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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 humans 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 browridges.) 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, *Sahelanthropus 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. *Sahelanthropus* 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 *Sahelanthropus* 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 tugensis*, 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 *Sahelanthropus*. *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 kudus 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 fossils 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 bahrelghazali* 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

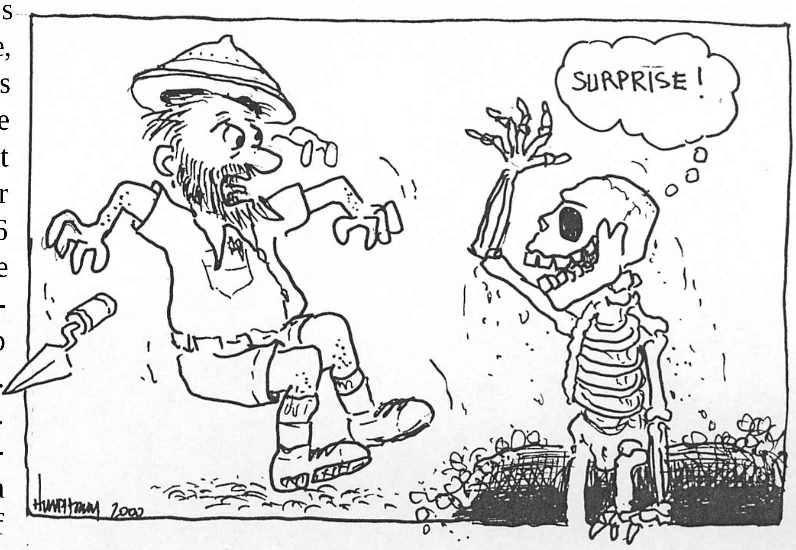
Does this new species push Lucy and all the australopithecines off the direct line to humans onto a side branch? In some ways, not only *Kenyanthropus* but even the ancient *Sahelanthropus* shared some advanced features with later *Homo* that are missing in *Australopithecus.* The new evidence makes 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 *Sahelanthropus*. Some species, such as the australopithecines, have flat projecting faces, large thick-enameled molars, and small canines. Others have large molars and thinner enamel (*A. bahrelghazali*) or larger canines and thinner enamel (*Sahelanthropus*, *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 definiton 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.

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Teacher's Corner: Archaeology for the Classroom

by Pamela Ashmore and Timothy Baumann

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The Center for Human Origin and Cultural Diversity (CHOCD) at the University of Missouri, St. Louis, represents a model collaboration between a college of arts and sciences and a college of education. Faculty, graduate students, and undergraduate students from the Division of Teaching and Learning and the Anthropology Department worked together to develop a program that uses state-of-the-art pedagogy to bring anthropological content to the K-12 classroom. The specific program described here focuses on archaeological content and activities in the pre-collegiate classroom.

Program Rationale

Teachers working at all grade levels, but especially those working with middle and high school students, have expressed the need to find interesting and innovative approaches to inspire and maintain student interest in math and science. It seemed probable to us that if we could get archaeology-based content into the classroom that students would be more readily engaged and interested in pursuing math and science-based activities. The National Science Education Standards for content in grades 5-8 stress the need to "think critically and logically to make the relationships between evidence and explanations" (National Resource Council, 1996, p.145). The recommendations of the Missouri K-16 Coalition underscore that "middle school mathematics teachers should be provided with ongoing professional development that will help them move from teaching mathematics as 'calculation' to incorporating more higher order mathematical reasoning and algebraic thinking into the classroom" (Missouri K-16 Coalition, 1999, p.10). Archaeology has the potential to address both of these educational goals. The holistic nature of archaeological investigation lends itself well across the content area and to a team teaching approach for a particular grade level.

