination to climb, so when they are released at the base of the statue, they grip it and move upward, ultimately ornamenting Saint Dominic's head. The organizers of the procession know their native snakes well, for they avoid using ground-dwelling species, which would not grip the statue and climb.

Many snakes are adept at climbing. A familiar North American species is the red rat, or corn, snake, well known for its ability to mount the vertical trunks of pine trees and search for birds' nests in the lofty canopy. Held against the tree as if by magnetic attraction, the snake glides upward by following depressions in the bark. The use of skin and muscle to secure a limbless body as it crawls against gravity evokes awe and curiosity. Equally amazing, however, is the snake's ability to maintain blood circulation when its long body is extended vertically.

Gravity affects all organisms, but terrestrial animals that are long or large are especially subject to disturbance of their body fluids. The giraffe has intrigued biologists for many years because its height requires high levels of blood pressure to maintain blood flow above the heart to its head, as well as rapid adjustments of pressure when the head moves up or down. Medical doctors concerned with high blood pressure in human beings began studying giraffes in the 1950s. Other investigations followed, and the giraffe became a textbook example of adaptation in the cardiovascular system.

Studies of blood circulation in snakes are now complementing studies of giraffe venous return. The green python, a nocturnal species that prowls the tropical rain forests of New Guinea and northern Australia, reaches a maximum length of just under six feet; its nonclimbing relatives may be up to thirty-three feet long.
raffes. For the past 20 million years, snakes have undergone an impressive adaptive radiation, attaining a wide diversity in terms of habitat and behavior. Today approximately 300 genera, comprising some 2,700 species, live in nearly every available habitat except for polar regions, higher mountaintops, and deep oceans. To take just the extremes, four families of snakes successfully inhabit the seas, where gravity problems are almost nonexistent, while numerous other lineages live in trees, where coping with gravity is a major challenge.

When a long animal assumes an upright, or vertical, position, blood pressure falls in the higher blood vessels and rises in the lower vessels. This gravitational pressure, which is caused solely by the weight of the blood, increases with depth so long as the blood column is continuous and regardless of whether the liquid is in motion. A seventeen-foot-long python that is fully vertical has a gravitational pressure in its tail of about 400 mm Hg (equivalent to the pressure of a column of mercury 400 millimeters high). When this pressure is added to the snake's normal arterial blood pressure, which in a horizontal posture is probably about 50 mm Hg, the blood pressure in the tail is roughly three times greater than the blood pressure measured in a hypertensive human being.

Because of gravitational pressure, the walls of the lowermost blood vessels stretch and blood tends to collect in them like water in the bottom of a water-filled balloon. Most of this pooling occurs in the veins, which are far more elastic than arteries. As a result, a considerable proportion of the blood may shift to the lower veins during upright posture. Unless automatic physiological reflexes or a change in the animal's behavior opposes this shift of fluid, less and less venous blood will return.
Its yellow color phase enables an eyelash viper, left, to blend in with palm fruits. An arboreal species found in Central and South America, the eyelash viper may spend hours, even days, coiled on branches or slender reeds, using its prehensile tail for attachment. Central and South America's chunk-headed snake, below, forages at night on small frogs that perch on leaves and small lizards that sleep on twigs. Adaptations of its muscles and vertebrae help this snake bridge gaps in the vegetation of up to half its three-foot length, while its extremely slender neck enables it to slide its head out to the tips of branches and leaves without startling prey.

Michael Fogden; Bruce Coleman Inc.

quently, he and I published a series of papers in which we reported that arboreal species maintain relatively high arterial pressures, averaging 50 to 90 mm Hg, sometimes overlapping values that are measured in mammals. On the other hand, fully aquatic species such as sea snakes have low blood pressures, typically between 15 and 30 mm Hg. Intermediate pressures are found in semiaquatic and nonclimbing terrestrial species.

The greater pressures in tree-dwelling snakes allow them to assume a head-up posture with little danger that a passive fall in arterial pressure will impair blood flow to the brain. Moreover, physiological reflexes that control blood pressure are well developed in these snakes and tend to compensate for gravitational disturbance. As in mammals, this control is exerted both by the pumping action of the heart and by the resistance to blood flow in the blood vessels. The latter is regulated by the smooth muscles that alter the diameters of the smaller arteries.

Studies of rat snakes have shown that when the head is elevated, the fall in gravitational pressure in the head arteries is rapidly compensated for by accelerated pumping of the heart and increased vascular resistance, particularly in the lower body. The changes of resistance distribute the blood upward so that it reaches critical organs such as the heart and brain. These responses vary in different species of snakes but are probably present in all terrestrial ones, which faint or quickly die if blood flow to the brain is stopped. (When snakes assume a head-down posture, the cardiovascular adjustments are generally the reverse: the heart rate tends to slow, vascular resistance tends to relax, and pressures at the head are prevented from reaching excessive levels.)

An aquatic snake has very different demands on its circulatory system because the gravitational pressure within its blood vessels is matched by the water pressure on its body. Since the water pressure similarly increases with depth, the distribution of blood is largely the same regardless of body position in the water. When in a vertical position, therefore, an aquatic snake does not require high blood pressures to support a blood column above its heart nor does it need to regulate blood pressure as it changes posture. When a sea snake is taken out of the water, however, and held head up for more than a few minutes, arterial pressures at the head fall toward zero as blood pools in the lower body, and the vessels near the head presumably collapse.

Aquatic snake species almost certainly to the heart, decreasing the heart’s output and jeopardizing blood flow to the brain. The magnitude of the problem depends on the angle of posture, the length of the animal, and the characteristics of the blood vessels.

Pumping hearts must overcome both frictional resistance to the movement of blood and the gravitational pressure of a blood column that might depart from horizontal. A little more than a decade ago, on a research expedition to the Visayan Sea (in the Philippines), Roger Seymour discovered adaptive trends in blood pressures in several species of snakes. Subsequently, he and I published a series of papers in which we reported that arboreal species maintain relatively high arterial pressures, averaging 50 to 90 mm Hg, sometimes overlapping values that are measured in mammals. On the other hand, fully aquatic species such as sea snakes have low blood pressures, typically between 15 and 30 mm Hg. Intermediate pressures are found in semiaquatic and nonclimbing terrestrial species.

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The venomous olive sea snake, right, cannot survive if taken out of water and held upright. Gravity will cause blood to pool in the lowermost veins and fluid to leak from capillaries into the lung and other tissues at the lower end of the body. Normally, the pressure of the water surrounding the snake's body offsets the downward pull on the circulation, regardless of the snake's posture. Diagram below: In aquatic snakes the pulmonary vessels (those that circulate blood to the lung for oxygenation) extend nearly the entire length of the lung. In arboreal snakes, however, the pulmonary vessels are much shorter, minimizing the leaking of blood fluid into lung tissue during upright posture. The heart is also farther forward in climbing species.

Joe LeMonnier after Harvey B. Lillywhite

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**Lung Anatomy of Snakes from Different Habitats**

Aquatic

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Semiaquatic

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Terrestrial, nonclimbing

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Terrestrial, semiarboreal

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Concentration of Pulmonary Blood Vessels

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Evolved from terrestrial relatives. The venomous sea snakes of the families Hydrophiidae and Laticaudidae, for example, apparently derived from terrestrial stock of the family Elapidae (which includes the cobras and kraits). In the process of adapting to aquatic habitats, the terrestrial ancestors lost their higher blood pressures and the effectiveness of reflexes that control blood pressure during disturbance by gravity. These same changes occurred independently in several distinct snake lineages, and are cases of what biologists call convergent evolution.

The "adaptive hypertension" of arboreal snakes is similarly found in other long terrestrial animals, such as the giraffe. The giraffe has the highest measured blood pressure of any animal. When erect, an average adult stands between fifteen and eighteen feet tall, with the neck making up about half this height. Giraffes are almost always in an upright posture, even when dozing. From their lofty vantage point giraffes can detect predators; they can also disperse widely while feeding and still maintain visual contact as a herd. Heat dissipates quickly from their lean bodies, an adaptation similarly thought to help the tall Watusi and Masai peoples of Africa endure a hot climate. The giraffe's greatest advantage is that it can browse on leaves up to a height of about twenty feet, whereas no other terrestrial mammal except the elephant can reach much above ten feet.

To insure adequate circulation to the brain, the giraffe's arterial blood pressures are as high as 260 mm Hg at the heart level. The pressure decreases with height above the heart, averaging about 100 mm Hg in the carotid artery at the base of the skull, approximately the blood pressure at heart level in human beings. Cardiovascular adjustments and the muscular carotid and vertebral arteries (the main arteries of the neck) evidently protect the brain from excessive pressure when the head is lowered, for example, during drinking.

The idea that hearts must pump blood more forcefully in order to overcome gravity has been challenged recently by Henry Badeer of Creighton University School of Medicine in Omaha. He suggests that by the action of blood descending in the veins toward the heart helping to lift blood in the arteries. Badeer proposes that the high arterial pressures of giraffes are necessary only to overcome vascular resistance and prevent the collapse of arteries in the head.

Others point out, however, that the operation of a siphon depends on the flow of liquid in a rigid tube. Unless the veins from the brain to the heart are kept open by the reinforcement of surrounding structures (as occurs in the skull bones), they are subject to collapse and this prevents a siphon effect. While the siphon principle could work, no animal is known to possess externally reinforced veins to take advantage of it.

Giraffes are the tallest animals whose blood circulation is accessible for direct study. These great mammals are dwarfed, however, by the giant dinosaurs that once roamed the earth. The circulation of
aquatic dinosaurs probably was not disturbed by gravity, as is the case among contemporary sea snakes. Many of the larger dinosaurs, however, were terrestrial. Paleontologist Robert Bakker argues in his recent book *The Dinosaur Heresies* that the gigantic late Jurassic sauropods were plant eaters that, like giraffes, browsed on high vegetation, sometimes rearing up on their hind legs and tail.

This has significant implications for cardiovascular problems, inasmuch as a number of long-necked brontosaurs could have reached upward thirty-five or forty-five feet. In the extreme case of *Barosaurus*, the heart would have had to pump out blood at a pressure in excess of 650 mm Hg just to support the blood column above the heart to the elevated head. If this dinosaur held its head erect most of the time, the stress on its heart would have demanded tremendous heart muscles. Hearts of giraffes are massive in comparison with those of other mammals. Although we do not know the actual sizes of dinosaur hearts, we do know that sauropods had very large chest cavities.

Because of their skeletal features, all quadripedal mammals and dinosaurs have hearts more or less in the same part of the body. As a result, a long neck inevitably means longer blood vessels leading from the heart to the head. Among mammals, the greater this distance, the greater the arterial pressure. In snakes, however, the heart position can vary considerably in relation to the total length of the limbless body. This anatomical freedom provides another weapon in the arsenal of adaptations that help these animals cope with gravity.

In aquatic snakes the heart is close to the body center, while in semiaquatic snakes the heart is located farther forward. Terrestrial and arboreal snakes
have hearts still farther forward, from 15 to 25 percent of the body length from the head. The forward heart reduces the distance to the brain, so that when the snake is in an upright position, the weight of the blood column above the heart is less of a challenge. In water, where gravity is not a problem, a more centrally located heart is favored because it does less work in moving blood to both ends of the body. When snake species are compared within one category of habitat, however, the absolute distance from heart to head increases with body length and so does blood pressure, just as in mammals.

The forward heart necessitates a very long venous flow to return blood to the heart from the tail; this becomes a problem when the animal is vertical or erect. In giraffes, compression as a result of skeletal muscle contractions helps the blood return to the heart, assisted by valves that prevent excessive backflow. The veins of snakes seem to lack valves, but recently I reported a type of behavior in some arboreal species that may compensate for this. When these snakes are upright or have been climbing for a while, they pause momentarily and, while stationary, wiggle the body so that laterally undulating waves advance from the lower torso toward the head. The advancing undulations squeeze the blood forward in the veins. Ultimately, the effect is to increase the output of blood from the heart and thereby increase arterial pressures. The behavior is not seen in aquatic species of snakes and presumably evolved specifically to assist the blood circulation in arboreal environments. Normal crawling movements also help, but they are less effective than this special wiggling.

Despite the various adaptations that maintain cerebral blood flow in an upright snake, there remains a serious problem at
High blood pressure, created by a powerful heart and maintained by thick-walled arteries, supports blood flow to the elevated head of a giraffe, left. When a giraffe drinks, below, adjustments in the circulatory system prevent the blood pressure in the head from mounting to a dangerous level. The tight hide that covers the giraffe's long legs is another adaptation that combats the pull of gravity by opposing the tendency of fluid to collect in the lower body.

Charles G. Summers, Jr.: Colorado Nature Photographic Studio

resistance reduces the flow of blood into the lower capillaries.

The general build of the animal affects the tendency of blood vessels and tissue to become distended with fluid. Tree snakes usually have slender bodies with firm muscles and tightly attached skin. This combination resists stretching caused by accumulating fluid better than that of a larger circumference body with looser tissue. In other words, the body covering behaves like the G-suit worn by pilots during maneuvers in jet aircraft. A research team led by Alan Hargens of the University of California at San Diego recently showed that the very tight skin on the legs of giraffes similarly functions to limit the swelling of their lower tissue.

Many aquatic and nonclimbing snakes have more flaccid bodies and looser skin than their arboreal counterparts. Terrestrial, nonclimbing vipers, for example, often have a large girth and sedentary habits. In the upright posture, a terrestrial rattlesnake is seven times more susceptible to blood pooling in the tail than arboreal pit vipers, which are short and slender. Of course, a heavy-bodied viper is less suited than a thin one to negotiating a maze of tree branches even if blood circulation is not a problem. A thin body may also have other advantages, such as camouflage. Nevertheless, the trait of slender-ness may well be a physiological prerequisite for active life in trees.

Lung tissues are especially apt to become swollen with fluid, in part because the capillaries in the lung must be highly permeable to enable the blood to acquire oxygen and give off carbon dioxide. Moreover, the inner lining of the lung is exposed to the air in the lung, and so is not protected from distension by the body's covering of skin and muscle. Theoretically, the longer and more stretched out the pulmonary vessels (those that circulate blood to the lung for oxygenation and return it to the heart to be pumped to the rest of the body), the greater the risk of edema during upright posture.

Once again, examination of different snake species shows that natural selection has produced the form appropriate for the corresponding gravitational environment. The pulmonary vessels extend almost the entire length of the body cavity in aquatic snakes, but occupy as little as one-tenth the body length in arboreal species—not even the full length of the lung. Semi-aquatic and nonclimbing terrestrial species fall somewhere in between these two extremes.

In arboreal snakes pulmonary blood pressures are kept constantly low, with
small gravitational effects during vertical movements. In contrast, if a sea snake is removed from water and tilted vertically in the air, pulmonary blood pressure at the lower end of the lung increases so much that serious edema ensues and the lung capillaries sometimes rupture. These conditions impair respiration and can kill a snake within a relatively short time. Normally, when the snake is in water, the pressure of the water surrounding its body causes the lower portions of the lung to collapse and increases pressure in any air spaces, thus counteracting the forces that promote edema.

Many sea snakes go to depths of 100 to 160 feet, and some species are thought to dive as deep as 325 feet. Since the pressure of seawater increases approximately 1 atmosphere for every 33 feet of depth, such deep-diving snakes experience high overall pressures of gases within their compressed lungs. Although the high gas pressures in the lung help to prevent edema, they also cause large quantities of nitrogen to dissolve into pulmonary blood. Under similar conditions, human divers risk decompression sickness (the bends) when they resurface. If the pressure is reduced too quickly, tiny bubbles form that can block blood vessels. Because sea snakes have more compressible bodies than humans, their lungs collapse more when they dive, reducing the amount of blood that comes into actual contact with the lung gas. The blood also loses excess nitrogen to the seawater through the skin, which is a permeable organ important to respiration. Roger Seymour has demonstrated that both of these factors—collapse of the lung and nitrogen loss through skin—protect diving snakes from getting the bends.

Does gravity constrain the overall length of snakes, as it does the length of their pulmonary vessels? The answer seems to be a qualified “yes.” The largest snakes include Asian and African pythons and South American anacondas and boa constrictors. Contrary to popular belief, these giant serpents, which reach lengths of from fifteen to nearly thirty-three feet, are mainly terrestrial or semiaquatic, and none are primarily arboreal. The image of giant pythons dropping onto people from trees is simply a myth created by Hollywood moviemakers. Truly arboreal constrictors belong to a group of snakes called tree boas, whose maximum length averages six or seven feet. These snakes are slender and possess prehensile tails.

Similarly, tree vipers are generally shorter, as well as much thinner, than the terrestrial members of the Viperidae family, which includes some of the stoutest of snakes. The longest vipers are the fer-de-lance and the bushmaster, which inhabit forested areas of tropical Central and South America and reach lengths of ten and thirteen feet, respectively. Although juvenile snakes of both species are arboreal and hunt prey in trees, the adults become terrestrial and seek prey on the forest floor. In the families Colubridae and Elapidae, however, some of the longer species (including the mambas, vine snakes, and various tree snakes) are, in fact, arboreal. These snakes, some of which may be ten or twelve feet long, are the slenderest of snakes and possess the shortest pulmonary vessels.

Apart from their physiological and anatomical adaptations, all snakes can combat gravity stress through behavioral adjustments. While climbing, they can form their flexible bodies into loops, as well as alter the angle of posture. In this respect, limbless snakes have more control over blood circulation than do such habitually erect animals as the giraffe.
Shadow World of the Javanese

In a marathon, all-night puppet play, one man is director, chief musician, and the whole cast of characters

by Ward Keeler

Thirteen years ago we challenged our cousins the Pandhawa to a game of dice. They lost and were obliged to leave their kingdom of Ngamarta for twelve years. In the thirteenth year, they were to go into hiding. If their identity was discovered, they were to forfeit control over Ngamarta for another twelve years. The thirteenth year is now at an end; my agents have failed to discover them. I ask you, my worthy elder, King Baladewa, what I should do now? Should I indeed honor the terms of the wager and return to them the kingdom of Ngamarta?

As he finishes speaking, King Duryudana, eldest of the Pandhawa's hundred cousins, the Kurawa, raises both his hands in a gesture of respect. Those hands, four elegantly curved digits with the thumb politely tucked into the palm, connect to the long arms jointed at the elbow that are a Javanese shadow puppet's only movable parts. The palm of each hand is tied by a thread to a long stick that hangs down below the edge of a screen. These sticks enable the dhalang (puppeteer) to manipulate the puppet's arms, while a third, more substantial stick, which runs up through the puppet's spine, allows him to move the figure as a whole.

The figure of King Duryudana is about fifteen inches high, larger than many puppets but, like all the others, cut from a single piece of water buffalo hide. Simple lines incised into the skin indicate the features of the king's face seen in profile—a large round eye and arching eyebrow, a wide mouth, and a long nose—and his bare chest. But the king's elaborate crown and golden armlets, the folds of his skirt, and the glow that shines about the head of a mystically potent person are all rendered in great detail, an intricate filigree of leather painted in bright colors.

An electric light suspended above the dhalang's head illuminates the flat puppet so that it casts a shadow on the white screen it is propped against. Although the part of the screen on which the play takes place extends only as far as the dhalang can reach to either side of where he sits cross-legged on the floor, the screen itself is about twenty feet in width, and dozens of puppets are lined up on either side of the playing area. Lithe knights, whose del-
Cut from single pieces of water buffalo hide and manipulated by means of sticks attached to their spines and arms, Javanese shadow puppets are observed through a screen. Such silhouetting emphasizes the intricate filigree of the cutting—but the bright colors are lost.

G. Schnee
icate proportions embody the restrained potency that Javanese idealize, and the diminutive princesses with downcast eyes who are their rightful mates stand nearest the center. Husky warriors and turbaned gods come next, and coarse giants with hairy bodies stand menacingly at either end of the screen.

Seated behind the screen are a few dozen people invited to attend the performance. They see only the puppets’ shadows: the bright colors of the puppets are lost but the intricacy of the cutting shows much more clearly, and as the dhalang moves the puppets toward and away from the screen, he plays on the size and clarity of the shadows they project.

The dhalang in this performance is Ki Dhalang Jaka Raharja of Ceper, a village in Central Java, Indonesia. He is dressed in formal attire: a short, dark jacket, an ankle-length batik skirt, and a batik cap. A sash wrapped several times around his waist secures the skirt and also, at the small of his back, a kris, a Javanese dagger often thought to be endowed with mystical power.

Ki Jaka himself, like all accomplished dhalangs, is thought to possess considerable spiritual potency. It is no wonder people believe this since his talents are impressive—and many. He must manipulate all the puppets, which requires both skill and stamina. He must speak all their parts, endowing each character with a distinctive voice and speaking style, while improvising all the dialogue as the play proceeds. He sings and also directs the orchestra and singers arrayed around him. He accents moments in the drama by tapping a wooden mallet against the puppet box to his left and by striking bronze plates hung on the side of the puppet box with his foot. And he does all this while sitting cross-legged throughout the eight-hour, night-long performance—never standing up or even uncrossing his legs. Although members of his troupe snack, drink tea, and eat a full meal during the performance, the dhalang takes only a bit of tea as refreshment and smokes heavily scented clove cigarettes as a stimulant. The musicians and singers, the invited guests, casual spectators, and people behind the scenes who make and serve meals all get sleepy during the long night, and most of them nod off at some point. Only the dhalang never falters.

Ki Jaka’s dress and the puppets he uses reflect the style of the royal courts of Solo, whose princes once held this area of Central Java under their authority. Although their political control has long since been lost, the courts are still looked upon as the source of Java’s most refined styles—in language, dress, and the arts.

The Solonese influence also shows in the music, as performed by the percussion orchestra, or gamelan. The gamelan’s tone is alternately bright and ringing, when the many bronze keys and gongs are struck firmly, and soft and warm, when the quieter, subtler instruments of the ensemble, such as the wooden xylophone (gambang) and the two-stringed rebab, come to the fore. Of the singers, three are women and two are men. The women usually sing individually, the men in chorus, although at times all five sing in unison.

At the point in the play, however, when
King Duryudana has put his question to King Baladewa about how best to proceed in the matter of control over the Pandhawa's kingdom, it is Ki Jaka who sings. Accompanied by only a few instruments, he sings lines of poetry excerpted from classical Javanese literature. The language is obscure and its content is far removed from the story at hand. Nevertheless, suluk, as the dhalang's sung verses are called, occur frequently in performance, and they afford Ki Jaka the opportunity to display the beauty of his singing voice, for which he is famous. This particular suluk indicates to the audience that the important issue of the plot is about to be broached. The performance began at nine in the evening, but in the half hour since then Ki Jaka has described the Kurawa's kingdom of Ngastina, brought forward the puppets appearing in the first scene, and narrated the florid and stereotypical greetings exchanged among all the characters present. Only now will the story really get under way, and only now do the invited guests, and the many uninvited spectators watching from behind the gamelan, start paying serious attention to the action on the screen.

Baladewa, King of Madura, is a large and imposing figure. Like Duryudana, he wears the crown and ornaments of a king. But his gaze is less downcast than his host's, his body is heavier set, and he stands with feet spread farther apart. In all these ways his appearance indicates his more forthright manner, and Baladewa does indeed speak his thoughts more directly than other, more refined characters in the wayang (shadow play) repertoire. Javanese culture lays much store by discretion and a circumspect manner in encounters. Baladewa fails to meet those standards of polite interaction, but his incorruptible integrity wins him respect, and his inclination to excitement makes most spectators smile indulgently.

On this occasion he responds to Duryudana with characteristic bluntness:

You shouldn't even need to ask the question. To return control of the kingdom of Ngamarta is to fulfill the terms of your pledge, as is the duty of all persons of honor. So you have no decision to make. Furthermore, by peaceably ceding sovereignty over one half of the kingdom of Ngastina [control of Ngastina is contested among the two sets of cousins], as your cousin Puntadewa has suggested, you will prevent civil war with the Pandhawa. Should that war, the Bratayuda, take place, think of the suffering that will follow, think of the mothers who will weep for their slain sons, of the children left orphaned, think of the maidens left calling out for their beloved. Think, too, of all the hardships the Pandhawa have already suffered at your hands.

As Baladewa begins to recount the many treacherous deeds perpetrated by the hundred Kurawa against their five righteous cousins, he becomes increasingly indignant. He speaks more swiftly, his voice gets louder and shriller, and his hands beat the air. Too excited to care about the niceties of others' feelings, he makes cutting reference to the deceitfulness of the Kurawa's prime minister, Sangkuni, who is also present at the royal audience. Sangkuni defends himself in his slow but cunning way, then others present begin to make accusations and counterclaims, and things get quite unruly.

Duryudana puts an end to these arguments by noting that Baladewa's younger brother, Kresna, has long been out of touch with both the Pandhawa and the Kurawa. Duryudana has been given to understand that whoever can enlist Kresna's support will prove victorious in the struggle for Ngastina. He therefore invites Baladewa to proceed to Kresna's kingdom of Dwarawati, attended by himself and other members of the Kurawa court. Baladewa agrees and Duryudana orders Sangkuni to prepare the troops to escort the royal party to Dwarawati.

Ki Jaka pulls each puppet's central
stem out of the banana trunk support that runs along the base of the screen, and in time with the gamelan's musical accompaniment, moves the puppets off-screen. To maintain the impression of the puppets' autonomous movement for those watching on the shadow side, he makes sure that his own hands cast no shadow on the screen and that the puppets are well away from the screen before he lowers them out of sight. He then brings out a number of Duryudana's younger brothers, commanders of the Kurawa troops, and Sangkuni comes on to give them their orders. Before Sangkuni speaks, however, the gamelan falls silent and Ki Jaka places a large, all-purpose prop, the kayon, shaped like an inverted cone, over the center of the screen. He passes the microphone he has been wearing around his neck under the screen, whereupon it is handed to a man who proceeds to give a speech during a break in the performance.

The man is a notable in the village of Karanganom, where the wayang performance is taking place. After flowery greetings expressed in very formal and refined Javanese, he informs those present of what virtually all of them already know: this performance is being held in honor of the spirits of the dead buried in a cemetery nearby. A wayang is held each year for this purpose in the lunar month of Ruwah, the month in which Javanese are enjoined to pray to God for the well-being of their deceased kin, and to those ancestors themselves that they may grant blessings to their living descendants. Such observances in honor of the dead are performed both by individual families, who must clean their ancestors' graves and make them offerings of food, flowers, and incense, and by whole hamlets, which hold a ritual gathering in their collective ancestors' honor in the month of Ruwah. In the case of this performance, families living in three contiguous hamlets all have pe-pundhen ancestors buried in the cemetery, and these families have made monetary contributions to defray the expenses of the wayang. Men have also contributed their labor to set up the screen and gamelan in a gathering hall near the cemetery, and women have contributed their labor to cook food for all the participants. So this performance is truly a community effort, fulfilling Javanese ideals of cooperation among neighbors. As the speaker also notes, Ki Jaka has been kind enough to waive his usual fee—probably, in view of his fame and popularity, a considerable one—and to accept whatever sum the villagers could raise for the event.

