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## News

### NEOLITHIC AGRICULTURE: The Slow Birth of Agriculture

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#### **New methods show that around the world, people began cultivating some crops long before they embraced full-scale farming, and that crop cultivation and village life often did not go hand in hand**

According to early Greek storytellers, humans owe the ability to cultivate crops to the sudden generosity of a goddess. Legend has it that in a burst of goodwill, Demeter, goddess of crops, bestowed wheat seeds on a trusted priest, who then crisscrossed Earth in a dragon-drawn chariot, sowing the dual blessings of agriculture and civilization.

For decades, archaeologists too regarded the birth of agriculture as a dramatic transformation, dubbed the Neolithic Revolution, that brought cities and civilization in its wake. In this scenario, farming was born after the end of the last Ice Age, around 10,000 years ago, when hunter-gatherers settled in small communities in the Fertile Crescent, a narrow band of land arcing across the Near East. They swiftly learned to produce their own food, sowing cereal grains and breeding better plants. Societies then raised more children to adulthood, enjoyed food surpluses, clustered in villages, and set off down the road to civilization. This novel way of life then diffused across the Old World.

But like many a good story, over time this tale has fallen beneath an onslaught of new data. By employing sensitive new techniques--from sifting through pollen cores to measuring minute shape changes in ancient cereal grains--researchers are building a new picture of agricultural origins. They are pushing back the dates of both plant domestication and animal husbandry (see sidebar, p. [1448](#)) around the world, and many now view the switch to an agrarian lifestyle as a long, complex evolution rather than a dramatic revolution.

The latest evidence suggests, for example, that hunter-gatherers in the Near East first cultivated rye fields as early as 13,000 years ago.\* But for centuries thereafter, they continued to hunt wild game and gather an ever-decreasing range of wild plants, only becoming full-blown farmers living in populous villages by some 8500 B.C. And in some cases, villages appear long before intensive agriculture (see p. [1442](#)). "The transition from hunters and gatherers to agriculturalists is not a brief sort of thing," says Bruce Smith, an expert on agricultural origins at the Smithsonian Institution's National Museum of Natural History in Washington, D.C. "It's a long developmental process"--and one that did not necessarily go hand in hand with the emergence of settlements.

Similar stories are emerging in South America, Mesoamerica, North America, and China. Although cultivation may have been born first in the Near East, the latest evidence suggests that people on other continents began to domesticate the plants they lived with--squash on the tropical coast of Ecuador and rice along the marshy banks of the Yangtze in China, for example--as early as 10,000 to 11,000 years ago, thousands of years earlier than was thought and well before the first signs of farming villages in these regions. To many researchers, the timing suggests that worldwide environmental change--climate fluctuations at the end of the Ice Age--may well have prompted cultivation, although they are still pondering exactly how this climate change spurred people around the world to begin planting seeds and reaping their bounty.

### **Cultivating the green hell**

Perhaps the most dramatic and controversial new discoveries in ancient agriculture have emerged from the sultry lowland rainforests of Central and South America. These forests, with their humid climate, poor soils, and profusion of pests, were long considered an unlikely place for ancient peoples to embark upon the sweaty toil of farming, says Dolores Piperno, an archaeobotanist at the Smithsonian Tropical Research Institution in Balboa, Panama. "If people were going to have a hard time living in [these forests], how were they ever going to develop agriculture there?" she asks. And most research suggested that these forest dwellers were relative latecomers to agriculture, first cultivating crops between 4000 to 5000 years ago.

But tropical forests harbor the wild ancestors of such major food crops as manioc and yams. Back in the 1950s, American cultural geographer Carl Sauer speculated that these regions were early centers of plant domestication, but there was little evidence to support the idea, as the soft fruit and starchy root crops of these regions rapidly rot away in the acid soils. The better preserved evidence found in arid regions, such as seeds from grain crops in the Near East, captured the attention of most archaeologists.

In the early 1980s, however, Piperno and colleague Deborah Pearsall, an archaeobotanist from the University of Missouri, Columbia, began searching the sediments of rainforest sites in Panama and Ecuador for more enduring plant remnants. They focused on phytoliths, microscopic silica bodies that form when plants take up silica from groundwater. As the silica gradually fills plant cells, it assumes their distinctive size and shape. Piperno and Pearsall came up with ways to distinguish phytoliths from wild and domestic species--domestic plants, for example, have larger fruits and seeds, and hence larger cells and phytoliths. Then they set about identifying specimens from early archaeological sites.

