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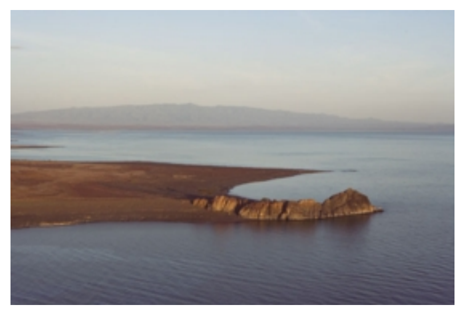
# New Evidence Shows How Human Evolution Was Shaped by Climate

Swings between wet and dry landscapes pushed some of our ancestors toward modern traits—and killed off others

Aug 19, 2014 | By Peter B. deMenocal |



AMID THE DESERTS of East Africa, Lake Turkana has swelled and disappeared dozens of times while our ancestors were evolving here.

MICHAEL POLIZA *National Geographic*



Scrambling up the steep bank of a small wadi, or gully, near the western shore of Lake Turkana in northern Kenya, I stop on a little knoll that offers a view across the vast, mostly barren desert landscape. The glittering, jade-blue lake contrasts in every way with the red-brown landscape around it. This long, narrow desert sea, nestled within Africa's Great Rift Valley, owes its existence to the Omo River, whose winding flow delivers runoff that comes from summer monsoon rains in the Ethiopian highlands, hundreds of miles north.

The heat here has to be respected. By noon it feels like a blast furnace. The sun beats down, and the hot, stony ground fires it back upward. Scanning the dusty horizon, with the lake winking in the distance, I find it hard to imagine this place as anything but a desert.

Yet evidence for much wetter times is everywhere. Indeed, the little hillock under my boots is a thick chunk of ancient lake sediments that date back 3.6 million years, when a much larger and deeper Lake Turkana filled this basin to the brim. The glassy remains of fossil lake algae make up white, sandy layers, and large fish fossils are common. At times in the past, this rocky desert was carpeted with grasslands and trees and lakes.

Such climate changes may have played a big role in shaping human evolution, a growing number of scientists believe. The Lake Turkana region, together with other sites in East and South Africa, possesses most of the fossil record of early human origins and our evolutionary journey since our lineage split from African apes more than seven million years ago.



Remarkably, major shifts in African climate coincide with two moments on that ancestral path, roughly a million years apart, that mark significant changes in our family tree. The first evolutionary shake-up happened between 2.9 million and 2.4 million years ago. The famous ancestral lineage of “Lucy” and her ilk (*Australopithecus afarensis*) became extinct, and two other, quite distinctive groups appeared. One of them had the hints of some modern-looking traits, including larger brains. Their owners were the very first members of our own genus, *Homo*. The first crude stone tools apppeared near these fossils. The other group besides *Homo* that emerged at this time looked different: a stoutly built, heavy-jawed and ultimately unsuccessful lineage known collectively as *Paranthropus*.

The second shakeup occurred between 1.9 million and 1.6 million years ago. An even larger-brained and more carnivorous species, *Homo erectus* (called *Homo ergaster* by some scientists), appeared on the scene. Its taller, more lithe skeleton was nearly indistinguishable from that of modern humans. This species was also the first to leave Africa to populate Southeast Asia and Europe. Stone tool technology also got a major upgrade: the first hand axes showed up, with large blades carefully shaped on two sides.

Why were these evolutionary milestones, harbingers of modern humanity, so clustered in time? A number of scientists now think two episodes of climate change may have been the cause. These two ecological jolts, coming after long periods of extremely gradual change, moved the cradle of humanity toward increasingly dry and open grasslands. While these broader shifts were happening, the climate whipsawed rapidly between wet and dry periods, so to thrive, our ancestors had to adapt to rapidly changing landscapes.

The evidence comes from an array of new data that tell us how and why African climate and vegetation changed during these big human evolutionary moments. Scientists are now able to extract and analyze molecular remnants of ancient African vegetation from layers of sediments such as the ones I stood on. Chemical analyses of our ancestors' teeth reveal what they ate as the landscape changed. The creatures that adapted to these shifts—those that showed flexibility in what they ate and where they lived—appear to be the ones that prospered. This emphasis on flexibility in the face of new environmental challenges seems to be a trait that carries forward in the human lineage. Other forebears, who did not appear to change with the times, died out. Rick Potts, a paleoanthropologist at the Smithsonian Institution, calls the role of flexibility in making us what we are “variability selection.”

