

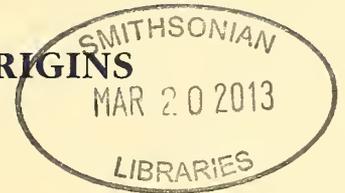
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NEW RESEARCH IN EARLY HUMAN ORIGINS 7 TO 1 MILLION YEARS AGO

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The last decade has witnessed a dramatic increase in the pace of new discoveries about human beginnings. Many aspects of the human story as we knew it a decade ago have changed, and we continue to be surprised by the variety, adaptations, and sophistication of our earliest ancestors.

The number of new finds is truly extraordinary. In the 26 years between 1964 and 1990, for example, only four new species (two species in the genus *Australopithecus* and two in the genus *Homo*) were added to our hominin family tree, and no new genera were proposed. In only eleven years between 1991 and 2002, eight new hominid species were proposed, four of them so distinctive that they were placed in new genera, implying they were at least as different from previous finds as chimpanzees are from us or from gorillas.

Why this sudden increase in the rate of discovery? In part it is due to an increasing number of workers in the field and to the opening or reopening of new areas to researchers. For example, Ethiopia, home to two of the new species, was largely closed to international researchers for ten years before 1991. The desolate region of Chad, where two other new species were found, had hardly been explored before 1994. Another factor is the expanded funding available to an increasingly multinational research effort. It is not unusual for today's exploration teams to consist of scientists from a dozen different nations, including African, Asian, South American, and Pacific ones. The diversity of new finds has been accompanied by advances in the reconstruction of ancient environments and how hu-

mans adapted to them, and by new ways of studying and understanding physical differences among fossils. This review will discuss the impact of these new finds, as well as the new analytical methods for studying them.

The Family Tree in 1990

Have these new finds really changed anything about how we view our earliest beginnings? The answer is yes. As recently as 1990 the family tree itself seemed rather simple and straightforward; the most common model was a tree with only seven or perhaps eight species in all, and only one or two side branches. Most of the time the hominid niche was filled by only one species, except between about 2.6 and 1.3 million years ago (mya), when related species occupied the side branch. First, or so we thought, there was "Lucy" (*Australopithecus afarensis*), from about 3.6 to 2.9 mya. *A. afarensis* was small but walked bipedally—an adaptation, we thought, to life in the open savanna as Africa became drier and its forests shrank. Then there were more "evolved" australopithecines who came in two varieties: the gracile type (*Australopithecus africanus*) and the robust type with huge teeth and a bony crest on top of the skull (*Australopithecus robustus*, *A. boisei*, and *A. aethiopicus*). The former group was thought to have evolved into an early form of our own species, *Homo*, while the latter side branch became more and more specialized, lived alongside early *Homo* for a while (for perhaps as much as a million years), and then died out. Early *Homo*, in turn, supposedly went through a direct progression from *H. habilis* to *H. erectus* to *H. sapiens*, marked by increasing brain size

and decreasing tooth size. Neanderthals might have been another late, side branch. Until about 1.3–1.4 mya, Africa, specifically eastern and southern Africa, was considered the only home of our ancestors. And the first migrants out of Africa, *H. erectus*, went not to Europe but to Asia, arriving in China and Java only about 1 mya, or so it was thought. No firm evidence existed in 1990 for the occupation of Europe prior to 500,000 years ago—and as of 1990 the earliest known occupants of that continent did not fit into *H. erectus* but were more advanced toward *H. sapiens*—with larger brains, rounder skulls, smaller teeth, or other more specialized features.

Before Lucy

To call a new fossil a hominin, or a member of the human lineage, palaeontologists look for evidence of our most unusual features: bipedalism, thick dental enamel and large flat molars for chewing tougher foods, and differences in the canine teeth—male apes have big sharp ones used to threaten other males, and humans all have small blunt ones. If leg and pelvic bones are missing, bipedalism can be inferred indirectly because it changes the shape of the vertebrae and ribs. Bipedalism also changes the place where the spine enters the braincase—the entry hole (foramen magnum) is further forward under the skull rather than toward the back. Australopithecines who lived until ca. 1.3 mya had small brains not much larger than chimpanzees, very large chewing teeth, and a large projecting, almost concave or dish-shaped face, together with bony ridges and even crests on the skull where the large chewing muscles attached. Fossils classed in our own genus, *Homo*, which first appears around 2.3 mya, have larger brains, smaller molar teeth, and a nose that projects from the plane of the face—they are also often associated with clear evidence of technology such as chipped stone artifacts and bones cut with stone tools.

