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New research sheds light on a key dietary change in early human evolution

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Recently published research provides a strong new line of evidence that the evolutionary split between hominins (the group that includes modern humans and their ancestors) and great apes (gorillas and chimpanzees) involved a major change in diet.

Three articles in the June 25, 2013 issue of *Proceedings of the National Academy of Sciences* (PNAS) report on research using carbon isotopes in the tooth enamel of a large sample of early hominin fossils. The result more precisely defines when these human ancestors shifted from a diet focused on woodland plants to one including significant quantities of grasses and other open-land plants.

Each article focuses on data from a different country—Ethiopia, Kenya, and South Africa—which has yielded numerous early hominin fossils. The research was done by over two dozen scientists from institutions in Africa, Europe and North America. It supports the previous interpretation, based on fossil morphology and environmental setting, that early hominins underwent a significant change in diet as part of their adaptation to a new environment. It also provides additional details regarding the timing of this important aspect of their evolution.

The first article reports on research which examined fossils from the Hadar Formation in Ethiopia, the second on studies of specimens from the Turkana Basin in Kenya, and the third on South African specimens from a number of localities. These are accompanied by an overview article by Richard Klein.

Together, these studies indicate that the earliest hominins, dating to before 4 million years ago (mya) had a diet not distinguishable from that of chimpanzees. By 3.5 mya, however, a notable shift had taken place—the inclusion of a significant proportion of grassland resources in their diet. This may even have included meat from grazing animals that ate such plants (i.e., by hunting or scavenging), though there is at present little corroborating evidence for this possibility.

The dietary change combined with the earlier adoption of bipedalism (upright walking) to mark the definitive break by hominins from the forest-dwelling great apes and set them on an evolutionary path that ultimately produced modern humans.

The last common ancestor of humans and great apes, possibly the species *Ardipithicus ramidus* or a close relative (see “ New fossils provide insights into early human evolution ”), dated to 4.4 million years ago, was a forest dweller, but may have been at least partially bipedal.

During the Pliocene geological epoch (5.3 to 2.6 mya) extensive tropical woodland areas in Africa began to shrink in response to gradual drying and cooling of the climate, which eventually led to the ice ages of the Pleistocene. Populations of the last common ancestor were faced with the option of either trying to survive in the shrinking forests or to venture out onto the expanding grasslands. Those that did the former eventually became the modern great apes. Those that followed the latter course evolved into hominins. A number of lines of evidence have helped to elucidate this transition.

Evidence of bipedalism can be clearly seen in the major modifications to the skeletons of early hominins, in particular the feet, lower limbs, pelvis, and spine. Changes in the diet have been inferred based on modifications of dentition (from teeth designed for chopping vegetation to ones better suited for grinding seeds), as well as a reduction in prognathism (forward projection of the jaws), also to assist in grinding food. The environmental settings in which early hominin fossils have been found also suggest a change in diet from forest to grassland resources. However, these indicators of dietary change are all indirect—they form the basis for inference about the use of new food sources, but are not remains of the foods themselves.

The evidence presented in the new papers published in PNAS represents actual traces—in this case isotopes of carbon atoms—from the foods our ancestors ate. Carbon atoms have two stable variants (isotopes) that are found throughout nature. Ratios of isotopes, such as those in fossilized tooth enamel, often give insight into biological or physical processes, revealing important information about the diets or environments of animals from the past.

Studies of carbon isotopes over the last 20 years have helped show how grasslands spread throughout Africa, pushing back forests, for more than 10 million years. This has been possible because many grasses use a special photosynthetic pathway—called a C4 pathway—that sequesters more of the heavier carbon isotopes into plant tissues than ordinary “C3” plants. These heavier isotopes from plants make their way into soils, and into the bones and teeth of animals grazing on the landscape. Isotopes from fossils in Africa show that as grasslands expanded, more and more herbivores began eating C4 grasses instead of other plants.

The newly reported research in PNAS used these differences in plants to assemble information about the diets of our early ancestors. It provides an independent line of evidence that tends to support the previous interpretation of a shift in early hominin diet as a characteristic of the initial development of this lineage. Furthermore, it indicates that this shift must have taken place prior to 3.4 million years ago, since all the specimens of *Australopithecus afarensis*, the species that includes the famous fossil “Lucy,” which date to that time, show the chemical signature of the changed diet, encompassing a wide range of foods.

This dietary shift most likely occurred during the movement of early hominins onto the grasslands, beginning at least a million years earlier, perhaps represented by the earlier australopithecine species—*Australopithecus anamensis*. Specimens of this species that have been tested, dating to between 4.1 and 3.9 million years ago, do not show elevated C4 plant consumption. This suggests that the dietary shift occurred sometime between 3.9 and 3.4 million years ago, a time span from which no suitable fossils are currently available.

The presumed ancestor of the australopithecine line and perhaps of great apes as well, *Ardipithicus ramidus*, dating to 4.4 million years ago, shows little evidence of consuming C4 plants. By contrast, later species of East African *Australopithecus* show ranges for C4 consumption similar to those for *Australopithecus afarensis*.

Based on their data, the researchers propose that *Australopithecus afarensis* was a “generalist omnivore,” consuming a wide variety of plants, insects, and even small game, perhaps by scavenging.

Data derived from specimens of *Australopithecus africanus* and *Paranthropus*, South African hominins that date to around 2.5 mya, indicate a continuing omnivorous diet, including both C3 and C4 plants for the former and a focused C4 plant diet for the latter, suggesting a concentration on grasses. *Paranthropus*, the specialized grazer, eventually became extinct. *Australopithecus africanus*, on the other hand, may be closely related to the earliest members of the genus *Homo*, the lineage that ultimately gave rise to modern humans. This suggests that dietary flexibility may have been an important component of human adaptation.

The next big shift in hominin diet occurred with the appearance of the earliest members of the genus *Homo*, about 2.5 million years ago (overlapping in time with the later australopithecines), when the first evidence of stone tool use as well as of meat consumption is found.

What is not fully understood is the apparent lag between the adoption of bipedalism and the dietary shift. Perhaps the movement out of the forest was very gradual, involving a long period during which the earliest hominins remained largely on the forest fringes rather than going permanently out onto the savannah, continuing to rely on food sources found in the former while beginning to experiment with those of the latter. New forms of social organization necessary to adapt to the alien environment (collective defense against predators, for example) and the initial development of technology are likely to have taken time to evolve.