This spring, after nearly 20 years of research, the team published its findings in a book entitled *The Origins of Agriculture in the Lowland Neotropics*. In one study, they measured squash phytoliths from a sequence of layers at Vegas Site 80, a coastal site bordering the tropical forest of southwestern Ecuador. From associated shell fragments as well as the carbon trapped inside the phytoliths themselves, they were able to carbon-date the microfossils. A sharp increase in phytolith size indicated that early Ecuadorians had domesticated squash, likely *Cucurbita moschata*, by 10,000 years ago--some 5000 years earlier than some archaeologists thought farming began there. Such timing suggests, she notes, that people in the region began growing their own plants after much local game went extinct at the end of the last Ice Age and tropical forest reclaimed the region. "I think that's the key to the initiation of agriculture here," says Piperno. If this find holds up, the Ecuador squash rivals the oldest accepted evidence of plant domestication in the Americas--the seeds of another squash, *C. pepo*, excavated from an arid Mexican cave and directly dated to 9975 years ago (*Science*, 9 May 1997, pp. [894](#) and [932](#)).

The phytolith technique is also pushing back the first dates for maize cultivation in the Americas, says Piperno. Phytoliths taken from sediment samples from Aguadulce rock-shelter in central Panama by Piperno and her colleagues and carbon-dated both directly and by analyzing shells from the same strata imply that maize cultivation began there as early as 7700 years ago. That's not only more than 2500 years earlier than expected in a rainforest site, it's also 1500 years earlier than the first dates for maize cultivation anywhere in the more arid parts of the Americas. Almost certainly, the oldest partially domesticated maize at the site came from somewhere else, because the wild ancestor of corn is known only from a narrow band of land in Mexico. But the squash data raise important questions, says Piperno, about where agriculture first emerged in the Americas. "Clearly tropical forest is in the ball game."

But the community is split over whether to accept the phytolith evidence. Some critics question the dating of the phytoliths themselves, saying that carbon from other sources could have become embedded in the cracks and crevices on the fossil surfaces, skewing the results. Others such as Gayle Fritz, an archaeobotanist at Washington University in St. Louis, point out that the shells and other objects used to support the dates may not be the same age as the phytoliths. "I would be as thrilled as anyone else to push the dates back," says Fritz, "but my advice now is that people should be looking at these as unbelievable."

However, proponents such as Mary Pohl, an archaeologist at Florida State University in Tallahassee, note that the Piperno team typically supports its claims with multiple lines of evidence, so that even if one set of dates is suspect, the body of work makes it clear that some domestication took place startlingly early in the rainforest. "The data seem irrefutable to my mind," she says.

If so, they overturn some basic assumptions about the relationship between village life and agriculture in the tropical forest. For years, says Piperno, researchers believed that the first farmers there lived in villages, like the well-studied Neolithic grain farmers of the Near East. "Because settled village life is just not seen in [this part of the] Americas until 5000 years ago, [researchers thought] that means food production was late too," says Piperno. "But it doesn't work." In her view, farming in the region came long before village life. For thousands of years, she says, "you had slash-and-burn agriculture instead of settled village agriculture."

## Taming wild rice

At the same time as early Americans may have been planting their first squash, hunter-gatherers some 16,000 kilometers east along the banks of the Yangtze River were beginning to cultivate wild rice, according to new studies by archaeobotanist Zhijun Zhao of the Smithsonian Tropical Research Institution and colleagues. Rice, the most important food crop in the world, was long thought to have been cultivated first around 6500 years ago in southern Asia, where the climate is warm enough to support luxuriant stands of wild rice. But in the 1980s, ancient bits of charred rice turned up in a site along the banks of the middle Yangtze River, in the far northern edge of the range of wild rice today. Directly carbon-dated to 8000 years ago, these grains are the oldest known cultivated rice and suggest that the center of rice cultivation was actually farther north.

Now the dates have been pushed back even farther, revealing a long, gradual transition to agriculture, according to work in press in *Antiquity* by Zhao. He has analyzed a sequence of abundant rice phytoliths from a cave called Diaotonghuan in northern Jiangxi Province along the middle Yangtze, which was excavated by Richard MacNeish, research director at the Andover Foundation for Archaeological Research in Massachusetts, and Yan Wenming, a Peking University archaeologist in Beijing.



**Neolithic evolution.** Around the world, societies tamed the plants and animals at hand, but didn't embrace full-scale farming until thousands of years later.