But what came before *Australopithecus afarensis*, who already had reduced canines and large molar teeth and also walked bipedally and may have climbed trees to feed or sleep at night? Only a couple of indeterminate teeth and scraps of bone filled the gap between the presumed split with the chimpanzee

lineage, estimated at ca. 5–9 mya on genetic grounds, and *A. afarensis*. *A. afarensis* was the only example of what a hominin from 3.5 mya might look like, and there are no diagnostic fossils of chimpanzee or gorilla ancestors after about 8 mya. (There are at least two fossil species just before this time that may be related to the lineage of the African great apes and humans: a gorillalike upper jaw from the Samburu Hills of Kenya [*Samburupithecus*] dated to 9.5 mya, and several fossils from Greece dating to 9.5–8.5 mya [*Graecopithecus*] with large canines and apelike brow-ridges.) Now six new species, provisionally classed with the hominins and dated to between 7 mya and 3 mya, suggest considerable diversity among our earliest ancestors.

The newest find and the oldest fossil of these is also the most unexpected: a beautifully preserved skull complete with a face, published in 2002 and given a new genus and species name, *Sabelanthropus tchadensis*. First, it does *not* come from East Africa, but from the site of Toros-Menalla in the flat desert margin of the Sahara (the Sahel) in the west-central African country of Chad. Second, the fossil mammals found with it include not only species such as saber-toothed cats, three-toed horses, and elephants with upper and lower tusks that lived about 6–5 mya in Africa, but also very primitive animals, called anthracotheres, that lived in Libya and other places until around 7 mya but died out shortly afterward, placing this new hominin between 6 mya and 7 mya. The cranium and teeth do not look at all like what we might have expected in a “missing link” between *Australopithecus* and a chimpanzee ancestor. *Sabelanthropus* had a very small brain no larger than that of a chimp, massive brows larger than those of a gorilla, and thin dental enamel (though thicker than a chimpanzee’s). But it also possessed rather small canine teeth and a surprisingly small and vertical (nonprojecting) lower face, closer to *Homo* than to *Australopithecus*. The spinal column entered the base of the skull relatively far forward suggesting bipedal posture, but definitive determination of this awaits the discovery of diagnostic pieces of the lower limb or pelvis. And while there were many fossil animals at the site whose teeth suggest that they ate grass, the

immediate environment of *Sabelanthropus* was more like a swampy gallery forest (along a river or flood plain) than a savanna, judging by the hippos, crocodiles, otters, fish, and monkeys found along with the fossil.

Back in Kenya, a 6-million-year-old hominin, *Orrorin tugenensis*, also known as “millennium man,” was found in the Baringo basin of central Kenya in the fall of 2000 and published in 2001. The geological layer in which the fossils were found is dated to between 5.6 and 6.2 mya by the relatively accurate argon-argon dating technique, which measures the regular decay of radioactive potassium atoms into argon gas in volcanic sediments. The thirteen skeletal fragments from possibly five individuals (more bones have reportedly been discovered since) included teeth and jaw fragments, a left thigh bone, a finger bone, and bones from the arm. While not yet well studied or published, the fossils show a mix of primitive and advanced traits. The canines are large and the premolar is described as “apelike,” but the molars are small, with thick enamel. Similarly, the arm and finger bones are curved for climbing in the trees, but the femur (thigh bone) is very large and robust, and its shape and large hip joint suggest bipedalism to its discoverers, if not to many skeptics. *Orrorin* lived alongside hippos, rhinos, and antelopes.

Ardipithecus* and Early *Australopithecus

In northern Ethiopia’s Middle Awash valley south of Hadar (where Lucy was found), two new sites dating to 5.8-5.2 and 4.4 mya, respectively, have yielded remains of yet another ancestral hominin species: *Ardipithecus ramidus* (from ardi meaning “ground” or “floor” and ramid meaning “root” in the local Afar language). Fossils of the earlier subspecies (*Ardipithecus ramidus kadabba*) included a toe bone described as similar to a bipedal one. Both this subspecies and the later one (*Ardipithecus ramidus ramidus*) have teeth and jaws that combine a different mosaic of traits than *Orrorin* or *Sabelanthropus*. *Ardipithecus* had relatively large canines compared to *Australopithecus*, but blunter and smaller than those of apes; the premolars are similarly intermediate in their asymmetry; the molars are smaller and more elongated than in *Australopithecus*, and the dental

enamel is thinner. The ear opening is small, as in apes, rather than large, as in hominins. Other fossils of *Ardipithecus* await the tedious and painstaking task of restoration, which the bones’ fragile and fragmentary condition requires before any scientific comparisons can be made. *Ardipithecus* was also not a savanna animal—the most common other fossils at the later site belonged to kudu and colobus monkeys, along with bats, a primitive bear, and a number of small mammals.