**Life Shaped by Climate**

Theories linking climate change and evolution go back to Charles Darwin. His premise was that large-scale shifts in climate can shake up the kinds of food, shelter and other resources available in a given region. The disappearance of a favorite food or the replacement of a long wet season with a longer dry one create pressures that lead, eventually, to adaptation, extinction or evolution into different species. The environment, set by climate, will favor creatures with genes for certain advantageous traits, such as larger brains. Over time, those creatures and the genes they carry will come to dominate because more of them will survive. In *On the Origin of Species*, Darwin noted that seasons of extreme cold or drought were effective checks on species numbers.

This process of change is not always subtle or gentle. Each of the “big five” mass extinctions over the fossil record of life on earth during the past 540 million years was accompanied by an environmental disruption. During each of these events, between 50 and 90 percent of all species perished, but this was followed by bursts of new, very different species. These episodes define the major chapters in the history book of life, when new biotic worlds emerged and flourished. We mammals owe a debt of gratitude to the Manhattan-size meteorite that struck the Yucatán Peninsula in what is now Mexico about 66 million years ago. It killed off the dinosaurs (and numerous other less charismatic species), ushering in the rapid radiation and diversification of mammals.

One group of those mammals led, after many more branchings and a lot of time, to us. For these hominins (modern humans and our extinct relatives), scientists have tried out several ideas about the way the environment shaped evolution. The “savanna hypothesis” was one. In its earliest incarnation, scientists proposed that our early human ancestors, with burgeoning bipedality, large brains and toolmaking, were better suited to rapidly expanding savanna grasslands, where competition for resources was fiercer, and they left our apelike forebears behind in receding forests.

This dated view, which still shows up in some textbooks, is incorrect. There was no one-time habitat switch from forests to grasslands but rather a rapid succession of wet-dry cycles that moved, in distinct steps, toward drier conditions. Also, we did not acquire human traits in one single moment but rather in a series of concentrated bursts just when the environment was shifting.

**Wet and Dry Cycles**

Evidence for these bursts of landscape change and evolution comes not just from land but from the sea. African ground sediments are often hard to analyze because of erosion and other geologic disturbances. In the deep oceans, however, they remain undisturbed. By drilling into the seafloor near the African coasts, geologists like myself have been able to penetrate a multimillion-year time capsule, recovering long cores of sediments that preserve complete records of past African environments. To get these cores, we need a special ship. That is why a team of 27 scientists and I spent two months in the fall of 1987 on the 470-foot drilling vessel *JOIDES Resolution*.

“Core on deck!” squawked the driller over the PA system in his Texan twang. We scientists groaned, donned our hard hats, and marched out of the ship's cool, comfortable laboratories into the blinding Arabian sun to carry yet another 30-foot segment of deep-sea sediment core inside for analysis. The *Resolution* is an internationally funded research ship designed to explore and drill the ocean bottom and recover the earth's history recorded there. We were drilling through layers of deep-sea sediment in the Arabian Sea in a mile and a half of water, taking cores nearly half a mile into the sea bottom. Since the divergence of great ape and human lineages several million years ago, the ocean bottom here had accumulated nearly 1,000 feet of deep-sea mud in the dark, peaceful abyss, at a rate of about one and a half inches every 1,000 years.

The sediments here consist of mixtures of fine-white calcium carbonate fossil shells from ancient ocean plankton and darker, silty grains of dirt blown from areas of Africa and Arabia by windy monsoons. When the mix looks darker and gritty, it indicates drier, dustier times. When it looks lighter, that reflects wetter, more humid conditions.

Laying the split sediment core on a table inside the ship's spacious research labs, we could see that the alternating light and dark layers repeated every three feet, more or less, which meant they changed about every 23,000 years. It was clear that African climate history had been one of continuous swings between wetter and drier times. That was nothing like a single, sharp shift to a savanna.

These swings reflected the known sensitivity of African and Asian monsoonal climates to the earth's orbital wobble, which occurs as a regular 23,000-year cycle. The wobble changes the amount of sunlight hitting our planet in a given season. For North Africa and South Asia, more or less heat during the summer increased or decreased monsoon rainfall, making these regions either much wetter or drier as our planet wobbled back and forth.

