lopes. Even for the 53 species common to both studies, there is little sign of a Turkana pulse, says Behrensmeyer.

Slowing the pace of the shift toward grassland-adapted animals and starting it earlier blurs Vrba's link between evolutionary change and Africa's jump to a new climate mode. Instead, the Turkana data suggest that the fauna was steadily nudged toward grassland-adapted species by a global cooling and related African drying. "There isn't a pulse," says paleontologist David Pilbeam of Harvard University, who has seen the Smithsonian data. "I had considered that maybe around 2.5 million years ago there was sufficient environmental change that you would get a turnover pulse, but the evidence would now suggest that you didn't."

Exactly why Vrba's record for African antelopes is punctuated and the Turkana record isn't remains unclear. One possibility is that variations in fossil abundance through time skewed Vrba's data, creating a false peak. Another is that the Turkana rift valley—which held a river bounded by woodland at this time—was buffered from the dramatic climatic shifts, suggests paleontologist Steven Stanley of Johns Hopkins University. Testing whether the Turkana region was typical of Africa isn't yet practicable, says Pilbeam, noting that only in the Turkana basin is the African mammalian record detailed enough to offer a more or less complete documentation of the changing fauna. "If you really want to know what happened in Africa over the past 2 to 3 million years, you need many such [records]," he says. "The quality of record that we would need [to test the turnover pulse hypothesis] is way beyond what we currently have, and it may indeed be beyond what we are ever likely to have."

Detailed comparisons of methodology may eventually sort out why these African studies differ, but they are not likely to settle the broader question of how climate influences mammalian evolution. On that the record is mixed. In addition to Vrba's pulse and Behrensmeyer's slow drift, there are also reports of no mammal response at all to abrupt climate change. At the NAPC meeting, Donald Prothero of Occidental College in Los Angeles argued that two major cooling events 37 million and 33 million years ago failed to affect North American mammals, although these cold spells apparently triggered extinctions in the sea and among terrestrial nonmammals. "The mammal response is negligible," Prothero says. "There is no turnover pulse, at least in North America."

Yet previous studies have shown that climate can have at least an indirect effect on mammal evolution. For example, 33 million years ago, when North American mammals were blithely ignoring climate change, European mammals were suffering through "La Grande Coupure," or the great break. It was a brief but momentous evolutionary event in which up to 60% of European mammals went extinct, to be replaced by more modern forms (*Science*, 18 September 1992, p. 1622). But researchers think climate's role was indirect: A burst of glaciation created a land bridge to Asia, and the European mammals lost out to Asian invaders.

The dearth of evidence that climate change has forced mammalian extinction and speciation has Prothero and others questioning traditional assumptions. "We've oversold the idea that animals, especially land mammals, are responsive to environmental change," he says. "Animals seem to be remarkably resistant to a lot more change than we thought." All of which leaves open the question of why our favorite mammals, our ancestors, emerged in Africa as Earth was entering its ice age.

**–Richard A. Kerr**

ARCHAEOLOGY

# How the Ancient Egyptians Brewed Beer

**CAMBRIDGE, U.K.**—Ancient Egyptians evidently had a fondness for bread and beer, judging from the many contemporary written and pictorial references to them. But just how these staples were made has remained tantalizingly vague, for no one has ever found a recipe. Some clues can, however, be found in tombs, where these items were often left for sustenance in the afterlife. Now a Cambridge archaeologist has culled enough evidence from beer residues and dry crumbs that have survived in the arid atmosphere to challenge existing theories of how ancient Egyptians brewed and baked. "This is the first real scientific evidence for the ancient brewing techniques," says archaeologist Glynis Jones of the University of Sheffield, who studies traditional cereal-processing methods.


FLETCHER MORGAN

**Mummy's tipple.** Delwen Samuel and the re-created ancient Egyptian beer.

Historians have widely believed that beer was made by crumbling bread into water, followed by fermentation of the resulting liquid. But archaeologist Delwen Samuel of the University of Cambridge reports on page 488 that when she put this theory to the test using knowledge from modern research on food processing, it didn't hold water.

Samuel focused on starch granules from cereal grains. When starch is exposed to limited amounts of water, such as in modern bread dough, the granules swell but remain largely intact. In contrast, when starch is heated in water, the granules swell and fuse into one another and look quite different under a scanning electron microscope. The malting process, which is the key to modern brewing, also leaves its mark on starch granules, which become pitted as enzymes turn the starch into sugars.

Samuel used an electron microscope to study remains of bread and the linings of beer vessels from tombs and settlements dated at about 1500 B.C. She found that most of the starch in the bread remains was in the fused form, suggesting that the dough had been very moist, unlike doughs used in modern bread. If beer had been made by simply crumbling bread into water, starch granules in the beer dregs would also be mostly in the fused form. Instead, they ranged from undistorted but pitted to completely fused. "The presence of the pitted, undistorted granules suggests a malting process was used in brewing," she says. "Malting is a complex process, and this work will encourage other researchers to look afresh at some of the artifacts from this period," says Harvard University archaeologist Mark Lehner.

From these clues Samuel believes that the ancient Egyptians carried out a two-step process: First cereal grains were malted and heated to provide sugar and flavor, and these grains were then mixed with sprouted, unheated grains in water. The resulting sugar and starch solution was then decanted and fermented to make the beer.

With a bit of guesswork, a team led by James Merrington at the Scottish and Newcastle brewery in Newcastle, one of the sponsors of the research, tested Samuel's theory. Using emmer wheat, a species used by the Egyptians, and coriander and juniper flavoring, which were also widely available at the time, the team followed Samuel's process and came up with a pleasant surprise. "The beer was delicious with a long, complex aftertaste," says Samuel. But Merrington doubts that the exotic beer has a commercial future. "It'd be difficult to make another batch the same—but it was a nice experiment bringing science, industry, and archaeology together in one pot," he says.

**–Nigel Williams**