By 4.2-3.9 mya the first species of *Australopithecus* appears in northern Kenya’s Lake Turkana region, but in a different, more primitive form than *A. afarensis* (Lucy). The new species is called *Australopithecus anamensis* (for anam, “lake” in the Turkana language). It was definitely bipedal, judging from the large size of the tibia (shin bone) and the asymmetry and elongated shape of its upper end that forms part of the knee joint. The hand, nonetheless, was large and strong, for climbing in the trees. Like other species of *Australopithecus*, this one had larger square-shaped molars with thick enamel, but the canine and first lower premolar were intermediate in size and shape between those of Lucy and *Ardipithecus*, and the ear opening was small, as in apes and *Ardipithecus*. This first *Australopithecus* didn’t live in a savanna either, although the environment may have been more open than that of *Ardipithecus*. At one site (Kanapoi) *A. anamensis* shared the environment with fish, hippos, kudu, and impala, suggesting a bushy woodland, while at another site (Alia Bay) the environment was more likely a riverine gallery forest.

Lucy’s cousins

New finds and species of the last eleven years are not limited to the period before 4 mya. Many new finds have expanded our knowledge of *A. afarensis* itself, suggesting a very large degree of sexual dimorphism and further evidence that this species both walked bipedally and retained considerable ability to climb trees. *Afarensis* has been joined in the 4-3 million-year range by new fossils of *A. africanus* in South Africa, and by two new species in western and eastern Africa, respectively. The new early South African fos-

sils include a set of foot bones (nicknamed “Little Foot”) dating to at least 2.9–3.1 mya at the cave of Sterkfontein (Member 2). While similar to the feet of later bipeds, this one may have retained some ability to grasp tree limbs, although the reconstruction is controversial. In 1998 much of the rest of the skeleton was found embedded in the cave floor where it fell, millions of years ago, but will require years of painstaking work to excavate from the solid limestone conglomerate or breccia that formed around and over it. New paleobotanical studies at Sterkfontein from the main australopithecine level (Member 4) recovered fossilized vines that today occur only well inside the tropical forest far to the north. No open savannas here either!

Another new find in this time range is remarkable for its location—1,500 miles west of Lake Turkana in another region of Chad called Bahr el Ghazal. *Australopithecus babrelghazali* is dated to around 3.0–3.4 mya based on rough ages of the primitive fossil elephants, horses, pigs, and rhinos found with it. These are interpreted as inhabiting a mixed forest-woodland, rather than an open savanna. The fossil, a mandible, is similar to *A. afarensis* but with thinner tooth enamel and other distinctive traits. The second new species, from the fossil-rich region of Lake Turkana, is so different from *Australopithecus* that it has been placed in a different genus entirely: *Kenyanthropus platyops* (flat-faced Kenya man). This fossil, an almost complete skull, lacks the browridges, concave or “dished” face, large molar teeth, or other features of *Australopithecus* and has a more rounded braincase and smaller teeth. In some ways it most resembles later fossils attributed to our own genus, *Homo*, including the famous fossil KNMER-1470, attributed to *H. rudolfensis*.

New Views of Human Ancestry

Does this new species push Lucy and all the australopithecines off the direct line to humans onto a side branch? In some ways, not only *Kenyanthropus* but even the ancient *Sabelanthropus* shared some advanced features with later *Homo* that are missing in *Australopithecus*. The new evidence makes it difficult to describe human ancestry in such a linear way. The period leading up to and including Lucy is now represented by a confusing diversity of not-quite-human forms: at least four species before *A. afarensis* and three *A. afarensis* contemporaries. Most or all may represent experiments with some form of bipedalism, almost always combined with an ability to grasp tree limbs. The evidence for bipedalism is strongest where the leg bones are represented—definite in the australopithecines, including *A. anamensis*, likely for *Ardipithecus*, and more debated for *Orrorin* and *Sabelanthropus*. Some species, such as the australopithecines, have flat projecting faces, large thick-enamelled molars, and small canines. Others have large molars and thinner enamel (*A. babrelghazali*) or larger canines and thinner enamel (*Sabelanthropus*, *Ardipithecus*), or smaller canines, smaller molars, and thick enamel (*Orrorin*). Faces were variously vertical or projecting, with or without large browridges. In short, it is as if there were a large basket of possible dental, facial, and cranial traits, and each species pulled out a few different traits almost at random. What is implied is a long period of experimentation within a new ape niche, part arboreal, part terrestrial. Efforts to compress this into a tree, with definite ancestor and descendant relationships or even groupings, will depend entirely on which traits the palaeo-anthropologist chooses to emphasize. But which traits did evolution emphasize?