The Field School

During the summers of 2000 and 2001, the CHOCD implemented an archaeological field school specifically designed for teachers. Funding for these programs was obtained through grants from the Eisenhower Professional Development Program of the Missouri Coordinating Board for Higher Education. The underlying philosophy of the grant proposals was as follows: by providing teachers with first-hand experience in scientific research, including excavation methods and laboratory procedures, and by modeling effective teaching strategies, the teachers could more effectively translate and infuse archaeology-based content into their classroom teaching. To ensure enrollment in the programs, we established partnerships with specific local school districts. Decisions about which school districts to approach were based on several factors. We identified 1) schools that had requested Timothy Baumann as a guest lecturer for the classroom, 2) districts that had poor test scores in the areas of math and science, and 3) teachers from previous associations who had demonstrated a willingness to try new approaches. The grant covered program expenses for the teachers who received three graduate credit hours once the program had been successfully completed. The teachers paid a nominal registration fee if they desired the credit hours.

The field school program schedule was as follows: a day-long orientation held at the university before the end of the academic year; and two weeks of field work in July, held five days a week, eight

hours a day. Two weeks after the field school, the teachers handed in their preliminary lesson plans. During the orientation, we introduced teachers to the field of archaeology, presented an overview of the sites where the excavations would be conducted, addressed teachers' needs and concerns regarding their participation in the program, and defined program requirements. Meetings with the teachers were held throughout the following academic year and the participants were required to implement an archaeology-based lesson plan in their classroom to be observed by either Baumann or Ashmore. To reduce the demands placed on the teachers conducting this lesson plan, we offered as much assistance as possible.

During the summer 2000 and 2001 field schools, teachers were exposed to both historic (Arrow Rock) and prehistoric archaeology (Cahokia Mounds), respectively. When housed at Arrow Rock, we spent three days at Cahokia and when housed at Cahokia, we spent three days at Arrow Rock. Throughout the field schools, we conducted a series of late afternoon workshops, demonstrating various ways archaeological content can be incorporated into classroom teaching.

Arrow Rock

The summer 2000 field school took place at Arrow Rock, Missouri, a bustling river town community in the 1880s where Conestoga wagons set forth on the Santa Fe Trail. The town had a significant African American community, and our goal was to identify the contributions and activities of the members of this community.

Teachers were exposed to a variety of archaeological sampling procedures and excavation techniques at two different sites—the site of an Emancipation Day picnic located alongside an old speakeasy and the grounds of the early twentieth century African American school house. Teachers learned how to work with a transit, how to establish a sampling grid to conduct post hole testing, how to excavate units, and how to keep records. Teachers also spent time in the lab washing, sorting, and re-bagging artifacts and floral and faunal remains, conducting preliminary inventories, and processing flotation samples. An added feature of the field school program was the opportunity for the teachers to work alongside college students who had enrolled in the Department of Anthropology's summer archaeology field school program.

At Arrow Rock, we combined teachers from the Greater St. Louis urban area with those who work in rural school districts. This allowed for the additional sharing of teaching strategies and challenges. Teachers were strongly encouraged to develop a photographic record of all aspects of the archaeological excavation in such formats as bulletin boards, overheads, slides, pictures, posters, or materials for power point presentations for the classroom. What most impressed and surprised the teachers about the excavation process were the extent of required notes, the diversity of record keeping forms, and the repetition of the identification of location.

Cahokia Mounds

The 2001 field school was housed at Cahokia Mounds State Historic Site in Illinois, the largest prehistoric site north of Mexico. In this field season we were looking for evidence of the western wall of a large fortification fence or palisade that was built and rebuilt at least four times, circa A.D. 1175-1275. Excavations focused on the identification of wall trenches, post holes and bastions.

Archaeology Lesson Plans

The efforts of 34 teachers over the last two years has resulted in the production of 68 lesson plans that range across the various content areas and encompass grades 2-12, including special education students. Archaeological content was introduced within the following content areas: math, science (biology and earth science), social studies, communication arts, and art. For each year's project, a Resource Activity Book was assembled and distributed to all participants. These books contain complete instructional materials needed to implement any of the lesson plans. Half of the lesson plans have been field-tested in classroom situations, and any revisions made are included in the final format of these plans. All lesson plans are linked to either the Missouri Show-Me Knowledge and Performance Standards, or the Illinois Learning Standards. Two lesson plans are described below.

