

Secrets of the Alpaca Mummies

Did the ancient Inca make the finest woolen cloth the world has ever known?

By Heather Pringle

Photographs by Grant Delin

In November 1533, Francisco Pizarro rode triumphantly into Cuzco, the royal capital of the Inca empire, and took stock of its storied treasures. With just 180 hardened soldiers of fortune at his command, the cunning Spanish conquistador had ambushed—and then executed by strangulation—the emperor Atahualpa, prompting the royal Inca army of 30,000 to retreat. Pizarro, a former foundling and swineherd, could scarcely believe the booty that awaited him. Some of his men had already pried loose golden plaques from the temple of the sun and filled their saddle packs with silver statues. They had stripped golden masks and staffs from the mummified bodies of Inca sovereigns and eyed the vast estates they would soon claim for their own. But Pizarro and his plundering band of adventurers ignored perhaps the greatest treasure of all: the rare and luxurious fabrics that were the foundation of Inca wealth.



Shearing clippers lie forgotten amid a tangle of coarse fleece in a modern Peruvian fiber factory. Nearly half of Peru's alpacas produce fleece that is either unusable or suitable only for rough blankets. But the alpaca mummy (right) had fleece fine enough to make fabric fit for royalty. The alpaca, a two-year-old male, was buried 1,000 years ago with a color-matched guinea pig offering placed on its chest.
Photo by Grant Delin

The Inca were cloth makers, the likes of whom Europe had never known. Inca weavers made bridges from cords, wove roofs from fibers, and counted their wealth not in scribbles on a page but in patterns of knots on woolen strands. And they wove a woolen fabric from the fleece of the alpaca, a small, slender member of the camel family, that was so soft and alluring it was prized above almost all else in the highland empire centered in what is now Peru. Among the people of the Andes, cloth was currency. Inca emperors rewarded the loyalty of their nobles with gifts of soft fabric made by expert weavers. They gave away stacks of fine woolen textiles to assuage the pride of defeated lords. They paid their armies in silky smooth material. For an emperor intent on glory, as most Inca emperors were, cloth making was a major enterprise of state. The imperial textile warehouses were so precious that Inca armies deliberately set them afire when retreating from battle, depriving their enemies of that which made them strong.

Pizarro and his comrades had crossed an ocean in quest of glittering gold and silver, not fabric. And the viceroys who succeeded Pizarro were similarly oblivious. In the chaos and devastation that

followed the Spanish conquest, the soft seductive cloth coveted by Inca royalty disappeared with the Inca themselves. Meanwhile, all across remote Andean valleys, once prosperous villages fell into a poverty that has endured for five centuries.



El Yaral and Chiribaya Alta, two sites where naturally desiccated alpaca and llama mummies were found, are located in one of the driest places on Earth—a coastal desert that receives less than four fifths of an inch of water annually.
Graphics by Matt Zang



The fabled fabric of the Inca was seemingly lost forever until Jane Wheeler, an American archaeozoologist, made a surprising discovery a decade ago while examining some mummified alpacas and llamas that her colleagues had unearthed in the small pre-Columbian village of El Yaral. The ancient animals were almost perfectly preserved, right down to the fringes of their eyelashes. "It was just incredible," recalls Wheeler. "The animals were invaluable, a thousand years old and still intact." When Wheeler later examined skin samples from the animal mummies in microscopic detail, she noticed something more remarkable. The ancient fibers of the alpacas' fleece were as soft as a baby's hair compared with that produced by the alpacas that are ubiquitous in modern Peru. If only Peruvians could resurrect these lost breeds, she mused, they could produce textiles rivaling cashmere and, in the process, lift themselves out of poverty.

Wheeler took up the crusade. She knocked on embassy doors, cultivated Peruvian textile manufacturers, buttonholed politicians, and mustered an international team of geneticists and biodiversity experts. Today Peru is still years away from reproducing those pre-Columbian animals or producing Inca-quality cloth, but Wheeler has clearly proven that her quest is not quixotic. She has established a major alpaca DNA bank in Lima, shed light on the mysterious origins of the alpaca, devised tests for discerning alpaca hybrids from purebreds, and mapped out a project to search for the alpaca's fine-fiber gene. "She's worked extremely hard," says English archaeozoologist Juliet Clutton-Brock, the managing editor of the *Journal of Zoology* and one of the world's leading authorities on the origins of animal domestication, "and she's produced some excellent results."