Just how wet things got is recorded in magnificent rock art drawn between 10,000 and 5,000 years ago by humans during the most recent wet period in North Africa. Art found across the Sahara depicts lush landscapes filled with elephants, hippopotamuses, giraffes, crocodiles and bands of hunters chasing gazelles. The Sahara was covered with grass and trees; lake basins, now overrun by sand dunes, were filled to the brim with water. A swollen Nile River rushed into the eastern Mediterranean, and black, organic-rich sediments called sapropels accumulated on the Mediterranean seafloor. They alternated with whiter layers laid down during dry periods, a bar-code message telling of African climate cycles reaching deep into the past, just like the changing dust layers recovered from the Arabian Sea.

**The Last of Lucy**

Superimposed on these orbital wet-dry cycles were larger steps toward dry and open grasslands. Small patches of grasslands first expanded in East Africa nearly eight million years ago. But vast grassy plains such as the Serengeti were only established permanently after three million years ago. Just about this time, our evolutionary history was given a jolt as well.

We lost Lucy. Her extremely successful species, *A. afarensis*, had survived in East Africa for 900,000 years, starting at about 3.9 million years ago. But just under three million years ago, Lucy's kind disappeared from the fossil record.

Next the *Paranthropus* group appeared, followed 2.6 million years ago by the first signs of stone choppers and scrapers and then in a few hundred thousand years by early *Homo* fossils.

We know these changes in our family tree and in technological invention happened during a shift in overall climate because of some clever scientific detective work, tracing the fingerprints left by some plants that flourished in wetter environments and others that thrived in drier times.

Savannas are open tropical ecosystems composed of grasses and sedges, sometimes spotted with clusters of woody trees. Savanna grasses do very well in hot, dry regions because, to take up carbon from the atmosphere, they use a specific photosynthetic pathway called C4. This set of reactions is miserly with carbon and water, an adaptation to life in dry and low-$CO_2$ environments. Woody vegetation such as trees finds homes in wetter ecosystems because it uses another photosynthetic pathway called C3, which requires much more water.

Thure E. Cerling and his colleagues at the University of Utah developed a way to reconstruct the vegetation history of ancient landscapes. Some years ago researchers discovered that C4 grasses have a greater abundance of the heavier but rarer carbon 13 isotope relative to the lighter, more abundant carbon 12 isotope. But C3 shrubs and woody plants have a lower carbon 13/12 ratio. The scientists discovered that they could take samples of soil or nodules of rock from a given landscape, analyze the carbon ratios, and use them to accurately estimate the percentage of C4 grasses versus C3 woody plants that were once in that area.

When they looked at the East African sediment from sites that had yielded fossil hominins, the researchers learned that East African landscapes were predominantly C3 forest and shrublands before eight million years ago. After that, the proportion of C4 grasslands increased gradually. Then a relatively large and fast shift occurred between three million and two million years ago.

During this shift, grasslands expanded rapidly across present-day Kenya, Ethiopia and Tanzania. The spread was accompanied by a rise in the proportion of grazing mammals, shown by their abundant fossils. As time ticked forward, closer to two million years ago, African antelopes—their horns, whose different shapes indicate different species, are well preserved—seem to have undergone extensive speciation, extinction and adaptation, rather like our hominin forebears.

Bovids, the family to which these even-toed ungulates belong, represent roughly one third of all African fossils. Thus, they provide a much larger data set than do the much scarcer hominins. Paleontologist Elisabeth Vrba of Yale University conducted an all-Africa analysis of bovid evolution spanning the past six million years. Her study identified specific times when rates of bovid speciation and extinction were well above normal background levels. The two largest of these events occurred near 2.8 million and 1.8 million years ago, coinciding with the periods of grassland growth that geologists observe, although recent work by René Bobe, now at George Washington University, and Anna K. Behrensmeyer of the Smithsonian Institution suggests these events may be more muted. The anatomy of these fossils hints that some of them were taking advantage of the landscape change. For example, many new grazing bovid species appeared with specialized molars for chewing the abrasive, grassy diet.