Observations and Recommendations

Based on student comments, assessments of student performance, and observations by project staff, the teachers' lesson plans have been well received in the classroom. Student comments indicate that they find the content interesting and the activities fun. We too have observed the obvious engagement and investment of students in the various activities. Lesson plan quiz scores are high and teachers acknowledge that the students are learning the content. However, the teachers have also voiced concerns regarding the time constraints under which they must operate to conduct oftentimes highly involved hands-on activities in their classrooms. They also describe the difficulties in either having their efforts not totally supported by their administrators or, most commonly, that they do not have time to teach anything not specifically covered in either state or national standardized assessments.

Although we acknowledge the reality of the environments in which teachers work and the validity of their concerns regarding implementation, we assure teachers they are teaching more than content. Implicit in the methodologies associated with archaeology is the promotion of critical thinking skills. Archaeology-based content can successfully promote critical thinking skills that we believe will improve the performance of students on standardized exams. Based on the results of these two programs, it is our observation that, in addition to increasing knowledge of past events, archaeology-based content successfully enhances math and science literacy in the K-12 classroom.

CLASSROOM ACTIVITIES

Reconstructing Pots Activity (grade 6)

Show Me Standards M2, FA1

Goals: Students will calculate the diameter of a ceramic artifact and model the process of reconstruction.

Objectives: Students will work in teams to distinguish different ceramic types, calculate diameter, inventory pieces, reconstruct vessels, assess function, and draw their ceramic artifact.

Materials needed:

Black markers, white glue, plain paper, lined paper, colored pencils, regular pencils, copies of diameter chart, straight rulers.

Terra cotta flower pots of various colors

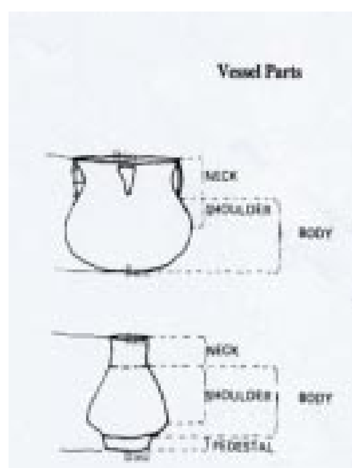
Stoneware cups of various colors

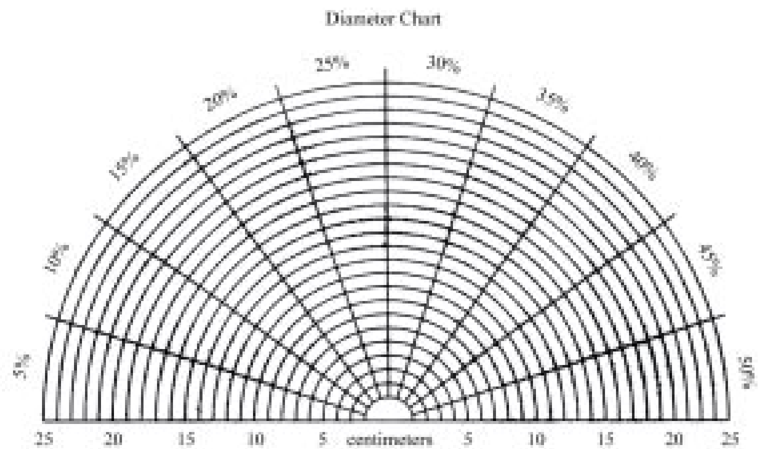
(Each cup or terra cotta pot should be a different color and the number of items needed is dependent on the number of groups).

Set up:

Prior to class, the teacher carefully breaks the ceramic items (make sure the pieces are not too small or too sharp) and mixes the sherds together in a box.

