ARCHAEOLOGY:

New Trips Through the Back Alleys of Agriculture

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When did hunter-gatherers begin trading the wild life for farming and herding? Creative techniques offer new answers to agriculture's oldest question

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The stuff of early agriculture is garbage. Charred plant seeds, buried animal bones, starch grains stuck to stone tools: These throwaways are treasures in disguise, clues to our earliest farming days. Increasingly, scientists are sifting through the litter to uncover history in new ways.

Their questions, if not work habits, are simple: When and where did hunter-gatherers begin to settle down, content to grow plants and tend animals at home? Over the past decade, with advances in molecular biology, accelerator mass spectrometry (AMS) dating, and other techniques, the picture of early agriculture has grown richer, like an outlined portrait being colored in (*Science*, 20 November 1998, p. 1446). Between 10,000 and 5000 years[*] ago, current theory goes, people in at least seven places, including Mexico, the Near East, and South America, independently domesticated crops and creatures. But big gaps in the historical picture remain.

To fill in those gaps, scientists are expanding their search in creative ways. Some are taking a closer look at museum collections, previously studied and shelved. Others are exploring tiny plant remains trapped beneath ancient food residue or stuck to excavated tools and teeth. "A lot of the answers are right under our noses, hiding in plain sight," remarks archaeologist Melinda Zeder of the Smithsonian Institution in Washington, D.C., who points to new data on the domestication of cattle, goats, and maize.

Boning up

This week in *Nature*, for instance, scientists retrace the early days of European cattle--a tale told, in part, by ancient ox bones borrowed from small British museums. Researchers have suspected that cattle were first domesticated in the Near East some 8000 years ago. Early herders then made their way across

Europe, bringing cattle along. But did these imported eastern cattle alone give birth to today's European varieties? Or did Europeans catch on to the domestication idea and begin breeding wild oxen about the same time?

To find out, a team of scientists led by geneticist Daniel Bradley of Trinity College in Dublin first collected mitochondrial DNA (mtDNA) from 392 modern cattle in Europe, Africa, and the Near East. Comparing mtDNA sequences, the researchers found striking genetic similarity between today's predominant *Bos taurus* cattle in Europe and those in the Near East, suggesting that today's European cows descended from the Near East variety.

To shore up the evidence, the researchers went knocking on the doors of British museums, looking for fossils of extinct British wild oxen. If Europeans did not domesticate this ox, the team reasoned, its ancient genetic profile would be unique--isolated and starkly different from modern cattle. "It turns out that some small, regional museums in England just happened to house the key material to look at these questions," remarks co-author Andrew Chamberlain, a biological anthropologist at the University of Sheffield, U.K.

Chamberlain helped select four wild ox fossils (3700 to 7500 years before present) from the museums. And sure enough, their DNA was distinctly unique. Comparing a 201-base-pair region of wild ox mtDNA, the researchers found eight characteristic mutations that are absent or rare in modern cattle. "This particular wild ox species in Britain has different DNA from all the modern breeds," says Chamberlain. The team concludes that migrating Eastern herders get full credit for domesticating cattle in Europe, although they caution that paternal cattle DNA is needed for proof.

Getting your goat

Ancient ox fossils aren't the only collections getting a closer look. The Smithsonian's Zeder recently rediscovered a trove of modern bones that hold the history of another animal: the goat.

Like cattle, goats were first domesticated in the Near East--specifically, in the eastern Fertile Crescent, a broad arc of land that stretches from present-day Turkey to Iran. The Fertile Crescent hosted the world's earliest agricultural society, but questions dot the calendar. When, for instance, did precocious farmers first bring wild goats home to keep?

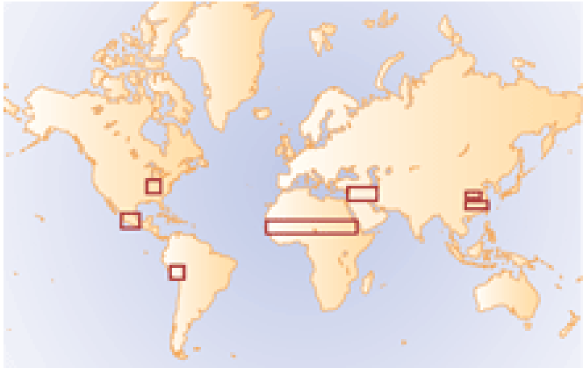
Researchers have hoped to pinpoint changes in goat populations between the late Pleistocene era--when goats were known to be wild in the Fertile Crescent--and the early Holocene, when domesticated goats thrived. The transition from hunting to herding, the logic goes, should be marked by a clear shift in the age and sex of goats killed. Before the animals were domesticated, hungry hunters would primarily kill adult males; later, herders would instead target younger males, keeping females and a few adult males alive much longer for breeding.

Until now, however, researchers have lacked the fossil collections and analytical techniques to detect this demographic shift. Part of the problem, Zeder says, is that for decades, zooarchaeological collections were like baseball cards: traded between museums, forgotten in dark drawers as history collected dust.

Working on a project at the Field Museum in Chicago 5 years ago, Zeder realized that she was looking at a pivotal piece of goat chronology: bones from 37 modern wild goats collected in Iran and Iraq during the 1960s and 1970s. This collection provided a benchmark population: a baseline set of measurements that enabled Zeder to distinguish male from female goats, based on bone size. With these measures, Zeder could finally build demographic profiles of goats killed thousands of years ago in the same eastern mountain valleys.