Not all wayang performances are held in honor of the dead, and not all are sponsored by whole communities in this way. In fact, many villages have ceased to mark ritual occasions by means of wayang, whether because the costs are thought too burdensome or because religious reform movements have branded many aspects of traditional Javanese practice, particularly those practices concerning the dead, heterodox and backward. (Most Javanese are Moslems, although indigenous religious notions filter their perceptions and practice of Islam to varying degrees.) Probably a majority of wayang are now sponsored by families to mark life passage rituals—most often a daughter's wedding or a son's circumcision; less frequently, a woman's first pregnancy, the birth of a child, or the last in a series of funerary observances. Particularly as the costs of sponsoring a performance rise, and as modern consumer goods compete for a family's disposable income, people of moderate

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Danielle Toth
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A dhalang (puppeteer) sits before the screen with the puppet box to his left. On the edge of the box, next to his left arm, are a number of metal sheets that he raps with his right foot to accentuate the dialogue and give musical cues to the orchestra. Behind the dhalang sits the gender player, who plays softly and almost continuously throughout the performance, providing the dhalang with a pitch for the singing and for the puppets’ distinct voices. The woman in the blue blouse is the female vocalist.

Danielle Toth

means are less and less likely to sponsor shadow plays as part of their ritual celebrations, leaving this to wealthier families. But that doesn’t mean that only the wealthier people get to see them. During the first half of a performance, only guests invited by the sponsors watch from inside the sponsors’ home, on the shadow side, but anyone can sit outside, behind the gamelan, and watch the puppets on the dhalang’s side. There is no admission charge for a traditional wayang, and a popular dhalang can keep a great crowd of people sitting on the ground in the front of the house—or even perched in trees—late into the night.

No matter what occasion a wayang marks or who sponsors it, the performance is looked upon as a significant event. If the words “puppet” and “puppeteer” bring to an English-speaker’s mind children’s entertainment and its practitioners, those associations are inappropriate to the Javanese shadow play tradition. Not that Javanese children fail to appreciate the excitement and comedy that a night-long wayang provides. Children come in great numbers to a performance, either escorted by their older kin or, especially if the performance takes place in a village, simply in the company of their peers. They watch avidly the many battles among knights, princes, monsters, and gods that punctuate the performance, and they sleep contentedly, sprawled about on mats and crowded up against one another, through talkier scenes that advance the plot. But adults take just as great an interest in the performance as their juniors, and they accord the dhalang himself great respect. They consider him the guardian of an ancient tradition, one in which the binding moral truths and esoteric mystical notions of Javanese culture reach their most perfect expression. Westerners sometimes claim that a dhalang also enjoys a unique right to voice political criticism. Actually, his status does not depend on any such polemical role: political commentary in wayang rarely consists of anything more pointed than exhortations to righteous governance. Yet in a society in which a great many performing arts flourish, shadow plays hold undisputed preeminence as the most prestigious and revered of all art forms, both because of their ancient origins and because of their undiminishing entertainment value.

Many people in Java, however, particularly city dwellers, are unfamiliar with the shadow play tradition and uninterested in it. In some conservative Moslem quarters, wayang has long been shunned as an unfortunate vestige of Java’s pagan past, and other, less religiously committed Javanese often prefer folk drama or movies or tele-

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vision. Nevertheless, shadow plays still attract large audiences from all social strata, both in urban settings, where performances are often sponsored by government offices, and in rural ones, where prominent families display their wealth and their munificence by means of these public entertainments. Old people justify their interest in wayang by alluding to its weighty moral instruction; young people are franker about enjoying the battles and the often hilarious clowning routines that fill out much of a performance. Stately, obscure, boisterous, sententious, and action-packed, a shadow play portrays a mythological world filled with all manner of characters—heroic, divine, or comically mundane—that are as familiar to many Javanese as their kin.

The speaker concludes his remarks by urging the invited members of the audience, the men seated behind the screen watching the shadows, to enjoy the meal of rice and side dishes, plus heavily sweetened tea, they have been served. These men are heads of the households that have made a contribution toward the costs of the event. Women are not present in this area but, in a kitchen off to one side, many women are busy preparing the snacks and meals served both to the invited guests and to the musicians. Among the men eating their meal, the tone is amiable but restrained; among the women in the kitchen, conversation is more raucous and lighthearted. Moving back and forth between the kitchen and performance area are village youths, dressed in white shirts and ties and dark slacks, carrying food and tea on trays. As they enter the area where men are sitting on mats, the youths must drop to their knees and "walk while kneeling," a difficult movement but one necessitated by the obligation to show their elders respect.

When the performance recommences, Sangkuni gives the commanders their orders, and there is arguing and joking among them. Then the gamelan plays a martial tune and Ki Jaka portrays the characters' departure, each one moving in a style indicative of his temperament. This "departure of the troops" scene is included in every shadow play performed in...
the Solonese style. While it does not advance the story, it affords the dhulang an opportunity to display two important skills: his ability to differentiate the characters' voices in their banter, and his dexterity in representing their movements as they set out from court.

Many parts of a shadow play are highly conventionalized in this way, and the particular story selected for a given performance must be fitted into a fairly rigid series of scenes. Members of the audience who are familiar with the stories, derived from the Indian epic, the Mahabharata, that are most often presented in Javanese shadow plays, can tell from the first scene that this evening's story is Kresna Gugah, "Kresna's Awakening." They know how the story will turn out, but they watch to see how Ki Jaka improvises dialogue to fill the story out—he uses no script—and how he fits the story to the exigencies of a shadow play's unvarying structure.

The third major scene takes place in Kresna's kingdom of Dwarawati. Kresna is absent and his representative, Raden Setyaka, is under strict instructions not to disturb Kresna under any circumstances. At the Kurawa's approach, Dwarawati's troops must do battle to prevent them from entering Kresna's private chambers. But on learning that Kresna's older brother, Baladewa, is among the Kurawa party, Setyaka feels he must yield, and this first battle of the evening ends, as it always must, in a draw. Setyaka now prepares to counter Kresna's orders and inform him of the embassy's arrival.

For the next few scenes, Ki Jaka, following the example of his late predecessor, the controversial but immensely popular Ki Dhalang Nartosabdho, switches to a Jogjaneese performance style. Jogja is the second major court center in Central Java, having split from the Solonese court in 1753, and it has developed a distinctive style in the arts. The musical accompaniment and the metal plates that Ki Jaka taps with his foot distinguish the Jogjaneese style most obviously.

Kresna is revealed to be in the company of his sister, Lara Sumbadra, who is deeply distressed but has so far refused to explain the cause of her unhappiness. Finally, she reveals to her anxious brother that she misses her husband, Arjuna, the third of the Pandhawa brothers, whom she hasn't seen in all the years of the Pandhawa's banishment. Kresna consoles her, but as she reverts to silence, his disarray causes him to take on his alternative, monstrous form. He resolves to undertake a form of meditation in which his body appears to sleep, while his spirit leaves his body and travels to the realm of the gods.

Ki Jaka introduces moral instruction in
an encounter between Kresna’s spirit and
two monsters engaged in an argument,
and some light entertainment in a scene in
which four servant-clowns appear, along
with their master, Arjuna. At the end of
the latter scene, at about two in the morn-
ing, most of the men sitting behind the
screen go home. Boys and youths then
stream inside to find places behind the
screen where most of them stay awake
only just long enough to see Arjuna battle
some monsters. A few women also venture
into this area to watch the performance
now, although shadow plays are thought
to be primarily a masculine entertain-
ment, too serious for women’s lighter,
more romantic tastes.

In the remaining scenes, the Pandhawa
gather by Kresna’s sleeping body and
Arjuna pursues his spirit to heaven, where
Kresna has learned from the gods how
each side will fare in the carnage of the
Brayatuda about to begin. The Kurawa
try to rouse Kresna and fail, but then
claim triumph when Kresna does wake
up, following Arjuna’s success in retriev-
ing his spirit. Kresna offers Duryudana
the choice between obtaining either his,
Kresna’s, support in the Brayatuda or that
of a thousand allied kings. Foolishly,
Duryudana chooses the latter. Finally, Kresna
persuades his brother, Baladewa, to do
meditation while standing under a water-
fall, tricking him in this way so that he will
not intervene, in contravention of fate and
justice, on either side in the imminent civil
war. As the Pandhawa drive off the
Kurawa troops, and the sky outside turns
dawn’s blue-gray, the performance ends,
the shadows lose their clarity, the puppets
cease to move, and their epic world is
replaced by reality.

The crowd that has gathered and
swelled behind the gamelan, especially as
neighbors got up to catch the battles in the
last hour or so of the performance, now
disperses. While youths put the puppets
and gamelan away, the dhalang, singers,
and musicians sit down behind the screen
to have a meal. Ki Jaka takes his seat in
the place of honor at the center, the mem-
bers of his troupe sitting to either side of
him. He smiles broadly. Remarkably, he
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A River of Birds
by Kenneth R. Margolis

The Pacific flyway is the name we give to the western migratory route for birds that breed in Alaska, Canada, and the northern United States. A vague, mysterious domain, its boundaries are etched in the sky by the pattern of available resting and feeding habitat on the ground below. Staging for the earliest winter migrations begins on the great arctic deltas, and the birds move as far south as the marshes of Mexico and Central America. A few species, like the arctic tern, go even farther. Bounded by the Continental Divide on the east, the pathway stretches west across the Pacific to Hawaii and Tahiti.

In Tracks in the Sky, writer Peter Steinhart and photographer Tupper Ansel Blake try to convey something of what the flyway is, what it means, and what is happening to it. “The fact is,” writes Steinhart, “the great migrations are reflections in the sky of the waters of the globe. The Pacific flyway is but a corridor connecting the wetlands of the west.” In spite of the book’s title, Steinhart has little to say about the sky—the book is an exploration and contemplation of mud and water and the creatures that live in and above them.

There is a rather persuasive school of thought that considers “coffee table books”—and Tracks in the Sky is certainly a member of the species—an abomination: beautifully produced collections of overgrown postcards, accompanied by text as rich, and about as nutritious, as mounds of butter with no bread beneath them. They are books for people who do not like to read, filled with ready-made pictures for those who do not have the gumption to look for themselves.

Happily, this volume is proof that the genre can capture both glory and substance. Steinhart, who teaches at Stanford and produces a regular column for Audubon, writes to communicate, not to dazzle. His style is expressive without being showy, and his long essay here is driven forward by a narrative architecture that, as in any good story, does not fully reveal itself until the final pages. He starts with the wonder of migration, “the beauty of vast numbers of self-willed, purposeful, independent creatures, lending the magnificence of their impulse to our sometimes drab, stay-at-home existence.” Steinhart makes it clear that wetlands constitute the irreplaceable thread of the migratory journey, even for terrestrial species. He then describes some of the different kinds of wetlands, not only the great bodies of water we may first think of but also the springs and ponds in dry places that are often crucial for the survival of populations or even of whole species. He makes a brief but reasonably convincing case that wetlands have also served as the cradle and table of humankind and goes on to sing of the glories of mud, “one of those rare edges where sun, earth, and water come together, and the combination authors whole libraries of life.”

Having convinced us of the beauties and values of wetlands, the author then delivers a devastating cannonade of facts, statistics, and examples of destruction. Half the original wetlands of the United States are gone, along with 90 percent of those that originally existed in Canada. What is left is assaulted by chemical wastes, draining and filling, water diversion, and lowering of water tables. In the few remaining wetlands, hunters pop away, and planes and helicopters circle and hover. Diverse wetland vegetation is replaced by monocultures. We picture millions of dead birds. By the end of this section, the reader is reeling, hopeless. Steinhart then takes us, emotionally torn and bleeding, to Portland, Oregon, where Althea and Jack Broome decided not to destroy a dam that beavers had built on a stream running through their farm. The fields began to flood, geese came, and today, the Broome farm is a managed marsh. Because the farm is threatened by the development of surrounding areas, the city has created a special wetlands protection zone for it.

In the same area, urban naturalist Mike Houck of the Portland Audubon Society practices a kind of guerrilla education: he locates urban wetland sites, gets them mapped and inventoried, and organizes excursions to them. Businesses that have marshes next to them find themselves receiving awards for protecting the marshes, sometimes signs saying Wildlife Refuge will mysteriously appear at such places. By changing peoples’ consciousness, Houck has been instrumental in the protection of hundreds of acres of wetlands. These and other examples remind us that good will, good works, and a little human

Tracks in the Sky, by Peter Steinhart. Photographs by Tupper Ansel Blake. Chronicle Books, $35.00; 176 pp. illus.
Reviews

ingenuity will continue to spring up in the cracks between the alarming statistics of destruction.

Most of us would rather visit a wetland than look at pictures of one, but Tupper Ansel Blake helps us see things that we cannot always see on our own. He spent three years traveling the flyway in order to put together this collection of images, and the results are stunning. Blake's images convey a personal modesty, the photographer is not present. He has vanished, leaving us face to face with his vision.

One of the things Blake sees is detail. Over and over, his close shots of birds show fine texture and color variations, down to an individual feather. A canvasback duck taking off from Buffalo Lake reveals hard-edged, yet delicate, striations of blue-gray-white, shading into a satiny, mother-of-pearl pinion. A moose shows lean, almost menacing musculature. A horned grebe stares at us with its eerie, innocent, laser-red eye.

In fact, nearly all of Blake's close shots show us the animals' eyes. The body postures and faces are expressive, but with no trace of anthropomorphism. These animals are totally themselves and totally alive in the moment the shutter snaps. Blake does not bring them to us so much as he allows us to come to them. The other thing he sees is pattern. A few of his land-

![Snow geese fly over the Butte sink, Sacramento Valley, California](image)
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Much of Crowley’s Ridge consists of fine, windblown soil, known as loess, which accumulated after the last Ice Age ended, about 12,000 years ago.

All photographs by David Smart
Crowley’s Ridge, Arkansas

by Robert H. Mohlenbrock

Extending nearly 200 miles from southeastern Missouri into Saint Francis National Forest in eastern Arkansas, Crowley’s Ridge is a conspicuous, one- to twelve-mile-wide feature that sometimes rises more than 200 feet above the flat Mississippi River floodplain. Inland seas, glacial melting, and westerly winds all had a role in its creation.

Twice during the past fifty million years, a shallow sea extended from what is now the Gulf of Mexico up along the Mississippi Valley, depositing sediment through wave and tide action. After the shoreline finally retreated gulfward, weak stream patterns developed on both sides of what later became the ridge. These were carved into deep trenches by glacial meltwater released as the last Ice Age drew to a close, between 14,000 and 12,000 years ago. Subsequently, strong winds picked up fine soil particles from the floodplain and redeposited them along the narrow ridge. This windblown material, known as Beechdrops is a parasite that draws its nutrients from the roots of beech trees.
Crowley's Ridge

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loess, accumulated up to fifty feet thick. In Saint Francis National Forest, nearly half the ridge consists of this buff- or ash-colored soil.

Standing alone like an island, Crowley's Ridge has a flora generally unlike that found in the flatter parts of Arkansas and Missouri, which because of poorer drainage are characterized by huge stands of silver maples and cottonwoods. Most of the vegetation that colonized the ridge and adapted to its varied exposures and moisture patterns apparently came from mountainous areas to the east. White oak, red oak, and black hickory are the most common trees; shortleaf pine abounds on the drier ridgetops; and American beech and tulip poplar dominate the moist, well-drained lower slopes. More than 1,500 different kinds of flowering plants are found along Crowley's Ridge, many of them concentrated on the rich forest floor beneath the beech trees.

Many of the plants that grow on the ridge are on the extreme western edge of their range. Among them are bartonia, a slender member of the gentian family; the nut sedge, with its shiny, white seeds; the attractive white rein orchid; and climbing schisandra, a rare vine belonging to the magnolia family. But perhaps the most peculiar is beechdrops, one of relatively few flowering plants that are parasites.

Parasitic flowering plants were a puzzle to early botanists; one, writing in 1789, considered them to be not individual species but simply evidence of "a diseased sap of the plant on which they grew." In 1828, botanist Leopold Trattinick, trying to decide how to classify such a diverse group of organisms, noted that "we have no choice but to cast them together, as oddities, into their own category, much as in an asylum we bring together the mentally ill, whose mania are extremely varied, but of whom no one is really what he pretends or imagines to be."

There are three basic types of parasitic flowering plants. Those in the first group, which includes Indian paintbrushes, houseworts, and the bastard toadflax, possess both chlorophyll and roots in the soil, but nevertheless attach themselves to chlorophyll-bearing hosts for additional water and nutrients. Others, such as the mistletoe, similarly manufacture some food material by photosynthesis but obtain all their water through attachment to plants. Beechdrops, however, falls into a third group, along with Indian pipes, coralroot orchids, broomrapes, and dodders. These plants lack chlorophyll and must depend entirely on other plants for water and nutrients.

Unlike many species in this last group, beechdrops survives only if it becomes attached to a specific host, the root of a beech tree. Following germination of a beechdrops seed, the white seedling, only one-tenth of an inch long, sends forth a mass of curved and twisted roots, called grapples, which seem to take hold of every object within their reach. If one of these objects happens to be a beech root, the grapples wrap themselves tenaciously around it. In response to the attack by the grapples, the beech root produces large amounts of soft tissue around its circumference, from the point of attachment of the grapples to the end of the root. Despite this defense mechanism, the parasite easily penetrates the root and begins to direct the flow of nutrients produced by the tree into its own system. Eventually the entire current of sap in the beech root enters the parasite, and the beech root that extends beyond the point of attachment dies.

Although beechdrops seeds germinate in mid-June, the mature plants are conspicuous only from late August until the end of the growing season. Their purple-brown, twiglike, branched stems, which bear tiny, brown structures known as scale leaves, stand up to one foot tall. They are usually found a few feet from the trunk of a beech tree, although some grow as much as thirty feet away. There is no indication that these plants are attached to the host unless one carefully digs into the humus and fine soil to locate the point of their attachment.

During late autumn, beechdrops produces two kinds of flowers. Those high on the plant are very slender, up to one inch long, and white speckled with purple. They are sterile, having lost the ability to form seeds. The lowermost flowers are tiny and inconspicuous, but are fertile. Why this arrangement has evolved is still a botanical mystery.

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The Sun Also Surprises

New evidence suggests that our star can change its spots

by Stephen P. Maran

After centuries of study, astronomers are making radical changes in our understanding of the solar sunspot cycle. This famous “eleven-year” rise and fall in the number of spots on the sun has been blamed for such patently unrelated events as stock market booms and busts and the onset of plague in Central Asia. Sunspots are, however, definitely related to the heating of the earth’s upper atmosphere—and the consequent reentry and fall of artificial satellites—and to interference with radio communications, terrestrial magnetism, and even the navigation of homing pigeons. Astronomers are now confirming what a few have suspected for some time—that the sunspot cycle lasts considerably longer than the previously accepted figure of eleven years.

The latest concept of the solar sunspot cycle was presented at a meeting of the American Astronomical Society in Pasadena, California, in January 1987, by three investigators, Herschel B. Snodgrass, Peter R. Wilson, and Richard C. Altrock, who independently and by separate lines of investigation reached similar conclusions.

The essence of the new theory about the sunspot cycle is that it begins near the solar north and south poles with the occurrence of various phenomena that, unlike sunspots, are not detectable in ordinary telescopic photographs. These phenomena include magnetically disturbed areas known as ephemeral active regions and also the polar wind streams, which are distinct structures in the solar wind that emerge over the sun’s poles. The conventional view of the sunspot cycle, in contrast, concentrated on the regions where most sunspots form, zones between latitude 35° and the equator in each solar hemisphere.

Sunspots generally appear in so-called bipolar magnetic groups. This is as though the two poles, or ends, of a horseshoe magnet were sticking up through the sun’s surface, each end corresponding to one or several members of a sunspot bipolar group. These spots are cooler than their surroundings owing to a poorly understood effect of their strong magnetic fields on the upflow of heat from deeper layers in the sun. Being cooler than adjacent areas, sunspots look darker, but if you were to see
an isolated sunspot against a dark background, it would seem quite bright.

Since sunspots constitute intense solar magnetic disturbances, might there not be less intense disturbances from somewhat weaker magnetic fields that produce correspondingly less cooling and thus do not cause the pronounced darkening that characterizes a sunspot? Studies in the 1960s and early 1970s showed that such diminished disturbances do occur. Small arch-shaped structures with modest magnetic fields—so-called arch filament systems—were found on the sun; these often develop into small sunspots and may represent the emergence of lines of magnetic force from beneath the visible surface of the sun.

A more interesting and weaker type of solar magnetic disturbance was described in two highly significant scientific papers published in 1973 and 1979 by Karen Harvey and Sara Martin, astronomers now associated, respectively, with the Solar Physics Research Corporation in Tucson, Arizona, and CalTech in Pasadena, California. The spotless areas they studied were the above-mentioned ephemeral active regions, so named because they are short-lived, usually forming and dissipating in less than a single day. Harvey and Martin found that a typical ephemeral active region (ER) is bipolar, like a sunspot group, but its longest dimension extends only about 6,000 miles, whereas sunspot groups often exceed 60,000 miles in length. In rare cases, ERs may evolve into sunspots, but most ERs disappear on the same day they form. Since hundreds of ERs are visible on any given day, new ones must therefore be forming regularly in large numbers.

To reach the above conclusions, Harvey and Martin monitored ERs with solar telescopes at Kitt Peak National Observatory.
in Arizona and at the Lockheed Solar Observatory in California. The two solar astronomers also discovered that ERs occur all over the solar surface, unlike sunspots, which are largely confined to the sunspot zones that flank the equator. And they found that the number of ERs tends to vary with time much as the number of sunspots does, but that ERs of the "new" sunspot cycle may occur "quite a few years before the first new cycle sunspots make their appearance."

Astronomers have long understood that the traditional successive eleven-year sunspot cycles may overlap each other by as much as three years, a phenomenon marked by the simultaneous presence on the sun of sunspot groups belonging to both the old and the new cycles. This was known because whether a sunspot group belongs to the old or the new cycle can be determined by two characteristics: the group's latitude and its magnetic field orientation. In a given solar hemisphere, say the northern hemisphere, all the magnetically bipolar spots of a given cycle normally have the same magnetic orientation.

For example, the easternmost spots in each group might have north magnetic polarity and the western spots in each group would then have south magnetic polarity. When that is the case in the northern hemisphere, then the opposite would hold for the southern hemisphere, with the easternmost spots in each group in that hemisphere having south magnetic polarity. Although that sounds complicated, it has been repeatedly observed and is readily predictable.

A further complication, but a systematically observed one, is that the pattern reverses in a new cycle. If the sunspot groups in the northern hemisphere during the old cycle had north magnetic polarity at their east ends, then the sunspot groups in the same hemisphere during the new cycle will have south magnetic polarity at their east ends. Thus, measuring the magnetic polarity in different parts of a sunspot group indicates whether it is an old-cycle group or a new-cycle group. Which it can be checked by the position of the sunspot group: sunspots belonging to an old sunspot cycle in its last years are usually near the equator, while those of a new cycle are up near latitude 35°. Harvey and Martin reported in 1979 that by similar means they could identify ephemeral active regions that belong to old and new cycles, and they found that "the outgoing and incoming solar cycles may co-exist on the sun longer than the 0–3 year period of overlap between successive cycles" that was already known from earlier sunspot observations.

Although Harvey and Martin’s reports did not attract much attention when they first appeared, further evidence supporting their conclusion that there is more overlap between successive sunspot cycles than previously believed came in March 1981 with the publication of a landmark study of solar and geomagnetic activity by two French investigators of solar-terrestrial relations. Using measurements of the solar wind made over seventeen years and data on sunspots counted during more than a century, they found that the two phenomena are correlated in a cycle that they suggested begins every eleven years but lasts for seventeen years. Specifically, they found that solar wind streams related to the new cycle are active near the poles of the sun, while sunspots of the old cycle are still present at low latitudes. According to their findings, the overlap period—when spots or other solar phenomena associated with one sunspot cycle are present on the sun, along with phenomena of the next cycle—lasts six years. This is in agreement with Harvey and Martin’s determination that the overlap lasts more than three years.

Confirming evidence for the existence of much overlap and a long sunspot cycle was reported to the American astronomers’ meeting in January 1987 by Richard Altrock, a U.S. Air Force scientist at the Sacramento Peak Observatory in Sunspot, New Mexico. He studied data from an instrument called the photovoltaic coronal photometer, which was put into operation at Sacramento Peak in 1973 to make daily measurements of the intensity of light from high-temperature electrified iron atoms in the sun’s corona, its outer atmosphere. Such emissions originate in disturbed regions of locally enhanced temperature, density, and magnetism in the corona. Altrock found that there is a cyclic variation of coronal “activity,” or disturbances, that begins at latitudes 70° to 80°, far outside the sunspot zones, and moves slowly toward the equator. Thus, he found in the corona a pattern of latitude and time changes not unlike that which Harvey and Martin found for the ER disturbances in the solar surface layer. Furthermore, like the French astronomers, Altrock concluded that the sunspot cycle is longer than eleven years; he estimated its length as seventeen to nineteen years.

What makes solar activity, such as the coronal disturbances observed by Altrock, the ERs of Harvey and Martin, or sunspots themselves, move toward the sun’s equator? A major finding reported in 1982 may help answer the question. On that occasion, two astronomers at CalTech discovered a previously unsuspected pattern
of motions in the solar atmosphere.

Astronomers had known that the sun exhibits differential rotation, meaning that regions of the solar atmosphere located at low latitudes make one turn around the axis of the sun in less time than those at high latitudes. The 1982 finding, however, showed that this phenomenon is more complex than it seems. The sun acts as if horizontally blowing winds alternately reduce or increase the rate at which rotation occurs in a given band of latitudes. Also, the zones of enhanced or reduced rotation rate slowly drift toward the equator with time. This is a phenomenon confined to the outer regions of the sun, like the ocean currents that flow on earth without regard to the exact rate and direction in which the earth itself rotates.