We cannot understand the large amount of variation among early hominins by just listing and comparing all the traits. Instead we need to understand how traits are linked functionally, how they develop during growth, and how they are related to genetic changes. A very small genetic change in the pattern of growth, speeding up or slowing the growth of one body part relative to another, could fundamentally alter the resulting body shape. The fact that we share 95–98 percent of our genes with chimpanzees, and even 80 percent with a laboratory mouse, means that genetic control of how the face or limbs grow, for example, may be very similar across all the mammals. Some genes just turn on earlier and allow longer or faster growth of certain body parts in chimpanzees, other parts in humans. And one genetic change may have multiple effects on the resultant body. Since bodies also respond to function and usage during growth, anthropologists are conducting

laboratory experiments on many different species other than primates to help them understand how the interplay of function and genetics can help explain differences in the fossil record. In the past five years George Washington University scientists have studied how lower limbs respond to walking stress by observing sheep on treadmills, and how jaws and cranial bones respond to chewing stress by feeding hyraxes different diets. Modeling techniques derived from engineering studies of design stresses help to interpret the data, and CT scans of the animals help scientists see the changes as they develop.

For the moment, the best strategy is simply to divide the most archaic forms from the australopithecines, and to recognize that experimentation and diversity continued, even during the apparent dominance of *Australopithecus* between 3.5 and 2 mya. Exploration of new regions in Africa may continue to provide radical challenges to our models of human ancestry. For example, while these early bipedal experimenters inhabited different environments, none of them seemed to have lived in the savanna, and all of them retained an ability for tree-climbing.

The Emergence of *Homo*

The 3–2 mya period is perhaps the most critical for the emergence of our own genus, but new finds of five different species have questioned the direct ancestry or even the definition of *Homo*. *A. africanus* continues in South Africa, but in East Africa *A. afarensis* disappears early in this time range, and two developments follow. The first is the appearance of robust australopithecines (or *Paranthropus*) by 2.6 mya, with extra-large molar teeth and sagittal crests along the top of the skull (in *A. aethiopicus*, and *A. boisei*). This is followed around 2.3 mya by the appearance of

Homo (including *H. rudolfensis*), with a slightly larger brain and/or smaller molar teeth.

Explorations at Bouri in the Middle Awash region of Ethiopia at 2.6 mya have revealed a new species, *Australopithecus garhi* (*garhi* means “surprise” in the Afar language), contemporary with the earliest robust australopithecines from Lake Turkana (*A. aethiopicus*). *A. garhi*'s big molars and thick enamel recall the robust australopithecine, but it lacks their reduced incisors and dished face. In addition, arm and leg bones of a single individual found within 300 meters of the skull may or may not belong to the same species. The bones are unique for their time period—arms as long as Lucy's for climbing, but much longer legs for walking. This suggests that bipedal walking may have become well established before humans gave up the trees altogether.

The oldest known stone tools also come from 2.6–2.5 mya in Ethiopia, but about 100 kilometers to the north at Gona, near Hadar. Other stone tools from Hadar, from Lokalelei on Lake Turkana, and from Kanjera on the east side of Lake Victoria date to around 2.1 to 2.3 mya. How did stone tool making originate? Chimpanzees use many kinds of simple tools, fashioned from sticks, leaves, and stones, and their hands are well adapted to manipulating objects. In Côte d'Ivoire chimpanzees use stones to crack nuts, transporting the stones several hundred meters near nut-bearing trees, and occasionally detaching stone chips and flakes as an unintentional by-product of nut cracking. The potential for transporting stone and

manipulating it to make stone tools may have been present in our most distant common ancestor. The early stone tools at Lokalelei, Gona, and Hadar, however, are surprisingly elaborate, involving the removal of as many as thirty flakes from a single core. Many of the flakes were quite



thin and/or regularly shaped. Attempts to teach orangutans, chimps, and bonobos to flake stone show that the early tools from East Africa required a degree of spatial cognition and manual dexterity (including the ability to use the fourth and fifth fingers to stabilize the stone being struck) that may be beyond the apparent abilities of chimpanzees. It is likely, then, that human stone technology is older than 2.5 mya, although the concentration in space and intensity of stone-tool use and manufacture that resulted in the formation of archaeological sites may not predate the Gona finds.