1. Introduce the idea that many artifacts are often found in pieces and archaeologists need to put them back together (reconstruct) in the lab. Pieces of pottery, called sherds, are common from both historic and prehistoric sites. Ask students: Why do you think that things like pots are often found in pieces? Using geometric relationships, archaeologists are sometimes able to reconstruct pots from pieces (even if some pieces are missing) to determine the original size and shape of a vessel. It is almost like putting together the pieces of a jigsaw puzzle! Ceramic pots are made up of several sections.





(Use the diagram on the previous page to draw the illustration of a vessel on a board or use as an overhead). The top of the vessel is called the rim, under the rim is the neck, under it the shoulder, and the body of the pot sits on the base. The base may be in the form of a pedestal (a platform that the pot sits on). If the students have just a rim piece, they can use a diameter chart (above) to figure out from the size of the curve of the rim piece how big the vessel opening was. From the chart, students also can estimate the percentage of the entire rim that their piece represents. They are now going to work to reconstruct a pot that will be assigned to their group. They will have to work together to identify the elements of the pot just identified and then use a diameter chart to calculate the diameter of the top (rim) of the pot. The diameter chart can be put on an overhead projector.

2. Divide students into archaeological teams of three students each.

3. Assign a particular terra cotta pot or stoneware cup (i.e. Stoneware Blue) and letter to each team.

4. Have each team retrieve the appropriate pieces of their pot or cup from the box.

5. Using black markers, ask students to label the pieces with their assigned letter plus a sequential number. For example, the group assigned letter A will number their pieces A-1, A-2…

6. Students should sort pieces by rim, base, and body.

7. Next, have students inventory their ceramic pieces and list them on the inventory sheet.

8. Using the diameter chart, have each student calculate the diameter of their vessel using three different rim pieces (either the inside or outside of the curve of the rim piece should be matched to a curve on the diameter chart). Also have each student determine the % of the vessel their rim piece represents as indicated by the diameter chart.

NOTE: A diameter chart can be made by using a protractor and drawing concentric circles 1 cc apart. If a half circle is used, as is shown in this diagram, then the calculation is based on the radius of the opening to calculate the diameter, the value of the radius has to be doubled. Diameter gauges can be ordered from www.archaeogear.com

9. Have the students reconstruct their vessel using white glue.

Inventory Sheet

	Number of Pieces		
Sherds			
Handles			
Bases			
	List each rim Separately	Diameter (rim)	% of Vessel (rim)
Rim 1	1		
Rim 2	1		
Rim 3	1		
Rim 4	1		

10. Have each student draw their reconstructed vessel and write a description of it. This should include color, mention of any design elements, and measurements of its size (height and diameter of top). Students can then write a story that describes what their pot was used for (its function).

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Excavation of Room ___ (Grade 7)

Show Me Standards MA2, SS7

Goals: Students will properly measure and grid artifacts in a unit. Based on the kinds of artifacts and their patterning in a unit students will interpret human behaviors.

Objectives: Students will work in archaeological units to map the location of artifacts located within an excavation unit. Students will make assessments as to the type of activity that might have occurred in their unit.

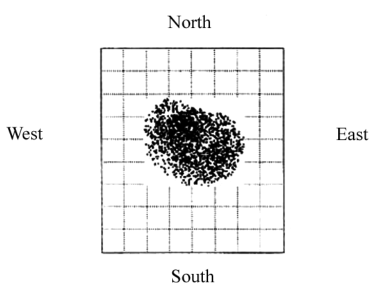
Materials Needed:
Yardsticks, masking tape, photocopies of pictures of artifacts, graph paper, rulers, pencils, and copies of a worksheet.

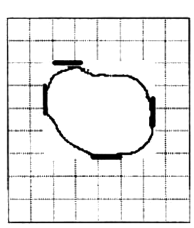
Set up:
Before class, mark the classroom floor with masking tape in rectangular units of 2'x3', one unit for each group of students. Inside these units tape pictures of artifacts (flakes, projectile points, ceramic sherds, worked shells, and/or bones). Pictures of artifacts can be easily found in issues of *National Geographic* magazine. Try to select artifacts from a particular culture *i.e.* Navajo of the Southwest and also try to create a pattern with the artifacts, such as flakes in the same section as stone tools.

