EVOLUTION

New Mammal Data Challenge Evolutionary Pulse Theory

Paleontologists anxious to make sense of the rise and fall of species in the fossil record have long invoked climate change as a prime mover in evolution, a force that triggers the evolution of new species while condemning others to extinction. But although there are plenty of rough correlations between climate change and evolution, proving a causal link has been difficult, given the imperfect preservation of the geologic record.

In the 1980s, however, paleontologist Elisabeth Vrba of Yale University documented a striking coincidence in the African geologic record about 2.6 million years ago, when a major climatic step toward the ice-age world occurred just as African antelopes underwent a burst of evolution and extinction. Adding popular appeal to the work, the human family tree branched out at about the same time, giving rise to the lineage that eventually led to *Homo sapiens*. Vrba proposed that a single climate-driven "turnover pulse" involving antelopes, hominids, and other animals had in a geologic moment turned evolution in a fateful new direction.

The idea attracted much attention, but few paleontologists managed to test it. Now new data reported at the North American Paleontological Convention (NAPC) in Washington, D.C., last month raise doubts about the theory. One of the richest, best dated African fossil records—which includes some of the same species Vrba studied—shows no sign of a turnover pulse. Rather, it shows "a more sustained shift" over a million years or more from woodland species toward grassland species, says Anna K. Behrensmeyer of the Smithsonian Institution's National Museum of Natural History, who led the study. "There was global change," she says, "but its effect on the fauna was not punctuated."

This and other new work could provide new ammunition to those who see a limited role for climate change in evolution. "I'm a real skeptic" about the effects of climate change, says mammal paleontologist Richard Stucky of the Denver Museum of Natural History. "When you look at the whole range of species, very seldom is there a climate event that changes the course of mammalian evolution." But even as new data come in, it's clear that the subject of how changing climate affects mammalian evolution continues to spark a range of opinions, with Stucky's minimal role at one extreme, Vrba's turnover pulse at another, and Behrensmeyer's prolonged shift somewhere in between.

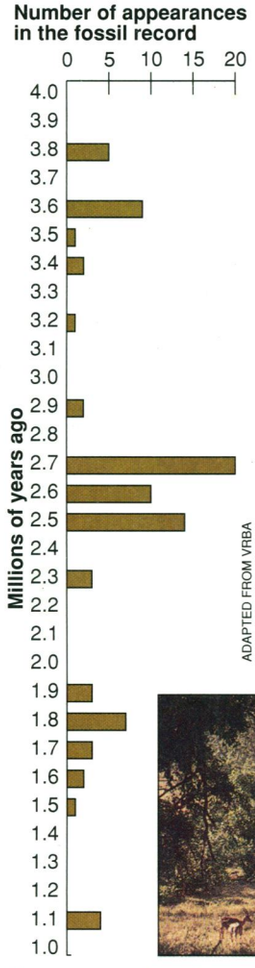
Vrba wasn't at the meeting to defend the turnover pulse idea—she's on sabbatical in South Africa. (She also could not be reached for this article, despite repeated attempts to locate her through colleagues in the United States and Africa.) But her latest data were published late last year in two conference proceedings chapters. She compiled her own and published records of the first and last appearances of 147 species of African antelopes, most from eastern and southern Africa, during the past 7 million years. That analysis showed that from 3 million to 2 million years ago, the total number of species doubled, and 90% of all species recorded in that interval either first appeared or went extinct during that time. Furthermore, almost all of this considerable turnover was concentrated between 2.7 million and 2.5 million years ago. Meanwhile, although the exact timing is in dispute, the genus *Homo* also appeared between 3 million and 2 million years ago, possibly right about 2.5 million years ago.

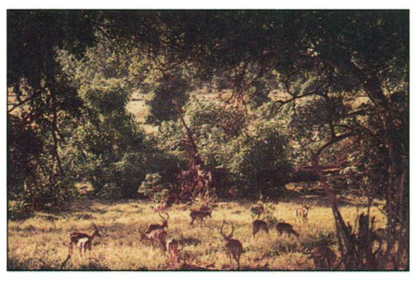
Climatic data are consistent with Vrba's theory too. After about 3 million years ago, Earth was gradually cooling, as the climate system headed toward glaciation in the Northern Hemisphere. But Africa didn't slide smoothly toward the ice ages—it jumped, according to Peter deMenocal of Columbia University's Lamont-Doherty Earth Observatory (*Science*, 14 January 1994, p. 173). By analyzing climate indicators in marine muds off the African coasts, he showed that between 2.8 million and 2.6 million years ago, subtropical Africa's climate abruptly shifted from one mode of operation to another, switching from a 20,000-year beat controlled by Earth's wobbling on its rotation axis to a more intense, 40,000-year beat driven by the changing tilt of the axis. This new regime left tropical Africa oscillating between a warmer, wetter climate and a cooler, drier one.

Vrba suggests that the longer, cooler episodes drove antelope evolution by means of a classic mechanism—breaking up the antelope's preferred woodland habitat into isolated ecological islands scattered among grasslands. The small woodland populations then spawned new species better adapted to the grasslands. Her hypothesis predicts that other species, including hominids, would respond the same way. As might be expected, such a sweeping generalization drew strong reactions. Those who didn't see pulses in their data were doubtful, while those whose world view includes abrupt evolutionary steps were enthusiastic. "The idea is wonderful," says Niles Eldredge of the American Museum of Natural History in New York City, co-creator of the theory of punctuated equilibrium.

But testing Vrba's idea requires an unusually rich and well-dated fossil record. One such record is a new computerized database developed under the Evolution of Terrestrial Ecosystems program run by the National Museum of Natural History. This includes the first and last appearances of 510 mammal taxa ranging from antelopes to baboons for the past 6 million years. For their test, the group focused on the fossiliferous and well-studied Lake Turkana region of East Africa, which has yielded a variety of animals, including hominids. What's more, the Turkana fossils are the best dated in Africa for the period from 1 million to 4 million years ago, thanks to repeated volcanic eruptions that blanketed the region with radiometrically datable ash layers.

When the Smithsonian team plotted the pace of evolution in the Turkana fauna about 2.5 million years ago, the turnover pulse theory "just didn't seem to hold up," says Behrensmeyer. "Clearly, there was a shift going on, but I think we can show the event was occurring over at least a million years and doesn't qualify as a pulse." Instead of a 90% turnover in a few hundred thousand years, the team found a 50% to 60% turnover spread between 3 million and 2 million years ago. Diversity during the period rose 30% rather than doubling, as Vrba reported for the ante-




A. K. BEHRENSMEYER

Checking a pulse. Vrba's data suggest that climate change drove a burst of antelope speciation.

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