S. BAUER/ARS; G. HEILMAN; S. DALTON/OSF/EARTH SCENES; B. WRIGHT/ANIMALS ANIMALS; B. FRITZ/ARS

Radiocarbon dates for the site seemed to have been contaminated by groundwater, so Zhao constructed a relative chronology based on ceramic and stone artifacts of known styles and dates found with the phytoliths. In recent weeks, Zhao has further refined his *Antiquity* chronology as a result of a joint study with Piperno on paleoecological data from lake sediments in the region.

To trace the work of ancient cultivators at the site, he distinguished the phytoliths of wild and domesticated rice by measuring minute differences in the size of a particular type of cell in the seed covering. With this method, which Zhao pioneered with Pearsall, Piperno, and others at the University of Missouri, "we can get a 90% accuracy," he says.

By counting the proportions of wild and domesticated rice fossils, Zhao charted a gradual shift to agriculture. In a layer dated to at least 13,000 years ago, the phytoliths show that hunter-gatherers in the cave were dining on wild rice. But by 12,000 years ago, those meals abruptly ceased--Zhao suspects because the climate became colder and the wild grain, too tender for such conditions, vanished from this region. Studies of the Greenland ice cores have revealed a global cold spell called the Younger Dryas from about 13,000 to 11,500 years ago. Zhao's own studies of phytoliths and pollen in lake sediments from the region reveal that warmth-loving vegetation began retreating from this region around 12,000 years ago.

As the big chill waned, however, rice returned to the region. And people began dabbling in something new around 11,000 years ago--sowing, harvesting, and selectively breeding rice.

In a zone at Diaotonghuan littered with sherds from a type of crude pottery found in three other published sites in the region and radiocarbon-dated to between 9000 and 13,000 years ago, Zhao found the first domesticated rice phytoliths--the oldest evidence of rice cultivation in the world. But these early Chinese cultivators were still hunting and gathering, says Zhao. "The cave at that time is full of animal bones--mainly deer and wild pig--and wild plants," he notes. Indeed, it was another 4000 years before domestic rice dominated wild rice to become the dietary staple, about 7000 years ago.

It makes sense that the transition to farming was slow and gradual and not the rapid switch that had been pictured, says MacNeish. "Once you learn to plant the stuff, you must learn to get a surplus and to get the best hybrid to rebreed this thing you're planting," he notes. "And when this begins to happen, then very gradually your population begins going up. You plant a little bit more and a little bit more." At some point, he concludes, the hunter-gatherers at sites like Diaotonghuan were unable to gather enough wild food to support their burgeoning numbers and so had little choice but to embrace farming in earnest.

## The cradle of civilization

In the Near East, archaeologists have been studying early agriculture for decades, and it was here that the idea of the Neolithic Revolution was born. Yet even here, it seems there was a long and winding transition to agriculture. And although settled village life appeared early in this region, its precise connection to farming is still obscure.

The latest findings come from Abu Hureyra, a settlement east of Aleppo, Syria, where the inhabitants were at least semisedentary, occupying the site from at least early spring to late autumn, judging from the harvest times of more than 150 plant species identified there to date. Among the plant remains are seeds of cultivated rye, distinguished from wild grains by their plumpness and much larger size. University College London archaeobotanists Gordon Hillman and Susan Colledge have now dated one of those seeds to some 13,000 years ago, according to unpublished work they presented at a major international workshop in September.† If the date is confirmed, this rye will be the oldest domesticated cereal grain in the world.

These dates are nearly a millennium earlier than previous evidence for plant domestication. And the rye is not even the first sign of cultivation at the Abu Hureyra site: Just before the appearance of this domestic grain, the team found a dramatic rise in seed remains from plants that typically grow among crops as weeds. All this occurs some 2500 years before the most widely accepted dates for full-scale agriculture and populous villages in the Near East. Although the semisedentism of the inhabitants fits with earlier ideas, the long time span contradicts ideas of a rapid agricultural "revolution."

The early date for plant domestication in the Near East is not entirely unexpected, says Ofer Bar-Yosef of Harvard University. For example, inhabitants of Ohalho II in what is now Israel had made wild cereal seeds a major part of their diets as early as 17,000 B.C., according to published work by Mordechai Kislev, an archaeobotanist at Bar Ilan University in Ramat-Gan, Israel. Moreover, as close observers of nature, these early foragers were almost certain to have noticed that a seed sown in the ground eventually yielded a plant with yet more seeds. "These people knew their fauna and flora very well," says Bar-Yosef, "and they probably played with planting plants long before they really switched into agriculture."