Recent work by Herschel Snodgrass, who is with Lewis and Clark College in Portland, Oregon, suggests that these moving bands of solar-velocity patterns are the surface manifestation of deeper phenomena, so-called azimuthal convection rolls. The azimuthal rolls are doughnut-shaped zones in the solar atmosphere and the layer below the visible surface of the sun in which gases rise and fall in a pattern of constant turnover. A given roll circles the whole sun, so that a roll near the equator has a much bigger circumference than one near a solar pole. Snodgrass found from observations made at the Mount Wilson Observatory in Pasadena that "there is a system of from three to four rolls per hemisphere, which migrate from near the poles to the equator" over about eighteen years. Along with Peter Wilson, a mathematician and astronomer at the University of Sydney, in Australia, Snodgrass has concluded that this migrating pattern of solar gas rolls is responsible for bringing solar activity from the sun's poles to its equator, and in so doing the magnetic disturbances are enhanced, producing the conspicuous and longer-lived sunspots at lower latitudes in contrast to the ephemeral active regions found near the poles.

In the new view of the sunspot cycle, cycles last seventeen to twenty-two years, but new cycles begin about every eleven years, so there is considerable overlap and, in fact, two distinct sunspot cycles are usually simultaneously under way. The course of solar activity now appears to be less simple than previously believed but perhaps even more intriguing.

Stephen P. Maran is a senior staff scientist in the Laboratory for Astronomy and Solar Physics at NASA's Goddard Space Flight Center in Greenbelt, Maryland. The opinions expressed here are his own.
No Brass Ring for Jupiter

by Thomas D. Nicholson

The full moon of November 5 is the hunter’s moon this year, the moon that, because of the low angle its orbit makes with the eastern horizon, seems to rise in twilight for several nights in a row, full or nearly full, brightening the early evening hours and continuing to shine until well past midnight. For the three or four nights in early November when the hunter’s moon is best, Jupiter, a bright starlike object, will be seen rising in the east almost simultaneously with the moon just after dusk. On November 2, Jupiter is to the moon’s left; on the 3d, it is slightly below the moon; and on the 4th, 5th, and 6th it is increasingly to the moon’s right.

Jupiter’s brightness and its location are the obvious clues to its identity; among the starlike objects of the night, only Venus is brighter. But we would never see Venus rising in the east when the sun is setting; it never appears that far from the sun. Jupiter, on the other hand, farther from the sun than from the earth, can appear at any distance from the sun along the ecliptic (the annual path of the sun in the sky). Whenever it is visible, Jupiter easily outshines every star and planet (except Venus and occasionally Mars). Now farthest from the sun and at its closest approach to the earth, it is at its brightest for the year, virtually twice as bright as it was six months ago at conjunction with the sun and more than three times brighter than any star we can see on November nights.

Jupiter’s opposition last month (when the earth is between the planet and the sun) combined with several other factors to make the planet brighter this year than it has been since 1975. These same factors also make it appear larger in the sky; not only is Jupiter the brightest it has been for more than a decade, it is also at its largest angular diameter, or size, as seen from the earth. Its brightness and size make it an especially appealing target this year for viewing with a small telescope or even binoculars if they can be held steady enough.

About 186 million miles closer to the earth at opposition than at conjunction (on the far side of the sun as seen from the earth), Jupiter can be 60 percent brighter at opposition. But its brightness changes yearly because Jupiter and the earth travel around the sun in elliptical orbits, and their distances from the sun and from each other vary from one opposition to another. Jupiter’s actual brightness depends on its distance from the sun, which varies some 47 million miles from perihelion, when it is closest to the sun, to aphelion, when it is farthest from the sun. Jupiter is brightest when it is nearest the sun and we are farthest from the sun.

The planet was at perihelion on July 10 this year, and the earth was at aphelion on July 3. That’s almost as close as we can get to the ideal for brightness. Jupiter’s opposition this year was on October 18, close but not close enough to take the brass ring. Still, it produced the brightest Jupiter we have seen for the past twelve years or will see for twelve more.

Events in the calendar below are given in local time unless otherwise indicated.

November 1: Moonlight brightens the sky until well after midnight. Although the moon has four more days to go before becoming full, it rises only about two hours after sundown. Jupiter moves up the sky behind it.

November 3: The South Taurid meteors reach maximum today. Moonlight will definitely interfere, but meteors from this sparse, diffuse stream (up to fifteen per hour) can be seen for most of November in the after-midnight hours.

November 3–4: Jupiter is just below the rising moon, which drifts slowly left past the planet during the night, passing closest at about 2:00 A.M., EST, on the 4th.

November 5: Full moon (the hunter’s moon) is at 11:46 A.M., EST. Mercury ends its retrograde motion and now separates more slowly to the left of the sun.

November 6: The moon sits almost on top of the Pleiades (Taurus’s tight little star cluster) early this evening, but scattered moonlight may hide the dim cluster. For a better view, try binoculars.

November 7: The effect of the hunter’s moon is obvious as the moon rises in brilliant twilight tonight 2½ days after becoming full. Ordinarily the gibbous moon this late in the cycle would rise in darkness.

November 7–13: The moon, rising at about midnight, joins an impressive lineup of bright stars stretching from brilliant Jupiter, high up in the south, down leftward to Taurus’s Aldebaran, then to the bright twin stars of Gemini—Pollux and Castor—and finally to Regulus in Leo. It moves nightly from star to star down the line, passing above Aldebaran on the 7th, below Pollux and Castor on the 10th, and above Regulus on the night of the 13th.

November 11: Venus and Mars are still above the horizon mostly in daylight hours, but moving far enough from the sun during the month to become twilight objects: Mars in the morning sky; Venus in the evening. Mars is near Virgo’s bright star Spica in the east this morning. The moon, at apogee (farthest from the earth), approaches Regulus after midnight.

November 13: Last-quarter moon is at 9:38 A.M., EST, but it doesn’t rise until after midnight. Mercury is at its greatest westerly elongation (to the sun’s right), and this will be a relatively good morning elongation for the planet. You can find it low in the east before sunrise for about a week, brightening steadily but rising later from day to day.
November 17–18: If the Leonid meteors put on a good show this year, tonight is the night to see it. Look after 1:00 A.M., for the bright meteors from the shower, usually only about fifteen per hour, but noted for great storms in the past.

November 18–20: The moon passes Spica (occulding it over the Pacific) and Mars on the 18th, and Mercury on the 19th. All are in the morning sky, low in the east. Venus and Saturn, both evening stars, are in conjunction on the 20th.

November 21: New moon is at 1:33 A.M., EST.

November 22: The young crescent moon passes Saturn at about 4:00 P.M. and Venus at about 8:00 P.M., EST. Look to the right of the crescent during evening twilight for both planets; Venus is the brighter.

November 23–24: The moon is easily visible low in the southwest, in Sagittarius both nights, but the constellation’s stars are probably too low to be seen. Perigea moon (nearest the earth) is on the 24th.

November 25–26: The fattening crescent moon stays up later nightly, moving through Capricornus’ dim stars.

November 27: First-quarter moon, in Aquarius, is at 7:37 P.M., EST.

November 28–30: The waxing gibbous moon spends these nights in the constellation Pisces. Look for the Square of Pegasus above it, four stars arranged in a giant box standing on one of its corners. The bright object to the left of, and higher than, the Square is Jupiter, a good guide to use in following the moon’s motion through Pisces. The moon and the planet are in conjunction on the 30th.

Editor's Note: The Sky Map in the October issue shows the evening constellations and stars for this month and gives the dates and times for use.

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Why the Shark Bites

by Bruce Stutz

Internal memorandum. Proprietary (restricted). Solely for authorized persons who have a need to know.

Since the onset of the shark attacks on the OPTICAN-I SL cable system, Department 54325 has instituted a program to study the shark bite phenomenon. The objectives of the program have been:
1. Generate a database of shark attacks on all undersea cable systems.
2. Determine the cause of the attacks.
3. Characterize the distribution of sharks so that a risk-assessment model can be formulated.
4. Design a fish-bite-protected SL cable (FBP) capable of preserving the integrity of the polyethylene insulation in the face of shark attacks.

AT&T's very first stretch of submarine light wave (SL) cable, from Tenerife to Gran Canaria, lay lifeless on the ocean floor 9,000 feet down. Shark teeth—fifty teeth from three separate bites—were all Department 54325 had to go on. In some places the teeth had penetrated the hard polymer coating of the garden-hose-thick cable right through to the steel core. Silicon-quartz fibres threaded through the core can carry 40,000 conversations at once on pulses of light. When the sharks bit, the electric current, which flows through the line to boost the light signals, arced into the sea and short-circuited. At a quarter of a million dollars a splice, AT&T was anxious to know which shark was the culprit and why, so they brought their extracted evidence to the American Museum where shark teeth are as common as shark teeth.

This abundance has little to do with either the fortitude or good fortune of collectors. Sharks, from their small Devonian beginnings 350 million years ago to their imposing Hollywood descendants, have always been distinguished by the number, kind, and size of their teeth. Even their rough skin, known as shagreen, is covered with tiny, hard denticles, each sticking up and bending toward the animal's tail. Each of these denticles is rooted in the shark's skin as a tooth is rooted in the gum. Each shark species has a unique set of denticles that differ at various parts of its body—sharp-edged denticles on the fins, for instance, may improve the fish's hydrodynamics. Like teeth, denticles are lost and replaced as the shark grows. A shark's jaw may have twenty rows of teeth; each row moves up in turn to replace the phalanx of white barbs that preceded it. A shark may lose and replace 20,000 teeth in a lifetime.

Sharks are cartilaginous fishes, whose skulls and vertebrae are not bone but hardened cartilage, which disintegrates quickly after death. Their teeth, however, contain the same calcium phosphate as bone, and consequently are all that remain of most ancient sharks. Wherever there were ancient seas, there are shark teeth to be found. These seas must have teemed with sharklike fishes—thousands of species, most of them just a few feet long, struggling to survive among the great armored fishes of Paleozoic seas. Whorled, scalloped, or fanglike fossil teeth permeate geologic deposits in the American Midwest, Europe, Russia, and North Africa. From these teeth paleontologists recreate a gallery of chimaeras, sharks, and rays. From the evidence of six-inch fossil teeth, the late Prof. Bashford Dean of the American Museum imagined the jaws of Carcharodon megalodon, a monstrous, ancient relative of the present-day white shark. His plaster re-creation became a solid Museum attraction. Another Museum curator, John Maisey, later found evidence that Dean's "Jaws" were three or four times too large. Maisey's scaled-down version, which still makes the shark out to be a substantial forty feet long, rather than the legendary one hundred feet, now hangs in the Smithsonian Institution.

Identifying a shark from tooth fragments, even those extracted from a cable, is not unusual. Guido Dingerkus, a former field associate at the American Museum, a past curator at the New York Aquarium, and now a private biological consultant, told AT&T technicians they had run afoul of at least three species. A common whitetip shark, brown and broad backed, which reaches a length of twelve feet, had taken a bite of the cable at about midwater, perhaps as the cable was being lowered to the sea floor. This is a fast-swimming shark that eats nearly anything, fish to turtles, that comes its way. Deeper down, judging from the long narrow-cusped teeth, the culprit appeared to be a crocodile shark, a slender-bodied fish with huge dark eyes. And at 9,000 feet, where the cable lay along the barren sea bottom, the biter may have been a goblin shark: as one field guide puts it, a species "remarkable for being the ugliest of living sharks," with "a long, flat, daggerlike snout, tiny eyes, a soft flabby body, and long protrusible jaws with large, slender, needlelike teeth."

The crocodile and goblin sharks, said Dingerkus, snag small prey with their fanglike teeth. A shark like the whitetip uses broad, triangular teeth to hold its catch and shakes it from side to side to tear a piece out. Researchers Perry Gilbert and James M. Snodgrass, working out of the Lerner Marine Laboratory in the Bahamas (run by the American Museum from 1948 to 1974 and now Bimini police headquarters), found that sharks such as the whitetip can bite down with a force of 44,000 pounds per square inch. (A human jaw can just about crunch down at 150 pounds per square inch.) All these sharks, Dingerkus asserted, could bite with at least that much pressure. Furthermore, he could name at least three dozen other species that might bite the cable, although it neither looks nor smells like prey. The problem was not with the
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sharks, Dingerkus told the company, but with the cable.

Sharks have been called swimming noses, hounds of the sea. One part tuna extract to 25 million parts seawater will lead a lemon shark to dinner. A blacktip shark will respond to one part grouper juice in 10 billion parts seawater. Reflective retinas enable sharks to see well in the deep, and their hearing, aided by sensitive pores along their flanks, is also keen. Fijian Islanders call sharks with coconut shell rattles. Vibrations of struggling fish or swimmers, lower than the human ear can detect, will bring a great white homing. Being one of the sea’s most sensitive creatures, as well as its most prodigious teether, brought sharks to the top of the marine food chain 200 million years ago. They know prey when they find it. “Around here we call the cable ‘yum-yum,’” says Andrianus Kalmijn of the

At the American Museum

Caribbean Month
November is Caribbean Month in the Leonhardt People Center at the American Museum of Natural History. Programs each weekend will feature Cuban son, Latin jazz, and *musica jibara* as well as Taino legends, Afro-Puerto Rican poetry, and Antillean tales. A Trinidadian–Tobagonian carnival with steel band music, dancing, masqueraders, and calypso singing will be re-created in the Kaufmann Theater on Sunday, November 22, at 2:00 and 4:00 P.M.

Traditional African Rituals in New Lands
On Wednesday, November 4, at 7:00 P.M. in the Kaufmann Theater, Sheila S. Walker, scholar-in-residence at the Schomburg Center for Research in Black Culture, will discuss how enslaved Africans retained some of their religious practices when forced to convert to Christianity. This slide lecture will show how Africans perceived similarities between Catholic saints and traditional African spiritual beings and used statues of the saints to represent their own deities.

Frank Grillo ("Machito"), pioneer of Afro-Cuban jazz in the United States, is the subject of a documentary film to be shown at the Museum during Caribbean Month.
Languages of Afro-Cuban Faiths
On Wednesday, November 18, at 7:00 p.m. in the Kaufmann Theater, Isabel Castellanos, linguist and faculty member at Florida International University, will explore the ritual role of the four principal languages used in Afro-Cuban religious rites: Lecumi, Congo, Abakua, and Bozal.

Ethnobotany and the Afro-Cuban
“Science of the Concrete”
On Wednesday, November 25, at 7:00 p.m. in the Kaufmann Theater, anthropologist Morton Marks will discuss how Afro-Cuban herbalists classify plants in terms of their ritual applications and curative powers. The Museum has a pay-what-you-wish admission policy, but there is no additional charge for the above programs. For further information call (212) 769-5315.

Desert Fish
For the past ten years, Michael Smith, assistant curator in the Museum’s Department of Ichthyology, has studied the nearly 150 species of fish that inhabit some of North America’s most arid regions. On Tuesday, November 17, at 7:30 p.m. in the Main Auditorium, Smith will present a slide lecture illustrating the physical and behavioral characteristics that enable these fish to survive in their extreme environments. This program is free to members and $5 for nonmembers. For information call (212) 769-5600.

Chemistry for Kids
Watch as an ordinary banana, made rigid and strong as a hammer, drives a nail into wood. See a living rose shatter like glass upon impact with a table. These and other experiments presented by chemistry professor Patricia Ann Redden will introduce youngsters to the mysteries of chemistry on Sunday, November 15, at 1:00 and 3:00 p.m. in the Kaufmann Theater. Tickets are $2.50 for members and $5 for nonmembers. For further information call (212) 769-5600.

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"In the fish that sharks take as prey," wrote Kalmijn (Natural History, March 1978), "the mucous membranes lining the mouth and the gill epithelia in the phar-ynx create direct-current fields that fluctuate with breathing movements. These currents flow through the water along field lines around the animal." This barely measurable bioelectricity, produced in water by all living creatures, is well within the shark's sensory capabilities. Kalmijn found that within the frequency range of direct current up to about 8 Hz, sharks respond to fields of voltage as low as a hundred-millionth of a volt per centimeter. That would be equivalent to the field of a flashlight battery connected to electrodes spaced a thousand miles apart in the ocean.

Kalmijn tested his theory in two experiments now considered classics by students of shark behavior. In the first, he put a live flounder in an odor-proof, agar-coated box and buried it in a tank of hungry sharks. The sharks attacked the box just as they had previously attacked the fish. When chunks of fish were put in the box, however, the sharks ignored it. But given the shark's sensitivity to electrical disturbances, testing in an indoor tank would be, said Kalmijn, like testing someone's hearing by whispering to them in a noisy factory. So he tested his theory in the waters of Vineyard Sound off Cape Cod, Massachusetts. He lowered plastic tubing from a boat to the seabed. At one spot in the tubing, an opening released an odorous fish extract. Two sets of electrodes that simulated a flounder's electrical field had been placed twelve inches from each side of the opening. As dogfish sharks arrived in search of the source of the odor, they circled, looking for the prey. When they homed in, they swam toward the odor-releasing hole, but at the last moment they lunged at the electrodes. Hundreds of sharks snapping at the electrodes over a period of several days convinced Kalmijn that while sharks may depend on their eyes, ears, and nose to locate prey, the prey's bioelectric field induces the final attack. A wounded fish or a cable with a current passing through it, he concluded, would get savaged in the same way.

Meanwhile, at sea off the Canary Islands, the Dingerkus cruise was catching sharks as they had never been caught before. They were using a commercial fishing method called long-lining, which Dingerkus and Jack Musick, of the Virginia Institute of Marine Sciences, had adapted for their purpose. They ran a thick line under the side of the ship from a large reel. Every few feet they placed a length of fishing line baited with squid or a chunk of fish. Cyalume light sticks, which are tubes containing chemicals that glow when mixed, were attached to attract at-
tention to the bait. Under the ocean the line dangles like a long strand of Christmas lights.

For a number of years Musick had been studying how fish communities change with ocean depth. Organic matter washed out to sea from inshore estuaries, along with the fecal matter of organisms that live on the surface of the ocean, is the raw material of the oceanic food chain. In relatively shallow waters, such as those in the Atlantic Ocean off the continental shelf, these materials sink to the bottom where they are enriched by plant and animal material. Sun and wind create upwelling currents that return the material to the surface, where it feeds fresh colonies of microscopic plants and animals that in turn feed fish and crustaceans. The greater the depth, however, the less material reaches bottom: less than 5 percent gets down to 9,000 feet. As a consequence, at greater depths the number and variety of marine life declines. With little prey, the predators disappear. Musick’s thesis was that the number of sharks able to survive in deep water indicates how rich in nutrients those waters are; conversely, only the most highly productive waters would be full of deepwater sharks.

The waters off the Canary Islands, where rocky coral and sponge slopes run into deep sand plateaus where no light ever penetrates, produced a shark bonanza. Sharks were caught in abundance as far down as 7,000 feet (in contrast to parts of the western Atlantic where sharks are caught down to just 6,000 feet or the Arctic Ocean where there are few sharks below 1,500 feet). Of 150 hooks per set, as many as 50 came up with sharks. The catches were so good, Dingerkus and his crew had to quit fishing until they could replenish their supply of preservative.

There were gupper sharks, six-gill sharks, twelve feet long and weighing 800 pounds, great lantern sharks, kitesfin sharks, and dogfish sharks. Most conspicuous were 55 Portuguese sharks, one of the world’s deepest-living sharks. The two false cat-sharks they caught brought to only a dozen the number in museums worldwide.

AT&T wanted to test Musick’s theory further. Their plan was to eventually lay SL cable across the entire North Atlantic. Would they have to encase thousands of miles of cable in steel to protect it from sharks? Musick said no, the Mid-Atlantic Ridge was too far from land, not nearly productive enough to support deepwater sharks. AT&T wanted proof. The calm of the Canaries was a fond memory as the expedition hit forty-knot winds in the northern mid-Atlantic. Some of the crew became ill, and it was all they could do to keep from getting washed overboard as they hauled up the long lines of gear. The hooks were bare. They were fishing to prove they wouldn’t catch fish, and despite the cold and high seas they succeeded.

AT&T had their answer. But at the Museum, where the specimens from the Canaries and the few from the mid-Atlantic stewed in plastic Manzanilla olive barrels waiting to be cataloged, the questions began. For instance, few of the sharks were pregnant. At such depths, where no light penetrates, do the sharks still observe a breeding season? Is breeding based upon the availability of food? How often do the sharks feed at such depths? The first evidence is that they gorge themselves on whatever drifts their way. One shark had a can of Coke, a pack of cigarettes, a whole pear, and boiled potatoes in its gut. Dingerkus believes they have found three new species of shark and one or two new species of skate. The only questions that still remain to be answered are those that have to do with the cable-gouging crocodile and goblin sharks. Not one was ever caught.
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Odd and Unusual Tastes

Food experts gather in England for some gastronomic exploration

by Raymond Sokolov

Shortly after the very first symposium—the drinking party attended by Socrates and Alcibiades—someone asked another guest named Apollodorus to give an account of the discussion, which had focused, notoriously, on love. Apollodorus complied, Plato transcribed, and the resultant dialogue has stood ever since as the model for reports on intellectual meetings.

I wish to draw no close parallels, invidi-
ous or otherwise, between the Platonic symposium and the one that takes place, each summer now, at Saint Antony’s College, in Oxford, England. While this latter-day gathering can certainly claim title to intellectual distinction, its proceedings would not always merit verbatim preservation. And though some very distinguished figures participate, I hesitate to point a finger at one or another and pronounce this one our high-minded, hard-drinking Socrates; call that one our swashbuckling, sexy Alcibiades; or single out any woman present as our transcendentally wise Diotima.

On the other hand, among the nearly 200 food experts—historians, bibliogra-

phers, nutritionists, cooks, winebibbers, restaurateurs, truffle swineherds, horticulturists, and plain old gluttons—who assembled for the annual round of lectures, chat, food, and drink, there was this year a special bond to be felt with Plato’s philosophers at table. At the original symposium, discussion turned notoriously to “eroticoi logos,” the erotic discourse of Socrates and Alcibiades and the others, while this year at Saint Antony’s, the subject proposed by Alan Davidson and the other organizers of the occasion broached the issue of sensuality, always immanent in gastronomy. Our topic was taste. And, like Apollodorus, I am going to try to rehearse for you the dicta of this summer’s symposiasts at England’s Athens-by-the-Cherwell.

David Pears, the Oxonian disciple of the philosopher Ludwig Wittgenstein, delivered a keynote lecture in which he attempted to illuminate “taste” with the techniques of ordinary language philosophy. This maxii-tutorial did not win the hearts or the minds of the overflow crowd in Saint Antony’s dining hall. In general, those sessions that referred most directly to the solid world of eating and cooking were also the most successful. Harold McGee of Palo Alto, California, put on an especially effective demonstration, the more remarkable because it dealt with complex facts drawn from the cutting edge of organic chemistry, not an area in which most of us had shown prior aptitude or zeal. McGee, known for his classic, On Food and Cooking: The Science and Lore of the Kitchen, set up two burners at one end of the dining room and began to cook two liquids in glass beakers. We were all invited to sniff these bubbling brown potions and then to guess what they were. I am happy to report that the correspondent from Natural History correctly surmised that he had encountered the odors of meat stock and burning styrofoam. McGee had, in fact, started with two colorless, single amino acids and then heated them separately until they turned brown and emitted aromas normally associated with more complex substances.

Scientifically, we had witnessed two “browning reactions,” chemical changes induced by heat in amino acids present in meat and styrofoam. These reactions are not completely understood but they are responsible for important and characteristic flavors.

Another acute Californian, the Los An-
geles Times restaurant critic and Near Eastern specialist Charles Perry, had risked his life to produce his symposium paper on "Medieval Near Eastern Rotted Condiments." Having read ecstatic descriptions of kamakh, murrh, and bun in Arabic poetry, Perry undertook to make them at home in Sylmar, California, a most appropriate venue for mortal peril since it was the epicenter of the serious earthquake of 1971.

Perry began in the classic manner by producing thoroughly rotted barley dough (budhaj). "On February 28, 1987," Perry wrote, "I began roting barley with the aim of making bun. After waiting the canonical forty days, while a raw wheat-barley loaf wrapped in grape leaves (instead of the traditional fig leaves) decomposed, he ended up with something "surprisingly white" that "smelled faintly but not unpleasantly of rot." Some whole-wheat flatbread had "rotted vigorously and in the end looked like a furry black kitten with pink patches."

Of the three preparations Perry sampled, one had a faint barley flavor, a second was neutral, the third, bun, a spiced mixture of rotted barley and flour derived from rotted bread, "developed a curious richness of aroma, like that of a ripe salami." Perry consumed all of these recherché condiments with extreme care and in small quantities because rotted grains abound in the highly carcinogenic compounds called aflatoxins. Medieval life expectations were too short for this danger to have been noticed. So why did rotted grains disappear? Perry falls back necessarily on speculation here, invoking "the depression that settled over most of the Arab world after the fifteenth century and helped to erode various aristocratic tradi-

tions," the spice-disdaining new Ottoman cuisine, and competing new ingredients from the New World. "At any rate," Perry concludes, "one thing is sure: of all medieval foods, these are the least likely to experience a revival."

Indeed, Constance B. Hieatt soon stepped forward with a far more palatable insight into medieval taste, exploring various sources in search of a concrete definition of "poignant" in medieval cookery. What did Chaucer, for example, mean by a sauce that was "poynant and sharp?" Citing several manuscripts, Hieatt demonstrated that he must have meant the sauce was "pointed" with vinegar.

Other contributions ranged far forward in time and covered everything from the ethnographic and social implications of the hot dog (Bruce Kraig) to a horticultural, nutritional, folkloric, and even a semiotic portrait of the olive in Spain by Lourdes March and Alicia Rios of Madrid. There were animadversions on Anatolian pekmez (concentrated grape juice), on taste in eighteenth-century Naples, and on the exotic foods, particularly mountain ram, from the remote fastnesses of Soviet Daghestan and Chechen-Ingush in the northeast Caucasus.

As these fascinating papers were presented, I did from time to time think that, despite the richness of the program, an opportunity had been missed to invite scientists professionally engaged in the laboratory study of taste (gustation) and smell (olfaction). McGee's demonstration had whetted my appetite for more science. This hunger was only sharpened by Joan Morgan's encyclopedic discussion of apple varieties once available in amazing profusion and now preserved only on a research basis or by boutique orchardists.
Morgan has eaten and cooked dozens of these rarities, but she brought none with her, no doubt because it was so early in the season.