A typical burial shroud of the Chiribaya people, precursors of the Inca, features elaborate llama icons. Lice clung to llama fleece (below) found in one grave, suggesting that the Chiribaya were canny ritualists who sacrificed diseased or inferior animals to the gods and saved the healthy ones.

Photo by Grant Delin

Wheeler, 57, is a visiting professor at San Marcos University in Lima and supports her research by stringing together grants. In her small, cluttered office in a veterinary science building, she fumes as she lists some of the recent obstacles she's encountered in her work: recalcitrant Peruvian customs officials who refused to clear the expensive radioactive isotopes she needed for DNA testing; thieves who made off with her camera and best lens; and an absentminded laboratory assistant who blew the power supply of an expensive American machine for analyzing DNA by plugging it into a 220-volt Peruvian outlet. Wheeler takes each setback personally. "Sometimes I really feel like quitting," she says, shaking her head.



What keeps her going is a love of Peru and its alpacas. Wheeler's office is just around the corner from a campus clinic that tends to alpacas. Her Peruvian husband, a veterinary pathologist, is an expert on the quarantine of alpacas. Wheeler dines regularly on alpaca meat, preferring it to beef, dresses in alpaca-wool sweaters, and sports an alpaca brooch. Her 4-year-old son Daniel has spent so much time in the company of alpacas that he has assumed some of their manners. When he gets angry, he spits.

Before her encounter with mummified alpacas, however, Wheeler had no inkling that living alpacas would become such a fundamental part of her life. A decade ago, while a professor of anthropology at the University of Colorado at Boulder, she was analyzing ancient animal bones in Peru when archaeologist Gloria Salinas invited her to see El Yaral's dusty mummies. Buried beneath house floors for nearly 1,000 years, the alpacas and llamas had grazed El Yaral's pastures 500 years before the rise of the Inca empire. With their legs folded under them and their heads craned across their shoulders, they looked like a sleeping herd. For Wheeler, who had devoted her career to counting and measuring tiny fragments of bone, the sight of ancient animals with their nubbles of shorn fleece and their long, lank ears was a shock. "I was really afraid to touch the mummies," she recalls. "I had no experience working with them." Curiosity, however, won out. Aging and sexing each of the alpacas and llamas, she searched for signs of disease and injury and took tissue samples. Most of the animals were male and under two years of age, and all but one had died from a conchoidal fracture of the skull made by a vigorous blow with a hard object. Almost certainly, says Wheeler, the animals were ritually sacrificed by El Yaral's inhabitants. People in the Andes still sacrifice adult llamas for the gods and bury llama fetuses beneath their houses as sacred offerings.

Wheeler snipped off bits of skin and fiber from 11 standard spots on each mummy and took them with her on a visit to the Macaulay Land Use Research Institute in Aberdeen, Scotland. There laboratory researchers individually mounted 200 fibers from each sample on slides and measured them by means of a projection microscope. As the data rolled in, Wheeler was amazed. El Yaral's animals were remarkably uniform in both color and fiber size. And their fleece was astonishingly fine. Indeed, some alpacas possessed uniform fibers of 17.9 micrometers— 4 micrometers, or sixteen hundred-thousandths of an inch, smaller in diameter than those of a modern alpaca.

This minuscule difference holds enormous economic implications. Among woolen manufacturers, the finer the fiber, the softer the fabric and the higher the price. Cashmere fiber, for example, measures just 16 micrometers in diameter. As a result, it has become one of the world's most desirable woolens, fetching about \$70 a pound. By comparison, the slenderest alpaca fiber today measures 22 micrometers and commands only \$9 a pound. But even that high quality fiber is uncommon. More than 90 percent of all modern alpaca fleece is considerably coarser, bringing only a few dollars per pound.

Wheeler was completely taken aback by the quality of El Yaral's ancient llamas' fleece as well. In Peru today, llamas possess fiber so coarse and scratchy that it is rarely used for textiles. Most Peruvians employ llamas strictly as pack animals. But the llamas of El Yaral felt silky to the touch and their fiber gleamed lustrously. Wheeler's analysis showed why. Many of the animals had a uniform fleece of 22.2 micrometers, as fine as the best alpaca. Moreover, as Wheeler could see from the unshorn animals, some had been walking fiber factories. One 12-month-old llama, for example, had grown fibers seven inches long— a length only reached in modern animals at 24 months.