(continued on next page)

1. Explain to the students that artifacts can be pretty to look at (have pictures to show), but that we really need to know about the physical distribution (location) of artifacts in time and space. When archaeologists find artifacts, they need to know precisely where in the excavation unit the artifacts are located. Ask the students to think about a police detective who is trying to solve a robbery case. The detective needs to look for clues at the crime scene and needs to see where everything was when the crime was committed. These clues might enable the detective to find the evidence needed to solve who committed the crime and when.

Archaeologists attempt to figure out how people of the past used a particular place. What activities did they engage in? How did they live their lives? The evidence for this is, in part, to be found in the artifacts that have been left behind. The types of artifacts and the pattern of how they are laid out in space will help archaeologists to determine what types of activities occurred in specific locations. Archaeologists have to be able to recreate on a piece of paper in the lab where all of the artifacts in their excavation unit were found. Show students on the board or overhead how to measure the location of an artifact in a unit.





NOTE: To gauge (measure) an artifact in your archaeological unit, measure from the edge of the unit to the artifact. Measure the distance from the northern edge of the unit to the closest edge of the artifact. On the graph paper make a mark where that distance would be. Next measure from the eastern edge of the unit to the closest edge of the artifact and make a mark on the graph paper where that would be. Continue until you have a mark for all sides of the artifact. Finally look at the artifact and draw within your marks the shape of the artifact. See diagram below.

2. Explain to the students that their classroom has been turned into an archaeological excavation. Students will work in groups of two to four.

3. Each group will identify the northern "wall" of their unit. Using rulers, students will measure the unit and the location of the artifacts and draw them on their graph paper. One inch will represent one square.

4. Students will label each artifact on their graph paper.

5. Finally, they will write the names of their group members and answer the following questions on their worksheet:

Room ___ Excavation

1. What kind of artifacts did you find in your unit? What did you notice about the locations of the artifacts in your unit? Are they spread out or are they all together?

2. What do you think the artifacts were used for? What kind of activity do you think went on in your unit? Why do you think this?

(*continued on page 18*)

IS IT REAL? LISTENING FOR IMPORTANT QUESTIONS ABOUT THE PAST

by M. Elaine Davis

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Is it real? Anyone involved in public archaeology or museum education is probably familiar with this question; it may, in fact, be the question most frequently asked by members of the public. At Crow Canyon Archaeological Center where I am director of education, the question of "realness" arises so often that it has almost achieved a taken-for-granted status. It is unfortunate that redundancy often works to make things seem less, rather than more, important. Twenty-five years of experience in the field of education has taught me that the persistent questions students pose can provide valuable insight into how they construct knowledge and how they make meaning of it.

It is important to examine frequently asked questions and doing so can lead to more appropriate and effective instructional strategies. In this article I examine the question, "Is it real?" by looking at when the question is asked, where it is asked, by whom, and what is meant by the word "real."

"Is it real?" is asked numerous times each day by students enrolled in Crow Canyon's public archaeology programs. The question always comes up when students are involved in the inquiry lesson where artifact assemblages are used to represent different time periods in Pueblo cultural history. When children pick up a replica of a Mesa Verde Black-on-White mug and ask if it is real, educators sometimes answer, "Of course it's real, it's a real replica." The students are then forced to clarify their meaning and will often rephrase the question, saying, "What we meant was, is it really old?" The question of realness is also brought up on visits to archaeological sites. These are generally not active research sites but, rather, sites that have been previously excavated, stabilized, and cleaned up for public visitation. When we take visitors to tour Cliff Palace or one of the other cliff dwellings at Mesa Verde National Park, they understand that they are viewing an actual ruin, but they want to know what **parts** of the ruin are, in their words, real. What are these interested members of the public trying to ask and why are they so concerned with the realness of objects? In this case, as in the one of the artifact assemblages, I think they are asking the same thing: they want to understand the authenticity, the genuineness, of the objects and architecture they have come into contact with. When children say they want to know if the mug is old, they are really trying to understand who actually constructed it. They want to know if it was an ancestral Pueblo person or if it was some contemporary person who just copied it.