The wine experts present did have a chance to practice their skill and to join the rest of us in various potlucks. But two of them also did much to delineate and clarify the fundamental questions of how taste is taught and how it intersects with the other senses and with the speech center of the brain. Jules Davidoff of the Department of Psychology at University College, Swansea, Wales, presented the results of his research on wine tasting. In practical taste tests, he pitted experts against amateurs to determine if wine expertise was a bogus business of jargon and pretense or if "wines actually taste differently to wine experts." Some simple tasting experiments left no doubt that the experts were "seeing" more than the amateurs in the same wines. This may seem like an obvious point, but to prove it in anything more than a trivial way is not as easy as it may sound. Without repeating the bulk of Davidoff's paper, I can say that, in essence, he found that experts could articulate more complex reactions in convincing, ordinary language.

In the discussion that followed his talk, it became clear that expertise in wine tasting was the result of an elaborate process of self-education in which the taster had trained himself to attach words to quite specific taste (and smell) sensations. This

Three Recipes with Unusual Tastes

| Charles Perry's Badhijinan Muhassa
| of Ibn al-Mahdi |
|---|---|
| (Adapted from Symposium Fare, Prospect Books) |
| 1½ pounds eggplant |
| 1 cup walnut meats |
| Wine vinegar |
| Salt |
| Oil for frying |
| 1 tablespoon ground caraway seeds |
| Pepper |
| 1 large onion, peeled and chopped |
| 1. Cook eggplants until soft by baking, boiling or grilling over the fire, leaving them whole. Cool, remove loose skin, drain bitter liquor and chop the flesh fine, but leave it coarser than a true purée. |
| 2. Grind walnuts fine and make into a dough with vinegar and two teaspoons salt. Form into a patty and fry on both sides in a small amount of oil over medium heat until the taste of raw walnut is gone. The vinegar hinders scorching of the mixture. |
| 3. Mix the walnut puree into the chopped eggplant and season to taste with vinegar and caraway seeds, salt, and pepper. Serve with topping of chopped onion, raw or browned in oil. |

Note: This particular recipe does not call for garlic as do other recipes for badhijinan muhassa, but the dish is improved with one or two crushed cloves of garlic.

| Sabzi Rahwash |
| (Spinach with rhubarb, adapted from Noshe Djan: Afghan Food and Cookery, by Helen Saberi, Prospect Books) |
| 2 pounds spinach, washed, stemmed, and chopped |
| ½ pound Chinese chives (gandana) or leeks, trimmed and chopped |

| Yield: 4 servings |

Fresh Water Chestnut Dessert with Rum Butter Sauce

| (From Ken Hom's East Meets West Cuisine, Simon and Schuster) |
| ½ pound fresh water chestnuts, peeled and sliced |
| ¼ cup fresh lemon juice |
| 2 tablespoons sugar |
| ¼ cup rum |
| 2 tablespoons butter |
| 1. In a medium-sized skillet, cook the water chestnuts, lemon juice, and sugar for 5 minutes over low heat. Raise the heat to high, add the rum and butter, and flambe. When the flame has subsided, reduce the liquid to a thick syrup. Serve at once. |

Yield: 4 servings
Clearly, the same orderly meditation on the reactions of the nose and tongue that contribute to wine expertise could be applied to food. And if ordinary people put themselves through rigorous taste exercises when they eat, working out a vocabulary to describe their sensations, they would soon be able to judge and appreciate food with subtle discrimination. I am not talking only about the ability to do blind identifications of specific tastes (meat stock or burning styrofoam), but also about developing taste memory and the ability to subdivide complex tastes, such as that of salmon broiled over apple wood in dill mayonnaise, into their component parts and then to think them back together into an integrated impression of a dish. This is intelligent sensuality or at least one form of it—achieved only by daily effort to connect sensations with precise verbal tags.

Max Lake, the Australian wine maker and author of the “Start to Taste” series, confirmed these ideas and went on to discuss the often subconscious effect that wine flavors exercise on experts and amateurs alike. Lake is a serious pedagogue of taste. His books attempt to guide readers toward the practical development of a taste-smell link between mind and body. Among the benefits of such a skill is an openness to new flavors and to new gastronomic experiences. People eager to expand the range of their palate will not fall into the arrogant xenophobia so elegantly portrayed by Jill Tilsley-Benham in her paper. Her many examples of how otherwise cultivated Western visitors to the Middle East recoiled from the “strange” food they found there would be hilarious if it were not so sad a commentary on human nature.

For example, she quotes the Victorian traveler Edmond de Amicis’ reaction to the streets of Fez, “heavy with the penetrating odour of aloes, spices, incense, kiff. We seemed to be promenading through a huge druggist’s establishment.” He thought that “one mouthful” of the local sweetmeats “ought to atone for the commission of a bloody crime.” And after a meal at the palace of the grand vizier, he wrote: “I will not describe the dinner, it seems useless to reawaken distressing memories; suffice it to say that there were thirty courses, and that each of the thirty was a misfortune in itself, without counting the minor offensives of the sweetmeats.”

Raymond Sokolov is a writer whose special interests are the history and preparation of food.
Green Mansion

A traffic light dangling above a street corner in Tucson, Arizona, may not seem like the best place to raise a family, but a house sparrow's clutch stays warm and dry there. As their history shows, these opportunistic birds—which are actually Old World weaver finches, not true sparrows—can live in almost every human habitat.

Since 1850, when about fifty of the birds were brought to New York City from Europe to reduce the caterpillar population, their numbers have burgeoned, placing them among the five most numerous bird species in North America. Even the National Audubon Society no longer attempts to count house sparrows, simply placing the number at "lots and lots." Worldwide, scientists estimate, the species can be found in one-fourth of all habitable lands.
House sparrow success began when humans became agriculturists, producing the seeds and cereals that make up a large part of the birds’ diet, at which point sparrows became “used to living in a human-modified environment,” explains Peter Lowther, a biologist who wrote his doctoral dissertation on the species.

In addition to supplying the sparrows with prodigious amounts of food, the human life style also creates countless ready-made nesting sites. House sparrows prefer roofs over their heads, so almost any prefabricated nook or cranny will do for a home. The one place you might have to struggle to find a house sparrow’s nest is a tree since, according to Lowther, only 5 percent of the birds choose the arboreal life.

Vince Cassone, an assistant professor of neurology at SUNY/Stony Brook who studies the species, has become convinced the birds prefer the accoutrements of the city to any rural alternative. Although he mostly feeds his captive birds millet, “they clearly prefer hamburger rolls. I guess that’s why they spend so much time around McDonald’s.” Now explain traffic lights.

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Having set out to do fieldwork in a Pakistan community that did not engage in
blood feuds, R. Lincoln Keiser (page 8) was surprised to find the practice widespread among the villagers of Thull.
Now completing a book on his experience, he hopes to study a more peaceful group on his next field trip to Pakistan.
An associate professor of anthropology at Wesleyan University in Middletown, Connecticut, Keiser (third from left) previously described Thull in an article about basketball (“Foul Shots and Rifle
Fire,” Natural History, September 1986). For additional information, readers can see “Marriage as Warfare,” by
Charles Lindholm and Cherry Lindholm (Natural History, October 1979);
Cohesive Force: Feud in the Mediterranean and the Middle East, by Jacob-
Black Michaud (New York: St. Martin's Press Inc., 1975); and Blood Revenge:
The Anthropology of Feuding in Montenegro and Other Tribal Societies,
by Christopher Boehm (Lawrence: University Press of Kansas, 1984).

George D. Stanley, Jr. (page 36) has had a passion for geology since he began
collecting fossils and rocks at the age of ten. Now an associate professor of geology at the University of Montana, Stan-
ley was a research associate and geologist at the Smithsonian Institution and spent a year as a U.S.-West German

Fulbright scholar studying the fossil reefs of the Alps. His fieldwork has also taken him to the Peruvian Andes and the
cordilleran region of the United States and Canada. Stanley's current projects include the evolution of reefs, the geo-
chemistry of fossil corals, and Andean stratigraphy and palentology. He hopes to use invertebrate fossils to elucidate
plate tectonic theory. When not scaling slopes on field expeditions, Stanley keeps in practice by backpacking in
Montana. For further reading he recommends “The Evolution of Reefs,” by
Norman D. Newell (Scientific American, June 1972, pp. 54–65); “The
Growth of Western North America,” by
David L. Jones, et al. (Scientific American, November 1982, pp. 70–84); and
Currently a postdoctoral research fellow at Princeton University, Joyce H. Poole (page 46) dates her work with elephants back to 1975, when she took a year off from Smith College to return with her family to Kenya, her childhood home. There she met Cynthia Moss, who invited her to join a long-term study of the elephants in Amboseli National Park. Moss, whose focus was on female elephants, assigned Poole the task of observing the males. At first, Poole's work was restricted to summer vacations, but her involvement soon became more intense: she has spent five and a half of the last seven years in Amboseli. Her life in the field revolves around the elephants and the day-to-day chores of keeping a camp running, but she tries to go to Nairobi once a month, for supplies and to fill her confessed desperately needed quota of dancing. For more about African elephants, readers can turn to Iain Douglas-Hamilton's Among the Elephants (London: Collins and Harvill Press, 1975) and Cynthia Moss's Portraits in the Wild (Chicago: University of Chicago Press, 1982).

Philip G. Koehler and Richard S. Patterson (page 28) first combined their respective interests in the chemical and biological control of insects five years ago. Their collaboration resulted in the development of hydropene—birth control for cockroaches—which was found to be effective in home use. Koehler, above, a professor of entomology at the Institute of Food and Agricultural Sciences of the University of Florida, had his first assignment in cockroach control when he served in the Navy as a medical entomologist and the insects were a shipboard pest. Patterson, below, began his career with the World Health Organization and for the last twenty years has been a research entomologist with the Department of Agriculture. Both plan to continue working on what Patterson calls "integrated pest management" for the suppression of insect pests—cockroaches, flies, and fleas—that affect humans and livestock. One of the first challenges is the Asian cockroach.

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As a visiting lecturer at Monash University in southeastern Australia twelve years ago, Harvey B. Lillywhite (page 58), together with his colleague Roger Seymour, wondered how snakes could climb trees and still maintain adequate blood flow to their heads. They tested a variety of snakes, ranging from aquatic to arboreal species, to see how well each could control blood pressure when tilted from a horizontal to a head-up posture. Lillywhite, now a professor of zoology at the University of Florida in Gainesville, is still hooked on the anatomical and physiological adaptations of snakes and other long-bodied animals. For additional reading he recommends Snakes: Ecology and Evolutionary Biology, edited by Richard A. Siegel et al. (New York: Macmillan, 1987); “The Physiology of the Giraffe,” by James V. Warren (Scientific American, May 1974, pp. 96–105); The Giraffe: Its Biology, Behavior and Ecology, by Anne I. Dagg and J. Bristol Foster (New York: Van Nostrand Reinhold, 1976); and Physiology and Biophysics of the Circulation, by Alan C. Burton (Chicago: Yearbook Publishers, 1972).

At present an assistant professor of anthropology at the University of Texas at Austin, Ward Keeler (page 68) first became interested in Indonesia as an undergraduate at Cornell University. “As a conscientious objector during the Vietnam War,” he says, “I taught anthropology at a university in Central Java as my alternate service and had many opportunities to see shadow plays during the two and a half years I was there.” Deciding to focus on Javanese shadow plays for his doctoral research at the University of Chicago, Keeler spent almost two years living with a puppeteer and his family in a small village in Java. “I am an avid opera fan,” says Keeler, “and one reason I was attracted to Javanese shadow plays was that it seemed like an equally stylized and extravagant art form.” Keeler’s research resulted in his book Javanese Shadow Plays, Javanese Selves (Princeton: Princeton University Press, 1987). For a more general view, Keeler suggests reading Clifford Geertz’s The Religion of Java (Chicago: University of Chicago Press, 1976).

About twenty years ago, Charles Allan Morgan (page 108) realized that because he needed so many lenses, his hobby—wildlife photography—had become too expensive. So he decided to sell his photos of animals to pay for his expenditures. Four years later, in 1972, he quit his job as an electronics engineer and became a full-time free-lance photographer. Since then, he has taken pictures throughout the Southwest and California. Based at present in Tucson, Arizona, Morgan frequently leads Pacific whale watches and other marine natural history tours off the coast of California but still finds time to photograph urban environments. To photograph this month’s “Natural Moment” of a sparrow nesting in a traffic light, Morgan rose early one Sunday morning, and since there wasn’t much traffic at that hour, stood in the middle of the road, focused his Canon Al (fitted with an 800-mm lens), and waited for the light to turn green. Morgan speculates that the birds are imprinted on the light as they have been nesting there for three years. “These [birds] are opportunists,” he says. “I just worry that someone will take the nest out.”
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Cover: In Mark Hallett's Awakenings of Hunger, Tyrannosaurus rex is lively, colorful, and even more frightening than in earlier interpretations. The painting (© 1985 by Mark Hallett. All rights reserved.) is part of an exhibition now at the American Museum of Natural History. Story on page 46.
Runaway Sexual Selection

Can choosy females account for the extravagant diversity of male genitalia?

by William G. Eberhard

Biological puzzles often take the form of unexplained shapes. Consider the wild variety of flower forms and designs in groups like the orchids (shown by Darwin and others to facilitate pollination by different insects); the imposing array of beetle horns (used, at least in some cases, in combat between rival males); and the weird spikes, curves, and balls that adorn the backs of some treehopper insects (still, to my mind, unresolved). But the most puzzling structures of all are not limited to particular groups but are carried by the males of most animal species—their external genitalia.

As the work of taxonomists in group after group of animals has testified, the forms of animal genitalia are endlessly varied. How can the single, seemingly simple process of transferring gametes from one sex to the other account for the astonishing assortment of intromittent organs and other structures, such as claspers, involved in copulation? The development of elaborate grasping and intromittent organs, with each species displaying a different design, is one of the basic themes of animal evolution. The list of groups with species having unique sexual organs reads like a who’s who of internal fertilization and includes nematodes, flatworms, mollusks, arrowworms, earthworms, sharks and rays, guppies and related fish, snakes and lizards, insects, spiders, mites, and crabs and other arthropods. Even rodents and bats have complex male copulatory organs with species-specific shapes. Yet, despite the universality of this phenomenon, no cogent explanation has yet accounted for the proliferation of male genital forms.

The scientists most thoroughly acquainted with genitalic diversity are taxonomists. Species-specific genitalic forms have been a boon to taxonomists trying to distinguish between closely related species. But of necessity, these scientists usually have deep knowledge of only certain groups, and what they discover and publish generally has a limited audience of fellow specialists. Stationed as they are on the frontiers of our knowledge of the natural world, taxonomists are often hardheaded empiricists little given to speculating about function. This reluctance may account for the meagerness of explanations for genitalic evolution.

Probably the oldest theory, and one that is still widely invoked despite a substantial accumulation of evidence to the contrary, is the so-called lock-and-key hypothesis. The French beetle specialist Dufour proposed in the 1840s that since hybridization between species almost always results in inferior offspring, the females of each species have evolved mechanical barriers ("locks") designed to allow only the genitalia of males of their own species (the correct "keys") to penetrate and inseminate them. Selection for species recognition is expected to be stronger on females rather than males because females generally invest more time and energy in their young; a male can usually make some mistakes and still have plenty of sperm left to sire a normal complement of offspring. Every time a new species evolves, a new lock and a new key are necessary, so this could explain the diversity of genitalic forms. But while the lock-and-key idea might be feasible for some insects and spiders in which females have hard and structurally complex genitalia, it cannot be applied to many other animals—such as flatworms, nematodes, slugs and snails, squids and octopuses, bats, rodents, snakes, lizards, sharks and rays, and various bony fishes—in which female genitalia are soft and incapable of excluding the wrong keys and in which the males nevertheless have complex, species-specific genitalia. Detailed studies show that even the less flexible female genitalia of some insects and spiders cannot exclude the male genitalia of closely related species. As a general explanation, lock and key clearly fails.

The only other commonly cited hypothesis is essentially a dignified way of throwing up one’s hands in despair. Some theorists speculate that differences in genitalia are functionally unimportant, being only chance byproducts of differences in genes that affect other, selectively important body characters and that just happen to affect genitalia too.

This hypothesis is hard to accept because it does not explain why these chance byproduct effects should consistently occur in the genitalia. Why not the tail or the respiratory organs or the external ears? And it becomes completely unacceptable when one considers the numerous animals in which fertilization is indirect, with some body structure other than the primary genitalia used to introduce sperm into the female. The palps of spiders, for example, are specialized for sperm transfer, as are some of the arms of squids and octopuses and the mouthparts of some mites. In group after group employing such secondary genitalia, the primary genitalia are very simple and uniform, while the secondary genitalia are diverse and elaborate. This relocation of chance byproduct effects is just too consistent to be due to chance.

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revival of interest in Darwin’s idea of sexual selection, particularly in sexual selection by female choice. Darwin thought that some bizarre and complex structures enable males to compete more successfully for mates. Perhaps females discriminate among males on the basis of the stimulatory and/or mechanical properties of the males’ genitalia.

This hypothesis—that sexual selection can account for genitalia diversity—grew out of thinking about a pattern that is so nearly universal that no one seems to have wondered why it should be so: in group after group, males (sperm producers) rather than females (egg producers) have intromittent organs. This is true despite the independent evolution of internal fertilization in many different groups. Why this consistency? Why don’t females ever deposit their eggs in males and have them fertilized there? An answer is suggested by using a classic biological technique—look for an exception to the rule and check this exception for any other unusual traits.

The one well-documented exception occurs in the sea horses and their relatives. Female sea horses have organs that they insert into males’ pouches to deposit eggs, and the males then shower sperm onto the eggs to fertilize them. These fish are a sexists’ nightmare, because the roles of the sexes are also reversed before copulation. The female actively courts the more coy male, and the male retains the fertilized eggs in his body and, at least in some species, nourishes the young as they develop there. Role reversal is the key. In these unusual animals, the female’s parental investment may be less than the male’s, and the females have evolved intromittent organs.

Zoologists have realized for some time that in species with males that contribute more parental effort than females, for example, water birds such as jaegers and phalaropes (see Natural History, August 1985), role reversal consistently occurs in courtship behavior. Extending the reasoning derived from this pattern to the similar pattern in genitalia, I propose that intromittent organs can be considered implements of courtship. A female could choose to accept or reject a male as a father in a number of ways: she can stay or not stay coupled long enough to receive his sperm, transport or not transport sperm to her storage organs, avoid or not avoid subsequent advances from other males, and oviposit rapidly or slowly.

Female choice could give rise to an evolutionary phenomenon called runaway sexual selection. One of the very few basic aspects of natural selection not touched upon by Darwin, the idea was developed by the British geneticist and mathematician Ronald Fisher. If a female benefits from discriminating among males of her species on the basis of stimuli she receives from them (if, for example, she has superior offspring by choosing mates that are more agile or better at obtaining food), then female discriminatory ability may become common in that species. Now, if among the males some are no worse than average in a trait such as agility, but are somewhat better than average at impressing (stimulating) females, these males will sire more offspring. Then those females that discriminate more consistently in favor of these more stimulating males as mates will be favored by selection. This is because their sons, being no worse than average in agility, will be superior courters and thus sire more grandchildren. The ability to stimulate females can thus become an end in itself.

This process is termed runaway because the females’ criteria will continue to change in step with new male inventions—a brighter patch of plumage to catch the female’s eye, a new step in a courtship dance, or a new way to nod the head—and will only be checked by eventual selection by other factors, for example, a male’s becoming so brightly colored that he is more easily captured by predators. The direction these changes will take is in some sense arbitrary, since none of the criteria (bright spots, for example) necessarily means that the male is more agile. This line of reasoning has been used to explain seemingly extravagant characteristics like the plumages of peacocks and birds of paradise. I think it can also be applied to genitalia, which, in their extravagance, are second to none.

How well does this idea fit the facts? As intimated above, little is known about the functions of the variations in most male mating organs, but several observations suggest a role for sexual selection.

First of all, one stimulus every female is certain to receive in mating is the tactile sensation of the copulation itself, and in many species, internal processes such as sperm transport, ovulation, and acceptance of further matings are cued by this stimulus. This provides the naturally selected original advantage of discriminating among males on the basis of their genitalia that can initiate a runaway sequence: those males better able to trigger these processes in their mates should be favored by selection.

Second, the design and use of some male mating structures seems inexplicable except in terms of stimulation. In some groups of beetles and butterflies, for instance, complex parts of the male’s genitalia never enter the female but instead are tapped and rubbed gently back and forth on the surface of her abdomen during copulation. Perhaps the most dramatic examples of stimulatory structures are the male genitalia of some moths that have the same file and scraper mechanism classically used by insects to produce sound; in these moths, however, the female is not known to have hearing organs, so the male’s song probably arrives via her genitalia. Other bizarre designs, like the planarians with multiple penes arrayed in rows even though there is only a single female sexual opening and the dramatic spines, barbs, and brushes of hair on the penes of many sharks, mammals, and insects may also be stimulating devices.

Third, males of some species (some spiders, some millipedes) with secondary genitalia regularly copulate with females before loading their intromittent organs with sperm, then (and only then) step...
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back, charge their organs with sperm, and copulate once again, fertilizing the female. The preliminary copulations cannot possibly serve for sperm transfer but could be stimulatory. Finally, experimental stimulation of females belonging to groups ranging from cockroaches to mice have shown that stimuli more similar to those normally received from males are better able to induce essential female reproductive processes, such as egg maturation and preparation of the uterus for implantation. If the sexual selection hypothesis is correct, there must be many more such response systems yet to be discovered.

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Freud's Phylogenetic Fantasy

Only great thinkers are allowed to fail greatly

by Stephen Jay Gould

In 1897, the public schools of Detroit carried out an extensive experiment with a new and supposedly ideal curriculum. The centerpiece of first-grade education would be "The Song of Hiawatha" because children at that age were supposedly recapitulating the "nomadic" and "savage" stages of their evolutionary past and would therefore appreciate such a like-minded hero. During the same era, Rudyard Kipling wrote poetry's greatest paean to imperialism, "The White Man's Burden." Kipling admonished his countrymen to shoulder the arduous responsibility of serving these "...new-caught, sullen peoples/ Half-devil and half-child." Teddy Roosevelt, who knew the value of a good quip, wrote to Henry Cabot Lodge that Kipling's effort "was very poor poetry but made good sense from the expansion point of view."

These disparate incidents record the enormous influence upon popular culture of an evolutionary idea that ranks second only to natural selection itself for impact beyond biology. This theory held, mellifluously and perhaps with a tad of obfuscation in terminology, that "ontogeny recapitulates phylogeny," or that an organism, during the course of its embryonic growth, passes through a series of stages representing adult ancestors in proper order. The gill slits of a human embryo record our distant past as a fish, while our later embryonic tail (subsequently resorbed in most fetuses, but barely still present at birth) represents the reptilian stage of our ancestry.

Biology abandoned this idea some fifty years ago, for a variety of reasons chronicled in my book Ontogeny and Phylogeny (Harvard University Press, 1977), but not before it had served as the basis for an influential theory that many criminals are born to their role through unfortunate retention of apish stages successfully transcended in normal ontogeny; buttressed a variety of racist claims by depicting adults in "primitive" cultures as analogs of Caucasian children in need of both discipline and domination; and structured the primary school curricula of many a city by treating young children as equivalent to grown men and women of a simpler past.

The theory of recapitulation also had a profound, but almost completely unrecognized, influence upon the formulation of one of the half-dozen most influential movements of our century: Freudian psychoanalysis. Although the legend surrounding Freud tends to downplay the continuity of his ideas with preexisting theories, and to view psychoanalysis as an abrupt and entirely novel contribution to human thought, Freud was trained as a biologist in the heyday of evolution's first discovery, and his theory has roots in the leading ideas of Darwin's world. (See Frank J. Sulloway's brilliant and controversial biography Freud, Biologist of the Mind, Basic Books, 1979, with its argument that nearly all creative geniuses become surrounded by a mythology of absolute originality.)

The "three-fold parallelism" of classical recapitulation theory in biology equated the child of an advanced species both with an adult ancestor and with adults of any "primitive" lineages that still happen to survive (the human embryo with gill slits, for example, has its parallel in both an actual ancestral fish that lived some 300 million years ago and in all surviving fishes as well; similarly, in the racist extension, white children were compared both with adult Homo erectus and with adult Africans). Freud added a fourth parallel: the neurotic adult who, in important respects, is like a normal child, an adult ancestor, or a normal modern adult from a primitive culture. This fourth term for adult pathologies was not original with Freud, and arose within many theories of the time—as in Lombroso's notion of l'uomo delinquente (criminal man), and in various interpretations of neonatal deformity or mental retardation as the retention of an embryonic stage that was once normal in adult ancestors.

Freud often expressed his convictions about recapitulation. He wrote in his Introductory Lectures on Psychoanalysis (1916), "Each individual somehow recapitulates in an abbreviated form the entire development of the human race." In a note penned in 1938, he evoked a graphic image for his fourth term: "With neurotics it is as though we were in a prehistoric landscape—for instance in the Jurassic. The great saurians are still running around; the horsetails grow as high as palms."

Moreover, these statements represent no passing fancy or peripheral concern. Recapitulation was both central and pervasive in Freud's intellectual development. Early in his career, before he formulated the theory of psychosexual stages (anal, oral, and genital), he wrote to Wilhelm Fleiss, his chief friend and collaborator, that sexual repression of ol-
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factory stimuli represented our phyletic transition to upright posture: “Upright carriage was adopted, the nose was raised from the ground, and at the same time a number of what had formerly been interesting sensations connected with the earth became repellent” (letter of 1897). The later theory of psychosexual stages had an explicit basis in recapitulation: the anal and oral stages of childhood sexuality represent our quadrupedal past, when senses of taste, touch, and smell predominated. Upright posture fixed vision as our primary sense and reoriented sexual stimuli to the genital stage. Freud wrote in 1905 that oral and anal stages “almost seem as though they were harking back to early animal forms of life.”

In his later career, Freud used recapitulation as the centerpiece for two major books. In Totem and Taboo (1913), subtituling Some Points of Agreement Between the Mental Life of Savages and Neurotics, Freud inferred a complex phyletic past from the existence of the Oedipus complex in modern children, its persistence in neurotics, and from the workings in primitive cultures of incest taboos and totemism (identification of a clan with a sacred animal that must be protected, but may be eaten once a year in a great totemic feast). Freud argued that early human society must have been organized as a patriarchal horde, ruled by a dominant father who excluded his sons from sexual contact with women of the clan. In frustration, the sons killed their dominicing father but then, in their guilt, could not possess the women (incest taboo). They expiated their remorse by identifying their slain father with a totemic animal, but celebrated their triumph by reenactment in the annual totemic feast. Modern children relive this act of primal parricide in the Oedipus complex.