Such a desirable combination of traits was unlikely to have come about by chance. Wheeler believes the early Andeans had selectively bred their herds to supply the exact needs of an ancient textile industry. And her theory has been borne out by the calculating way in which families at El Yaral and at a neighboring site, Chiribaya Alta, chose animals for sacrifice and burial. They seldom slaughtered healthy, sexually mature animals. Instead they culled very young males, a choice that made perfect sense from an animal-breeding point of view. Only a few top-quality-fiber males were needed as studs for the females in a herd. The remaining males could be safely weeded out and butchered at a young age. "So maybe what we're looking at in the mummies are the animals whose fiber isn't good enough," Wheeler says. "And if these are the animals they sacrificed, they had better ones."

In Wheeler's view, the Inca who later ruled the region were likely to have been just as skilled as the herders of ancient El Yaral. The Spanish chronicles make several brief mentions of their prowess as breeders. The priests of Cuzco, for example, required animals of specific colors for various sacrificial rites, which included slowly starving llamas to death in the city's central square so the gods would hear their screams and let loose the rains. To supply ritualists with exactly what they needed, Inca breeders raised pure white, black, and brown stock. "Given such rigorous demands," says Wheeler, "it's likely that specific llama and alpaca breeds were maintained."

All Wheeler's research pointed to one conclusion: A critical secret of the wondrous cloth of the Andes lay in the tiny fibers of these animals' coats.



Archaeozoologist Jane Wheeler examines a mummified suri, a variety of llama that has virtually disappeared in Peru. The suri was found at El Yaral (below). Holes dug where houses once stood exposed 26 mummified alpacas and llamas among offerings of beads, feathers, and silver plaques. Photo by Grant Delin



On a sunny austral morning, Wheeler surveys a stone corral filled with the bobbing white heads of hundreds of alpacas. Up since five and plagued by a nasty head cold, she has spent the morning taking a photographer into the mountains outside Arequipa to see a sparse wild herd of vicuña, the smallest of the four camelid species that inhabit the Andes. Frustrated by their wariness, she has stopped on the drive back to check out a large herd of alpacas. Jammed head to tail inside a roadside corral, the fuzzy long-necked animals seem almost to vibrate, making a humming sound curiously akin to the swarming of a beehive. Wheeler watches intently as herders in threadbare jeans begin releasing animals through a narrow gate, sifting out two dozen or so marked individuals. Despite their nearly identical white coats, the milling animals each possess a striking individuality. "If you look long enough," says Wheeler with a smile, "you can see the face of everyone you have ever known in these herds."

In the cold, thin air, the herders wrap their arms around the chosen animals, wrestling them into compliance. Then they half push, half carry them toward a waiting truck that will take them to crossbreed with alpacas in other herds. One of the herders, a local veterinarian, approaches Wheeler. Slipping off his dusty baseball hat, he smiles. "Jane Wheeler," he says, "Jane Wheeler." A note of awe creeps into his voice. "I heard you speak at a conference a few months ago."

What he heard was one of the many pep talks that Wheeler has been delivering lately in Peru. While reporting on the progress of her research, she often sketches out the disasters that befell the lost Inca herds. The early Spanish, she explains, butchered prize alpacas for meat and rounded up entire herds to be sent to the silver mines as pack animals. They introduced foreign germs that may have decimated both the animals and their skilled tenders. Without the benefit of the breeders' knowledge, the surviving Andeans ended up applying traditional sheep-rearing practices to camelids. They ran alpaca and llama males with the females all year round, thereby inhibiting the males sexually. Alpaca and llama herds dwindled.

Ironically, Peru's modern textile industry further contributed to this agricultural catastrophe. Until recently manufacturers paid herders not by the fineness of their fleece but by its weight: The heavier the fleece, the higher the price. This system had the virtue of simplicity, but it led to other unfortunate breeding practices. To bolster their paltry earnings, Andean herders crossed alpacas with larger and heavier llamas. This produced animals enveloped in a coarse fleece riddled with useless guard hair, the antithesis of the fiber that made Inca cloth famous.

During Wheeler's student years at Cambridge University, one of her professors had insisted that to do good archaeozoology, a researcher had to understand and work with living animals. Wheeler never forgot. And seeing the sad state of modern alpacas and llamas has fueled her determination over the years to resurrect the Inca fiber.