Authenticity is important to students, adults and children alike, for at least two reasons. The first has to do with evidence. When students at Crow Canyon examine artifact assemblages or when visitors at Mesa Verde are standing in a cliff dwelling, they are **not** simply receiving and trusting information from a tour guide or educator. They are participating in the act of constructing the past. Interrogating evidence and thinking critically about its meaning are fundamental to archaeological and historical inquiry.

The second reason for asking, "Is it real?" is not so much intellectual as it is personal and emotional. When people witness for the first time the 800 year-old fingerprints in a corrugated vessel or an ancient hand print in a cliff dwelling, they are often struck with awe. Such items help us make a direct connection, not only with an ancient culture, but also with ancient individuals. A modern reproduction, no matter how closely it resembles the original, does not have the power to trigger the kind of emotional response that the real object evokes. The meaning of the replica and the meaning of the original—the authentic artifact—are very different.

Perspectives on Realness

It is important to note that although most of the students who come to Crow Canyon are concerned with the realness of the objects they encounter, and they have a similar understanding of the term "real," they do not all have the same motive for asking the question. Approximately 300 Native American students visit Crow Canyon annually; the majority of these young people are Navajo. When they raise the question "Is it real?", they are likely doing so for very different reasons. If they are from families who practice traditional cultural beliefs, they are asking the question in order to determine which objects they should not touch or perhaps come into contact with at all. For these students ancient artifacts made and used by people who lived and died hundreds of years ago are things to be very careful around. The traditional belief is that these objects might cause illness, and contact with these objects would require they go through a lengthy, and sometimes expensive, ceremony. Replicas provide an acceptable alternative for these groups of Navajo students: when they ask, "Is it real?" educators at the Center can say "no" and both they and the students feel relieved.

Another perspective on the realness of objects comes from collectors. There are probably not a lot of artifact collectors who participate in programs at Crow Canyon, or if they are collectors, they may actively conceal that information. When collectors ask if something is real, they are also referring to authenticity but for yet another reason. For collectors, the value placed on the real thing is probably not intellectual, emotional, or cultural, but economic. The real thing, whether it is a piece of art or an ancient pot, is associated with monetary value. The specific value is determined by criteria such as scarcity, condition of preservation, and quality of craftsmanship. Again, a replica identical to the original in every way does not have the same value as the original. The difference that makes a difference for collectors, as with the students previously mentioned, is with the hand that made the object.

Archaeologists, archaeological educators, and interpreters are also among the group of people who are concerned with the question of realness. Educators are cognizant of the importance of concrete objects—be they authentic or imitation—to the learning experience. Hands-on or experiential education is grounded in this understanding. Educators recognize the value of multisensory approaches to instruction in general, with some modalities, as they are referred to in the world of education, carrying more information than others. Visual and auditory top the list of sensory methods used in traditional instruction; the tactile or kinesthetic approaches that are prominent in experiential education increase the ways in which information can be passed on to students. From an educational perspective, real objects, as well as well-executed replicas, are powerful tools for teaching about the human past. However, it is because of this power that great care must be taken in the construction and display of replicas, and thought must be given to how they will be used to achieve educational objectives. Whether intentionally or accidentally, replicas and reproductions can, in some cases, cause harm. They can instill or reinforce negative stereotypes; they can be used to achieve political agendas; they can be commodified for economic gain. Parker Potter, Peter Stone and others have addressed these risks and raised the question of how we can use the real as well as the reproduction, without, in a sense, fooling people. In Peter Stone and Phillippe Planel's *The Constructed Past*, Sommer says:

> To make the past accessible, to help visitors to start a discourse of their own, we have to create images, albeit that they will always be false. The question we have to solve is how to make this obvious (1999: 166).

I would have to agree with Ulrike Sommer. We are never reconstructing the past but always constructing it or, at best, catching some partial reflection of it. Our responsibility as educators, archaeologists, historians or interpreters is to make obvious our role in the making of that history.

