Their results, which a team at the Keck II telescope on Mauna Kea, Hawaii, has confirmed, indicate that the source had a redshift (a cosmological measure of distance) of at least 1.6—equivalent to a distance of several billion light-years. Hubble Space Telescope observations made on 8 and 9 February picked out the actual explosion site: the outskirts of a very distant irregular star-forming galaxy.

Such a distant source makes GRB 990123 the most luminous gamma ray burst seen so far, putting the energy of the explosion that created it second only to the big bang itself. Assuming that the explosion did burst with equal intensity in all directions, it must have generated a colossal 3.4×10^{54} ergs—the energy you would get if you took two stars the size of the sun and converted all of their mass instantaneously into energy. In visible light alone, the burst shone as bright as a million normal galaxies.

Theorists are at a loss to explain this prodigious output. Originally, some suggested that a concentration of mass somewhere between Earth and the source might have acted as a gravitational lens, brightening the burst (*Science*, 29 January, p. 616). Now, astronomers invoke beaming: If the blast preferentially emitted gamma rays in two opposite directions, and we happen to look down one of the two jets, less energy could account for the observed luminosity.

In another article in next week's *Nature*, Shrinivas Kulkarni of the California Institute of Technology in Pasadena and his colleagues claim that they see evidence for beaming in their multiwavelength studies of the afterglow of GRB 990123: About 2 days after the burst, the afterglow started to fade faster than before. This "break" in the light curve, which is also seen by Alberto Castro-Tirado of the National Institute of Aerospace Technology in Madrid and collaborators (p. 2069), is what you would expect when a relativistic jet points more or less in your direction and, once it has cooled a certain amount, suddenly starts to expand sideways, increasing the cooling rate.

Although theorists say this doesn't yet amount to a smoking gun, other hints of beaming have turned up. A group led by Jens Hjorth of the University of Copenhagen studied the polarization of the afterglow—a signature of magnetic fields at the light's source—with the Nordic Optical Telescope (p. 2073) and, to their surprise, didn't find any polarization at all. "This could mean that the field is tangled," he says, or it could mean that the field is coherent but the burst is strongly beamed, pointing exactly toward us.

Some theorists are now coming up with explosion mechanisms that would naturally produce beams of radiation—emerging, for example, from the poles of a spinning black hole (see story, p. 1993). But others are withholding judgment. "The theoretical evidence for beaming is quite compelling," says Rees, "but the observational evidence isn't very strong yet." Another titanic burst, and another haul of data, may change that.

—GOVERT SCHILLING

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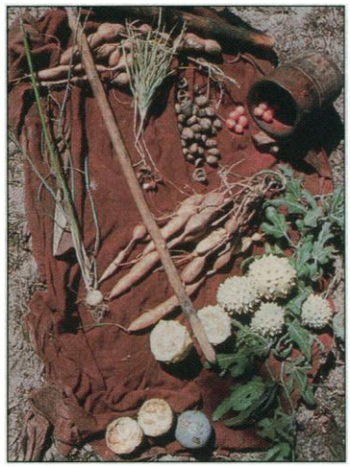
HUMAN EVOLUTION

Did Cooked Tubers Spur the Evolution of Big Brains?

A controversial new theory suggests that cooking—in particular, cooking tubers—sparked a crucial turning point in human evolution

Potatoes, turnips, cassava, yams, rutabagas, kumara, manioc—these are just a few of dozens of underground tubers that sustain modern humans, who boil, bake, and fry them for lunch, dinner, and sometimes breakfast. Now, a small but enthusiastic band of anthropologists argues that these homely roots were also pivotal in human evolution. In work in press in *Current Anthropology*, Harvard anthropologist Richard Wrangham and his colleagues announce that tubers—and the ability to cook them—prompted the evolution of large brains, smaller teeth, modern limb proportions, and even male-female bonding.



Daily "bread." The diet of modern Africans includes a variety of nutritious tubers.

