the meantime, many crystallographers say, the best hope for figuring out the structures of large proteins lies in combining direct methods with another technique called MAD (for multiwavelength anomalous diffraction) phasing, which has already gone a long way to speeding protein structure determination.

MAD phasing, developed in the early 1990s, works on modified proteins made by inserting the gene for the protein into *Escherichia coli* bacteria, then typically feeding the bacteria a version of the amino acid methionine whose sulfur atom is replaced by a heftier selenium atom. The bacteria incorporate these selenomethionine amino acids into the protein. When synchrotron x-rays are shot through the crystallized protein, they scatter strongly off the heavy selenium atoms. By studying how the diffraction pattern changes as the wavelength of the x-rays is varied, crystallographers can tease out the position of the selenium atoms, which then provides an edifice for determining the phases, and hence, structure of the protein. The procedure resembles the heavy-atom approach, but because it riddles the protein with more precise atomic landmarks, MAD phasing can be done with a single crystal.

Despite MAD's many successes, the technique has bogged down for large molecules, where the positions of many selenium atoms (more than 15 or so) need to be determined. Shake-and-Bake offers a quick way to map large numbers of selenium atoms, Hauptman points out. And for this task, coarse diffraction patterns are often good enough, as the selenium atoms are usually far apart in the molecule. At the meeting this summer, researchers from Cornell University reported using Shake-and-Bake to locate some 65 selenium atoms in a MAD data set, which enabled them to pin down some 25,000 atoms in the structure of a large enzyme that regulates antibiotic uptake in some bacteria. That structure is twice as large as any previously done with MAD, says Cornell's Deacon.

"The beauty of the method is things can happen very quickly," he says. "Once you have the protein and crystal, you can collect data and have the structure in a few days." So far only a few groups have followed suit, however. Says Deacon: "People probably don't realize the magnitude of what can be achieved with this." –DAVID KESTENBAUM

ECOLOGY

A Bold Plan to Re-Create a Long-Lost Siberian Ecosystem

An international team of scientists will test whether bison, horses, and other large grazers can bring back the mammoth steppe

CHERSKII, RUSSIA—Like a frog hopping from lily pad to lily pad, Sergei Zimov strides from one tussock to the next, wobbling for a moment on each sedge knob rooted in the sodden permafrost. Occasionally he misjudges a tussock's firmness and his leg disappears up to the knee into the marsh water. Within minutes, Zimov has reached higher ground and a carpet of mosses and lichens, birch bushes and scattered larches—hallmark features of a mixed tundra-taiga landscape that dominates much of this region above the Arctic Circle. It is a starkly beautiful, wild land, permeated with the fragrance of alpine sage. Zimov, however, wants to see it torn up and populated.

Zimov is no Soviet-style planner intent on draining the marsh and putting up drab high-rises: He's an ecologist and director of a lonely science outpost in the northeasternmost reaches of Russia. He points to a tangle of birch and willows several dozen meters away, where two of the agents he hopes will carry out his grand scheme are picking their way across a ridge. They are young male Yakutian horses—off-white and pepper-flecked, the color of snow near a Moscow highway. Zimov envisions dozens of these horses, along with moose, reindeer, and a herd of bison imported from Canada, ripping up the moss and shrubs with their hooves and teeth, allowing grasses to move in. Within a few years, he hopes, grazing animals will have supplanted the current ecosystem in a 160-square-kilometer preserve with a grassland resembling one that existed here during the last Ice Age. The idea is to reconstruct a small chunk of the mammoth steppe, a vibrant ecosystem that dominated much of Siberia before vanishing after the Pleistocene epoch ended 11,000 years ago.

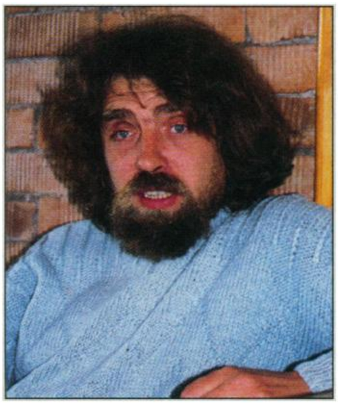
In creating what Zimov calls "Pleistocene Park," he, two U.S. ecologists—Terry and Mimi Chapin, a husband-and-wife team at the University of Alaska, Fairbanks—and a group of Canadian and Russian wildlife biologists are embarking on an ambitious experiment that aims to test theories about the forces that shaped, maintained, and ultimately vanquished a long-gone ecosystem. Some experts are calling the experiment a watershed in efforts to study lost ecosystems. "It's a very exciting idea whose time has come," says Paul Martin, who studies Pleistocene extinctions at the University of Arizona, Tucson. The experiment, he predicts, "is going to have a revolutionary effect on how we think about designing nature."