**Diets and Landscapes**

As was the case for bovids, this vegetation change most likely had a profound effect on our own ancestors because we do not just live in an environment—we eat it. Paleo diet research turns out to be quite useful for understanding how hominins were affected by changing landscapes. Just as isotopes in soils can be used to infer the relative abundance of grasslands in an ancient landscape, scientists have recently started to analyze the isotopic composition in our forerunners' fossil teeth. The carbon isotope analysis of a tooth from a modern American would sit squarely on the C4-grass side of the scale because much of what we consume—meat from cows, soft drinks, snacks, sweets—derives from corn, a C4 grass.

Prehistoric diet changes seem to be part of that second big evolutionary moment in our history, nearly two million years ago, when *Homo* fossils that looked more modern first appeared. Cerling and his many colleagues have been examining the teeth of Turkana Basin fossils. Last year they published a remarkable study that showed a dietary split between early members of our own genus, *Homo*, and members of the heavy-jawed *Paranthropus* group, at just under that two-million-year mark. One species, *Paranthropus boisei*, has sometimes been called Nutcracker Man because of its impressively large molars and massive jawbones. The carbon isotope tooth data from this species indicate it indeed ate a narrow, mostly C4-based diet. Fine microscopic scratches on the teeth, however, suggest it was not cracking nuts at all but rather eating soft C4 grasses and sedges.

The big surprise was for *Homo*. These early teeth recorded a diet that bucked the landscape trend toward greater C4 grass cover. The tooth isotopic data for early *Homo* indicate a strikingly mixed, roughly 65–35 diet of C3- and C4-based foods. It shows that *Homo* sought diverse foods from a landscape that was becoming increasingly uniform. Early *Homo* had a varied, flexible diet and passed its genes to subsequent lineages, eventually leading to us. *Paranthropus*, in contrast, lived in a narrow C4 dietary niche and eventually became extinct.

It is tempting to speculate that the more complex stone tools that first appeared with this group of *Homo*—hand axes, cleavers and the like, tools that required more effort to fashion and could be put to multiple uses—were better suited to help their owners exploit varying food sources. We are still not at all sure what these organisms were eating, but we do know which dietary adaptations were ultimately successful.

**Filling in the Climate Gaps**

This C3/C4 story, though intriguing, has some holes in it: in particular, gaps of several thousands of years in land sediment sequences. But again, the ocean sediments and their more complete records can help fill in the blanks. A very promising technique for continuously tracking vegetation changes has emerged in the past decade. All terrestrial plants have waxy leaf coatings that protect them from injury and dehydration. When plants die or become abraded, the waxy coatings are carried by the winds, along with mineral dust and other particles. These coatings are made out of tough little molecules, long carbon-based chains known as lipids. They are resistant to degradation and possess the carbon isotopic signature from their host plant type, C3 or C4. Once chemically isolated from sediments, these plant wax lipids can be measured, and their carbon signature determined as C3 or C4. The relative abundance of a particular type lets us estimate the amounts of grass versus trees and scrubs on ancient landscapes.

Sarah J. Feakins, now at the University of Southern California, and her colleagues applied this technique to reconstruct hominin environments. Analyzing sediments from a drilling site in the Gulf of Aden, she confirmed that East African grasslands expanded between three million and two million years ago, perhaps by as much as 50 percent. Feakins also found that these plant wax biomarkers varied within the dust layers that marked the short-term swings driven by orbital cycles and monsoons. The grasses and woodlands shifted back and forth on this shorter scale, and many of these swings were nearly as large as the long-term shift to more open, grassy landscapes. At the famous fossil site Olduvai Gorge in Tanzania, where hominins lived 1.9 million years ago, scientists Clayton R. Magill and Katherine H. Freeman, both then at Pennsylvania State University, found similar biomarker shifts.

We are closing in on a clearer picture of the how and why of human origins. Gone is the old image of our ancestors emerging from some ancient dark forest to assert dominion over the grassy plains. In its place is new evidence for a series of rapid climate cycles and two large shifts that established the African savanna we know today. Some evidence indicates that our most successful forebears had the flexibility to adapt to these changes. Researchers are already trying to firm up this connection between climate and these evolutionary events with more detailed investigations. Still, it appears as if an answer to the age-old question “How did I get here?” is no longer beyond our reach.

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## ABOUT THE AUTHOR(S)

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### MORE TO EXPLORE

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