1 / 18

Discovered by reindeer herders in Siberia, the near-perfect mammoth—frozen for 40,000 years—holds clues to the extinct species.

MAGAZINE

Ice Baby

A near-perfect frozen mammoth resurfaces after 40,000 years, bearing clues to a great vanished species.

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20 MIN READ

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The mammoth herd approaches the rushing river. A calf ambles close to her mother's huge legs, brushing their long, glossy hair now and then with her trunk. The sky is brilliant blue, and a dry wind hisses through the grasses, which billow like oceanic swells across a steppe 10,000 miles wide, spanning the northern arc of the Ice Age world. The long winter is over; birdsong and the scent of damp loam fill the air.

Perhaps the warmth of the sun makes the mother careless, and for a moment she loses track of her calf. The baby wanders toward the water. She stumbles on the slippery riverbank and slides into a slurry of clay, sand, and fresh snowmelt. She struggles to free herself, but every movement drags her deeper. The mud gets in her mouth, her trunk, her eyes; disoriented, she gasps for breath but gets a mouthful of muck instead. Coughing, gagging, caught in a riptide of panic, she makes a dreadful high-pitched shriek that brings her mother running. Inhaling with all her force, the calf sucks the mud deep into her trachea, sealing her lungs. By the time her mother reaches the bank, the baby is partially submerged in the ice-cold mire and flailing feebly, rapidly sliding into shock. The mother screams and mills on the soft bank, drawing the rest of the herd. As they watch, the calf sinks beneath the surface.

Night falls. The herd moves on, but the mother lingers. Yellow moonlight throws her humpbacked shadow across the glistening mud. The moon sets, and stars glow in the chill heavens. Just before dawn, she takes a last look at the spot where the earth swallowed her baby, then turns and follows the herd north, toward summer pastures.

On a May morning in 2007, on the Yamal Peninsula in northwestern Siberia, a Nenets reindeer herder named Yuri Khudi stood with three of his sons on a sandbar on the Yuribey River, holding council over a diminutive corpse. Though they'd never seen such an animal before, they knew it well from stories their people sang on dark winter nights in their storytelling lodges. This was a baby *mamont*, the beast the Nenets say wanders the frozen blackness of the underworld, herded by infernal gods just as the Nenets herd their reindeer across the tundra. Khudi had seen many mammoth tusks, the honey-colored, corkscrew shafts as thick as tree limbs

that his people found each summer. But he had never seen an entire animal, let alone one so eerily well preserved. Apart from its missing hair and toenails, it was perfectly intact.

Khudi was uneasy. He sensed this was an important discovery, one that others should know about. But he refused to touch the animal, because the Nenets believe that mammoths are dangerous omens. Some Nenets even say that people who find a mammoth are marked for early death. Khudi vowed to placate the infernal powers with the sacrifice of a baby reindeer and a libation of vodka. But first he traveled 150 miles south to the small town of Yar Sale to consult with an old friend named Kirill Serotetto, who was better acquainted with the ways of the outside world. Serotetto listened to his friend's story, then bustled him off to meet with the director of the local museum, who persuaded the local authorities to fly Khudi and Serotetto back to the Yuribey River in a helicopter.

When they arrived on the sandbar, however, the mammoth had vanished.

Mammoths are an extinct group of elephants of the genus *Mammuthus*, whose ancestors migrated out of Africa about 3.5 million years ago and spread across Eurasia, adapting to a range of woodland, savanna, and steppe environments. The best known of these proboscideans is the woolly mammoth, *Mammuthus primigenius*, a close cousin of living elephants and about the same size. It first appeared in the middle Pleistocene more than 400,000 years ago, probably in northeastern Siberia. The woolly mammoth was highly adapted to cold, with a dense undercoat, guard hairs up to three feet long, and small, fur-lined ears. Immense curving tusks, used primarily for fighting, may have also been handy for foraging beneath the snow. Because mammoths often died and were buried in sediment that has been frozen ever since, many of their remains have survived into modern times, particularly in the vast deep freeze of Siberian permafrost.

In fact, the Nenets' underworld tales are right: The Siberian subsoil teems with woolly mammoths. At ice-out each summer, hundreds of their tusks, other teeth, and bones appear on the banks of rivers and lakes and along the seacoast, freed by erosion from the frozen ground where they have lain for tens of thousands of years. Since the botanist Mikhail Ivanovich Adams recovered the first woolly mammoth carcass in Siberia in 1806, about a dozen other soft-tissue specimens had been found, including several calves ranging in age from newborn to about a year. Yet no carcass of any age was as complete as the creature Yuri Khudi had found—and now lost—on the Yuribey River.