Siberian Serengeti? Site of experiment aiming to restore the Pleistocene-era mammoth-steppe ecosystem.

The project also marks the first attempt to restock Siberia with bison, a species that went extinct in this region at least 2000 years ago. "It makes sense to reintroduce species that have been recently extirpated by human hunting or habitat encroachment," says Paul Koch, a specialist on Pleistocene-era mammals at the University of California, Santa Cruz. "It's just planetary hygiene."

But Koch and others point out that the project's main goal—restoring the mammoth steppe—could be doomed because some Pleistocene elements are impossible to reproduce: the namesake mammoths, of course, and certain climatic features, such as cooler temperatures and less carbon dioxide in the air. "You still don't have analogs for climate," says Russell Graham, curator of vertebrate paleontology at the Denver Museum of Natural History.

Weather is at the crux of the debate over whether Pleistocene Park will succeed. Most experts argue that Siberia in the Pleistocene was much drier than it is today. They point to Pleistocene sediments, which harbor pollen and other remnants of grasses that thrive in dry soil. These grasses, in turn, fed an array of large herbivores, including mammoths, steppe bison, horses, moose, reindeer, and woolly rhinos. Many scientists believe that a sudden and severe climate shift at the end of the Pleistocene—a warm-up of about 5 degrees Celsius in just 20 years and, perhaps, more rain and snow—set in motion a vast and inexorable turnover in which marsh-loving mosses and sedge conquered the circumpolar regions. The shift to low-nutrient mosses, coupled with a new actor—bands of human hunters—drove mammoths, steppe bison, and woolly rhinos to extinction.



Visionary. Zimov is known for a "brilliant speculative mind"—and a knack for getting things done.

Although Zimov agrees with much of that scenario, he takes issue with one key point. Climate change probably did not alter the balance of power among plants, he says. Zimov, whose staff at the Northeast Scientific Station has spent 2 decades probing Pleistocene sediments, argues that this rich soil appears drier than today's not because the region got less precipitation but because grasses are much better than mosses at sucking water from the soil and releasing it into the air. Indeed, he points out that northeastern Siberia's climate is very dry now: Cherskii, he says, receives on average less than 20 centimeters of precipitation a year.

Terry Chapin recalls being "intrigued" but "somewhat skeptical" about Zimov's ideas when they first met in 1991. But Zimov, who had developed a computer model that predicted how steppe or moss ecosystems might thrive under various ecological or climatic regimes, made him a believer. In a paper in *The American Naturalist* (November 1995, p. 765), Zimov, the Chapins, and three colleagues argued that precipitation levels in the Pleistocene could have supported today's mosses just as well as they did the mammoth steppe.

What kept the steppe covered in grass instead of mosses, they say, was the big grazers. By churning up the ground with their hooves, bison and other heavyweights could have prevented mosses from gaining more than a weak toehold on the landscape. The grazers' dung provided fertilizer for grasses that, in turn, nourished the animals. Aggressive hunting, they argue, decimated the big herbivores, and as they gradually disappeared the ground was disturbed less and grew poorer in nutrients—conditions that could have ushered in mosses and accelerated the herbivores' decline. Zimov points out that mammoth-steppe grasses persist today in areas of Siberia rich in nutrients—along rivers and streams, for instance—or in areas where mosses were disturbed by buildings, roads, fires, and other human activities. "We don't have this ecosystem now for the simple reason that we don't have enough animals," he says.

Zimov hatched Pleistocene Park as a way to test this idea. Last spring, he took the first step toward populating the park, buying 32 wild Yakutian horses with funds from the government of the Sakha Republic, which oversees the vast Siberian province called Yakutia, and bringing them about 1000 kilometers east to Cherskii. This breed can put on a thick layer of body fat during the summer and fall that gets them through winter. Next will come the bison.

Northern Siberia's climate is too harsh for North American plains bison or European bison. But a subspecies called wood bison (*Bison bison athabascae*), which is thought to be the closest living relative to the extinct steppe bison, should survive in the park. The species was presumed extinct until a small herd was discovered in northern Canada in 1959. Zimov and the Chapins plan to start with 25 to 28 bison—mostly young cows and a few young bulls to ensure "the maximum rate of reproduction," Zimov says. They would be flown from Canada to Cherskii and acclimatized in a 24-km^2 fenced-in section of Pleistocene Park. Within a few years, the growing herd would range freely in an existing national reserve that encompasses Pleistocene Park. Several years later, bison would be allowed to roam in the 500,000 km^2 of lowlands between Siberia's Indigirka and Kolyma rivers—a region haunted by the memory of Stalin-era prison camps.

Trailgrazers. Wild Yakutian horses (and bison) should tear up mosses and allow steppe to make a comeback.