Freud’s last book, Moses and Monotheism (1939), reiterates the same theme in a particular context. Moses, Freud argues, was an Egyptian who cast his lot with the Jews. Eventually, his adopted people killed him and, in their overwhelming guilt, recast him as the prophet of a single, all-powerful God and also created the ethical ideals that lie at the heart of Judeo-Christian civilization.

A new discovery, hailed as the most significant in many years by Freudian scholars, has now proved that recapitulation was even more central to Freud’s theory than anyone had ever imagined or been willing to allow—although, again, almost every commentator has missed the connection because Freud’s biological influences have been slighted by a taxonomy that locates him in another discipline, and because the eclipse of recapitulation has placed this formerly dominant theory outside the consciousness of most scholars. In 1915, in the shadow of war and as he began his sixtieth year, Freud labored with great enthusiasm on a book that would set forth the theoretical underpinnings of all his work—the “metapsychology,” as he called it. He wrote twelve papers for this project but later abandoned his plans for unknown reasons much mulled over by scholars. Five of the twelve papers were eventually published (Mourning and Melancholia is best known), but the other seven were presumed lost or destroyed. In 1983, Ilse Grubrich-Simitis discovered a copy, in Freud’s hand, of the twelfth and most general paper. The document had resided in a trunk, formerly the property of Freud’s daughter Anna (who died in 1983), and otherwise filled with the papers of Freud’s Hungarian collaborator Sándor Ferenczi. Harvard University Press published this document in 1987 under the title A Phylogenetic Fantasy (translated by Axel and Peter T. Hoffer and edited and explicated by Dr. Grubrich-Simitis).

The connection with Ferenczi reinforces the importance of recapitulation as a centerpiece of Freud’s psychological theory. Freud had been deeply hurt by the estrangement and opposition of his leading associates Alfred Adler and Carl Jung. But Ferenczi remained loyal, and Freud strengthened both personal and intellectual ties with him during this time of stress. “You are now really the only one who still works beside me,” Freud wrote to Ferenczi on July 31, 1915. The height of his collaboration with Ferenczi occurred in preparing the metapsychological papers—an interchange so intense that these works might almost be viewed as a joint effort. The twelfth paper, the phylogenetic fantasy, survived only because Freud had sent a copy in the form of a letter to Ferenczi for his criticism. Ferenczi had the best biological training of all Freud’s associates, and no one else in the history of psychoanalysis had so strong a commitment to recapitulation. When Freud sketched his phylogenetic fantasy to Ferenczi on July 12, 1915, he ended his letter by stating, “Your priority in all this is evident.”

Ferenczi wrote the remarkable work Thalassa: A Theory of Gentility (1924), perhaps best known today in mild ridicule for its notion that much of human psychology represents our unrecognized yearning to return to the comforting confines of the womb, “where there is no such painful disharmony between ego and environment that characterizes existence in the external world.” By his own admission, Ferenczi wrote Thalassa “as an adherent of Haeckel’s recapitulation theory.”

Ferenczi viewed sexual intercourse as an act of reversion toward a phyletic past in the tranquility of a timeless ocean—a “thalassal regressive trend... striving toward the aquatic mode of existence abandoned in primateal time.” He interpreted the weariness of postcoital repose as symbolic of oceanic tranquility. He also viewed the penis as a sort of symbolic fish reaching toward a womb that represents the primeval ocean; moreover, he pointed out, the fetus arising from this union passes its embryonic life in an amniotic fluid that also recapitulates the aquatic environment of our ancestors.

Ferenczi tried to locate ever earlier events in our modern psychic lives. He also found in the repose following coitus a striving further back to the ultimate tranquility of a Precambrian world before the origin of life. Ferenczi viewed the full sequence from absolute beginning to end of a human life—from coitus of parents to death of offspring—as a recapitulation of the gigantic tableau of our entire evolutionary past (Freud would not proceed nearly so far into this realm of confining possible symbol with reality). Coitus, in the repose that strives for death, represents the early earth before life, while resultant impregnation betokens the dawn of life. The fetus, in the womb of its symbolic ocean, then passes through all ancestral stages from the primal amoebo to a fully formed human. Birth represents the colonization of the land by reptiles and amphibians, while (believe it or not) the latency period following youthful sexuality and before full maturation repeats the torpor induced by ice ages.

With this appeal to human life during the ice ages, we can connect Ferenczi’s thoughts with Freud’s phylogenetic fantasy—for Freud, eschewing Ferenczi’s overblown, if colorful, inferences about an earlier past, begins with the glacial epoch in trying to reconstruct human history from current psychic life. The basis for Freud’s theory lies in his attempt to classify neuroses according to their order of appearance during human growth.

Theories inevitably impose themselves upon our perceptions; there is no one objective or obvious way to describe nature. Why should we make a primary classification of neuroses by their time of appearance? They might be described and ordered in a hundred other ways (by social effect, by common actions or structures, by emotional impacts upon the psyche, by chemical changes that might cause or accompany them). Freud’s decision stems
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directly from his commitment to an evolutionary explanation of neurosis—one that would find its primary evidence in the theory of recapitulation. In this view, sequential events of human history set the neuroses—for a neurotic is a person who becomes fixated at a stage of growth that normal people transcend. Since each stage of growth recapitulates a past episode in our evolutionary history, each neurosis fixates on a prehistoric stage in our ancestry. These behaviors may have been appropriate and adaptive then, but they produce neuroses in our vastly different modern world. Therefore, if neuroses can be ordered by time of appearance, we will have a guide to their evolutionary meaning (and causation) as a linked and sequential series of major events in our phylogetic history. Freud wrote to Ferenczi on July 12, 1915, “What are now neuroses were once phases in human conditions.” In the Phylogenetic Fantasy, he asserts that “the neuroses must also bear witness to the history of the mental development of mankind.”

Freud begins by acknowledging that his own theory of psychosexual stages, combined with Ferenczi’s speculations, may capture some truly distant aspects of phylogeny by their appearance in the development of very young children. For the phylogenetic fantasy, however, he confines himself to more definite (and less symboitic) parts of history that lie recorded in two sets of neuroses developing later in growth—the transference neuroses and the narcissistic neuroses of his terminology. As the centerpiece of the phylogenetic fantasy, Freud orders these neuroses in six successive stages, the three transference neuroses—obsessivness hysteria, conversion hysteria, and obsessive neurosis—followed by the three narcissistic neuroses—dementia praecox (schizophrenia), paranoia, and melancholia-mania (depression).

There exists a series to which one can attach various far-reaching ideas. It originates when one arranges the ... neuroses ... according to the point in time at which they customarily appear in the life of the individual ... Anxiety hysteria ... is the earliest, closely followed by conversion hysteria (from about the fourth year); somewhat later in pubescent (9-10) obsessive neurosis appears in children. The narcissistic neuroses are absent in childhood. Of these, dementia praecox in classic form is an illness of the pubertal years, paranoia approaches the mature years, and melancholia-mania the same time period, otherwise not specifiable.

Freud interprets the transference neuroses as recapitulations of behaviors that we developed to cope with difficulties of human life during the ice ages: “The temptation is very great to recognize in the three dispositions to anxiety hysteria, conversion hysteria, and obsessive neurosis regressions to phases that the whole human race had to go through at some time from the beginning to the end of the Ice Age, so that at that time all human beings were the way only some of them are today.” Anxiety hysteria represents our first reaction to these difficult times: “Mankind, under the influence of the privations that the encroaching Ice Age imposed upon it, has become generally anxious. The hitherto predominantly friendly outside world, which bestowed every satisfaction, transformed itself into a mass of threatening perils.”

In these parlous times, large populations could not be supported and limits on procreation became necessary. In a process adaptive for the time, humans learned to redirect their libidinal urges at other objects, and thereby limit reproduction. The same behavior today, expressed as a phylogetic memory, has become inappropriately and therefore represents the second neurosis—conversion hysteria: “It became a social obligation to limit reproduction. Perverse satisfactions that did not lead to the propagation of children avoided this prohibition ... The whole situation obviously corresponds to the conditions of conversion hysteria.”

The third neurosis of obsession records our mastery over these difficult conditions of the Ice Age. We needed to devote enormous resources of energy and thought to ordering our lives and overcoming the hostilities of the environment. This same intensely directed energy may now be expressed neurotically in obsessions to follow rules and to focus on meaningless details. This behavior, once so necessary, now “leaves as compulsion, only the impulses that have been displaced to trivialities.”

Freud then locates the narcissistic neuroses of later life in the subsequent, postglacial events of human history that he had already identified in Totem and Taboo. Schizophrenia records the father’s revenge as he castrates his challenging sons:

We may imagine the effect of castration in that primeval time as an extinguishing of the libido and a standstill in individual development. Such a state seems to be recapitulated by dementia praecox which ... leads to giving up every love-object, degeneration of all sublimations, and return to auto-eroticism. The youthful individual behaves as though he had undergone castration.

(In Totem and Taboo, Freud had only charged the father with expelling his sons from the clan; now he opts for the harsher punishment of castration. Commentators have attributed this change to Freud’s own anger at his “sons” Adler and Jung for their break with his theories and foundation of rival schools. By castration, Freud could preclude the possibility of their success. I am not much attracted to psychoanalytic speculations of this genre. Freud was, of course, not unaware that a charge of castration posed difficulty for his evolutionary explanation—for the mutilated sons could leave no offspring to remember the event in heredity. Freud speculates that younger sons were spared, thanks to the mother’s intervention; these sons lived to reproduce but were psychologically scarred by the fate that had befallen their brothers.)

The next neurosis of paranoia records the struggle of exiled sons against the homosexual inclinations that must inevitably arise within their bonded and exiled group: “It is very possible that the long-sought hereditary disposition of homosexuality can be glimpsed in the inheritance of this phase of the human condition ... Paranoia tries to ward off homosexuality, which was the basis for the organization of brothers, and in so doing must drive the victim out of society and destroy his social sublimations.”

The last neurosis of depression then records the murder of the father by his triumphant sons. The extreme swings in mood of the manic depressive record both the exaltation and the guilt of this action: “Triumph over his death, then mourning over the fact they all still revered him as a model.”

From our current standpoint, these speculations may seem so far-fetched that we are tempted simply to dismiss them as absurd, even though they emanate from such a distinguished source. This would be a great mistake. They are, to be sure, wrong based on knowledge gained in the past half century. (In particular, Freud’s theory is fatally and falsely Eurocentric. Human evolution was not shaped near the ice sheets of northern Europe, but in Africa. We also have no reason to think that the European Neanderthals, who were probably not our ancestors in any case, suffered unduly during glacial times with their abundant game. Finally, we have not a shred of evidence that human social organizations once matched Freud’s notion of a domineering father who castrated his sons and drove them away—an awfully precarious way to assure one’s patrimony.)

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dismiss Freud's theory as absurd lies in its consonance with biological ideas then current. Science has since abandoned the biological linchpins of Freud's theory, and most commentators don't know what these linchpins entailed or that they ever even existed. Freud's theory therefore strikes us as a crazy speculation that makes absolutely no sense according to modern ideas of evolution. Well, it is bold, wildly beyond data, speculative in the extreme, idiosyncratic—and wrong. But it is not crazy. It makes perfect sense once you recover the two biological centerpieces of its justification.

The first is the theory of recapitulation itself, as discussed throughout this essay. Recapitulation must provide the primary warrant for such a theory, for it allowed Freud to interpret a normal feature of childhood (or a neurosis interpreted as fixation to some childhood stage) as necessarily representing an adult phase of our evolutionary past. But recapitulation is not enough, for one needs a mechanism to convert the experiences of adults into the heredity of their offspring. Conventional Darwinism could not provide such a mechanism in this case—and Freud was acutely aware that his theory implied allegiance to a different version of heredity.

Freud's theory requires the passage to heredity of events that occurred tens of thousands of years ago at most. But such events—anxiety at approaching ice sheets, castration of sons, and murder of fathers—have no hereditary impact. However traumatic, they do not affect the eggs and sperm of parents and therefore cannot pass into heredity under Mendelian and Darwinian rules. Even if they could, the time available is far too short, for Darwinism is a slow process of accumulating small variants generation by generation.

Freud, therefore, firmly held to his second biological linchpin—the Lamarckian idea, then already unfashionable but still advocated by some prominent biologists, that acquired characters are inherited. Under Lamarckism, all theoretical problems for Freud's mechanism disappear. Any important and adaptive behavior developed by adult ancestors can pass directly into the heredity of offspring—and quickly. A primal parricide just ten or twenty thousand years ancient may well be encoded as the Oedipal complex of modern children.

I credit Freud for his firm allegiance to the logic of argument. Unlike Ferenczi, who concocted an untenable melange of symbolism and causality in Thalassa (the placenta, for example, is a newly evolved adaptation of mammals and cannot, therefore, house a phyletic vestige of the primeval ocean), Freud's theory obeyed a rigidly consistent biological logic rooted in two notions since discredited—recapitulation and Lamarckian inheritance.

Freud understood perfectly well that his theory absolutely depended upon the validity of Lamarckian inheritance. He wrote in the Phylogenetic Fantasy, "One can justifiably claim that the inherited dispositions are residues of the acquisition of our ancestors." He also recognized that Lamarckism had been falling from fashion since the rediscovery of Mendel's laws in 1900. In their collaboration, Freud and Ferenczi dwelt increasingly upon the necessary role of Lamarckism in psychoanalysis. They planned a joint book on the subject, and Freud dug in with enthusiasm, reading Lamarck's works in late 1916 and writing a paper on the subject (unfortunately never published and apparently not preserved) that he sent to Ferenczi in early 1917. But the project never came to fruition, as the privations of World War I made research and communication increasingly difficult. When Ferenczi nudged Freud one last time in 1918, Freud responded, "Not disposed to work...too much interested in the end of the world drama.

Ilogic is slippery and vacuous (Thalassa can never be proved or rejected; it has simply been forgotten). The problem with logic is that one must live or die by the validity of premises required for the argument. Lamarckism has been firmly rejected, and Freud's evolutionary theory of neurosis falls with it. Freud himself chronicled with great remorse the slippage of Lamarckism from responsibility. In Moses and Monotheism, he continued to recognize his need for Lamarckism while acknowledging the usual view of its failure:

This state of affairs is made more difficult, it is true, by the present attitude of biological science, which rejects the idea of acquired qualities being transmitted to descendants. I admit, in all modesty, that in spite of this I cannot picture biological development proceeding without taking this factor into account.

Since most commentators have not grasped the logic of Freud's theory for failure to recognize the roles of Lamarckism and recapitulation, they are left in something of a dilemma, particularly if they are generally sympathetic to Freud. Without these linchpins, the theory sounds plain crazy. Could Freud really mean that these events of recent history somehow got into the inheritance of children and the fixated behavior of neurotics? Consequently, a muted or kindly tradition has arisen among commentators for viewing Freud's claims as merely symbolic. He didn't really mean that exiled sons actually killed their father and that Oedipal complexes truly reenact a specific event of our past. Freud's words, they claim, are just colorful imagery that provides insight into the psychological meaning of neurosis. Daniel Goleman, reporting on the discovery of A Phylogenetic Fantasy (The New York Times, February 10, 1987), writes:

In the manuscript, according to many scholars, Freud appeared to be turning to a literary mechanism he would use often in the explanation of his ideas; he put forward a story that might or might not be grounded in reality but whose mythological content revealed what he saw as basic human conflicts.

I strongly reject this "kindly" tradition of watering down Freud's well-formulated mechanism to myth or metaphor. In fact, I don't view it as kindly at all, for in order to make Freud appear cogent in an inappropriate context of modern ideas, it sacrifices the sharp logic and consistency of his actual argument. Freud's writing gives no indication that he intended his phylogenetic speculation as anything but a potentially true account of what actually happened. If he had only meant these ideas as metaphor, why work out such a consistency with biological theory based on Lamarckism and recapitulation? And why yearn so strongly for Lamarckism after its popularity had faded?

Freud knew that he was speculating of course, but he meant every word as potential reality. In fact, the end of Totem and Taboo features an incisive discussion of this very subject, with a firm denial of any metaphorical intent. Freud writes:

It is not accurate to say that obsessional neurotics, weighed down under the burden of an excessive morality, are defending themselves only against psychical reality and are punishing themselves for impulses which were merely felt. Historical reality has a share in the matter as well.

Freud's closing words then reiterate this argument with a literary fillip. He quotes the famous parody of the first statement in the Gospel of John the Evangelist ("In the beginning was the word"), spoken by Faust in Part 1 of Goethe's drama—Im Anfang war die Tat (In the beginning was the Deed).

Finally, in explicating Freud's belief in the reality of his story, and in recognizing the firm logic of his argument, I do not also defend his method of speculation devoid of any actual evidence in the historical or archaological record. I believe that
such purely speculative reconstructions of history do more harm than good because they give the study of history a bad name. They often lead students of the “hard,” experimental sciences to dismiss the investigation of history as a “soft” enterprise unworthy of the name science. But history, pursued in other ways, has all the care and rigor of physics or chemistry at its best. I also deplore the overly adaptationist premise that any evolved feature not making sense in our present life must have arisen long ago for a good reason rooted in past conditions now altered. In our tough, complex, and partly random world, many features just don’t make functional sense, period. We need not fob them off on an old adaptation that has become unhinged. We need not view schizophrenia, paranoia, and depression as postglacial adaptations gone awry: perhaps they are immediate pathologies, with remediable medical causes pure and simple.

Freud, of course, recognized the speculative character of his theory. He called it a phylogenetic “fantasy,” and he ultimately abandoned any thought of publication, perhaps because he regarded the work as too outré and unsupported. He even referred playfully to the speculative character of his manuscript, begging that readers “be patient if once in a while criticism retreats in the face of fantasy and unconfirmed things are presented, merely because they are stimulating and open up distant vistas.” He then wrote to Ferenczi that scientific creativity must be defined as a “succession of daringly playful fantasy and relentlessly realistic criticism.” Perhaps the phase of relentless criticism intruded before Freud could publish his phylogenetic fantasy.

We are therefore left with a paradoxical and at least mildly disturbing thought. Freud’s theory was a wild speculation, based upon false biology and rooted in no direct data at all about phylogenetic history. Yet the manuscript is published and analyzed with painstaking care and love more than half a century later. Hundreds of unknown visionaries develop equally far-fetched but interesting and coherent speculations every day—but we ignore them or, at best, laugh at such crazy ideas. Rewrite the Phylogenetic Fantasy to remove the literary hand of Freud’s masterly writing, put Joe Blow’s name on it, and no one will pay the slightest attention. We live in a world of privilege, and only great thinkers are allowed to fail greatly.

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

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Vines and mosses cling to the dwarfed, twisted trees on Pico del Este.
Photographs by Ray Pfeiffer, Peter Arnold, Inc.
Climbing through the rain forest that cloaks Puerto Rico's Luquillo Mountains and up past the thickets of palo colorado trees and occasional stands of sierra palms that ring the mountains between 2,000 and 2,500 feet, one may suddenly come upon a windswept, misty landscape crowded with dwarfed, twisted trees. This elfin forest grows on the few ridges that rise above 2,500 feet: on Pico del Este, Pico del Oeste, Mount Britton, and at 3,281 feet, the highest peak, El Yunque, all within the Caribbean National Forest (see Natural History, February 1987).

Draped with flowering air plants, mostly of the pineapple and orchid families, and veiled (as is the ground) with a layer of mosses, liverworts, and occasional shiny masses of terrestrial algae, forty-six species of trees and shrubs live in the elfin forest. Entanglements of morning glories and other vines climb over the treetops, distorting and often breaking the branches in the crown. Ropelike clusters of aerial roots help anchor some of the trees pulled over by this heavy growth.

Among the trees adapted almost exclusively to this upland habitat are a species related to the North American catalpa (Tabebuia rigida), a tropical relative of the sassafras (Ocotea spathulata), a tropical cunonia (Weinmannia pinnata), and a tropical myrtle (Eugenia borinquensis). Other elfin species grow at lower elevations as well, but there they may look quite different—taller, with straight, spreading branches. Several environmental factors account for the stunted and gnarled forms of the elfin forest trees.

The soil, developed from fine-grained volcanic rock by the weathering action of rain, is relatively poor because it is both highly acidic and boggy. Throughout the year, including the dry season, the Luquillo mountain peaks are enshrouded in fog and clouds, and rain falls nearly every day, often at night but most heavily in daytime. The densely packed trees act as a filter, capturing or delaying the water as it makes its way to the ground (during one eleven-minute period of precipitation, when 0.54 inches of rain fell above the forest, only 0.38 inches of rain reached the ground, some of it dripping down
Elfin Forest

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two minutes after the rain had stopped.

As a result of the abundant rainfall and
constant dripping of water from leaves,
the soil is saturated for nearly a foot
beneath the covering of mosses. These condi-
tions would severely inhibit plant growth
if it were not for the giant, olive-colored
earthworms, some up to two feet long and
one-half inch in diameter, that tunnel into
the muck, ingesting organic and mineral
matter and returning them to the soil in a
churned-up condition. The large earth-
worm tunnels aerate the soil and promote
water circulation.

Trade winds, constantly blowing over
the peaks at up to thirty-two miles per
hour, also limit tree growth, leveling the
tops to a uniform eight to twelve feet. At
similar elevations where there is shelter
from the wind, the elfin forest is replaced
by a normal-looking forest dominated by
sierra palms.

Perhaps what most stunts the trees,
however, are the overcast conditions on
the fog- and cloud-bound peaks. Botanist
David Gates has noted that the primary
influence of climate on a plant is through
the transfer of energy, which is consumed
in many biological processes. Plants ab-
sorb light and heat radiation from direct
sunlight, scattered sky light, and reflected
light, as well as additional heat radiation
from the ground, surrounding vegetation,
and air. The biochemical reactions, in-
cluding photosynthesis, that take place in
the leaves and elsewhere usually depend
on the level of heat and light. If conditions
are less than optimal for a particular spe-
cies—too warm or too cool, too bright or
too dim—vital processes slow down.

Gates found that in the elfin forest, leaf
temperatures drop as low as 59° F and
never rise above 77°—temperatures
slightly below optimum for the same spe-
cies growing at lower elevations. The rate
of photosynthesis is sometimes only half
the maximum rate for the species, conse-
quently reducing growth rates and result-
ing in stunted trees.

"This Land" highlights the biological
phenomena of the 154 U.S. national for-
est. Robert H. Mohlenbrock is Distingui-
shed Professor of Botany at Southern
Illinois University at Carbondale.

Like other peaks in the Luquillo range, Mount Britton is
almost always veiled in fog and clouds.
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Through the Eye of the Beholder

by Michael Harwood

*Eliot Porter* amounts to a luxuriously done-up, hard-cover catalog for a traveling retrospective exhibition of Porter photographs. The exhibition opened October 31 in Fort Worth, Texas, at the Amon Carter Museum, the institution Porter has designated as the ultimate repository of his work. From Fort Worth the show will move next spring to the Bowdoin Museum of Art in Brunswick, Maine, then to the Huntsville Museum of Art in Huntsville, Alabama, during the summer, and elsewhere after that.

The book comprises a selection of 128 large plates of Porter photographs and a modestly sized autobiography illustrated with 33 small photos, mostly made by the author. In some respects it is a patchwork book. Many of the Porter photographs have been published before, and the text is pieced together from texts of earlier Porter books and some new material. When Porter writes about matters he feels passionately about, he can write very well indeed, and passion flames up here and there in this autobiography. But elsewhere it sometimes reads like a letter from a nonliterary uncle—one given to repetitions, narrative loops, words, and sentences that don’t quite achieve his intentions. He tends to introduce the names of people and places with little or no description or explanation, as if he expected you, as a member of the family, to know whom and what he was talking about. Where have the good editors gone?

All that said, Porter's story is an interesting one, and the selected photographs are mostly wonderful and wonderfully presented. Porter is an American icon who...
deserves to have such a major exposition in his eighty-sixth year. He has been an important figure in the art of photography for half a century, and his photographs of nature have had a profound impact on the cause of conservation.

Eliot Porter was born in Winnetka, Illinois, in 1901. As we say in this house, he chose his parents with care. His paternal grandmother's family had the forethought to buy property in Chicago before the Civil War. The grandmother's siblings decided that Chicago had a dim future, sold their shares in the real estate to her, and moved away. But she hung on, and by the time her son, Porter's father, came of age, the real estate was worth a good deal. That, as it turned out, limited the opportunities in Porter's father's life, for he took it upon himself to manage the family property for his mother rather than become a scientist or architect as he evidently would have liked. But it opened pathways for his children.

Porter's mother was a Bryn Mawr graduate, a feminist and suffragist, liberal and literary. She introduced her children to books; they met nature, science, and the outdoors through their father.

In 1910, Porter senior bought Great Spruce Head Island in Penobscot Bay, Maine, and began building a summer residence there. From 1912 on the family spent its summers there (and still does):

We gathered shells along the high-tide wrack: powder blue and purple mussels in all sizes that nested together in compact families; pale green sea urchins washed clean of their spines; and the perfectly preserved, brilliant orange carapaces shed by the small, brown-green crabs that live in the rock weed of the littoral zone. We collected starfish, sunstars, and sand dollars, and dried them under the kitchen stove. From the shallow edge of the sea we dredged up anemones, sea cucumbers, limpets, and
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Water Lilies, Rocky Creek, Ozark Mountains, Missouri, May 20, 1978

coral-like calcareous algae. Our father explained the names and relationships of all these creatures to us, and took an even greater interest than we in this ever-present museum of marine biology. So it was that we began to live by lunar time. A deep feeling for nature began to grow in me.

Young Eliot started photography with a box camera and after a while graduated to a Graflex. Very early on birds became a major subject. He was also mechanically handy, had an instinct for how things fit together and worked, and loved experimenting with chemicals.

By the time he graduated from Harvard in 1924, he wanted to become a biochemist, and for that reason entered Harvard Medical School. After two years he was very uncomfortable: the teaching was clinically oriented and he wasn't learning what he wanted. The bacteriologist Hans Zinsser, a charismatic teacher who seems to have had a mesmerizing effect on Porter (not altogether a good one, although Porter would disagree with that), suggested that Porter take a year off to study biochemistry at Cambridge University, for which Zinsser made the key arrangements.