In the time of the mammoths, the landscape over most of their range looked very different than the barren heaths and boggy tundra surrounding the river today. The air was drier, cloud cover was limited, and strong winds swept the electric blue skies. In place of tundra grew a vast, arid grassland that paleobiologist R. Dale Guthrie has called the mammoth steppe, stretching from Ireland to Kamchatka and across the Bering land bridge to Alaska, the Yukon, and much of North America. The grasses, broad-leaved herbs, and low shrubs of the steppe provided nutritious food, and in addition to mammoths, nourished a profusion of other outsize, exuberantly hairy mammalian megafauna—woolly rhinoceroses, enormous long-horned bison, and bear-size beavers, as well as the fearsome carnivores that hunted them: saber-toothed cats, cave hyenas, and giant short-faced bears.

Then, between 14,000 and 10,000 years ago, the mammoths disappeared from most of their range, along with most of the other large mammal species in the Northern Hemisphere—as many as 70 percent in some regions. These extinctions were so sweeping that scientists have evoked a

number of cataclysmic events to explain them—a meteorite strike, killer fires and droughts, and a virulent, cross-species hyperdisease. Since the extinctions coincided with the end of the most recent ice age, however, many researchers believe that the primary cause of the great die-off was the sharp rise in temperature, which dramatically altered the vegetation. A recent computer simulation of landscape changes during the late Pleistocene suggests that 90 percent of the mammoth's former habitat disappeared. "We have strong evidence that climate change played a significant part in their extinction," says Adrian Lister, a paleontologist and mammoth expert at the Natural History Museum in London. "In Eurasia, the timing of the two events matches closely."

The extinctions also coincided, however, with the arrival of another ecology-altering force. Modern humans arose in Africa about 195,000 years ago and spread into northern Eurasia some 40,000 years ago. As time went on, their expanding populations brought increasing pressure to bear on prey species. In addition to exploiting mammoths for food—a big male killed in the autumn would see a band of hungry hunters through many lean winter days—they used their bones and ivory to make weapons, tools, figurines, and even dwellings. Some scientists believe that these human hunters, using throwing spears fitted with deadly stone points, were as much to blame as climate change for the great die-off. Some say they caused it. The debate over the megafaunal extinction is one of the liveliest in paleontology today, and not one likely to be resolved by a single specimen, no matter how complete. But Khudi was right that the now missing baby—its flesh, internal organs, stomach contents, bones, milk tusks and other teeth, all intact—would be of enormous interest to the outside world.

He also suspected that a person willing to handle such a thing would probably turn a nice profit—ivory traders regularly visited the region to buy mammoth tusks, and who knows what they'd pay for an intact mammoth? Khudi's suspicions soon fell on one of his own cousins, whom some local Nenets had seen on the sandbar and later, riding away on his reindeer sled toward the town of Novyy Port.

Khudi and Serotetto set off in pursuit on a snowmobile. When they arrived, they found the little mammoth propped up against the wall of a store. People were taking snapshots of it on their cell phones. The shop owner had bought the body from Khudi's cousin for two snowmobiles and a year's worth of food. Though it was no longer quite perfect—stray dogs had gnawed off part of its tail and right ear—with the help of some local police, Khudi and Serotetto managed to reclaim the infant. The body was packed up and shipped by helicopter to the safety of the Shemanovsky Museum in Salekhard, the regional capital.

"Luckily there was a happy ending," says Alexei Tikhonov, director of the St. Petersburg Zoological Museum and one of the first scientists to view the baby, a female. "Yuri Khudi rescued the best preserved mammoth to come down to us from the Ice Age."

Grateful officials named her Lyuba, after Khudi's wife.

Tikhonov knew that no one would be more excited by the find than Dan Fisher, an American colleague at the University of Michigan. Fisher is a soft-spoken, 59-year-old paleontologist with a bristly white beard and clear green eyes who has devoted much of the past 30 years to understanding the lives of Pleistocene mammoths and mastodons, combining fossil studies with some very hands-on experimental research. Curious to know how Paleolithic hunters managed to store mammoth meat without spoilage, Fisher butchered a draft horse using stone tools he'd knapped himself, then cached the meat in a stock pond. Naturally preserved by microbes called lactobacilli in the water, the flesh emitted a faintly sour, pickled odor that put off scavengers even when it floated to the surface. To test its palatability, Fisher cut and ate steaks from the meat every two

weeks from February until high summer, demonstrating that mammoth hunters might have stored their kills in the same way.

Tikhonov invited Fisher to Salekhard in July 2007, along with Bernard Buigues, a French mammoth hunter who had helped arrange scientific study of several previous mammoth discoveries. Both Fisher and Buigues had examined several other specimens, including infants. But they were in relatively poor condition, and little hands-on work was possible. Lyuba was another story entirely.