Already this work, which Wrangham has presented at meetings, has provoked skepticism, for it challenges the current dogma that meat-eating spurred the evolution of *Homo erectus*, the 1.8-million-year-old species whom some anthropologists say was the first to possess many humanlike traits. But the idea dovetails with another challenge to the primacy of meat-eating as an evolutionary force: the notion that gathering by females was crucial, which another team of anthropologists will present in the May issue of the *Journal of Human Evolution (JHE)*. And some researchers find the new perspective, based on a potpourri of data from both archaeology and modern human societies, quite refreshing. "Cooking as making such a difference is not something that I had previously considered," says Andrew Hill, a paleoanthropologist at Yale University. "It's nice to have this put forward."

But skeptics say there is a very good reason why this idea may be half-baked. If early humans did cook tubers, then they must have controlled fire about 1.8 million years ago—but the first clear evidence for hearths isn't until about 250,000 years ago. "The application of heat for food was a late thing," says C. Loring Brace, an anthropologist at the University of Michigan, Ann Arbor. "I think [Wrangham] is on the wrong track."

Invoking diet to explain the differences between *H. erectus* and earlier forms such as *H. habilis*, a species known only from fragmentary fossils, and our more apelike ancestors, the australopithecines, is nothing new. The size difference between males and females in *H. erectus* is narrower than it is in the australopithecines of half a million years earlier. And the brains of both sexes grew larger while their guts and teeth shrank; the most dramatic changes occurred between specimens assigned to early *Homo* species and those classed in *H. erectus*. "There's no other point [in time] when you get such large changes," says Wrangham.

The traditional dietary explanation, however, is a shift from nuts and berries to meat. Cut marks on animal bones suggest that humans had mastered meat-eating, perhaps by scavenging carcasses, by 1.8 million years ago. Many researchers have assumed that this high-quality food fueled the rise of *H. erectus*, enabling it to process food with smaller teeth and guts and nourishing larger brains and bodies. And with more food to go around, females began to catch up with males in size.

But Wrangham and his Harvard team think a range of evidence, from archaeology to studies of primates and modern human societies, argues against that scenario. They

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question whether scavenged carcasses could have been a major staple. And they point to hints that even the more apelike australopithecines may have consumed meat more than a million years earlier (*Science*, 15 January, pp. 303, 368), without evolving big brains or changing their overall size; indeed, other modern omnivores eat meat without large increases in body size.

Nor do modern tropical hunter-gatherers rely heavily on meat. Among modern tropical African tribes, "there is no case of [people] eating more meat than plant food," Wrangham points out. For example, anthropologists James O'Connell and Kristen Hawkes of the University of Utah, Salt Lake City, found that although a hunter belonging to the Hadza tribe of Tanzania on average might catch one large animal per month, often weeks would go by with no kills. The Hadza hunt with bows and arrows, technology far more advanced than that of any early humans, yet even for these modern hunters, "this is no way to feed the kids," says Hawkes.

But if meat wasn't responsible for the increase in brain size 1.8 million years ago, what was? Cooked tubers, says Wrangham, arguing that these starchy roots would have been quite abundant on the plains of Africa 2 million years ago, even when drier climates made fruits, nuts, and perhaps animal prey scarce. Today, there are 40,000 kilograms of tubers per square kilometer in Tanzania's savanna woodlands, for example. Other tuber-eating animals, such as wild pigs, thrived in Africa during this time, and Wrangham notes that fossil mole rats, which subsist almost entirely on tubers, have been found among hominid remains from 2 million years ago.

Observations of living apes also offer some precedence for primates digging up roots. For example, chimps in a dry region of the Congo dig down an arm's length to reach the root of a particular vine, then chew on its moist root and carry it as a canteen for long trips. Some apes pull up lakeside herbs and eat the subterranean parts, says Wrangham.