To cover the estimated $330,000 cost of readying, shipping, and acclimatizing the first batch of bison, Zimov and the Chapins have applied for a grant from the Turner Foundation, a nonprofit organization established by TV magnate and bison lover Ted Turner. If they get their money, the bison could arrive as early as March 1999. Heeding the *Field of Dreams* mantra, "if you build it, he will come," Zimov last week finished building a fence around the marsh in which the bison will adjust to their new climate.

The scientists expect it will take several years for the animals to churn up and fertilize the ground enough for Pleistocene grasses—present in small patches throughout the park—to become widespread. Even now, Zimov says, the park has enough nutritious grasses and sedge meadows to sustain dozens of horses and bison; in case of a hard winter or unforeseen circumstances, however, he has stockpiled enough forage to sustain 150 big grazers for a few years.

If the bison take to their new environment, Zimov has plans to reintroduce other animals that could make the ecosystem balanced and self-sustaining. For starters, he plans to bring in musk oxen, already restored to central Siberia's remote Taimyr Peninsula. And he would like to bolster the ranks of predators. Already the park is home to a wolf family, but Zimov also hopes to add big cats—such as the Siberian or the Amur tiger, now threatened with extinction due to habitat loss—that would act as surrogates for extinct Pleistocene lions.

All that sounds quite radical, but some ecologists believe it may not be radical enough. Koch, for example, predicts that bison and other grazers won't inflict sufficient damage on the mosses. Mammoths and woolly rhinos, he says, were more effective landscapers, clearing snow, rooting up vegetation, and knocking down bushes and small trees. So Koch suggests that it might make sense to introduce their closest living relatives: Asian elephants and white rhinos. He acknowledges, however, that even if these species were able to adapt to the Siberian climate, "my guess is that most contemporary ecologists and conservation biologists would become apoplectic at the thought of releasing exotic living organisms of this size and ecological consequence."

Even without elephants and rhinos, Zimov's bold plan might seem a fantasy in the grim realities of Russia's downward spiral. Daniil Berman, an entomologist at the Institute for Biological Problems of the North in Magadan, Russia, says with affection, "Sergei is crazy to build Pleistocene Park in our economic situation." But he and others marvel at how Zimov has prevailed so far despite the odds. Anticipating the inflation that would make rubles essentially worthless in the early 1990s, Zimov went on a spending spree, buying everything from wood for posts to a heavy-duty tractor for clearing land for a fence. "Zimov has a brilliant speculative

CREDITS: MUTSUMI STONE

mind, and on the other hand he is a man of action," says Andrei Sher, a Pleistocene expert at the Severtsov Institute of Ecology and Evolution in Moscow.

Zimov also won important allies in the Sakha government. Aware that Sakha could neither rely on subsidies from Moscow nor revenue from its abundant but hard-to-extract nonrenewable resources—gold, diamonds, oil, and natural gas—Sakha President Mikhail Nikolaev has embraced wildlife stewardship as a potential source of meat for the local population and, perhaps, tourist dollars. Although it may be difficult logistically for Russians—let alone foreigners—to get to Cherskii, Zimov predicts that adventure tourists could boost the region's fortunes. "I hope the density of animals in the park in 20 years will be the same as in the Serengeti," he says.

Even if Zimov doesn't manage to create a Siberian Serengeti, the grand ecosystem experiment he is embarking on is likely to keep researchers busy for decades to come. "Scientists are tired of discussing the greenhouse effect," Zimov says with a twinkle in his eye. "Now, maybe it will be interesting for them to discuss ecosystem reconstruction." Sher certainly thinks so: "I am looking forward to the start of this great enterprise."