Working back through collections of ancient bones, she calculated sex-specific age profiles of goats in the Fertile Crescent through time. And in fact, the results did show the striking demographics of herd management in the Zagros Mountains about 10,000 years ago, as Zeder and co-author Brian Hesse, an anthropologist at the University of Alabama, Birmingham, reported last spring in *Science* (24 March 2000, p. 2254). "There is a distinct kill-off pattern," Zeder says, "with young males and old females disappearing from the record."

Today, major museums curate zooarchaeological collections more carefully--and the cattle and goat studies, Zeder says, show that the effort is worthwhile. "Now, with a sharper perspective for early agriculture, we can glean a lot more information from collections we've had for some time," she adds.



Seven wonders. In at least seven places, scientists say, early farmers and herders independently domesticated plants and animals.

SOURCE: BRUCE SMITH/SMITHSONIAN INSTITUTION

Sticky situations

Fresh techniques are also taking root in the field. For years, Dolores Piperno, an archaeobotanist with the Smithsonian Tropical Research Institute in Balboa, Panama, has argued that lowland tropical forests were home to some of the earliest farmers. But evidence has been elusive, because the standard macrofossils--say, squash rinds or maize kernels--quickly rot in the sultry climate. Piperno has turned instead to microfossils, tiny remains of organisms that must be studied under a microscope. As described in a study published last fall in *Nature*, she and her colleagues dug up stone tools from a Panamanian cave site known as the Aguadulce Shelter, which dates back about 12,700 years.

In the lab, the team recovered starch grains stuck to the tools' grinding edges. Analyzing the shapes and features of the grains, the researchers concluded that they were remnants of arrowroot, yam, maize, and manioc plants; radiocarbon dating of surrounding soil suggests these remnants are 7800 to 5500 years old. "These starch analyses and other microfossil strategies add empirical data, indicating that lowland tropical forests were indeed crucial to the origin and early spread of domesticated crops," Piperno says.

But new techniques bring new caveats. Unlike bigger plant remains, such as whole seeds or bits of corn cobs, individual microfossils cannot be directly dated, leaving their age open to some debate. It's also hard to distinguish wild from domesticated varieties by simply comparing the characteristics of individual starch grains, which naturally vary, says archaeobotanist Lee Newsom of Southern Illinois University in Carbondale. "I think these microbotanical techniques have a lot of potential," says Newsom. "There are still some complexities, however, that need to be worked out."

Creative cooking may offer one solution. Thousands of years ago, villagers often cooked meals in the same pot repeatedly, without scrubbing out their cookware. Yesterday's charred and crusted leftovers built up inside the pot, trapping microfossils from cooked plants beneath the baked-on food. Robert Thompson, an archaeologist at the University of Minnesota, Minneapolis, calls these food residues, which are large enough to be directly dated using AMS, "the ideal untapped environment for studying microfossils."

Thompson has used food residues to probe a classic crop mystery: the early days of maize. Most researchers agree that Mexico was the birthplace of maize, a crop first cultivated from the wild weed teosinte. The question is when. In the 13 February *Proceedings of the National Academy of Sciences*, Piperno and archaeologist Kent Flannery of the University of Michigan, Ann Arbor, reported that AMS-dated maize cobs found in an Oaxaca, Mexico, cave are roughly 6250 years old--the oldest cobs on record in the Americas. This finding calls into question some of Piperno's earlier work suggesting that maize microfossils found in Ecuador could be much older, dating 7000 to 8000 years back.

To help clear up the clockwork, Thompson teamed up with University of Illinois, Chicago, anthropologist John Staller. In the mid-1990s, Staller excavated a coastal Ecuadorian settlement, La Emerenciana, that included an ancient ceremonial center used for funerals and ritual offerings. At the site, Staller's team discovered sherds, or fragments, of cookware and four partial human skeletons. Thompson and Staller have now reexamined 10 pottery sherds and the teeth of three skeletons in search of maize phytoliths--tiny chunks of leftover plant silica--trapped in food residue.

Working with the pottery, the researchers scraped away and chemically treated food residues. Three of the pottery sherds did, indeed, reveal phytolith assemblages, or groupings, similar to those found in maize chaff. The researchers also found maizelike phytolith assemblages in tartar on the teeth of two skeletons, evidence that the maize was eaten. After using AMS to date the food residues and doing related experiments, Thompson and Staller concluded that maize was present in coastal Ecuador about 4200 years ago. That timing supports the idea that maize was first domesticated in Mexico, as Piperno and Flannery reported in February, and subsequently spread, fairly recently. The study will be published this fall in the *Journal of Archaeological Science*.

Bruce Smith, director of archaeobiology at the Smithsonian Institution and author of the book *The Emergence of Agriculture*, calls the new study a "significant breakthrough" in tracing the movement of corn from southwestern Mexico into the Neotropics. "Not only can AMS dates on the residues be tightly linked to the maize cob phytoliths, but the phytoliths in turn are from the plant part actually eaten and are recovered from cooking residues, making a very compelling case," says Smith, who helped provide funds to date the residues.

Archaeologists agree that our earliest farming days--and decisions--still hide in history's shadows. "Why did [one group] do this, when the people in the next valley didn't?," asks Flannery. "It almost requires climbing into a time machine and traveling backward to find out." Until that time machine is invented, scientists will keep digging, as creatively as they can.

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* All dates are calendar years.

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Volume 292, Number 5517, Issue of 27 Apr 2001, pp. 631-633.

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