Thus even *Australopithecus* may have munched tubers. But the real revolution came once human ancestors tasted a tuber baked in a lightning-sparked grass fire and realized the value of cooking, Wrangham asserts. Heat turns hard-to-digest carbohydrates into sweet, easy-to-absorb calories. Using the protein, fat, and carbohydrate makeup of modern fruits, seeds, meats, and tubers, Wrangham's team calculated the caloric value of diets containing various proportions of these foods, assuming a constant total amount of food dry matter. A diet of 60% cooked tubers, about the proportion used in modern native African diets, and no meat boosts caloric intake by about 43% over that of humans who ate nuts, berries, and raw tubers, says Wrangham. A 60% meat diet offers just a 20% advantage.

"There seems to be a genuine energetic advantage in cooking food," agrees Yale's Hill. "This could lead to a shift in human behavior" as well as physical changes such as smaller teeth. "Tubers have a lower fiber content [than other plant foods], and that would fit very nicely with this [idea]," adds Leslie Aiello, an anthropologist at the University College in London. "And cooking would just accentuate this."

Wrangham takes his tubers even farther, arguing that they set off another whole chain of evolutionary events. As a valuable resource, cooked tubers needed to be safeguarded from theft. Because cooking requires food to be gathered and held in one place rather than eaten during foraging, males could simply wait until dinner was done, so to speak, and steal it from females.

According to Wrangham, females attempting to thwart theft would use sexual attractiveness to recruit the best male defenders. This tended to offer plenty of mating opportunities for males and less rivalry among them, hence less selection for large males. Thus, while females evolved a larger body size—either to better produce and nourish babies or to fend off stealing—males stayed about the same size, and the size gap between the sexes narrowed. At the same time, the rudiments of the modern human social system—pair-bonding in family groups—took shape.

To some, that scenario doesn't add up. "I can't imagine there was such a dependency on females cooking tubers that males did nothing," says Anna K. Behrensmeyer, a paleoecologist at the Smithsonian National Museum of Natural History in Washington, D.C. But another group of anthropologists agrees that gathering and cooking tubers could have altered human behavior. In their upcoming paper in *JHE*, O'Connell, Hawkes, and Utah colleague Nicholas Blurton-Jones assume that modern gender roles have their roots deep in the past, so that while men were out hunting or scavenging, females, including grandmothers whose own children were grown, brought home the daily bread. Earlier humans foraged for fruits and nuts, which children as well as adults can gather, says Hawkes. But tubers, with their high caloric value, offered a food source rich enough to feed the group without the children's contribution. This "means [the group] is no longer tethered to resources that children can get," explains Hawkes, and led to longer lived, better nourished populations of *H. erectus*. She and O'Connell also argue that these humans were then able to handle a wider range of environments, spreading into grasslands and cooler climates as the fossil record indicates.

Bigger, better. Brains expanded from *Australopithecus africanus* (*left*) to *Homo erectus* (*right*).

But Henry Bunn, a paleoanthropologist at the University of Wisconsin, Madison, has a more typical—and skeptical—reaction to the tuber theory. He says Wrangham's team "downplay[s] lots of sound evidence that we have [for meat-eating and fire use] and [accepts] at face value problematic evidence." A major problem for the theory, notes Hill, is that where there's cooking smoke, there must be fire. Yet he, Michigan's Brace, and most other anthropologists contend that cooking fires began in earnest barely 250,000 years ago, when ancient hearths, earth ovens, burnt animal bones, and flint appear across Europe and the middle East. Back 2 million years ago, the only sign of fire is burnt earth with human remains, which most anthropologists consider coincidence rather than evidence of intentional fire.

O'Connell counters that fires for cooking tubers rather than meat "might have been very ephemeral" and left few traces, but most of his colleagues remain unconvinced. "I think there would be evidence if it were [behind] as important an evolutionary leap as [Wrangham's team] suggests," says Behrensmeyer.

Even Wrangham agrees that more evidence is needed. "There hasn't been enough satisfactory archaeology for people to get their teeth into," he says. But he also contends that the more he looks into the question, the more convinced he is of cooking's great importance, even 1.8 million years ago. "What could be more human," he asks, "than the use of fire?"

—ELIZABETH PENNISI