For a number of years Porter would waffle and agonize over what he saw as his lack of genius and direction in his chosen field. He now fretted away a summer on the continent, chafed in an unfamiliar education system for only one term at Cambridge, and came home at Christmas to reenter Harvard Medical School. He married for the first time in 1928, received his M.D. in 1929, became thrice a father, was divorced in 1934, married Aline Kilham, a Boston painter, in 1936, and started a second family.
Meanwhile, he had gone to work in Zinsser's department at Harvard. Zinsser, says Porter,
loved me like a son . . . a responsibility that weighed heavily on me at times. A facet of [his] romanticism was a belief that a dedicated researcher could lose himself in his work to such an extent that he would sooner or later have to be rescued by his colleagues from starvation or nervous collapse. I never attained that state of immersion, for which I felt the guilt that comes from failing to live up to the expectation of another. I had started with the conviction, which became a hope but finally a despair, that I would make discoveries. I did not clearly understand that research mostly involves a slow, painstaking gathering of information, and my unrealistic views . . . resulted in disillusionment about my inherent capacity.

He was taking photographs in his spare time, and his younger brother, the realist painter Fairfield Porter, introduced him to Alfred Stieglitz, the photographer and art impresario, who owned an important gallery in New York, An American Place. Stieglitz agreed to look at Porter's photographs. "He treated me kindly, contrary to what I had been led to expect," writes Porter, "but his comments were far from encouraging. He said [my photographs] were all 'woolly,' but that it was not a matter of sharpness—a description I never understood, as woolliness implied only one thing to me, and that was lack of sharpness." Nevertheless, Porter kept exposing new work to Stieglitz, and at last, in 1938, Stieglitz "looked at all the prints I had brought to An American Place, one by one, slowly replacing them in the box, and then went through them a second time, closing the box. After a pause he said to me, 'You have arrived, I want to show these.'" The show—landscapes, photographs of birds and birds' nests, and a stunning portrait of Porter's infant son Jonathan asleep in his crib—was a great success, and Porter decided the time had come to leave Harvard and science.

He and Aline spent that fall and winter in Santa Fe, and he began photographing there—particularly the Mexican-Spanish churches. He was now also working in color, which made him a pioneer among serious photographers because color photography was quite new and considered gimmicky and commercial—advertising stuff. To get the results he wanted he had to experiment with complicated, time-consuming methods of making prints from color transparencies. At the time he had the idea of producing a book of colored bird photographs; in fact, he seems to have regarded himself then as basically a photographer of birds.

Eventually he and Aline bought a house north of Santa Fe, which became their permanent home, and he also bought a war-surplus Army ambulance, which he rigged up as a combination camper and darkroom. He soon augmented the ambulance with a Jeep for backcountry, high-country expeditions where the going was too rough for the ambulance. He traveled widely in the Southwest, the East, and the upper Midwest, making his bird photographs. "By this time I was using sophisticated equipment involving electronic flash, which had to be operated by power from a storage battery and included three flash lamps. Thus my equipment was quite bulky, and I often had to make four trips from the car to the bird locations in order to carry it all in." He also photographed reptiles, spiders, and insects—items much loved by his children—and other close-up aspects of nature.

Aline got him going on his first publishable project. His colored bird photographs were exhibited from time to time in the 1940s and 1950s, but the cost of publish-
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Maple and Birch Trunks and Oak Leaves,
Passacondaay, New Hamphe, October 7, 1956

ing a collection of bird photographs in color became a major stumbling block, and even the editor who had inspired Porter to put together such a collection wasn't interested in that size financial risk. Alas, very much liked the close-up photographs that her husband had been making of things other than birds. She said they reminded her of Thoreau's nature writing, and she suggested he try combining his photographs with quotations from Thoreau. For more than twenty years, on and off, Porter worked on the collection, and eventually, in 1962, the Sierra Club published In Wildness Is the Preservation of the World and changed the course of Porter's career in his sixty-first year.

A few years ago he told me that although this Sierra Club book launched him on a new career as a nature photographer he does not make photographs "for any other purpose"—including a proconservational purpose—"than to satisfy my sense of what makes a good picture." It was clear when we talked that he was worried about having a reputation as simply a man with a cause—of being considered an illustrator rather than an artist. In Eliot Porter he expands on the subject: In Wildness, he says,

led to an association with the Sierra Club that resulted in widening the purpose and scope of my photography. I saw that the camera could be a powerful instrument for persuasion for other than exclusively esthetic and creative purposes, without diminishing in the slightest degree the artistic integrity of photography. Photography could be used, I began to realize, to open the eyes of people to the natural beauty of their surroundings, to the intricate relationships of plants and animals, to the continu-
ing processes of change in the living world of growth and death and transformation, in other words to the ecology of the wild environment.

In point of fact he did become a partisan and an activist on behalf of the beauty he loved—*honit soit qu'il y pense*—and he even served as a member of the Sierra Club board for a while.

After *In Wildness* appeared, Porter made expeditions to, and published photographic collections about, the Colorado River’s Glen Canyon, the Adirondacks, Penobscot Bay, the Baja peninsula, the Appalachians, the Galápagos, the Colorado River and Grand Canyon, East Africa, Greece, Iceland, Antarctica, and China. Several of the early books were published by the Sierra Club, but before long Porter found a permanent publishing home at E. P. Dutton, which also—at long last—published not one but two collections of his bird photographs, the majority of them in color.

I like his bird portraits very much (strangely enough, only one of the handful chosen for this exhibition and book comes within miles of the best of them, in my view). But as I wrote in a piece for *Harvard* in 1980, “perhaps Porter’s trade-mark has become the land- or seascape or other natural scene that, by its lighting and presentation, not only distills and illuminates the experience of being there at that precise moment, but transcends it into abstraction.” Porter himself says:

The relationships that are all important for me in nature photography are best illustrated in my close studies. Close is a relative term; it may refer to a spot of lichen or a reflecting pool in the sand, or more broadly in a larger connotation to a sheer cliff or a grove of trees. But in either case the photograph is an abstraction of nature—a fragment isolated from a greater implied whole, missed but imagined, a connection which assists in holding the viewer’s attention.

He also sees this close-up perspective as getting closer to the truth than our eyes normally achieve—disclosing shadow blues, as a good example, which most of us don’t look for, hence don’t see, because shadows are, as everyone knows, black or gray.

At their best his photographs are very painterly—in composition, in lighting, even sometimes in texture. That is particularly interesting, and touching, because of the connection that grew up between Porter and his brother Fairfield once Eliot switched careers. Until then, writes Porter, we had little in common besides the usual family intercourse. This was the situation for years, even when we were together in summer on the island. Not until I gave up science for photography did our interests begin to converge and finally become intimately interwoven. I was very affected by his paintings of the sea and sky and the spruce trees growing right down to the water’s edge, which captured the very essence of relationships in the natural world.

And Fairfield was affected in his turn. Near the end of his life he told Eliot that he had been influenced as a painter by Eliot’s photographs—“words of praise that I cherished.”

Porter concludes his text with an epilogue summarizing briefly his experience and purpose as an artist—a splendid essay that redeems any literary flaws one might have found earlier. Then one turns the page to the first plate and enters the marvelous world of his firmest, clearest voice.

Michael Harwood, who has written several books on birds and men, is coauthor with his wife, Mary Durant, of *On the Road with John James Audubon*.

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A Gathering of Eagles

Benjamin Franklin, who was appointed postmaster general by the Continental Congress, favored the wild turkey as the national bird. Perhaps that explains why the U.S. Post Office, which issued its first adhesive stamps (showing Franklin and George Washington) in 1847, did not honor the bald eagle until 1869. Since then, as this assemblage shows, the eagle has appeared on stamps many times, including 1987, left, as part of a pane of American wildlife.
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A herd of reindeer migrates through the Kilda Valley in northern Norway.

B. & C. Alexander
Lapp Life after Chernobyl

"You see... the same mountains and lakes, the same herds, but you know that there is something dangerous, something invisible, that can harm your children."

by Sharon Stephens

In January in northern Lapland, even the midday sun remains below the horizon. A twilight glow faintly illuminates stunted birch trees hung with delicate snow formations. The trees rise above the dark hills surrounding Hirvas-salmi, the reindeer straits, where migrating reindeer once crossed from winter forage in nearby forests to summer pastures on the high, open tundra. The air is 17° F. The warmth and color provided by campfires draw the reindeer herders within their bright circles. Herders in traditional deep blue Sami clothing, colorfully beribboned, walk beside others wearing parkas and jeans or even silvery metallic-looking snowsuits. Almost everyone wears warm reindeer-fur boots, often stuffed with dried grasses harvested the previous summer. The herders have arrived by car or snowmobile for the afternoon’s work—the separation of the collective herd so that individual owners may sell some reindeer, slaughter others, and let the rest go free to dig for lichen beneath the snow crust.

For the Scandinavian Sami who make up the majority of herders in the northern reindeer territories of Finland, separating the herd is a social as well as an economic event, combining the business of modern reindeer ranching with the traditions of Sami reindeer culture. There is talk of the weather, the health and fertility of animals, of market prices and new government herding regulations. Herders also exchange village news, trade traditional reindeer lore, and improvise on old Sami stories and songs. Reindeer meat and fresh blood pancakes cook over the fire and cups of thick, steaming black coffee (and often of stronger drink as well) are passed from hand to hand. Young people flirt under the amused eyes of their parents, while children dart in and out of the circle of firelight, holding antlers above their heads and lassoing one another.

Finally, people convene in the central separation corral. Part of the herd is driven in from the larger waiting pen, and the warm breath of people and of trotting reindeer rises in the diffuse glow of generator-powered bulbs. As herders try to identify the earmarks of their own animals, raucous laughter and occasional dis-
Several times a year the Sami round up the reindeer and herd them into outdoor corrals. In the autumn the animals to be slaughtered are lassoed and culled. In the late spring the young are earmarked and released.

B. & C. Alexander

Putting are heard above the sounds of panting reindeer and hoofs pounding the frozen ground. When they find one of their own reindeer, herders reach into the moving sea of antlers and drag the recalcitrant animal through narrow chutes to small family corrals.

Close connections between people and reindeer lie at the heart of the distinctive Sami ethnic identity, despite fundamental changes in the herding way of life. “Somehow for me the reindeer roundups and separations are central to what I see as Sami,” a young Sami woman tells me.

The rhythms of easy talk and intense activity, the sharing of food and participation of young and old, men and women, the freedom of making a living outdoors, from one’s own deer—these things and the feelings surrounding them are different from the way of life of most Scandinavians, even though Sami life has also changed in many, many ways since the early 1900s, or even the period before World War II, when some of our parents still lived in tents and migrated with their herds.

In December and January of 1986–87, I traveled through Scandinavia for five weeks in order to study the consequences of the Chernobyl nuclear accident in Sami areas. (I had previously spent eighteen months in Finland doing research on Sami cultural history and the economics of modern herding.) As I met with government officials and scientists, Sami politicians, journalists, herders and nonherders, I began to see how Chernobyl’s radioactive fallout had struck another blow against an already embattled culture.

Only about 10 percent of Scandinavia and Finland’s approximately 70,000 Sami herd the region’s 500,000 reindeer. Depending on the various criteria proposed for ethnic identity—from language to ancestral connection with traditional Sami territories to self-designation—Sami population estimates in Norway, Finland, and Sweden go as high as 100,000 or as low as 30,000. (Western scientists have not been allowed to study the Sami of the Soviet Union’s Kola Peninsula. The government has discouraged their ethnic independence and collective the Sami with other herders.) Sweden’s census figures designate as Sami only those whose families live by full-time reindeer herding, an occupation legislatively prohibited to others. But many Scandinavian and Finnish citizens who consider themselves to be Sami now make their living from fishing, stock farming and small-scale agriculture, the tourist business, crafts, or seasonal road building or logging. The work is often combined with some form of government welfare and occasional employment in southern cities. Nevertheless, the survival of a distinctive Sami minority culture within modern Scandinavia and Finland remains closely tied to the strength of northern reindeer herding, providing a livelihood for some and a symbolic tie to an ancient past for many more.

Sami hunters stalked wild northern reindeer in prehistoric times and painted vivid pictures of the chase on cliff walls. While physical data point to a European ancestry—Stone Age hunters who moved north with the retreat of the continental ice in pursuit of wild reindeer and other large game—the Sami language belongs to the Finno-Ugric language family and was probably brought to Scandinavia by hunting and fishing groups migrating west from the Volga region. About the third century B.C., “Sami people” may have come into existence when the large popu-
lations from the south came together with smaller groups of Finno-Ugric speakers from the east.

Two thousand years ago, small bands of Sami hunted and fished across the whole of present-day Finland, the Kola Peninsula in northwestern Russia, and wide regions of western Scandinavia. (Debates about the southern extent of aboriginal habitation figure prominently in current Sami litigation for land rights.) These Sami were seminomadic, living in bands of five to twenty families that occupied a common village in winter and dispersed in summer to outlying regions to fish and to hunt elk, bear, beaver, and wild reindeer. The sixth-century Byzantine chronicler Prokopios tells of a hardy northern people chasing down wild animals over snowy expanses on curious slats of curved wood—skis may have been the invention of Sami hunters.

Sami hunting families very early kept a few tame reindeer, not as a source of food, but as a means of transport and as decoys for hunting wild reindeer. In the sixteenth century, in response to diminishing wild reindeer stocks and pressure from colonists moving in from the south, some Sami groups migrated into the mountainous northwestern tundra regions. There they expanded their domesticated herds into food reserves on the hoof and developed the pastoral nomadic way of life that has since come to represent, for many Sami and non-Sami alike, the “authentic Sami culture.” These independent mountain nomads migrated hundreds of miles with herds that sometimes numbered in the thousands. While Scandinavian and Finnish representatives of church and state railed against the herders’ stubborn paganism and political independence, proud mountain Sami groups developed elaborate clothing and singing styles to distinguish themselves from neighboring rivals for pasture territories. When nomads rode into market centers both they and their reindeer were decorated with silver. Sami fisherman were referred to as “fish slime eaters,” and others traded with them only grudgingly.

Over the next centuries, reindeer pastoralism spread throughout most of the Sami region. Together with the incursions of colonists, herding led to the extinction of wild reindeer, which could not compete with the large, protected tame herds for scarce pasture. Some Sami hunting/fishing communities fragmented into groups of itinerant beggars or were assimilated into Scandinavian and Finnish settlements. Others developed the subcultures that still persist today: the South Sami of central Norway and Sweden and the East Sami of Finland and northwestern Russia,
families began to live in permanent houses in villages. Although young men still spend long periods camping out in the forests, and whole families may spend summers in tents or small cabins near their herds, compulsory education of Sami children (often at distant boarding schools) began early in this century and tied Sami herders to village living.

On modern reindeer herding lands, the animals run free for much of the year and are only periodically rounded up, sometimes with the help of helicopters and small planes. Government advisers and economic analysts counsel Sami herders on the economic rationalization of the reindeer industry. They call for more efficient, productive, and profitable herding, slaughtering, and marketing organizations. Since World War II, a market for reindeer meat as a luxury item has developed in Scandinavia and northern Europe, and last year — before Chernobyl — there was talk of a major marketing program to be launched in the United States. Reindeer hides are popular with tourists, and even the antlers have a market in the Far East, where antler powder is believed to have aphrodisiac powers.

Reindeer once supplied herding families with most of their needs — food, clothing, transportation, and hides for tents. Today’s Sami own radios, televisions, and even video recorders. They need money for housing, furniture, clothes, food, cars, and snowmobiles (called tinplate geldings by some because at times they seem like unproductive property, capable only of vacuously consuming herders’ time and money).

Older herders worry that young people will come to see the reindeer simply as cash-producing commodities. But state economists claim that rationalization programs have been hindered by the persistence of traditional Sami attitudes toward land and reindeer. Gerd Persson, mother of a South Sami herding family, explains:

Our men care for the reindeer and know them. When reindeer are slaughtered, it is done in special ways and with respect. We women know how to care for the meat, to use every bit — the blood, the head, even the feet in soup. We know how to make thread from sinew and how to prepare the skin and furs for clothing and shoes. The work of our hands puts food on our tables and clothing on our backs. We give our food to our guests and send dried meat to our children when they are away in school.

Especially in smaller-scale herding areas in the south, people speak of the importance of eating one’s own reindeer, raised in places one knows.

But there are dangers for modern Sami who identify themselves too closely with a herding livelihood. Government legislation has led to reduced numbers of herd- ers, as small herd owners who supplemented their incomes with other work (tourism, hunting, and fishing) are gradually eliminated from the herding force. In Sweden, their descendants two generations removed are legally barred from ever returning to the herding vocation, and thus also lose official Sami status.

The Sami were a threatened group even before Chernobyl. (Chernobyl, observed one Sami politician, was like pouring oil on a fire.) Fallout from the nuclear reactor explosion on April 28, 1986, affected Scandinavia more than the rest of Europe. Wind movements and local spring rains caused the heaviest fallout to occur in central Sweden and Norway, with levels decreasing toward the north. Finland and the most southern areas of western Scandinavia were spared. The primary contaminant was radioactive cesium 137, with a half-life of thirty years. The radioactive activity in plants and the animals that feed on them posed serious problems of widespread contamination of milk, vegetables, berries, and especially, reindeer. Lichen, the main reindeer grazing food, is a "radiation sponge." With no underground root system, lichens take all their nutrients from the air, and absorption of airborne cesium 137 by this slow-growing reindeer staple means that radioactivity in many northern pasturelands may not drop to "safe" levels for twenty to thirty years. But heated scientific debates abound over what is a safe level. In Norway, legally marketable reindeer may have 6,000 bequerels or less of radioactivity per kilo, compared with the current...
Swedish limit of 1,500. (A bequerel, bq, is a unit of radioactive measurement, representing one nuclear disintegration per second.) Reindeer slaughtered in central Norway in November 1986 averaged 70,000 bq per kilo (with some levels as high as 137,000), while two-thirds of the reindeer slaughtered in northern Norway were under the 6,000 bq per kilo limit and could be sold. No restrictions whatsoever were placed on Finnish reindeer. South Sami living in central Norway and Sweden were much harder hit by the fallout than Sami in the north and east.

Herders' immediate fears of economic disaster in heavily contaminated areas were eased by Swedish and Norwegian government promises to compensate reindeer owners for any slaughtered animals measuring above the legal limit. Herders were counseled to slaughter as usual, in order to prevent serious pasture depletions and to maintain herds for the future. The inedible meat was dyed bright blue to mark it unfit for human consumption and was sold as fodder to fox and mink farms or simply buried in large pits—essentially nuclear waste disposal areas—in uninhabited regions. Government intervention forestalled immediate economic collapse, but in South Sami areas—where small-scale, intensive herding involves especially close relations between people and reindeer—I was told the losses could not be compensated by any amount of money.

Economic compensation allowed people to buy food from stores or reindeer meat from uncontaminated regions to the north and east, but most of the South Sami with whom I spoke voiced fears of change symbolized by the loss of niestti, the meat taken from one's own herd. "This is not just a matter of economics," said Gerd Persson, but of who we are, how we live, how we are connected to our reindeer and each other. Now we must buy everything. Thread, material, food, shoes are now all different things, when they used to be part of one thing... Even if there comes a time when we can eat the reindeer again, it may be too late to pass the knowledge of how to take and use niestti on to our children.

"One of the worst things is the pretend-

Snowmobiles, below, revolutionized herding and are now indispensable to the Sami, despite some concerns that the use of the machines have hurt the birth rate of the reindeer and damaged the lichen upon which the herds graze. Along with snowmobiles, helicopters, right, are sometimes used to scout, herd, and in this case, transport reindeer carcasses.

B. & C. Alexander

We know that the work of our hands just ends in animals being thrown into the ground. But the only ways we know to handle the reindeer are the careful ways our fathers taught us and that we hope to teach our children. So we pretend and we hope. What else can we do? This is the life I know.

His wife, Sig-Britt Toven, added:

It seems sometimes that things have become strange and make-believe. You see with your eyes the same mountains and lakes, the same herds, but you know that there is something dangerous, something invisible, that can harm your children, that you can't see or touch or smell.

In the early days after the accident, rumors spread about unimaginably high bequerel levels requiring the immediate slaughter of whole herds, while others predicted the birth of genetic monstrosities during coming calving seasons. Some pregnant women sought abortions, while others agonized over the future of their children. Some believe that radioactivity can be "caught" by contact with contaminated material and watch in fear as helicopters land to test soils where their children have just played.

Regional differences in contamination exacerbated historical differences between South and North Sami. Radioactivity reduction programs—rounding up reindeer and feeding them with uncontaminated fodder—are most feasible in the north, where the reindeer are contaminated only slightly above government limits. Northern herders, seeking to rebuild a strong market for reindeer meat among wary consumers, worry that too much media attention given to the plight of South Sami herders may ultimately do more harm than good to the majority of Sami people. A North Sami politician privately observed, "It's simply pragmatic political sense to rebuild the reindeer economy as best we can, not just for the narrow economic good of any one group, but for the good of Sami culture as a whole." Northern herders have plans to bring young herders from southern areas north to show them there is a future in reindeer work.

In contrast, many South Sami express anger at what they see as neglect of their serious plight. The South Sami are a minority within a minority. Only about 2,000 strong, the South Sami have their own herding practices and their own dialect. South and North Sami must speak to one another in Swedish or Norwegian. Most Sami politicians, those who represent the Sami at the World Council of Indigenous
Skinned reindeer carcasses are hung on wooden frames, below, then picked up by trucks. Not knowing how badly the 1986 radiation affected their reindeer, herdsmen rounded up and slaughtered their animals as usual, only to be told that much of the meat was contaminated. It was painted blue and fed to fox and mink or buried in pits. For the Sami whose herds have been most severely affected by the radiation, the question is whether their pastoral way of life can outlast the twenty or thirty years their herds may remain contaminated.

M. Rikkonen

Peoples and deal officially with Scandinavian authorities, are North Sami.

Both South and North Sami, as well as Sami in different states, see at least one consequence of Chernobyl that will call for a united Sami political front. In response to the public outcry against nuclear power following the Chernobyl accident, Sweden promised that by the year 2010 it would phase out the twelve nuclear reactors that provide more than half its current energy. Unfortunately for the Sami, the most likely energy alternative will be massive hydroelectric development in Sami herding regions.

Networks of roads and electrical lines already cross more and more of this northern reindeer range (one Lapland hotel’s tourist brochure describes this “land of the midnight sun” as “the world’s most civilized wilderness”). Developers of mining, hydroelectricity, and tourism in the north seek legislative protection for their expansion into Sami areas where fragile lichen pastures are easily damaged and slow to regenerate. More and more reindeer are killed on the roads, and in some areas, herdsmen must move reindeer to seasonal pastures by truck. Large areas of rich pastureland have been flooded, and important reindeer river crossings no longer freeze because of extensive dam building. Large tracts have been set aside for military developments, such as the NATO bases in northern Norway.

In a world where political power is related to the size of voting and lobbying constituencies, the loss of the reindeer and the consequent reduction in official Sami census figures pose threats to the ancient culture that become increasingly difficult to fight. In the face of Chernobyl some parents teach their children the Sami language and show them how to prepare grasses for fur shoes or how to aid a calving doe. But they fear that Chernobyl may have damaged the children’s trust in the Sami way of life.

“When the children returned to school in September,” said Nora-Marie Bransfjell, a teacher at the South Sami school in Snåsa,

they spoke only of bequerels. They asked each other, “Did you eat fish from the lakes before you knew? Did you walk in the rain last spring?” They would open their lunch boxes and say, “I can eat this meat. My father bought it in the north so it has only 300 bequerels.” But by December I noticed that hardly anyone spoke anymore of Chernobyl. “Do you think about it?” I asked. A nine-year-old girl replied, “No, it’s like war. You know it’s real, but far away. You can’t see it, and you try not to think of it coming to you and your family.”
Cheated Cheetah

Text and photographs by Jon P. Rood

For several months each year, my wife, daughter, and I make our home at the Serengeti Research Institute in northern Tanzania. I have been going to East Africa for seventeen years to study mongooses, and even now I find that life amid vast numbers of free-ranging wildlife is full of excitement—and surprises.

One morning about ten o'clock, while I was driving home from my regular early morning dwarf mongoose watch, a nearby flurry of movement attracted my eye as I came around the curve of the track leading to our house. In an area that had recently suffered a dry season burn, a cheetah had just caught a Thomson's gazelle and was struggling to obtain a strangling grip on the underside of its neck. Excited at the opportunity to photograph a cheetah kill, I grabbed my camera and started taking pictures.

Every year toward the end of the dry season, some of the Serengeti's more than 250,000 Thomson's gazelles travel past the buildings of the institute, moving along the edge of the woodlands toward the open plains. And each year, cheetahs follow, for the little Tommies are their preferred prey. Cheetahs catch gazelles by stalking and then running them down, and the woodlands edge, with its open grassland interspersed with scattered trees and bushes, provides ideal habitat for the hunt.

Cheetahs usually kill their prey by strangulation. Their upper canine teeth are small for a carnivore and have correspondingly small roots, allowing increased air intake to the nasal passages. This adaptation enables the cheetah to maintain a relentless, suffocating bite. Certainly, this gazelle seemed doomed.

After a brief struggle, the cheetah appeared to have the hold it wanted and began to drag the gazelle toward the shade of a nearby acacia tree. The Tommie, however, was to have a second chance. The cheetah must have weakened its killing hold prematurely, for suddenly the gazelle twisted from its grasp and bolted past our house toward the safety of the belt of trees growing along a drainage line 400 yards away.

The cheetah raced after it but stopped after about 100 yards and watched its prospective meal disappear into the trees. Cheetahs are tremendously fast runners—with sprint speeds of up to sixty miles per hour—but they lack stamina and seldom keep up the chase for more than a minute. This animal, already tired and winded, didn't have the energy to try again. Walking slowly back past our house, it slumped in the shade of the tree where it had planned to dine on forty pounds of gazelle.

Jon P. Rood is a research associate at the Smithsonian Institution and an adjunct associate professor at Purdue University.
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The paintings of John Gurche may be the closest we can come to photographs of the Mesozoic world. His beleaguered iguanodont lived in the early Cretaceous, some 100 million years ago. The gigantic herbivore is too weak to whip around and use its thumb-spike or its tail in retaliation; its torn hide and glazed eye foretell its doom. A pack of Deinonychus, relatively small at ten feet long, hunt together like wolves to bring down their quarry. Springing off the ground with a semblance of grinning glee, the Deinonychus launch a high-speed, high-energy attack and will quickly overtake the lone iguanodont, perhaps culled from a herd because of age or disease. Deinonychus must often have delivered the coup de grâce with its switchblade, a second hind toe with a five-inch, curved, retractable claw, perfect for disemboweling fallen prey. Its long, stiffened tail may have served as a counterbalance or rudder that allowed for running, sprinting, and rapid turning. Discovered by John Ostrom in 1964, Deinonychus revealed many avian characteristics. Much of the controversy concerning warmbloodedness in dinosaurs centers on small carnivores such as Deinonychus.

