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PALEONTOLOGY

Siberian Mammoth Find Raises Hopes, Questions

In the first-ever operation of its kind, a team working in Siberia has excavated a huge chunk of permanently frozen sediment containing what it hopes are the remains of a woolly mammoth that died 20,000 years ago. On 17 October the crew airlifted the 22-ton block of tundra to a cavern hewed from the ice on Russia's Taimyr Peninsula, where scientists plan to thaw the block next spring to study what's left of the extinct beast inside—and perhaps even mount an effort to clone it. Expectations are high, but one Russian expert involved in the made-for-TV expedition is pessimistic: He contends that the find's significance has been exaggerated, and the team may end up with little more than 22 tons of dirt and meltwater.

If a carcass is indeed hidden in the ice, it won't be the first time the woolly mammoth, which made its last stand on an island in the Arctic Ocean about 3800 years ago, has seen the light of modern day. Several intact carcasses have been unearthed in the past 2 centuries—including a now-famous baby mammoth, nicknamed Dima, found in 1977—but some were already dried out and others quickly spoiled upon exposure to above-freezing temperatures. The latest find, claims paleontologist Larry Agenbroad of Northern Arizona University in Flagstaff, "is a first to bring an entire frozen organism out of the tundra complete."

The story began 2 years ago, when a family of nomadic reindeer herders dug up two huge mammoth tusks, each more than 2 meters long, protruding from the permafrost. The tale reached the ears of Bernard Buigues, an explorer with a Paris-based tourist firm called Polar Circles Expeditions, which uses the Taimyr capital, Khatanga, as a base for air and ski adventures to the North Pole. The native Dolgans led Buigues to the site near the Bolshaya Balakhnya River last year, where he recovered portions of the fractured mammoth skull, including pieces of hair, skin, and bone later used by researchers at the University of Utrecht in the Netherlands to date the remains. Buigues then organized a $2 million expedition—funded largely by the Discovery Channel, which is preparing a documentary on the Siberian adventure to air in March—to excavate the presumed carcass, called the Jarkov mammoth after the family that found the tusks.

Tusks aweigh! Dick Mol in front of permafrost block before it was airlifted *(inset)* to Russian lab.

Starting work last month in sometimes bitterly cold, windy conditions, Dolgan workers used jackhammers to carve around and under the 3-by-2-meter permafrost block thought to contain the mammoth, then slid an iron support beneath it. They prepared to haul it out of the ground by helicopter. At first the permafrost was going nowhere. "It seemed impossible to lift," Buigues told reporters last week. At last the block, with the two original tusks stuck into it to improve the TV images, rose up into a clear blue sky. It was then flown more than 300 kilometers to Khatanga for storage in an ice cave with a constant temperature of about 15 degrees Celsius below zero.

Starting next spring, scientists plan to use blow dryers to thaw the block and find out how much of the mammoth—known from its tusks to have been a male and from its teeth to have been about 47 years old—might be inside. "We have not yet seen any of the flesh or organs or so on," says Agenbroad, but ground-penetrating radar readings by Buigues indicate that substantial portions of the mammoth may remain. Not covered by glaciers during the last Ice Age, the Bolshaya Balakhnya region is a well-known graveyard for mammoths, woolly rhinos, and other extinct creatures, says Andrei Sher of the Institute of Ecology and Evolution in Moscow. If the radar does detect remains, says Sher, it will be a "powerful new tool that we could only dream about before."

But Alexei Tikhonov, a mammoth expert at the Institute of Zoology in St. Petersburg, Russia, says he doubts the block contains much of the beast. Tikhonov, who spent a week at the site last month, says only the top 80 centimeters of permafrost in the excavated block consists of sandy earth that's likely to preserve tissues; the remainder is an ice wedge that, he argues—based on 15 years of fieldwork on the tundra—is unlikely to contain remains, as it is a crack that widened slowly as it filled with snow and water. Moreover, the few bones found at the site are "very clean," with no signs of attached muscle. "All of this suggests that the find is not very important, not interesting for science," Tikhonov told *Science*. However, Tikhonov was not on site when the team worked around the clock for 3 days to thaw the top few centimeters of the block for the sake of the TV crew, says Dick Mol, a highly respected amateur Dutch paleontologist. "I was against this idea," says Mol, but the dryers did reveal lush gray and yellow hair that appeared to be rooted in flesh. "For me this is evidence there must be much more."

If Tikhonov is proved wrong, a nonprofit organization called Mammuthus, founded by Buigues, will oversee scientific studies of the remains in a cold lab open to researchers. One tantalizing long shot would be well-preserved sperm or other cells containing viable DNA that would allow scientists to attempt to resurrect the species. They could inject sperm into the egg of a close relative—the Asian elephant—to try to create a hybrid, or perhaps even attempt to clone a pure mammoth by fusing the nucleus of a mammoth cell with an elephant egg cell stripped of its DNA. According to Agenbroad, a reputable U.S. lab experienced in elephant breeding has already

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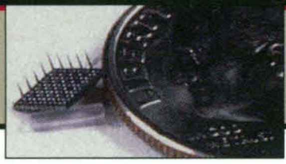
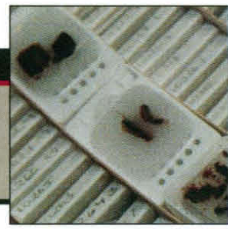




expressed interest in teaming up with Mammuthus. They aren't the only ones interested in resurrecting a mammoth: A Japanese team hopes to pull off a similar feat with mammoth remains it unearthed this summer in another region of Siberia.