As a first step, she needed a quick genetic test to distinguish alpaca hybrids from purebreds. Wheeler had to start from scratch, first building a DNA bank containing representative blood samples from all four species of South American camelid, including the vicuña, a species hunted almost to extinction for its superfine fleece, and the guanaco, another endangered wild species. Undaunted, she set off with her husband, Rael Rosadios, and British geneticist Helen Stanley on an extended road trip to remote mountain communities in Peru, Chile, Bolivia, and Argentina. At each stop, Rosadios bled the animals, storing the samples in rows of lilac-colored vacuum containers. Their small Nissan truck was



Researchers neatly laid out the El Yaral mummies in a museum in the nearby town of Moquegua. At an ancient cemetery (below) in Chiribaya Alta, southwest of El Yaral, grave looters scattered the remains of sacrificial llamas and alpacas found in tombs alongside mummified humans. Photo by Grant Delin



soon crammed with vials from 580 animals, the beginnings of a DNA bank that has now expanded to more than 2,000 camelids.

At the Institute of Zoology in London, geneticists Miranda Kadwell and Michael Bruford began analyzing the samples, searching for molecular markers capable of distinguishing one species from another. They concentrated on small, repeated nuclear DNA sections known as microsatellites, which have proven useful in detecting hybrids in other species. Bruford and Kadwell found two microsatellites whose variants clearly separated the two wild camelids—the vicuña and guanaco—from one another. Then they looked to see the proportion of these markers in the domesticated camelids. Wheeler had long maintained, based on her earlier work with camelid skeletons, that the alpaca was a domesticated vicuña and as such belonged in a different genus than the llama. Many zoologists had disagreed, tracing the lineage of the alpaca either to the guanaco or the llama on the basis of certain physical traits. But Bruford and Kadwell's work suggested that Wheeler was correct. "The vicuña are the most likely ancestor of the alpaca, and the guanaco are the most likely ancestor of the llama," says Bruford, a biodiversity researcher now at Cardiff University.

Next, Bruford developed a DNA test to identify purebred alpacas and llamas. With this, Wheeler and her Peruvian colleagues began methodically testing samples in the new gene bank. Hybridization, she soon discovered, was a far greater problem than anyone had suspected. Forty percent of the tested llamas were hybrids, with at least one or more alpaca or vicuña ancestor. Ninety-two percent of the alpacas were crosses. "The other thing that we discovered is that it's not possible to tell whether an alpaca or a llama is a purebred by looking at it," says Wheeler. "It's necessary to do DNA tests to certify purity."

With the new DNA testing, the team plans to survey alpacas and llamas across the Andes in search of relict purebred populations. Herders could then segregate the purebreds in elite herds and begin breeding animals with fine fleece much the way their ancestors did, by weeding out inferior males. "The basis will then be laid for improving alpaca fiber production in general because initial results indicate that there is at least some link between fine fiber and pure animals," says Wheeler.

She and Bruford are developing methods of improving herds by searching for a genetic marker for fine fiber. A simple DNA test for the trait would permit breeders to assemble purebred herds possessing exactly the right genes for producing superfine fiber. Breeders could then superovulate females from these herds and transfer their purebred, fine-fleeced embryos to low-quality-fiber females. "You could in a relatively short time have a herd with fine fiber that is genetically pure," Wheeler says.

As the team searches for financial sponsors for these projects, Wheeler is working on ways to lower the price of existing technology. At \$200 per animal, the DNA test for purity is too expensive for most Andean breeders. So she and Rosadios are developing one that eliminates the expensive imported radioisotopes. "In the very short term, we'll have the price down to less than \$50 and hopefully considerably lower," Wheeler says. Moreover, she is scouting for international backers for a new camelid research institute in Lima. "The idea is to include all aspects of the problem, from DNA tests to analyzing fiber, and getting the results out to benefit the herders."



In a Peruvian textile factory in the city of Arequipa, some 500 miles southeast of Lima, generations of women have learned to rapidly sort alpaca fiber into five qualities of fineness merely by touch, distinguishing diameter differences of as small as one micrometer— one hundred-thousandth of an inch.

Photo by Grant Delin

Wheeler acknowledges that many scientific and practical obstacles lie ahead before Peruvians can once again produce fabric as seductive as the cloth of the Inca. But her dogged quest has attracted interest from both international woolen experts and Peru's own textile manufacturers. "What we see with Jane's mummies is that the Inca were very good at developing the genetics of good quality and uniform-color fiber," says François Patthey, a director at Grupo Inca, one of Peru's largest alpaca-cloth manufacturers. "If we had that today, it would be really fantastic."



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