“When I saw her,” Fisher says, “my first thought was, Oh my goodness, she’s perfect—even her eyelashes are there! It looked like she’d just drifted off to sleep. Suddenly, what I’d been struggling to visualize for so long was lying right there for me to touch.” Other than the missing hair and toenails, and the damage she’d sustained after her discovery, the only flaw in her pristine appearance was a curious dent in her face, just above the trunk. But her general appearance and the healthy hump of fat on the back of her neck suggested the baby had been in excellent condition at the time of her death. A deeper examination into her teeth, internal organs, stomach contents, and other features promised to reveal a wealth of new information on normal mammoth biology and lifeways.

Fisher was particularly excited about one specific part of Lyuba’s anatomy: her milk tusks. Tusks are modified incisors that grow continuously in layers throughout an animal’s life. Over 30 years of studying mammoth tusks, Fisher had figured out that these deposits were laid down in yearly, weekly, and even daily increments, and that, like the rings of a tree, they contained a detailed record of the animal’s life history. Thick layers represented rich summer grazing, while thin ones indicated sparse winter fare. From a sudden narrowing of the strata around the 12th year, Fisher could discern when a young male became sexually mature and was driven away by its mother from the matriarchal herd; some years later came signs of the ferocious musth battles that adult males waged to determine who would win the opportunity to mate. Finally, in the layers at the root of the tusk that are the last to form, Fisher found clues to how an animal died—a slow dwindling caused by injury, illness, or environmental stress, or the sharp break of sudden death. He also found that the levels of certain chemical elements and isotopes in the tusks provided data on the animal’s diet, climatic situation, even major changes in location such as migration.

Through his career Fisher has taken hundreds of tusk samples, and he believes they suggest an answer to the vexing question of the great extinction in the late Pleistocene. At least in the Great Lakes region of North America, where the bulk of his samples were unearthed, mammoth and mastodon tusks show that these animals continued to thrive, despite late Pleistocene climate change. On the other hand, to Fisher, the tusks often revealed telltale evidence of human hunting. His samples from late in the mammoth’s reign frequently came from animals that had died in the autumn, when they should have been at their physical peak after summer grazing and less likely to die of natural causes—but also when human hunters would have been most eager to stockpile food for the coming winter. These tusks often came from males, who, like living elephants, probably lived alone and would have made easier targets for hunters than females traveling in matriarchal herds. Many remains were found in peat bogs and bodies of water, where according to Fisher early hunters may have submerged them to preserve the meat. The North American specimens also appeared to show a decline through time in the average age of maturation, which Fisher believes might also be caused by hunting pressure. He had done limited work in Siberia, but his measurements of tusks from Wrangel Island, off the coast of northeastern Siberia, where the last mammoths died out 3,900 years ago, suggest similar conclusions.

One problem with interpreting mammoth tusks, however, was that they almost never came with mammoths attached, making it hard for Fisher to test his inferences about health and age. Lyuba’s superb state of preservation promised to change that. By giving direct evidence of her diet

and state of health, her stomach and intestinal contents and the amount of fat on her body could provide an independent corroboration of the brief dietary "journal" recorded in her still unerupted milk tusks. "In this case we don't need a time machine to see how accurate our work is," Fisher says. Moreover, since the milk tusks grow from early in gestation to around the time of birth, Lyuba could shed new light on a critical period in a mammoth's life: the time in the womb (estimated to be 22 months, based on an elephant's gestation length), followed by birth. A traumatic event for any mammal, the moment of birth is recorded in tooth microstructure by a distinct neonatal line. By comparing her milk tusk development with that of elephants, the scientists initially estimated her age at death to be four months. Counting the increments of ivory laid down after the neonatal line would provide a much more accurate age.

Fisher was also intrigued by the forensic mystery of how and why such an apparently healthy young life had been cut short—and whether it had anything to do with the odd deep dent in her face. "That feature immediately leaped out, though at the time I had no idea what to make of it," Fisher says.

To begin the analysis, tissue samples from Lyuba were sent to the Netherlands, where carbon-14 dating revealed she had died some 40,000 years ago. For scientists to probe deeper into her life, however, she would have to travel herself. In December 2007 Buigues arranged for the specimen to be transported to Japan by refrigerated container to undergo a CT scan by Naoki Suzuki of the Jikei University School of Medicine. The test confirmed her skeleton, teeth, and soft tissues were undamaged, and her internal organs seemed largely intact. The end of her trunk and her throat, mouth, and windpipe were filled with dense sediment, which suggested to Fisher that she had died by asphyxiation in mud. The scan also revealed some odd x-ray-opaque blobs in her soft tissues and a distortion of certain bones. These anomalies underscored another conundrum: After 40 millennia in the ground—and who knows how long exposed on the surface—why was she so well preserved?