Evolving Views of Dinosaurs

Ever since Benjamin Waterhouse Hawkins reconstructed a life-sized Iguanodon for the Crystal Palace in Sydenham, England, in the 1850s, artists have worked with paleontologists to breathe life into fossils. Hawkins’s mentor was the British scientist Prof. Richard Owen, who invented the term dinosaur. In the United States, the thirty-nine-year collaboration of Henry Fairfield Osborn, a president of the American Museum of Natural History, and artist Charles Knight began in 1896 and resulted in a prodigious output of first-rate restorations of prehistoric life.

Dinosaurs Past and Present is an exhibition of drawings, sculptures, models, and paintings that celebrates the teamwork of the artist and the scientist. Older views of the dinosaurs as reptilian sluggards have eroded, and a new generation of paleoartists are drawing on the latest field discoveries and research. They show us a Mesozoic world in which dinosaurs raced and galloped, lived in large herds, courted mates with sexual displays, actively cared for their young, and swiftly dispatched their prey. Much has been extrapolated from modern studies of animal behavior, and many theories are still a source of debate. While the best of this recent artwork shows us dinosaurs as wildlife within a specific habitat, a touch remains of the ancient allure of “dragons.” In the words of paleontologist Dale Russell, “Artists are the eyes of paleontologists, and paintings are the window through which nonspecialists can see the dinosaurian world.”—J. R.

Organized by the Natural History Museum of Los Angeles County and guest curator Sylvia J. Czerkas, Dinosaurs Past and Present will be on display at the American Museum of Natural History in New York through January 3, 1988. It will then travel to the New Mexico Museum of Natural History in Albuquerque, the Tyrrell Museum of Palaeontology in Drumheller, Alberta, and the Royal Ontario Museum in Toronto. The two-volume Dinosaurs Past and Present, edited by Sylvia J. Czerkas and Everett C. Olson (Seattle: University of Washington Press, in association with the Natural History Museum of Los Angeles County, 1987), contains many color illustrations and includes discussions by artists and paleontologists of dinosaur behavior, anatomy, and restoration.
Painter Vladimir Krb sets his scene in Alberta, Canada, some 73 million years ago. A small group of Styracosaurus albertensis, perhaps on a foray, emerge from the greenery. While not lush, the landscape is verdant, one of many warm-temperate habitats that could be found in Alberta in the late Cretaceous. With their rugged jaws, teeth, beaks, and according to the latest thinking, big cheeks, styracosaurus probably ate tree branches and other coarse, vegetarian fare.

In addition to a long nose horn, these styracosaurus were arrayed with bony knobs and six spikes radiating from a frill. Such elaborate projections could have served for sexual display and threat as well as for real combat. Like deer in rutting season, male styracosaurus may have intimidated rivals.
and attracted mates with their complement of bone and horn. Like other horned dinosaurs, such as Triceratops, styracosaurus lived in herds. In Krb's band, the young of the previous year, their armature already sprouting, are flanked by their elders. Evidence for herd life comes from bone beds—dense aggregations of disarticulated bones—in Alberta's Dinosaur Provincial Park. At one site, all the fossils are those of a styracosaur relative, Centrosaurus, and the bones represent not just aged, young, or diseased individuals but animals of all ages, the members of a once-thriving herd. Evidence suggests that they drowned in a flash flood or while trying to ford a swelling river. In 1984, a new bone bed was discovered in the park; it contains only the remains of Styracosaurus albertensis.
In the Gobi Desert in 1922, an expedition from the American Museum of Natural History discovered a nest of dinosaur eggs. They belonged to Protoceratops, an early Cretaceous progenitor of the horned dinosaurs. The eggs were laid in hollows in a spiral formation. Protoceratops became the first dinosaur known to have nested collectively.

In 1978, paleontologist John R. Horner unearthed a duck-billed dinosaur breeding ground, complete with nests, eggs, embryos, and nestlings. Set in a rich Montana fossil zone known as the Two Medicine Formation, the site provided the first hard evidence that some dinosaurs may have actively nurtured their young. Under Horner’s guidance, artist Douglas Henderson has reconstructed a series of scenes from the life of the duckbill Maiasaura (good mother lizard). In this painting, adult Maiasaura, newly arrived at the breeding ground, hollow out their individual nests. Depressions in mud and fine silt, the rimmed nests are closely spaced, as are nests in some seabird colonies today. After depositing an average of twenty eggs, Maiasaura covered their nests with rotting vegetation, also a habit of some modern birds. The fermentation of plant material warmed the eggs. Parents may have provisioned the foot-long hatchlings, with berries or regurgitated, partly digested food. The presence of larger, approximately three-foot-long young within, rather than outside, the nests led to the theory that they were being fed, not foraging for themselves. The young may have gained several hundred pounds in their first year. Rapid growth and high metabolism suggest warmbloodedness, an issue still in contention among paleontologists. Horner, who continues to uncover eggs and nests, is investigating the growth rates of baby Maiasaura.
In Mark Hallett’s depiction of a classic late Cretaceous confrontation, a phalanx of armored Triceratops holds a pair of Tyrannosaurus at bay. Among the most abundant herbivores some 70 million years ago, Triceratops were also among the best equipped to withstand a predator’s assault. About one-third of the thirty-foot Triceratops frame was made up of the head. Backed up by a bony neck frill, the horns could be used for offense. Some of the Triceratops pictured seem ready to lunge and gore the carnivores.

Social animals, Triceratops roamed through much of North America in the safety of large herds. Hallett speculates that the herd members cooperatively defended their young; here they encircle the vulnerable calves and face their assailants, much as musk oxen do today when harried by arctic wolves.

Hallett portrays these dinosaur titans as alert, agile creatures. The Triceratops brandish their horns in combat but also act in concert to defend themselves. The Tyrannosaurus, with tails held above the ground, are shown as swift predators rather than slow-motion scavengers, cooperative rather than solitary hunters. In fleshing out the fossil evidence, Hallett says he works intensively with paleontologists: “Modern studies in biomechanics, behavior, and ecology... and an exciting menagerie of newly discovered dinosaurs are waiting to aid the artist intent on bringing the Mesozoic past back to life.”
Paleontologist and sculptor Stephen Czerkas delved into the 100-year mystery of one of the most famous dinosaur traits and surfaced with a new model of Stegosaurus stenops. The arrangement of the roughly triangular plates that adorn the necks, backs, and tails of stegosaurs has long been controversial. In the 1880s, one particular quarry in Como Bluff, Wyoming, under the direction of legendary paleontologist O. C. Marsh, proved to be a mother lode of stegosaur bones, and a quarry in Colorado produced a prize specimen—a near complete skeleton of Stegosaurus stenops. But evidence for the placement of the plates was still murky. Marsh reconstructed a stegosaur with the plates in a single row, but in writing, he contradicted his drawing and described the neck plates as paired. Subsequent restorations of the late Jurassic herbivore fell into two main categories: the plates were paired, or they were shown to alternate and overlap in a double row. In Frank Bond’s 1899 drawing, however, the shieldlike plates lie flat.

Meanwhile, paleontologists speculated on the function of the plates. They may have served as armor, shielding the back and flanks against attack while the machelike tail struck out at adversaries. Paleontologist James Farlow notes that the plates had a rich network of blood vessels and may have been a finely tuned heat-regulation system. Czerkas’s work may lead to a reevaluation of the plates’ form and function. Vindicating Marsh’s original sketch, Czerkas shows the plates, down to the two pairs of tail spikes, aligned in a single row. The parts of the plates seen to overlap in a side view are only those areas that fan outward after growing from the midline base.
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How Carthage Lost the Sea

Off the coast of Sicily, a Punic warship gives up its secrets

by Honor Frost

Phoenician seafarers from the eastern end of the Mediterranean dominated those waters from the eleventh century to the eighth century B.C., when their Punic heirs, who had colonized North Africa, turned the sea into a Carthaginian lake. Then the Romans built a navy that made the Mediterranean into what they viewed as mare nostrum. Without this takeover, in the mid-third century B.C., there would have been no Roman Empire, and without the Roman Empire the Apostles could not have traveled back and forth across the sea and along safe highroads spreading the word. In fact, Western civilization (as we understand the term) could hardly have existed. Unlike certain historical changes that only become apparent through hindsight, this seizure of sea power was so dramatic that its significance was realized at the time, prompting the Greek historian Polybius to write his Histories of the three Punic Wars. The First, 264-241 B.C., which was fought mostly in Sicily and at sea, saw this turning point in sea power. The Second, 218-202 B.C., was fought on land (Hannibal leading the Carthaginian army across the Alps with elephants). Half a century then elapsed before the Romans attacked and destroyed Carthage itself, in 146 B.C.

"One of the reasons that induced me to write the history of the war," wrote Polybius (who together with his friend, Gen. Publius Scipio Aemilianus, actually watched Carthage burn), is that my readers should not be kept in ignorance of the beginning—how, when and for what reasons the Romans first took to the sea. When they saw the war was dragging on, they undertook for the first time to build ships, a hundred quinqueremes [galleys with five men to an oar] and twenty triremes [galleys with oars on three levels]. As their shipwrights were absolutely inexperienced in building quinqueremes, such ships never having been in use in Italy, the matter caused them much difficulty, and this fact shows us better than anything else how spirited and daring the Romans are when they are determined to do a thing. It was not that they had fairly good resources for it, but they had none . . . , nor had they ever given a thought to the
sea; yet when they had once conceived the project, they took it in hand so boldly, that before gaining any experience in the matter they at once engaged the Carthaginians who had held for generations the undisputed command of the sea. . . . Not only had they not any decked ships, but no long warships at all, not even a single boat and borrowing fifty-oared boats . . . they took their troops across [to Sicily] at great hazard.

On this occasion the Carthaginians put to sea to attack them as they were crossing the Straits, and one of their decked ships advanced too far in their eagerness to overtake them and running aground fell into the hands of the Romans. This ship they now used as a model and built their whole fleet on its pattern. . . . Those to whom the construction of the ships was committed were busy getting them ready, and those who had collected the crews were teaching them to row on the shore in the following fashion. Making the men sit on rower’s benches on dry land . . . they accustomed them to fall back all at once, bringing their hands up to them, and again to come forward pushing out their hands. . . . When the crews had been trained they launched the ships as soon as they were completed, and having practiced for a brief time actually rowing at sea, they sailed.

The Romans did not, however, win the war simply by copying that Punic ship in 260 B.c. They went on learning. Eleven years later, both the seamanship of a Carthaginian captain, Hannibal, the Rhodian (not the later Hannibal of elephant fame), and the build of his ship were still so superior that, despite the blockading Roman fleet, he maintained sea communications between Carthage and Lilybaeum, thus preventing the besieging Roman army from taking that Punic stronghold in Sicily. Eventually the Rhodian was trapped; 200 copies were made of his quinquereme, and with this new fleet—as well as a good dose of luck—the Romans won the Battle of the Egadi Islands, which after eighteen years, ended the First Punic War.

As against the inherited woodworking and shipbuilding skills of the Carthaginians (whose Phoenician ancestors had been entrusted by Solomon with the building of the cedarwood Temple in Jerusalem), the landlubber Romans were good organizers and had good engineers. Not
only did they succeed in copying Punic ships, but they turned them out at a speed that seems incredible by modern standards of wooden shipbuilding. The Roman historian Pliny records the building of 100 replicas in sixty days while Polybius reports 220 ships in three months. The rate is about two a day, and the ships were large, decked, and well over one hundred feet long! How was it done? History is silent, while the hope that archeology could contribute to the answer long seemed remote.

After scuba diving started in the Mediterranean at the end of the Second World War, hundreds of Roman wrecks were investigated, but they were all of round, cargo-carrying ships, vastly different in build from the many kinds of long, fast ships used in warfare. The laws of nature made the discovery of a long ship seem impossible. On the seabed, ancient wrecks are usually found in sandy areas (ships that sink over rocks break, and the animals that inhabit the rocks eat the wood). After a ship falls, lists, and settles on a sandy bottom, the hull, softened by waterlogging, gradually flattens out, while the uprights—mast, stem, and sternpost—break off and disappear. A heap of solid cargo is left, and this obstructs the almost imperceptible movement of sand to and fro across the surface of the seabed. The sand piles up around the obstruction in a shallow mound, restoring the stability of the bottom and leaving only some protruding pot to mark the site.

Since warships keep their decks clear for action and carry no solid cargo, once their hulls flatten and become buried, nothing marks their presence. Or so it seemed to divers before the Punic wrecks I excavated were discovered off the town of Marsala in western Sicily. They lay close to the shore, in water so shallow as to be unattractive, and consequently unfamiliar, to divers. The survival of these wrecks was due to several factors, the principal one being that sand burial is quicker in shallow water.

I first visited Marsala (which is built on the ruins of ancient Lilybaeum) in 1969, soon after a commercial sand dredger had accidentally dug into a group of buried wrecks to the north of the town, opposite the Egadi Islands and a quarter of an hour by rubber dinghy from the site of the battle that ended the First Punic War. The following year, at the suggestion of a local enthusiast, Edoardo Lipari, and with the permission of the Italian government, I returned with a small expedition to survey the zone. The wrecks were distinguished by ballast stones rather than the usual amphorae. Not until 1971 did we come upon the sternpost of what turned out to be a long ship protruding from the sand at a depth of only eight feet.

The bottom being unstable, the movement of a sandbank had revealed the sternpost, at the same time endangering the ancient wood (which only survives under a protective covering of sand). Under these circumstances, the then director of antiquities in western Sicily, Vincenzo Tuza, decided that the remains should be excavated and raised. Digging—or rather the sucking away of the sand by dredges—began in 1971 and lasted four annual seasons of more than two months each. The hull was recorded on the bottom, then in greater detail on land after each plank and timber had been raised. To preserve it, the wood was kept wet until it could be treated with polyethylene glycol (a synthetic wax).

The wreck produced some forty feet of keel and about a third of the port (left) side of a long ship, as well as fragments of its starboard side and a length of wale (a strip of heavy timber incorporated in the hull along the waterline) that had broken off in antiquity and lay in two. The rarest and most significant structural discovery (since uprights usually disappear) was the sternpost. Without it, naval architects
could not have calculated the original shape of this hull. The angle of the keel in relation to the seabed was also unusual. Instead of lying flat on the seabed like other wrecks, this stern had been driven into the hard bottom consisting of compacted, alternating layers of seaweed fibers and sand. Since the water was shallow, the prow of the ship must have protruded above the surface on sinking (which accounted for its being broken off and lost). How the keel could have been driven into the exceptionally hard bottom, where it remained firmly lodged for several millennia despite the action of waves breaking onto the shore, can only be explained by some unnatural impact, such as ramming.

There was enough evidence to allow architects to estimate the shape of the ship from the stern up to its parallel midship section. At this point in our work no one knew what the stem was like (it might have been curved or it might have been straight), so there was no way to estimate the shape of the prow.

This wreck, which became known as the Punic Ship, contained clues to the men who had built it and crewed it. Fragments of human bones and those of a small dog were found in the bottom of the hull, where they had been held down by a tumble of ballast stones. Perhaps a man had been wounded and then trapped. The rest of the crew may have scrambled ashore with their weapons or possibly others may have salvaged these valuable items in antiquity. What remained on board was the crew’s crockery and food. In contrast with the pottery on merchant ships, all the crocks were small and suitable for individual snacks. The amphorae (those ubiquitous containers of antiquity that carried wine, water, or oil) were a mixed lot, unlike the standard containers—all from one maker and shipper—that constituted commercial cargoes. The food remains suggested that rowers and soldiers had fed like fighting cocks. Butcher-trimmed cutlet and other meat bones came from a variety of animals: ox, sheep, goat, fallow deer, horse, and pig. There were also olive stones, hazelnut shells, and fruit pits.

The most surprising discovery, how-
Naval architects and archeologists modeled and reconstructed a Punic warship based on the remains of two excavated ships: From one came hull planks and timbers that revealed the shape of the stern; the prow was what remained of the second vessel. The artist’s reconstructions, below, present a Punic warship from various perspectives. The side view at top shows the seventeen oars on the starboard side, the underwater ram (right) and the decorative curved extension at the ship’s stern (left). Next, a cutaway side view reveals interior timbers. Beneath that is a plan of the right half of the ship as seen from above. The lowermost perspective provides a view of the deck of the totally reconstructed vessel.

Illustrations by Michael J. Lee K

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Oars were spaced quite widely, perhaps so that two men could control each oar (cross section below). In that case, the ship carried a total of sixty-eight oarsmen, plus fighting men. Since military ships did not carry cargo, they had to be ballasted with stones (lower sketch). Piles of such stones found in the sand near the wreck were one of the first indications that the sunken timbers belonged to warships.

However, was the stems of a grass whose yellow color stood out among the dunnage (the layer of branches that protected the bottom of the hull from ballast stones). There was so much of this plant material that we could do no more than bag random samples for analysis at the Jodrell Laboratory, Royal Botanic Gardens, Kew. At the laboratory, another selection had to be made, for not every fragment could be thin-sectioned for anatomical identification. Thus it was that the yellow fragments of stem escaped the experts until the final season when, after excavating two basketfuls of them, we made a special request for their identification. The answer was, probably Cannabis sativa. The doubt was due to the decay of the minute hairs that would have differentiated these stems from two other plants: hops and stinging nettles. Given the choice, I accept cannabis; baskets of stinging nettles seem improbable and there is no record of Punic hop cultivation, whereas Herodotus, writing in the fifth century B.C., already refers to cannabis smoking. Very small doses of cannabis are used by homeopaths against fatigue, while ethnology attests to the use by workmen of hashish, ganja, or cannabis by any other name. Stems of the plant cannot produce a strong dose of the drug (this is obtained from the top shoots and pollen); stems could have been chewed, however, or infused like tea. The British navy issued a "tot of rum" to its seamen; perhaps the Carthaginian navy issued "a tot of pot" to its oarsmen.

More significant archeologically were the marks left on the hull by its builders: calligraphic letters of the Phoenico-Punic alphabet (including two words), painted and incised marks and guide lines, and accidental spills of paint. Ancient Mediterranean vessels were not built in the same way as medieval or contemporary wooden craft. Instead of laying a keel, erecting a skeleton of ribs, and nailing the lengthwise planks onto it, ancient ships were made shell first. With the stem and sternpost in place, the lengthwise planks were built up from the keel and fixed together by elaborate mortise and tenon joinery. As a result, the skin of the hull existed before the skeleton of floor timbers and frames was positioned inside it. Anyone who tries to imagine how to go about building the hydrodynamic shape of a large hull in this way will either give up or become hooked on nautical archeology.

Two questions that emerge are, Was the shape preconceived by an architect? And if so, how (since no blueprints have been found) did he communicate his ideas to the work force? People generally assume that tradition and good craftsmanship were sufficient to guide ancient shipwrights, but this is belied by archeological excavations. Even the wrecks of large, round merchantmen show a high degree of organization. The writing on the Punic ship includes one letter of the Phoenician alphabet, waw (which turned out to mean the place for a nail), painted in five different handwritings—implying a literate work force. Even contemporary shipwrights in the Mediterranean, building in the traditional way, are not given to expressing themselves in writing, while the carpenter's marks they make on wood are confined to rudimentary signs. As an expert in ship construction, Paul Adam has observed that the findings on the Punic ship show a degree of planning and organization that is without parallel until the Industrial Revolution.

William Johnstone, a professor of Se-
Before the discovery and reconstruction of the wrecked warships, drawings of Punic galleys were often fanciful and speculative. The ships in Jacques Martin’s 1977 adventure comic, Le Spectre de Carthage, are accurate.

mitic languages at the University of Aberdeen, was the one responsible for identifying the small and rapidly fading painted letters as well as the incised markings on the Punic hull. His lack of previous interest in boats, ancient or modern, removed all risk of any of the tendentious interpretations that would inevitably have occurred to a naval architect whose judgments were based on modern rules. Johnstone, who joined the excavation at the end of the fieldwork, examined the dismantled wood (by then in storage tanks), photographing and tracing every mark on it. Afterward, using the exhaustive records that had been made during excavation of the hull, he reestablished the original positions of the markings, a work that took him a couple of years.

The Phoenician alphabet (used in preference to numerals) had been set out along the port face of the keel where, from the outset, it had marked the future positioning of all the skeletal timbers that were to go inside the yet-to-be-built hull. Once part of the planking had been erected, the same letters were repeated inside the hull on the eleventh plank from the keel, where the builders could consult them as they adjusted the skeletal timbers they were starting to insert. As each of these timbers was being tried for fit, lines were scratched around it on the planking and marks made at the places where dowels would attach it to the hull. Holes were then drilled and the dowels inserted.

Even accidental spills of paint gave clues to this unknown kind of construction. For instance, imprints left by the dirty base of a paint pot straddled joins between planks on the nearly vertical side of the ship, where no paint pot could have stood. Apparently, these particular planks must have been assembled flat, before being joined to the rest of the hull.

As on all excavations, the Punic ship findings pose as many questions as they answer, and interpretation remains uncertain until comparisons can be made with similar excavations. But as yet (with the exception of the Punic “sister ship” described below), no writing has been found on any other wreck. Why? Although the calligraphy was very difficult to see (and often had to be revived by ultraviolet light for photography on land), I cannot believe we were superior to all other excavators. More likely, since no other long ships had been found, the signs were connected with fast military craft. To anyone who understood them, they would have contributed to the speed at which he could copy the vessel.

Unlike the structures commonly known through history and tradition, the strength of the Punic hull was not assured by the wood’s “suitability for purpose” but rather by the elaboration of the joinery. For example, instead of making a rib from a stout oak branch with a natural curve, the Punic shipwrights joined small pieces of wood together to make the preconceived shapes of various components. The elaborate joints, or scarf, gave the hull its strength, as we realized when we started lifting its remains. We could have raised much of the hull in one piece, but we would have found it impossible to treat such a large object with wax preservative or to restore the flattened wood to its original shape. Consequently, we lifted the hull in sections, dividing it at its weakest points, which were never the joins.

In 1974, after four years of fieldwork, the specialists who had been working out the shape and size of the vessel, through models, calculations, and iconography, had a pretty good idea of what it had been like from the stern up to the parallel midship section. But after that point, their work ended in midair, for there was no way of knowing how to bring these particular planks into a stem (although certain forms of prow were excluded for technical reasons). The answer lay nearby, but as often happens, it was not found until after the excavation had officially ended. Fate may even have been kind, for had it been found before this first long ship had
been studied, we might not have been able to make head or tail of it.

The rains came. The dredge was dismantled and I started shutting down the "dig" house. Our sailor returned to his farm for the winter. But before leaving Marsala, I went back to the site with an elderly sailor, in the oldest of our two boats (which sank shortly afterward while returning to its winter mooring). On another wreck, only 150 feet from the Punic ship, the movement of a sandbank had exposed the top of a curious upright timber that puzzled me. We had long known of this wreck's existence, calling it the sister ship, and during a rare period of leisure that season, John Wood, a volunteer diver, had made a plan of its newly exposed surface. I now went back to satisfy my curiosity. It took very little hand excavation to show that the upright timber was the straight stem of a prow.

With an underwater shovel designed and made overnight, I spent a week digging around, photographing, measuring, and drawing the prow. Attached to each side of the keel was a tusk-shaped timber about seven feet long that projected more than two feet forward of the stem, at which point they had been broken in antiquity. These were the sides of the first ancient ram to be found. Leaving the sister ship herself on the bottom for posterity, I raised one tusk of the ram. It was flimsy (for it was designed to break off on impact), and the whole ram structure was covered with a half-inch-thick layer of white resin the consistency of chewing gum. Headless nails and a small sheet of copper had fallen beside the ram, suggesting that it had been sheathed. I took a sample of the resin for analysis, then removed the rest. When the wood was revealed it bore one of the same Phoenician letters we had come to know on the other hull: a painted waw. The potsherds on both wrecks were also of the same period. The sister ship may be somewhat heavier in build than the first wreck, nevertheless both hulls were probably brought into the same form of upright prow.

The sister ship's ram would have been used to pierce an enemy ship below the water line; it would then have broken off like a bee's sting. Rams of this type were still being portrayed more than three hundred years later on Roman mosaics in Tunisia. Within five years of the discovery of this first Punic ram, the remains of two other kinds of rams (hitherto known only through iconography) were discovered in archeological contexts. In 1976 a "false ram" was excavated by Patrice Pomey and André Tchernia on a first century A.D. Roman cargo ship in France, at the Madrague de Giens. Structurally, this was an extension of the keel and would have sunk the ship it belonged to had it been used as a ram. Hydrodynamically, however, it was a useful appendage, a kind of cutwater. Before this archeological explanation materialized, representation of such rams on cargo-carrying sailing ships had so puzzled scholars that they sug-
gested such vessels might have been pressed into service as warships when occasion demanded. The third type of ram was found in 1981, lying isolated in shallow water off Athlit on the Israeli coast. It is an awesome weapon made of bronze that looks like a trident in profile but blunt-ended when seen from the front. Mounted at the juncture of the wale and the stem, it would have crashed against the enemy’s side, springing the planking and causing the enemy vessel to sink slowly.

By clarifying the structure behind the conventional profiles depicted in mosaic and bas relief, these archeological discoveries throw light on the performance of certain vessels and contribute to the understanding of naval strategy. Conversely, iconography goes on contributing to the interpretation of archeological finds. The Punic ship was, for instance, sheathed in lead (the lead itself was too decomposed to salvage, but the tack patterns are clear). This fact upset many people’s ideas of how fast, oared ships ought to have been built. Lucien Basch, who has researched a comprehensive book on nautical iconography, has pointed out, however, that the galley with the “bee’s sting” ram that decorated the threshold of a room in the Roman baths at Themetra, Tunisia, shows both metal sheathing and the tacks that at-
A mosaic that once decorated the Roman baths at Themetra, Tunisia, shows an oared galley of the type used in the Punic Wars. The Punic shipwreck probably once had such metal sheathing on its hull, and the narrow, "bee's sting" ram projecting from the prow (left) is of the type found on the wreck's "sister ship."