–RICHARD STONE

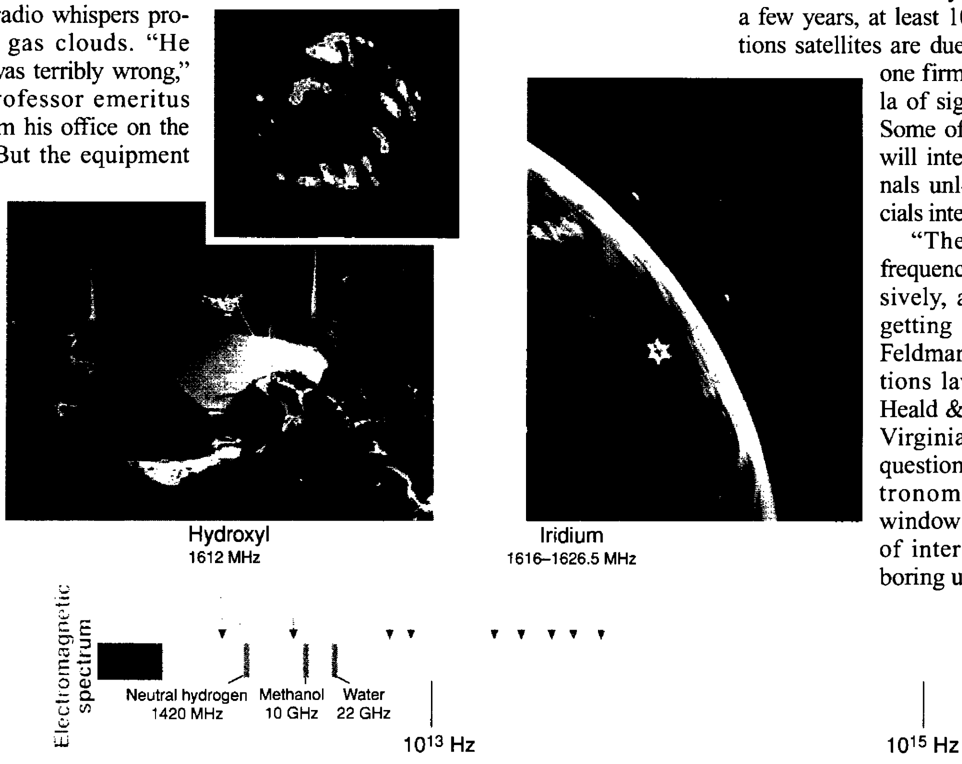
RADIO ASTRONOMY

Iridium Accelerates Squeeze on the Spectrum

A fleet of 66 satellites that will transmit near an important frequency for studies of the cosmos is the latest example of commercial assaults on the radio spectrum

Astronomer Harold Weaver was sound asleep when the phone rang one night in 1963. On the other end of the line was a colleague warning him about strange readings from the University of California's radio telescope in Hat Creek, whose sensitive antennae tracked the natural radio whispers produced by galactic gas clouds. "He thought something was terribly wrong," the 81-year-old professor emeritus recently recalled from his office on the Berkeley campus. But the equipment was working fine: The unexpectedly strong emissions were evidence of the first known natural maser, an intense blast of laserlike, organized radio waves unleashed by molecules excited by cosmic radiation.

Today, Weaver's maser—a signal produced by negatively charged hydroxyl ions composed of hydrogen and oxygen—is one of radio astronomy's most important beacons. The unusually bold spectral line it produces at 1612 megahertz (MHz) on the radio spectrum (see graphic) has led astronomers to new insights into how stars form and die. In particular, the maser's fluctuating intensity allows astronomers to estimate the temperature, composition, and other attributes of galactic gas clouds, including those that serve as stellar nurseries and those ejected by dying red giant stars. Hydroxyl masers are also one of the field's few reliable cosmic yardsticks: By measuring the time delay of the maser's signal between a red star's far and near sides, researchers can estimate the star's diameter and hence its distance from Earth. "The hydroxyl line is a real workhorse that has allowed some spectacular studies," says astronomer James Cohen of the Nuffield Radio Astronomy Laboratories at Jodrell Bank, England.



Electromagnetic smog. Iridium satellites *(right)* produce stray emissions that block important hydroxyl maser signals tracked by radio telescopes, such as the dish in Arecibo, Puerto Rico *(lower left)*. The signals help astronomers understand the gas shells that surround dying stars *(above)*.

Soon, however, astronomers may find that hydroxyl workhorse and other important spectral lines much harder to ride. Celestial signals at a growing number of important points along the radio spectrum are being blocked from Earth-bound telescopes by a blanket of electromagnetic smog laid down by communications satellites. This fall, that blanket will grow thicker when the mobile phone company Iridium LLC turns on a $5 billion, globe-girdling fleet of 66 satellites to serve customers who never want to be out of touch. And Iridium isn't the only threat to parts of the radio spectrum that astronomers once had mostly to themselves. Within a few years, at least 100 other communications satellites are due to be launched, and one firm has designed a flotilla of signal-relaying airships. Some of these new platforms will interfere with stellar signals unless government officials intervene, observers say.

"The demand for radio frequencies is growing explosively, and the spectrum is getting crowded," says Paul Feldman, a telecommunications lawyer with Fletcher, Heald & Hildreth in Rosslyn, Virginia. "Increasingly, the question is whether radio astronomers can keep their windows of discovery clear of interference from neighboring users."

The sound of snowflakes

Astronomers are vulnerable bystanders in the communications revolution because they operate some of the most sensitive passive radio receivers on Earth. Modern radio telescopes can detect distant energy emissions of less than a trillionth of a watt, signals equivalent to the energy ripple generated by a falling snowflake. As a result, some astronomy dishes are notoriously suscepti-

CREDITS: (CLOCKWISE FROM TOP LEFT) CHAPMAN/AAO/ATNF; KILLEEN/ATNF AND VAN LANGEVELDE/JIVE/JODRELL BANK OBSERVATORY; IRIDIUM LLC; NAIC