Lyuba's remarkable condition appeared all the more mystifying in May 2008, when Fisher and Buigues visited the Yuribey River. Just upriver from the sandbar where she'd been found stood a high, sheer bluff, which was being steadily undercut by the river. Blocks of permafrost, some as big as houses, hung out over the rim of the bluff. Perhaps Lyuba had been frozen in such a block that had collapsed into the water during the previous thaw, floated downstream, and come to rest on the sandbar when the thaw-swollen river had briefly risen to that level. There was only one problem: Yuri Khudi's sons had found her there in May 2007, before the spring ice-out. Unless she had risen from the underworld and walked up onto the bar on her own, the only explanation was that she had broken out of the permafrost and come to rest there nearly a year before she was discovered, during the ice-out of June 2006. To Fisher, standing on the spot two years later, it just didn't make sense.

"She'd have been lying on this riverside all that time," he said to Buigues, "including an entire summer exposed to the sun. So why hasn't she decomposed or been scavenged?"

Fisher and Buigues had done what they could to understand the circumstances of the calf's death and mysterious preservation. Further answers would have to come from Lyuba herself.

On June 4, 2008, in a genetics laboratory in St. Petersburg, Russia, Fisher, Buigues, Suzuki, Alexei Tikhonov, and other colleagues, dressed in white Tyvek suits and surgical masks, began a marathon, three-day series of tests and surgical procedures on Lyuba. As she lay on a Plexiglas light table in the middle of the room, Suzuki inserted an endoscope into her abdominal cavity, to explore an open space he'd seen during the CT scan. Other scientists used an electric drill to take a core sample of the hump of fat on the back of her neck, searched for mites in her ears and hair, cut into her

abdomen, and removed sections of her intestine to study what she had been eating. Finally, on the third day, Fisher cut into Lyuba's face and extracted a milk tusk, as well as four premolars.

Initially the researchers kept her frozen by surrounding her with plastic tubs of dry ice. Later, to facilitate the more invasive procedures, they allowed her to slowly thaw out, carefully monitoring her for signs of putrefaction. As her flesh warmed, Fisher noticed an odd, slightly sour smell, which he found familiar but couldn't quite place. "Like everybody else, I was suffering from sensory overload," he remembers. "We had to cram so much work into so little time. I just made a mental note and moved on." He also noticed that the mammoth's teeth were not held in their sockets by the usual connective tissue, and her muscles had separated from the bone in places where, in a normal specimen, they would have been firmly bonded. "That totally blew me away," Fisher says. "I kept asking myself, What's going on here? What does this mean? But there wasn't much time for reflection."

The x-ray-opaque areas visible on the CT scan turned out to be brilliant blue crystals of vivianite, probably formed from phosphate leached out of her bones. Fisher noted a dense mix of clay and sand in her mouth and throat, which would support the hypothesis from the CT scan that she'd suffocated, probably in river-bank mud. In fact, the sediment in Lyuba's trunk was packed so tightly that Fisher saw it as a possible explanation for the dent in her face. If she were frantically fighting for breath and inhaled convulsively, perhaps a partial vacuum was created in the base of her trunk, flattening its soft tissues against her forehead.

To Fisher, the circumstances of Lyuba's death were clear. (Suzuki would later propose a different interpretation, seeing more evidence for drowning than asphyxiation.) At the end of the autopsy, while Fisher and his colleagues were suturing up her little body, he also had a revelation about her peculiar smell. His mind at last relaxing after the intense effort of the past three days, he suddenly remembered his experiment with the draft horse and the smell that its bloated chunks of flesh, naturally pickled by lactobacilli, emitted as they bobbed on the surface of the pond. Lyuba had the same smell. Finally, her superb state of preservation made sense. She had literally been pickled after she died, which protected her from rot once her body was exposed again, thousands of years later. The lactic acid produced by the microbes also could have caused the odd bone distortion and muscle separation that Fisher had noticed during the autopsy, and perhaps even encouraged the formation of vivianite crystals by freeing phosphate from her bones.

So Lyuba was probably killed by a misstep in or near a muddy river, and preserved for science by a combination of biochemical serendipity and the singular resolve of a Nenets herder. Though studies are ongoing, she has also begun to shed the secrets of her short life and some clues to the fate of her kind. Her healthy, well-fed state was echoed in the record of her dental development, a gratifying confirmation for Fisher that such dental records are a faithful proxy for evaluating health on the basis of teeth alone—and thus key to investigating the causes of mammoth extinction. Analysis of her well-preserved DNA has revealed that she belonged to a distinct population of Mammuthus primigenius that, soon after her time, would be replaced by another population migrating to Siberia from North America. On a more intimate scale, Lyuba's intestine contained the feces of an adult mammoth, probably her mother's: evidence that mammoth calves, like their modern elephant cousins, ate their mother's feces to inoculate their guts with her microbes in preparation for digesting plants.

Finally, Lyuba's premolars and tusk revealed she had been born in the late spring and was only a month old when she died. The last layers of her tusk matched the pattern that Dan Fisher associates with accidental death: a series of even, prosperous days, coming to an abrupt end.