The first fossils attributed to *Homo*, especially new finds from Hadar, date to 2.3 mya, implying that the initiation of stone-tool making may precede the development of a larger brain and smaller teeth. No stone tools were found in direct association with *A. garhi*, but there was indirect evidence of their use. In the area that yielded the limb bones there were a number of bones of extinct horses and antelopes that showed signs of butchery. Deep scratches with the characteristic sharp edges of stone-tool cut marks indicate where meat and sinews had been sliced from the bone, and hammerstone impact fractures made while the bones were fresh show how they had been broken open for marrow. If this behavior can be attributed to *A. garhi*, then this hominid clearly shares behavioral features with later humans, even though its brain was still small and the teeth still large. It may be an early indicator of what we now recognize as a common pattern of *Homo*, in which new behaviors drive and select for changes in morphology—tools before brains.

In South Africa, *Homo* and stone tools appear together around 2 mya at Sterkfontein, followed soon thereafter by the first robust australopithecines, perhaps suggesting a spread of both ideas and species from the north. New South African data come from the lab as well as the field, as in, for example, a study of stable isotopes in robust australopithecine teeth. Most of the carbon in our bones and teeth is the common form, carbon-12, but a tiny amount is a stable isotope with an extra neutron: carbon-13. In tropical environments the amount of carbon-13 is higher in grasses than in trees, so grazers have higher amounts than browsers or fruit eaters. The study indicated that

the amounts in robust australopithecine teeth were high. Since members of the human family are unlikely to have eaten grass, the study's authors concluded that the australopithecines were occasional carnivores who preyed on grazing animals. But another possibility is that robust australopithecines ate the underground tubers of grassy plants or sedges high in carbon-13. Dating from tools, cut-marked bones, and stable isotopes combine to suggest major changes in diet in the course of early human evolution.

How Human are *H. habilis* and *H. rudolfensis*?

The earliest members of the genus *Homo* are *Homo habilis*, defined in 1964 on the basis of specimens found at Olduvai Gorge, and *Homo rudolfensis*, defined in 1986 on the basis of specimens found east of Lake Turkana. Since 1985 accumulating evidence has demonstrated that at least one of these species still maintained a number of specializations for life in the trees, like long arms, short legs, and curved fingers. In addition, these hominids exhibit very little of the marked reduction in tooth size that characterizes our genus and leads to our smaller faces. *Homo* was supposedly characterized by large brains, language, tool dependence, and manual dexterity. New data have shown that the brains of these fossils are not large compared to their body mass, and we cannot determine whether or not they had language abilities to a greater extent than the apes. Tools now appear before the first fossil attributed to *Homo* and occur with *Australopithecus* and *Paranthropus* as well. New studies of hand function show that the hand of *H. habilis* was not as fully modern as we had supposed. In a major review of these issues, Wood and Collard suggest that *H. habilis* and *H. rudolfensis* do not share the adaptations characteristic of later members of the genus *Homo* and should be grouped instead with *Australopithecus*. The first member of our own genus would then be *H. erectus* (or the early African variant *H. ergaster*), dating to not more than 1.9 mya.

Out of Africa?

For many years it was thought that the first humans to leave Africa were *H. erectus*. The date of their expansion out of Africa supposedly was not earlier than 1.4 mya, based on an early site of this age at 'Ubeidiya

In Israel. Lack of sites suggested that Europe was unoccupied until half a million years ago. But the last eleven years have changed these views as well. Old (but controversial) dates of ca. 1.8 mya have been proposed for both Southeast Asia and China—although there are questions about both the dates themselves and the human nature of some of the items being dated—for example, hominins and stone tools in South China. Perhaps the most exciting new finds come from the site of Dmanisi in the Caucasus Mountains of Georgia, at the gates of Europe. Here on a small promontory in sediments of an ancient lake and river margin, levels dating to just after 1.8 mya have yielded an unusual array of fossils. At least six individuals have come to light so far, some with very large jaws, others with small brains, thin browridges, and relatively large canine teeth for a member of the genus *Homo*. The associated faunal remains include other African migrants that spread easily across different habitats (e.g., ostriches and hyenas). The artifacts are simple flakes and cores, not the symmetrical handaxes of later *H. erectus*. The variability within the small number of fossils from this site is hard to understand, but the implications for an early exit from Africa are clear. Even if the Dmanisi dates are somewhat later, humans left Africa before they became large, before they had developed the more complex technologies and larger brains of later *H. erectus*, and possibly before they had fully abandoned the trees.

