

When African animals hit the hay: Fossil teeth show who ate what and when as grasses emerged

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An African elephant browses on leaves of an acacia tree. Modern elephants eat mostly tree leaves and shrubs, but a new University of Utah study shows that they once ate a diet of mostly warm-season grasses, starting about 7.4 million years ago. The study used fossilized teeth to reconstruct the dietary history of east African plant-eaters from 10 million to 3 million years ago, showing that different animals switched at different times from a salad-bar diet of trees and shrubs to a diet of warm season grasses. Credit: Kevin Uno, University of Utah

Fossil teeth of African animals show that during the past 10 million years, different plant-eating critters began grazing on grass at different times as many switched from a salad-bar diet of tree leaves and shrubs, says a University of Utah study.

The first animals to hit the hay - technically warm-season grasses known as C4 plants - were zebras' ancestors, starting 9.9 million years ago. Next, some but not all rhinos made the switch, beginning 9.6 million years ago. Grass-grazing spread 7.4 million years ago to the ancestors of elephants. Hippos began grazing on [grass](#) more slowly. And giraffes, with heads in the trees, never left the salad bar.

The study - by a Utah-led international team of researchers - was to be published online Monday, April 4 in the journal *Proceedings of the National Academy of Sciences*.

It constructed a 7-million-year record of dietary change - from 10 million to 3 million years ago - by analyzing carbon isotope ratios in 452 fossilized teeth from nine animal families living at three sites in Kenya also occupied by ape-like human ancestors.

"This record is the first to illustrate the dietary response among herbivore families to the appearance of warm-season grasses in East Africa" at least 10 million years ago, says the study's first author, Kevin Uno, a doctoral student in geology at the University of Utah. "Grass is now the main food for many herbivores there."

He adds: "The results paint a picture of differential dietary response to changes in climate and landscape from 10 million to 3 million years ago, a period that includes the appearance of hominids that eventually gave rise to humans."

The findings "demonstrate that different animals respond differently to ecological change," says geochemist Thure Cerling, the study's senior author and a distinguished professor of geology and geophysics, and biology at the University of Utah.

"This has implications for the future of our planet as climate and ecology change as a result of human activities - not only climate change, but land-use change such as agriculture and desertification," he adds. "And it is not always possible to predict how different parts of the ecosystem will respond to any of these changes."

Uno and Cerling did the study with John Harris of

the George C. Page Museum in Los Angeles; paleontologist Meave Leakey of Kenya's Turkana Basin Institute based at Stony Brook University in New York; and Japanese scientists Yutaka Kunimatsu and Masato Nakatsukasa of Kyoto University, and Hideo Nakaya of Kagoshima University.

You are What You Eat: True 10 Million Years Ago

You are what you eat - and the same was true for African animals that lived millions of years ago. Their diets were recorded by carbon isotope ratios in the enamel of their now-fossilized teeth. The ratios reveal whether an animal ate plants that used so-called C3 or C4 photosynthesis to convert sunlight to energy.

C3 plants include trees, shrubs and cool-season grasses. Most C4 plants are warm-season grasses and sedges commonly found in the tropics. Today in East Africa, nearly all grasses are C4 grasses. And, for the record, modern hays often mix C3 and C4 plants.

Dietary carbon is incorporated into tooth enamel, letting researchers determine whether long-dead animals grazed on C4 grasses or browsed on C3 trees and shrubs.



The chewing surface of a fossilized upper molar from an equid -- an ancestor of zebras -- that lived in East Africa 9.6 million years ago. University of Utah researchers studied 452 fossil teeth from nine families of animals to show that between 10 million and 3 million years ago, different East African plant eaters changed at different times from a diet of trees and shrubs to a diet of warm-season grasses. Credit: Kevin Uno, University of Utah

Global or regional changes in climate have the potential to transform a forest into grassland or vice versa. When this happens over large areas, animals must change their diets or deal with the consequences, which in extreme cases might mean moving to a new habitat or eventually going extinct.

The [diet](#) record of East African herbivores from 10 million to 3 million years ago shows dramatic change occurred at different rates and times. The change was a shift from eating C3 plants - trees, shrubs and cool-season grasses - to eating warm-season, tropical C4 grasses, which first appeared in East Africa 10 million to 15 million years ago.

The animals' switch to grasses began after warm-season grasses first appeared in East Africa, but long before grasslands began to spread rapidly in the region. Previous evidence indicates East Africa was dominated by C3 ecosystems (trees, shrubs and cool-season grasses) during the Middle and Late Miocene Epoch about 16 million to 5 million years ago, but that mosaic landscapes with C4 grasslands were present.

Cerling's previous research found no evidence of widespread grasslands earlier than 4.2 million years ago. "A major shift toward arid environments in the region began about 2.7 million years ago," Uno says. "And only during the past 1 million years did grasslands become as dominant as they are today in East Africa."

But even before 4.2 million years ago, "there was enough C4 grass around for a whole bunch of animals to make a living off of it," he adds.

The first herbivores to eat C4 grasses had longer teeth that took more time for abrasive grasses to wear down. The increased availability of C4

grasses meant there was a new food source available for any herbivore to try if they could digest the gritty grasses, which have more cellulose and lower nutritional quality than most C3 plants.

"If you lived in a town that only ate beef for dinner and the frozen fish stick guy came through selling TV dinners at half price (because everyone ate beef), wouldn't you at least try fish for dinner?" Uno asks. "That example is a bit anthropomorphized, but I see C4 grasses as new resources that may not have been as much in demand as C3 cool-season grasses, trees and shrubs. This could be because some animals had a hard time digesting C4 grasses."

A History of East African Plant Eating

The new study showed this dietary history for East African plant-eating animals:

- Ancient equids, from which the zebra evolved, were the first herbivores to develop a diet primarily of C4 grass. Between 9.9 million years ago and 7.4 million years ago, they made a rapid transition, geologically speaking, from eating trees and shrubs to eating almost exclusively C4 grasses.
- Relatives of the rhino also adopted primarily C4 grass diets before most other families, as far back as 9.6 million years ago. However, some kept browsing on trees and shrubs or had mixed diets of those plants plus C4 grasses. Thus, different rhino species were not necessarily competing for the same food - as is true with modern rhinos.
- Two elephant ancestral lines, elephantids and gomphotheres, did not begin their switch to C4 grass until about 7.4 million years ago, but once they did, they remained grazers until very recently, probably in the last million years or so. Today, African and Asian elephants eat mostly C3 trees and shrubs.
- Suids, ancestors of bushpigs and

warthogs, were slow to eat C4 grass. Few ate it more than 9 million years ago, and only from 6.5 million to 4.2 million years ago did suids have a diet that either was a mix of C3 leaves and C4 grasses or dominated by grasses. Modern suids occupy many ecosystems, so they have diets with both kinds of plants.

- The common hippo today eats mostly C4 grass, but 9.9 million years ago, its ancestors were only eating C3 trees and shrubs. The change was gradual.
- Bovids - which today include gazelles, wildebeest and cape buffalo - were eating C4 grass by 9.6 million years ago, but some species maintained C3 diets, some ate C4 grasses and others ate both.
- Now-extinct deinotheriids, which had two tusks in the lower jaw and were relatives of elephants, show no sign of C4 grass in their diet throughout their history.
- Giraffids, which gave rise to the modern giraffe, relied only on C3 plants throughout the record, in part because their long necks are designed to get to leaves in trees, not grass at their hooves.

Provided by University of Utah

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