Even if the Jarkov mammoth yields subpar tissue, scientists expect to learn more about the mammoth's habitat from plant material found underneath the permafrost block. And by keeping the remains at subzero temperatures for as long as possible, scientists hope to extract pathogens that could have contributed to its death. "People will speak of this discovery 100 years in the future," predicts Mol. Provided, that is, something emerges from the ice when the dryers are turned off.

–RICHARD STONE

EVOLUTIONARY GENETICS

The Why Behind The Y Chromosome

The human Y chromosome may be best known as a champion testosterone booster, but its functional powers are puny compared to those of its partner, the X chromosome: It is only one-third the size of the X and has only 1/100th as many genes. Despite this mismatch, scientists have long suspected that the X and Y were once equals, but they gradually diverged over time. Now, on page 964, two researchers report evidence for how this split occurred.

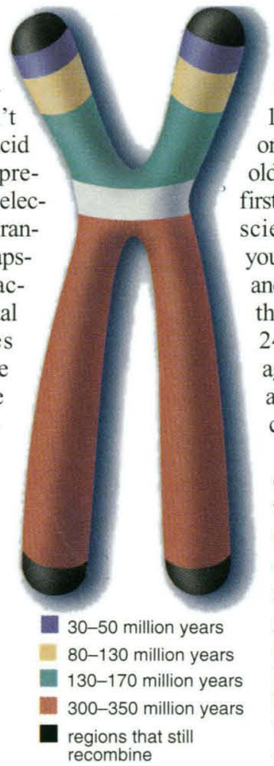
In a kind of molecular-scale fossil dig, geneticists David Page of the Whitehead Institute for Biomedical Research at the Massachusetts Institute of Technology and Bruce Lahn, now at the University of Chicago, analyzed genetic "fragments of history"—genes still found on both chromosomes that have remained relatively unchanged for millennia. They used these genetic relics to piece together a rough history of how the chromosomes drifted apart. The distinctions between X and Y didn't happen gradually, they concluded, but in a stepwise fashion, implying that at least four distinct events—most likely rearrangements of the Y chromosome—drove the chromosomes apart over hundreds of millions of years.

"It's fascinating work," says geneticist Huntington Willard of Case Western Reserve University School of Medicine in Cleveland. "It gives us an intriguing glimpse" into the evolution of the human sex chromosomes. The work may also shed light on the evolution of the sex chromosomes of birds and insects, which developed independently of the mammalian system.

The mismatch between the X and Y chromosomes creates some unusual biology. During the specialized cell division that creates sperm and eggs, most chromosome pairs are able to line up and swap pieces, a process called recombination. Like two friends who keep in touch despite being separated by long distances, this occasional exchange keeps the pairs up to date with each other. It also creates beneficial combinations of genes that can spread throughout the population. But recombination won't work if the pairs are a poor match, and in humans, the X and Y chromosomes recombine only at their tips.

Although X and Y look very different, in recent years geneticists have turned up at least 19 genes that are present on both—all of them leftovers from the days when the chromosomes were kept similar by recombination. Lahn and Page scored each gene pair for sequence similarity, focusing on the number of "synonymous" gene differences between them—changes in DNA that don't change the protein's amino acid sequence. These mutations presumably are subject to little selective pressure and accumulate randomly. Thus, as more time elapses, more mutations should accrue. If so, the number of actual synonymous gene changes should offer a rough estimate of the length of time that the genes have been evolving independently, Page explains.

When the researchers looked at this value for different parts of the chromosomes, they were "stunned," says Page. He wasn't expecting a clear pattern, but in fact the values for genes on the X chromosome grouped into four "strata" neatly arrayed along the chromosome's length. The genes on the chromosome's long arm were most different from their Y counterparts, and as the scientists examined the opposite end of the chromosome, the genes became more and more similar to their Y doubles.



Layers of meaning. The X chromosome diverged from the Y in four stages, as reshuffling on the Y prevented the exchange of genes between the X and Y. Colors indicate when each section diverged.

SOURCE: MODIFIED FROM B. LAHN AND D. PAGE; ILLUSTRATION: C. CAIN

To explain this pattern, Lahn and Page propose that the Y chromosome was reshuffled four times, perhaps through a process called inversion, in which a piece of chromosome breaks off, flips over, and reattaches so the order of the genes in that stretch is inverted. Each inversion prevented a stretch of the Y from aligning and exchanging pieces with the matching piece on the X. After all four inversions, the X and Y can now recombine only at their tips.

To get a rough estimate of when these inversions occurred, the scientists used divergence times that are known from fossils and genetic evidence. For example, two gene pairs in the fourth "stratum" of the X chromosome are still able to recombine in prosimians but have diverged in both Old and New World monkeys, so Lahn and Page estimated that the most recent reshuffling happened between 30 million and 50 million years ago, after monkeys diverged from prosimians but before New and Old World monkeys split. In a similar way, they estimate that the third inversion happened between 80 million and 130 million years ago and the second between 130 million and 170 million years ago. But because only a few genes remain similar in the oldest "layer," estimating the age of the first rearrangement was tougher. So the scientists used the ages of the three youngest strata as a rudimentary clock and concluded that the oldest section of the chromosomes diverged between 240 million and 320 million years ago—shortly after birds and mammals are thought to have split from their common, reptile-like ancestor.

Such a scenario fits with the biology of animals today: Many reptiles lack specific sex chromosomes (depending instead on temperature differences during development to modulate individual sex-determining genes), and presumably the reptilian ancestor of birds and mammals lacked sex chromosomes, too. In birds, the avian sex chromosomes, W and Z, seem to be derived from the chromosome pair that is today number nine in humans.

Indeed, "everything seems to fit together," says evolutionary biologist Brian Charlesworth of the University of Edinburgh. The result is "really pleasing," agrees evolutionary biologist James Bull of the University of Texas, Austin,