But where did they go? Evidence is accumulating for the early occupation of East Asia, as least as early as 1.3 mya. But solid European evidence beyond Dmanisi is lacking until around 800,000 years ago. At the Gran Dolina cave, near Atapuerca, Spain, a new species, *Homo antecessor*, is based on fragments from the TD6 level. Its approximate date of 800,000 years ago comes from the fact that the fossils lie below a magnetic change point. The sediments above have a magnetism similar to that of today's, but the sediments at the fossil layer and below it have a reversed magnetism, that is, the "north" recorded by the sediments is actually "south" today. Evidence of magnetic reversals occurs in sediments all over the world, and the most recent shift from "reversed" back to "normal" has been dated by argon laser techniques to 780,000–791,000 years. The fragments include the

lower face of a child with several teeth, a fragment of frontal bone (forehead region), a small piece of a jaw, and several long-bone fragments. At least six individuals are represented, and some of the bones show cut marks made while the bone was fresh, a possible sign of cannibalism. As at Dmanisi, stone tools at Gran Dolina also consist of very simple cores and flakes, rather than large bifacial handaxes.

The discoverers of *H. antecessor*, Bermudez de Castro and colleagues (1997), argue that the shape of the nose region is not that of *H. erectus* but instead resembles some features of *H. sapiens* and Neanderthals (hence the name *antecessor*). They argue that it is the ancestor of both Neanderthals and modern humans before the two lines diverged. Others suggest that it may be the ancestor of a Neanderthal lineage that split off from the modern human lineage before *H. antecessor*. Without more pieces from Gran Dolina or other European fossils from the same time period, however, it is difficult to say whether its separate status will continue. It could also prove to be just an early form of a European species known as *H. heidelbergensis*, which lived in Europe from about 500,000 to about 200,000 years ago. The dating is also only approximate since we do not know how much time elapsed between the burial of the fossil and the magnetic shift at about 790,000 years ago.

The interesting question raised by the naming of a new European species at an early date is the antiquity of the separation between a European human lineage leading to Neanderthals and an African human lineage leading to modern humans. Were Neanderthals, who do not appear until around 200,000 years ago, the final branch of a large European tree, all adapted to colder and more seasonal conditions than elsewhere in the Old World? Did the split between the two lineages occur after or before *H. antecessor*? In either case, if the split is ancient, how do we explain the later development of behavioral similarities between Neanderthals and their African and Near Eastern cousins? Could this be a case of parallel evolution? Or is this new member of the family tree just a temporary offshoot that died out without descendants?

Other new evidence for hominin presence in southern Europe at an early date includes several

sites from Italy that may be almost as old as Gran Dolina. The site of Ceprano includes human fossil material—the crushed skullcap with a relatively large cranial capacity of ca. 1050 cc may be comparable to *H. antecessor*, to late *H. erectus*, or to another human type more advanced than *H. erectus*. Dates at most of these sites are based on volcanic horizons that are correlated to nearby levels dated by argon-argon. Ceprano thus may be more than 700,000 years old, while the oldest levels at Notarchirico, which contain several bifaces, are more than 650,000 years old. Another Italian site, Isernia, with a simple flake-tool industry, may be of comparable age or up to 100,000 years younger. Like many early African sites and Dmanisi, these early sites appear to represent concentrations of human activity on lake shores, along with the cut and possibly scavenged bones of very large mammals such as elephants and rhinos. The oldest evidence from middle or northern latitudes of Europe, however, is much later, ca. 500,000 years ago. Only Notarchirico contains early bifaces, while all of the European sites older than 700,000 years ago contain only simple flake tools.

What enabled our early ancestors to expand out of their African homeland? Was it their use of underground food resources that allowed them to exploit dry and open habitats? (This might explain why the occupation of Europe was later, since most tubers don't survive if the ground freezes—the high-altitude-adapted-potato is the great exception). Were they simply following large mammals into the open grasslands of Asia, hunting and/or scavenging as they went? Did they control fire, or had they invented cooking or effective hunting techniques? How did they meet the competition from new carnivore species, like wolves and saber-tooth cats, as they moved into new territories? What did their simple technology allow them to do? How did their increasing technological competence enable the growth of human populations? Why do bifaces and large cutting tools appear to be common in some areas and environments and not in others? We hope that new research now under way in South China, Central Asia, Turkey, and southeastern Europe may provide new and exciting data bearing on these questions.