Just what spurred hunter-gatherers to begin regularly sowing seeds and cultivating fields, however, remains unclear. For several years, many Near Eastern experts have favored the theory that climate change associated with the Younger Dryas was the likely trigger. Bar-Yosef, for example, suggests that inhabitants of the Fertile Crescent first planted cereal fields in order to boost supplies of grain when the Younger Dryas cut drastically into wild harvests.

And at Abu Hureyra, Hillman thinks that the drought accompanying the Younger Dryas was a key factor. Before the jump in weeds and the appearance of domestic rye, the inhabitants relied on wild foods as starch staples. Over time, they turned to more and more drought-resistant plants--and even these dwindled in abundance. So "progressive desiccation could indeed have been the impetus for starch cultivation," says Hillman.

But new dates for the cold spell in the Near East paint a more complex view. At the Netherlands workshop, Uri Baruch, a palynologist at the Israel Antiquities Authority in Jerusalem, and Syze Bottema, a palynologist at the Groningen Institute of Archeology in



the Netherlands, announced that they had redated a crucial pollen core at Lake Hula in northern Israel. Their original published estimate put a retreat in the region's deciduous oak forest--due to cool, dry conditions believed to be the local manifestation of the Younger Dryas--starting about 13,500 years ago. But after correcting for contamination by old carbon dissolved in the lake water, they found that the cold spell in the Near East was a bit later, starting around 13,000 years ago and ending around 11,500 years ago.

These dates suggest that farmers of Abu Hureyra may have begun cultivating rye before the Younger Dryas set in, at the very end of the warm, moist interval that preceded it. "The domesticated rye dates and the pollen core don't match up so well at this time," says Mark Blumler, a geographer at the State University of New York, Binghamton.

Moreover, others point out that the clearest evidence for the domestication of grains such as wheat and barley in the Near East comes around 10,500 years ago, after the Younger Dryas had waned and the climate had improved again. By then, says George Willcox, an archaeobotanist at the Institut de Préhistoire Orientale in St-Paul-le-Jeune, France, other factors could have contributed to the transition. Hunter-gatherers in the region, for example, had settled year-round in small villages between 12,300 and 10,500 years ago. There, he says, rising human populations and overexploitation of wild foods could have driven people to take up farming. "Because people at this time appear to be living in one place," says Willcox, "they could use up all the resources in a particular area."

Putting the evidence from around the world together, a new picture of the origins of agriculture begins to emerge. In the Near East, some villages were born before agriculture and may even have forced its adoption in some cases. But elsewhere--China, North America, and Mesoamerica--plants were cultivated and domesticated by nomadic hunter-gatherers, perhaps to increase their yield during the dramatic climate shifts that accompanied the final phase of the last Ice Age. Either way, it no longer makes sense to suppose a strong causal link between farming and settled village life, Piperno says.

Indeed, in many regions, settled agriculturalists emerged only centuries or millennia after cultivation, if at all. Many ancient peoples simply straddled the middle ground between foraging and farming, creating economies that blended both (see sidebar, p. 1447). "For so long, we've put everybody in black boxes" as farmers or hunter-gatherers, notes Joanna Casey, an archaeologist at the University of South Carolina, Columbia, and a specialist in agricultural origins in western Africa. But mixed cultivation and foraging is not necessarily a step "on the way" to full-scale farming--it was a long-term lifestyle for many groups. "These societies in the middle ground are certainly not failures," says the Smithsonian's Smith. "They are not societies that stumbled or stuttered or got frozen developmentally. They're societies that found an excellent long-term solution to their environmental challenges."

Eventually, for reasons still unclear, many of the early domesticators did become true agriculturalists--by 10,500 years ago in the Near East, 7000 years ago in China, and later in the Americas and Africa. And during this transition, human populations did indeed soar, and hamlets became villages. Archaeological sites in the intensively studied Fertile Crescent, for example, increased more than 10-fold in size, from 0.2 hectares to 2.0 to 3.0 hectares, during this period of transition. The combination of settlement and reliable food probably brought about "a longer period of fertility for the now better fed women," says Bar-Yosef, setting the stage for cities and civilization.

So it seems that the ancient Greek legends got it half right when they told how seeds fell throughout the world, sparking independent centers of domestication on many continents. But cities and civilization did not necessarily arrive at the same time as the seeds. Demeter's priest apparently gave out only one blessing at a time.