Elizabeth Kitli, Musée du Bardo

These mosaics, made several centuries after the Punic ship was built, are a suitable point of reference because ship construction is a very conservative activity. Despite the known variations in shape between one region and the next, and indeed between one shipyard and another, certain well-tried principles of construction did persist.

To judge from various analyses of its contents, our particular Punic ship was probably built at a shipyard other than Carthage or Lilybaeum, but the planning and standardized parts evident in its construction clarify how the Romans, once they had such examples to copy, were able to produce an effective fleet. About 110 feet long and 16 feet wide, the Punic ship itself was neither a trireme nor a quinquereme (the battleships of the navies) but a Liburnian—a smaller kind of fast ship with seventeen oars on each side, each pulled by two rowers. It was probably used for scouting and sending messages, although it could have attacked with its ram. The dating, the absence of cargo, and the geographical position of the group of wrecks in which it lay, all point to its having been sunk in the battle of the Egadi Islands, which resulted in the fall of Lilybaeum and the end of the First Punic War. The Mediterranean never again was a Carthaginian lake.
The Treasures of Ancient Tunisia

The living Museum

The ancient North African city of Carthage, destroyed by Rome in the Third Punic War (149–146 B.C.), left a rich cultural legacy. Carthage: A Mosaic of Ancient Tunisia, which opens this month in Gallery 3 at the American Museum of Natural History, is the largest exhibition of Tunisian artifacts ever shown in the United States.

Carthaginian civilization began with the Libyans (Berbers) and was successively dominated by the Punic people (descendants of the Phoenicians), Romans, Vandals, Byzantines, and Arabs. The exhibit will present bronzes, jewelry, pottery, and other artifacts, including seventeen pictorial mosaics, unearthed during more than 100 years of international excavations in Tunisia.

According to the exhibition's guest curator, David Soren, a professor in the Department of Classics at the University of Arizona and a specialist in Roman art and Greek and Roman archaeology, Carthaginians may have invented mosaics in the fifth century B.C. The city became a center of North African culture and was noted for the art forms it created from multicolored local stone (mosaics made in Rome were traditionally black and white).

Some of the mosaics on exhibit are parts of larger mosaic floors, the largest of which was at least six and a half by twenty-seven feet in its original state. All date from the period of Roman control (first to fifth century A.D.). Before Carthage fell, Soren says, the mosaics were mostly simple floors without elaborate de-
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Facing Cocks

Lions Devouring a Wild Boar

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signs; styles depicting scenes of animals, people, and landscapes were not common until late in the second century A.D. Facing Cocks decorated the entrance of a fourth-century house. Aicha Ben Abed Ben Khader, director of the Bardo Museum in Tunisia, writes that this mosaic suggests a combat involving prize money for the victor. Soren adds that the birds holding money in their beaks may be a sign of good luck and prosperity. In Greece, the cock was dedicated to Asklepios, the god of medicine. Even today, in Portugal (which was once part of the Roman Empire) people exchange figurines of the bird for good luck—a tradition that dates back to the classical period.

Lions Devouring a Wild Boar and Tiger Attacking Two Onagers are parts of a large mosaic (A.D. 150–200) dedicated to Dionysos, the Greek god of wine, revelry, and fertility. These scenes, heavily influenced by Greek style, take place on a background of limited depth where each panel shows predators capturing prey. Soren says that “there was, among the Romans, a strong taste for violence as well as a great love of landscape, the outdoors and a naturalistic depiction of animals.”

Renée Bacher
At the American Museum

Winter Celebrations

December is Winter Celebrations Month at the Leonhardt People Center at the American Museum of Natural History. Weekend programs will feature Plains Indian winter dances, Native American crafts and tales, a Chanukah celebration, and black American Christmas traditions. For further information call (212) 769-5315.

Kwanzaa

Kwanzaa (Swahili for first fruit) is an African-American holiday founded in 1966 by Maulana Karenga, a noted black studies scholar. The seven-day holiday (from December 26 through January 1) is based on seven fundamental principles: unity, self-determination, collective work and responsibility, cooperative economics, purpose, creativity, and faith. The Department of Education, in cooperation with the New York Urban Coalition, will observe Kwanzaa with a series of lectures, workshops, and performances. For further information call (212) 769-5315.

Origami Tree

This month the Origami Holiday Tree will be on display for the fifteenth consecutive year. More than 3,000 silver stars will create a halo of mobiles around the twenty-five-foot-tall tree decorated with origami models of animals past and present. The tree represents more than 250,000 hours of volunteer time over the years. A Museum volunteer at the origami table adjacent to the tree will teach visitors how to make simple models. The tree will be on display through January 6.

African-American Poetic Expressions

Two evenings of poetry, music, and drama will be presented in the Kaufmann Theater this month. Wednesday, December 2, at 7:30 p.m., John S. Patterson will perform "Three Generations," with poetic selections from Paul Laurence Dunbar, Langston Hughes, and Alice Walker among others. Wednesday, December 9, at 7:30 p.m., Joanna Featherstone will perform "Poetic Visions," a celebration of poetry, dance, and music. For information call (212) 769-5315.

Carthage and the Mediterranean World

A symposium highlighting themes and objects from the exhibition "Carthage: A Mosaic of Ancient Tunisia" will examine the background and trace the international role of this ancient city through its archeological treasures. David Soren, curator of the exhibition, will moderate a panel of speakers on Saturday, December 5, at 2:00 p.m. in the Kaufmann Theater. For information call (212) 769-5305.

Hannibal—General of Carthage

The Department of Education presents a special showing of this classic film with Victor Mature portraying the life and exploits of Carthage's most famous military leader. David Soren introduces the film and discusses facts and fictions about Carthage on Tuesday, December 22, at 2:00 p.m. in the Kaufmann Theater. For information call (212) 769-5305.

Native American Film Festival

The fifth Native American Film and Video Festival will focus on contemporary Indian life throughout the Americas on Saturday, December 12, beginning at 10:30 a.m. Some of the films being shown are Martin Chambi, Coyote Tales, Popul Vuh, A Weave of Time, and Navajo Talking Picture. For information call (212) 769-5305.

At the Planetarium

The holiday Sky Show, at the Planetarium through January 3, takes viewers back in time nearly 2,000 years to view the skies of the first Christmas. The show explores the question "What was the 'star' that led the Wise Men to Bethlehem?" and shows how scientists, historians, and theologians have worked together to find possible answers. For further information call the Planetarium at (212) 769-5920.
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Video
An Odd Figure 8

by Thomas D. Nicholson

Analemma is the Latin word for sundial. The analemma we see on globes records how the point on the earth directly below the sun at clock noon changes during the year. The sun moves north of the equator in summer and south of the equator in winter. It is ahead of clock noon from September 1 to December 26, falls behind from December 26 to April 15, then moves ahead again until June 15, and falls behind again until September 1, alternately speeding up and slowing down with respect to clock time. It is exactly even with the clock four times a year—on December 26, April 15, June 15, and September 1.

The Analemma

Adapted from Physical Geography, by James S. Gardner. © 1977 by Harper and Row, Publishers Inc.
Celestial Events

8, called the analemma, that decorates some maps and globes.

Analemma is the Latin word for sundial. The analemma we see on globes records how the point on the earth directly below the sun at clock noon changes during the year. The sun moves north of the equator in summer and south of the equator in winter. It is ahead of clock noon from September 1 to December 26, falls behind from December 26 to April 15, then moves ahead again until June 15, and falls behind again until September 1, alternating speeding up and slowing down with respect to clock time. It is exactly even with the clock four times a year—on December 26, April 15, June 15, and September 1.

Two readers wrote to me recently to inquire why the analemma isn't symmetrical. The "8" crosses well above the equator; the top part is less than half as big as the bottom and the bottom is much wider. The right and left sides don't match either. That may be all right for the kind of 8 you and I usually write, but we expect more symmetry in form from nature. If it isn't there, some of us worry about it.

The analemma's north-south dimension reflects the changes of the sun's north-south position over the earth. The tilt of the earth's axis makes the sun appear to move from the equator in the spring and fall (when the sun crosses the equator at the equinoxes) to 23°27' north of the equator (March 21), 66°33' north of the equator (June 21), 23°27' south of the equator (September 22), and 66°33' south of the equator (December 21). These numbers are the solstitial declinations, the angles that the sun's rays make with the plane of the earth's equator. They are the dates of the solstices.

The analemma graphs the sun's declination and the daily difference between clock noon and noon by the sundial for every day of the year. Declination is the distance in degrees from the earth's equator north or south to the point on the earth directly under the sun. This solar "ground point" moves north and south throughout the year because of the tilt of the earth's equator to its orbit. Clock noon comes later than sundial noon during two periods of the year (illustrated by the left side of the analemma) and earlier than sundial noon during the two other periods (represented by the right side of the analemma).
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Leap Second

The word is out. Nineteen eighty-seven will be one second longer than most years. Everyone knows about leap years, but not too many people know about leap seconds, the extra second we have to add once in a while so that our clocks will accurately predict where the sun, moon, and planets will be.

Leap seconds don’t come up on any regular schedule. The last time we needed one was in 1985. We have to wait until astronomers at the United States Naval Observatory tell us that one is due. They did so this year, and by the rules of international timekeeping, the second goes in immediately after the sixtieth second of the last minute of December 31.

around the sun makes it seem to shift to the east by only about one degree per day.

There are two factors involved in the way the earth’s revolution around the sun changes the sun’s motion across the sky. One is that the earth’s orbital speed changes during the year, the other is a byproduct of the earth’s orbital inclination, or tilt. Since the earth revolves around the sun in an elliptical orbit, its orbital speed varies. The speed is greatest at perihelion (in early January, when the earth is closest to the sun) and slowest at aphelion (in early July, when the earth is farthest from the sun). This change in speed slows the sun’s westward motion across the sky more in the winter (when the earth is moving eastward fastest) than in the summer.

The earth’s rotation always makes the sun move parallel to the equator, but this is not true of the effect of the earth’s revolution. The earth’s orbit is parallel to the equator at the solstices, but it is inclined at an angle to the equator where it crosses at the equinoxes. So the easterly
retarding effect of the earth's revolution on the sun's apparent westerly motion is greatest at the solstices and least at the equinoxes. Taken in combination, this second factor and the variation in the earth's orbital speed, each operating in a different annual cycle, cause the rhythmic change in the sun's motion that affects its relationship with our uniformly running clocks. When these two factors, each with its different annual cycle, combine with the sun's changing declination—its distance north and south of the celestial equator—the lopsided form of the analemma is accounted for.

Events in the calendar below occur in local time unless otherwise indicated.

December 1: Venus became an evening star last August but hasn't put on much of a show until now. Chances for seeing it will improve late in the month. Jupiter is the bright object you see tonight near where the gibbous moon crosses from Pisces into Aries.

December 2-4: The waxing moon pacés off the distance between Jupiter and the Bull's bright star Aldebaran. The moon rises virtually together with Aldebaran on the 4th, well to the left of the star.

December 5: Full moon is at 3:01 a.m., EST. The star near it is Alnath, marking the Bull's left horn.

December 8: The moon is in Cancer, but lined up with Gemini's two bright stars, Pollux and Castor. The earliest sunset of the year occurs today.

December 11: The rising gibbous moon highlights the Lion's bright star Regulus after 10:00 tonight.

December 13: Last-quarter moon is at 6:41 a.m., EST. It climbs the sky behind Leo after midnight.

December 14: The waning moon spoils the maximum of the Geminid meteor shower, the second best shower of the year. You might, however, see some of the meteors after midnight, before the moon rises too high.

December 15-16: Saturn is in conjunction, in line, with the sun on the 15th and becomes a morning star; Jupiter, beginning its retrograde (westerly) motion, improves swiftly in the evening sky. The star near the crescent moon on both mornings is Spica in Virgo, occulted by the moon over the Indian Ocean earlier in the day.

December 17-18: The only bright object near the moon before dawn is Mars.

December 19: The moon occults Antares above our horizon, but in bright twilight or daylight.

December 20: New moon is at 1:25 p.m., EST.

December 22: Winter begins in the Northern Hemisphere when the sun reaches the solstice at 4:46 a.m., EST. Perigee moon (when it is nearest the earth) occurs a few hours later. Venus and the crescent moon should be visible in the west at twilight. Venus will be in about the same position nightly through the end of December, but the moon will move left and higher and grow in phase.

December 23: Mercury is in superior conjunction, in line with but beyond the sun, and becomes an evening star.

December 27: First-quarter moon is at 5:01 a.m., EST.

December 28: Jupiter and the moon are close again.

December 31: The evening moon is back in Taurus, just below the Pleiades (the Bull's hazy cluster of stars) in the early evening.

Editor's Note: The Sky Map in the October issue shows the evening constellations and stars for this month and gives the dates and times for use.
The Cream of the Crop

In England, Devon and Cornwall’s cows provide a regional delicacy

by Raymond Sokolov

The gourmet and the physician are often opponents in the battle over ideal diet. The gourmet wants to eat animal fats because they taste good. The physician counsels restraint or abstention, invoking cardiovascular peril. This conflict is a result of many positive parts of modern life: scientific medical treatment makes long life common, leaving more people old enough to contract degenerative diseases. Sedentary work situations make high-caloric traditional meals obsolete and also dangerous because they were designed for physically active people who would easily burn off calories. Everyone knows this, but not many of us have the will to do much about it. Diet books proliferate, but diet remains largely traditional because traditional foods are delicious. Chronic moderation, on the other hand, is a generally unrealizable goal, and no one has yet designed a healthful alternative to traditional food that appeals to more than an eccentric minority.

There are, however, some gastronomic perils that well-meaning governments have succeeded in protecting us from, sometimes against our will. I’m thinking of specific foods or food processes that are regulated or forbidden on health grounds. Most of these suppressed items or practices are not missed by the vast majority of Americans. Few people, I suppose, care deeply that pork blood is, in effect, banned as a food because it is too hard to collect in modern abattoirs in a clean enough condition (without pig hairs in it) to pass inspection. And so blood sausage in this country is almost always made from cleaner (inspectable) bovine blood.

Raw (unpasteurized) milk is also a casualty of perfectly reasonable pathophobia. No one wants to catch tuberculosis or the other diseases that can be spread by raw milk, least of all me. But the fear of contaminated milk abroad in the land is apparently so great in some quarters that I stirred up a controversy recently with a column that, if anything, was meant to debunk the notion that fresh cheeses made from raw milk tasted better than those made from pasteurized milk (all other factors being equal).

Let me be as clear as I can. The evident superiority of raw-milk, soft-ripened Bries and Camemberts is more likely to result from the small-scale, artisanal, high-quality dairies that produce these cheeses in France than from the flora allowed to remain in the milk. That is my opinion, but until one of those dairies conducts a respectable double-blind experiment with raw and pasteurized milk, we will never have a serious answer to this question. So what we are stuck with is an irritating dilemma. We can take a deliberate, if statistically limited, risk and consume raw-milk Brie in France (or here, if we happen on some that has slipped through customs) or settle for perfectly safe, guile, mass-produced, pasteurized-milk Brie.

Or we can hope that the same thing that has already occurred with goat cheeses will happen to the soft-ripened cheese industry here. Enlightened producers will arise who will perfect first-class cheeses made from pasteurized milk. That is my hunch. So let it be said, I do not advocate the consumption of raw milk even as cheese, even on gustatory grounds. But many rational people doubt that anyone can produce an outstanding soft-ripened cheese with pasteurized milk.

One of the most articulate of these traditionalists is Edward Behr of Peacham, Vermont, editor of the newsletter The Art of Eating. After I took issue with him in this magazine, he wrote me a long, interesting reply based on much experimentation with raw- and pasteurized-milk fresh cheeses. “The problem with comparing these fresh cheeses,” he wrote, is that pasteurization freezes one cheese at an early state, while the other cheese continues to develop, however subtly. All my tasters claimed to detect a difference between the two and all agreed it was very slight . . . . My primary conclusion is that it is very difficult to compare these two cheeses, because they are so simple and one of them is living, so to speak. . . . As to ripened cheeses, my assumption when I wrote was that the major strength of unpasteurized milk was its greater richness of microflora conducive to good flavor.

The key word in that passage is richness. Behr and other proponents of raw-milk cheese contend that the bacteria naturally present in milk (healthy milk uninfected by pathogens) are a better, more complex source of flavor than the starters and other microflora that can be deliberately added to milk after pasteurization. One way or the other, ripened cheeses get their flavor from bacterial action. So the debate really revolves around the best way to promote desirable bacterial growth and, ultimately, which bacteria are “desirable.”

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Ekmek Kadayif with Kaymak
(Adapted from A Book of Middle Eastern Food, by Claudia Roden)

3 1/2 cups sugar
1 tablespoon lemon juice
3/4-1 1/2 cups honey
1-2 tablespoons rose water
1 loaf French bread
Chopped unsalted pistachios
1 recipe kaymak (see below)

1. Dissolve sugar in lemon juice and 1 cup water and simmer mixture over medium heat until it thickens.
2. Stir in honey and rose water. Simmer two minutes longer.
3. Cut away the crust from the loaf, horizontally, so as to leave a long, sausage-like round 1/2 to 3/4 inch thick. Dry out in a very low oven.
4. Pour the syrup into a long pan that will hold the entire long piece of bread. Bring the syrup to a boil. Put the bread in and simmer very gently, pressing lightly with a spoon, to help the bread absorb the syrup. Cook until the bread is completely soaked with syrup, rich and heavy.
5. Turn out onto a serving platter and let cool.

Yield: Six servings

Kaymak

5 cups milk
1 1/4 cups heavy cream

1. Stir the milk and cream together in a wide, shallow pan.
2. Bring to a boil slowly. Simmer over very low heat so that it barely trembles for about one and one-half hours.
3. Let stand for about seven hours before refrigerating. Chill overnight before using.
4. A thick, solid layer of cream will have formed on the surface of the milk. Use a sharp-pointed knife to detach the edge of the cream layer from the pan and transfer to a flat surface. Cut in squares.

than cheesemaking. The taste of all dairy products is affected by the presence of bacteria. You know this if you have ever compared yogurt and discovered how much better a few are than the rest. The reason, of course, is the “culture,” the living microflora that ferment, or ripen, the milk in a desirable fashion. Some cultures are better than others. This is why crème fraîche, the lightly soured cream of France, tastes different from crème fraîche you and I make at home by ripening heavy cream (non-ultrapasteurized) with an admixture of buttermilk.

Such thoughts were much on my mind recently as I drove across the moors and densely hedged hilltops of Devon in search of clotted cream. This luxurious, nutty-flavored, yellow-crusted, solid buttermilk delicacy is the major regional delicacy of both Devon and Cornwall. It is still a tourist attraction in these areas, served with cakes at innumerable “cream teas.” But the real thing has all but vanished even on its home ground. Jane Grigson in British Cookery (Atheneum, 1985) quotes a Cecili Torr writing in 1918: “Now they are ruining the cream by using separators. Of course it is cream made in Devonshire, but it is not what was known as Devonshire cream. The stuff is not worth eating; but I suppose people will go on eating it as Devonshire cream.”

Indeed. Even Grigson is willing to endorse the quality of “modern” clotted cream, so long as it is based on “milk coming from the same herd or group of herds, feeding on the same pastures.” I take this to mean that good clotted cream can be made starting with mechanically separated cream instead of whole milk, all other factors being equal.

In the old-fashioned method, whole and unpasteurized milk from cows producing high-butterfat milk (usually Jerseys or Guernseys) was put on the stove and heated but not boiled, for about one and a half hours or longer until a yellowish crust formed on top. Then the bowl was left to ripen for a day or two, after which the crust (the clotted cream) was lifted off. Today, no commercial producer makes clotted cream from whole milk. And most clotted cream sold in markets, even in Devon, is concocted from the combined milk of many herds and, perhaps for other reasons, too, lacks character.

On the other hand, there remain a few farmstead producers who do make clotted cream from single herds. One of them is Nora M. Bishop of Eveleighs, the dower house of Crouyys Mordach, just out of Tiverton, Devon. The setting is even more idyllic than its name—up a steep hill, then another, and behind the fine farm buildings an even higher meadow grazed by fifteen peaceful Jerseys.

Bishop is a young woman whose life is everywhere connected to cows. Her “day job” is with a local livestock auction house, where she writes catalogs. At home, she manages her herd and operates a little clotted cream dairy whose estimable yield finds its way to London and to
As Harold McGee explains it in *On Food and Cooking*: The heat treatment denatures the whey proteins, unfolding the initially compact molecules into longer structures that increase the viscosity—thicken the texture—of the liquid. ... Apparently, when the lactoglobulin is denatured it re-acts and forms a complex with one of the casein subunits, and this complex interferes with the aggregation of casein micelles. It doesn't prevent this aggregation, but it limits it to such an extent that the micelles seldom get close enough together to squeeze out much whey. The result is a finer matrix, one in which the liquid and solid phases are well integrated. The aggregation of casein micelles is caused, of course, by the bacterial secretion of lactic acid, which lowers the pH from about 6.5 to about 4.5, thereby causing the micelles to shed their mutually repellent negative charge. And with nothing to keep them apart, their chemical similarity naturally brings them together.

To try this at home, you will have to add heavy cream (non-ultrapasteurized) to homogenized milk in a proportion of 1 to 5 (cream to milk). Heat in the widest pan possible (to get the largest surface area) only enough to make the liquid tremble, for one and a half hours. Then let stand for seven hours and then refrigerate overnight before using. A layer of solid cream will ripen and solidify. Working carefully with a knife point, loosen it and remove the sheet to a plate.

The substance you now have may not be quite as smooth and mellow as it would if you had begun with whole, unhomogenized milk warm from theudder of your own Jersey. And it may not have quite the complexity of flavor as it would if you had been operating on it over a longer period of time without benefit of refrigeration. But you have certainly got something nice to have with cake or with meringues, the inspired combination served at Sonia Stevenson’s idyllic Devon inn, the Horn of Plenty, at Gulworthy.

Your clotted cream is also a first cousin of what is known in Turkey as *kaymak* and in Arab countries as *eishta*. This Middle Eastern clotted cream is made from buffalo milk, just like the best Italian mozzarella. So the consistency is a bit different, but not enormously so. You are even closer to the Indian analog, *khoya*, the basis of scads of Indian desserts and puddings. Holy cow!

Raymond Sokolov is a writer whose special interests are the history and preparation of food.

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D. "Dinosaurs, An Illustrated History" by Edwin H. Colbert, Curator Emeritus of the American Museum of Natural History. Many colorful illustrations, nontechnical text, for the general reader, soft cover, $14.95. (Shipping & handling $2.50)
Brooding on the Tundra

Like tiny, battery-operated toys, newly hatched shorebirds are all wound up for short periods but often need recharging. Bursting with energy, these sanderling chicks repeatedly emerged from under the parental wing, motoring across the tundra of Canada's Jenny Lind Island in search of edible insects. After just a few minutes, however, and despite their downy insulation, they began to cool off and slow down and soon had to head back to the parents for another brooding session. The cycle is repeated incessantly for about two weeks, until the chicks are developed enough to keep up a constant body temperature. While the chicks forage, the parent stands guard and gives an alarm call if a predator approaches. The young seem “hard-wired” to respond to such calls and react by crouching motionless on the open ground, where their camouflage makes them virtually invisible.

Text and photographs by Bruce Lyon
The Natural Moment
HOW'D YOU LIKE TO FISH WHERE A 25-LB. TROUT ISN'T EVEN A KEEPER?

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EXPLORATION CRUISE LINES
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Sharon Stephens (page 32) followed the reports out of Chernobyl with particular concern. The cloud of radioactivity was headed north into Scandinavia, where the Sami herded their reindeer. Stephens had spent eighteen months living among these most-northern pastoralists and worried about the fate of families and friends she knew. In the winter of 1986, a grant from Cultural Survival allowed her to return to study the effects of the accident. Her findings are the basis for her article in this issue. An assistant professor of anthropology at the University of Chicago, Stephens has studied the Sami for ten years. (Her four-year-old daughter is named Kaisa, which means snowy mountain in Sami.) For further reading she recommends Ernst Manker's People of Eight Seasons: The Story of the Lapps (New York: Viking Press, 1964) and Hunters, Pastoralists, and Ranchers, by Tim Ingold (Cambridge: Cambridge University Press, 1980).

Interested in archeology ever since her childhood in Cyprus, Honor Frost (page 58) saw her first underwater Roman wreck in 1955 when she began diving near Cannes. Two years later, while working as a drafts-person at excavations of the ancient town of Jericho in Jordan, she resolved to document wrecks using the same thorough archeological techniques that are used on land. Now vice-president of the Society for Nautical Research in London, she has explored wrecks off Turkey and Malta, studied Bronze Age harbor installations near Lebanon, and surveyed the submerged remains of the Pharos at Alexandria. In 1969 she visited Marsala, Sicily, where she subsequently found, excavated, and raised the remains of the Punic warship described in this issue. Complete details on this find are in The Punic Ship: Final Excavation Report, by Honor Frost et al. (Rome: Supplement to Notizie degli Scavi di Antichità, vol. 30 of the Accademia Nazionale dei Lincei, 1976). The Punic Wars are described in Polybius's Histories (Cambridge: Harvard University Press, Loeb Classical Library nos. 128, 137-138, and 159-161). Carthaginian history and culture are presented in Carthage: A Mosaic of Ancient Tunisia, edited by Aicha Ben Abed Ben Khader and David Soren (New York: American Museum of Natural History, in association with W. W. Norton and Co., 1987).
In 1984, photographer and biologist Bruce Lyon (page 84) traveled with a fellow graduate student to Jenny Lind Island to study shorebirds breeding in the Arctic. “While on a hike across the island we came upon an agitated sandpiper. We suspected its nest or young were nearby, and while we watched for an hour, the bird returned several times to the same spot by a couple of small rocks, which we used as reference points. We eventually discovered that the ‘rocks’ were baby sandpipers. They had remained absolutely motionless for an hour.”

Lyon, who claims to have been “born with an interest in birds,” is working on his doctorate at Princeton University. His areas of interest include parental care, reproductive strategies, and sexual selection. He has done fieldwork in Kenya and Central America, but the Arctic remains his “favorite place on earth.” Lyon took this month’s “Natural Moment” with a Pentax camera, using an 85-mm lens for the chicks alone and a 200-mm lens for the family shot.

**ERRATUM: In October’s “Authors” column, we misstated the title of a 1987 book by chemical oceanographer Wallace S. Broecker. The correct title is How to Build a Habitable Planet. It was published by Eldigio Press, Box 2, Lamont-Doherty Geological Observatory, Palisades, New York, 10964.**
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