Further Reading

Asfaw, B., T. D. White, O. Lovejoy, et al. 1999. "*Australopithecus garhi*: A New Species of Hominid from Ethiopia." *Science* 284:629–35. See also: Locke, R. 1999. "The First Human?" *Discovering Archaeology* 1(4):32–39.

Bahn, Paul G. 1996. "Treasure of the Sierra Atapuerca." *Archaeology* 49(1):45–48.

Balter, Michael, and Ann Gibbons. 2002. "Were 'Little People' the First to Venture Out of Africa?" *Science* 297:26–27.

Bermudez de Castro, J. M., J. L. Arsuaga, E. Carbonell, et al. 1997. "A Hominid from the Lower Pleistocene of Atapuerca, Spain: Possible Ancestor to Neandertals and Modern Humans." *Science* 276:1392–95.

Brunet, M., A. Beauvilain, Y. Coppens, et al. 1995. "The First Australopithecine 2,500 Kilometres West of the Rift Valley (Chad)." *Nature* 378:273–75. (Comment by Bernard Wood on p. 239.)

Brunet, Michel, F. Guy, D. Pilbeam, et al. 2002. "A New Hominid from the Upper Miocene of Chad, Central Africa." *Nature* 418:145–151

Carbonell, E., J. M. Bermudez de Castro, J. L. Arsuaga, et al. 1995. "Lower Pleistocene Hominids and Artifacts from Atapuerca-TD6 (Spain)." *Science* 269:826–30. (Comment by J. Gutin on pp. 754–55.)

Clarke, Ronald J. 1998. "First Ever Discovery of a Well-Preserved Skull and Associated Skeleton of *Australopithecus*." *South African Journal of Science* 94: 460–63.

Clarke, Ronald J., and Philip V. Tobias. 1995. "Sterkfontein Member 2 Foot Bones of the Oldest South African Hominid." *Science* 269:521–24. (Comment on pp. 476–77.)

Delson, Eric, Ian Tattersall, John A. Van Couvering, and Alison S. Brooks, eds. 2000. *Encyclopedia of Human Evolution and Prehistory*. Garland Publishers. See especially articles on *Australopithecus anamensis* (by Fred Grine), pp. 123–24; *Australopithecus bahrelghazali* and *Australopithecus garhi* (by E. Delson), pp. 124–25; Ceprano (by E. Delson), pp. 163–64; Isernia (by A. Brooks) p. 351; and Venosa (by A. Brooks), p. 723.

Gabunia, L., and A. Vekua. 1995. "A Plio-Pleistocene Hominid from Dmanisi, East Georgia, Caucasus." *Nature* 373:509–12.

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Early Human Origins, continued from page 8)

Tabunia, Leo, Absalom Vekua, David Lordkipanidze, et al. 2000. "Earliest Pleistocene Hominid Cranial Remains from Dmanisi, Republic of Georgia: Taxonomy, Geological Setting, and Age." *Science* 288:1019–25.

Tore, Rick. 2002. "National Geographic Research and Exploration: New Find." *National Geographic* 202(2):n.p.

Traile-Selassie, Yohannes. 2001. "Late Miocene Hominids from the Middle Awash, Ethiopia." *Nature* 412: 178–81.

Timbel, William H., Donald C. Johanson, and Yoel Rak. 1994. "The First Skull and Other New Discoveries of *Australopithecus afarensis* at Hadar, Ethiopia." *Nature* 368:449–51. (Comment by L. Aiello on pp. 399–400.)

Timbel, W. H., R. C. Walter, D. C. Johanson, et al. 1996. "Late Pliocene *Homo* and Oldowan Tools from the Hadar Formation (Kada Hadar Member), Ethiopia." *Journal of Human Evolution* 31:549–61.

Tuman, Kathleen. 1994. "The Archaeology of Sterkfontein—Past and Present." *Journal of Human Evolution* 27(6):471–95.

Teakey, Meave G., C. S. Feibel, I. McDougall, and A. Walker. 1995. "New Four-Million-Year-Old Hominid Species from Kanapoi and Allia Bay, Kenya." *Nature* 376:565–71. (Comments by P. Andrews on pp. 555–56.)

Teakey, Meave, Fred Spoor, Frank H. Brown, et al. 2001. "New Hominin Genus from Eastern Africa Shows Diverse Middle Pliocene Lineages." *Nature* 410:433–40.

Tercader, Julio, Melissa Panger, and Christophe Boesch. 2002. "Excavation of a Chimpanzee Stone Tool Site in the African Rainforest." *Science* 296:1452–55.

Thorwood, M.J., P. B. O'Sullivan, F. Aziz, and A. Raza. 1998. "Fission-Track Ages of Stone Tools and Fossils in the East Indonesian Island of Flores." *Nature* 392:173–76. (Also commentary by A. Gibbons [1998], "Ancient Island Tools Suggest *Homo erectus* was a Seafarer." *Science* 279:1635–37.)

Trainger, Melissa, Alison S. Brooks, Brian G. Richmond, and Bernard Wood. 2002. "Older than the Oldowan? Rethinking the Emergence of Hominid Tool Use." *Evolutionary Anthropology* 11(6):235–45.

Pickford, Martin, Brigitte Senut, Dominique Gommery, and Jacques Treil. 2002. "Bipedalism in *Orrorin tugenensis* Revealed by its Femora." *Comptes Rendus Palevol* 1:1–13.

Plummer, Tom, Laura Bishop, Peter Ditchfield, and Jason Hicks. 1999. "Research on Late Pliocene Oldowan Sites at Kanjera South, Kenya." *Journal of Human Evolution* 36:151–70.

Richmond, Brian G., and William L. Jungers. 1995. "Size Variation and Sexual Dimorphism in *Australopithecus afarensis* and Living Hominoids." *Journal of Human Evolution* 29(3):229–45.

Richmond, B. G., and D. S. Strait. 2000. "Evidence That Humans Evolved From a Knuckle-Walking Ancestor." *Nature* 404:382–85. ("News and Views" comment by M. Collard, and L. C. Aiello [2000], "From Forelimbs to Two Legs." *Nature* 404:339–40.)

Roche, H., A. Delagnes, J. P. Brugal, C. Feibel, et al. 1999. "Early Hominid Stone Tool Production and Technical Skill 2.34 Myr Ago in West Turkana, Kenya." *Nature* 399:57–60.

Rowlett, R., M. G. Davis, and R. B. Graber. 1999. "Friendly Fire: The First Campfires Helped Hominids Survive the Night." *Discovering Archaeology* 1(5):82–89.

Ruff, C. B., Eric Trinkaus, and T. W. Holliday. 1997. "Body Mass and Encephalization in Pleistocene *Homo*." *Nature* 387:173–76.

Semaw, S., P. Renne, J. W. K. Harris, et al. 1997. "2–5 Million-Year-Old Stone Tools from Gona, Ethiopia." *Nature* 385:333–36.

Senut, Brigitte, Martin Pickford, Dominique Gommery, et al. 2001. "First Hominid from the Miocene (Lukeino Formation, Kenya)." *Comptes Rendus de l'Académie des Sciences de Paris, Série IIa* 332:137–44.

Sponheimer, Matthew, and Julia A. Lee-Thorp. 1999. "Isotopic Evidence for the Diet of an Early Hominid, *Australopithecus africanus*." *Science* 283(5400):368–70.

Swisher III, Carl C., G. H. Curtis, T. Jacob, et al. 1994. "Age of the Earliest Known Hominids in Java, Indonesia." *Science* 263:1118–21.

Vekua, Abesalom, David Lordkipanidze, G. Philip Rightmire, et al. 2002. "A New Skull of Early *Homo* from Dmanisi, Georgia." *Science* 297: 85–9.

Vignaud, P., P. Douring, H. T. Mackaye, et al. 2002. "Geology and Palaeontology of the Upper Miocene Toros-Menalla Hominid Locality, Chad." *Nature* 418:152–55.

White, Tim D., G. Suwa, and B. Asfaw. 1994. "*Australopithecus ramidus*, a New Species of Early Hominid from Aramis, Ethiopia." *Nature* 371:306–12. (Comments by Bernard Wood on pp. 280–81.)

Wood, Bernard. 2002. "Hominid Revelations from Chad." *Nature* 418:133–35.

Wood, B., and M. Collard. 1999. "The Changing Face of Genus *Homo*." *Evolutionary Anthropology* 8(6):195–207.

Wrangham, R.W., J. H. Jones, G. Laden, et al. 1999. "The Raw and the Stolen: Cooking and the Ecology of Human Origins." *Current Anthropology* 40(5):567–94.

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