At Crow Canyon

Moving back to my own work at Crow Canyon Archaeological Center, I will confess that just when I thought I had reached a comfortable understanding of the issues surrounding the question of realness, I have encountered yet another perspective not previously considered. The Center for the last fifteen or so years has used a replicated Basketmaker pithouse as the setting for teaching students about the ancient technologies associated with that time period. In that setting students attempt to make fires using a hearth board and spindle stick; they practice spear throwing with an atlatal; they grind corn; and sometimes they try weaving using yucca fiber. About three years ago a colleague and I were assessing student knowledge of Pueblo cultural chronology and were surprised to find that the Basketmaker period seemed to be much clearer in their minds than any of the other time periods. In a task analysis of our curriculum, the explanation for this became obvious; the pithouse itself created such vivid images in students' minds that they were learning about that time period at the expense of earlier or subsequent ones. In contrast with Basketmaker, the other time periods were merely fuzzy impressions for many of the children. This finding motivated us to revive a plan that had been discussed years earlier for building a structure that would represent a twelfth-century Pueblo house. This structure would provide an instructional tool comparable to that of the pithouse, which we could use to broaden our students' knowledge of Pueblo history.

It is our practice at Crow Canyon to conduct our work in consultation with the Center's Native American Advisory Group. It was when we began discussing the building of the structure with the advisory group that I realized I didn't know all there was to know about the question of realness. One of the things I have come to appreciate more through these discussions is how meaning is conveyed through objects and structures regardless of whether or not they are, as students say, really old. I even have come to wonder if these things become more problematic as they come closer and closer to resembling the real thing. Considering this causes me, once again, to call into question the definition of real. Maybe real does not always mean authentic or maybe authentic does not always mean old. Can a replica be real? Maybe an object is real based on its own characteristics and not necessarily on its creator? I have not yet reached clarity on these issues but pondering the nature of realness and the importance of this question to so many people has helped me understand the social complexity of using objects for teaching about the past—those that are real and those that are sometimes real.

In conclusion, I would like to return to the subtitle for this paper: *Listening for the Important Questions Asked About the Past.* I have tried to show that simple questions like "Is it real?" are anything **but** simple. They may very well carry some of the most important messages that we, as archaeological educators, need to hear. Listening to them and taking a reflexive view of them can provide valuable instructional clues. For example, I know that it is important to provide most of our students at Crow Canyon with opportunities to come into contact with authentic artifacts and the remains of ancient structures. We need to help them understand how the forces of time might have altered the objects, and we need to help them remember that we are all perceiving these objects through our own culture, our world views, and ourselves. I also know that it is just as important that certain other students not come into contact with the so-called, real thing, so as to not place them in a situation where they will feel harm might come to them. We need to provide good alternatives that increase their knowledge about the human past but that do not, in their mind, place them at risk. In any case, I do know that "real" is important, that "real" has multiple meanings, and that "real" evokes different responses in the contexts of different

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(**Teacher's Corner**, *continued from page 14*)

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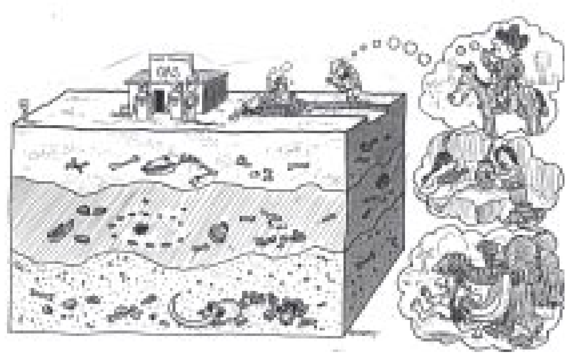

New Video: *Learning and Teaching Evolution*

This video was produced for the television program "Evolution" by WGBH Educational Programming and Outreach. For more information, visit www.wgbh.org.

(***Early Human Origins***, *continued from page 8*)

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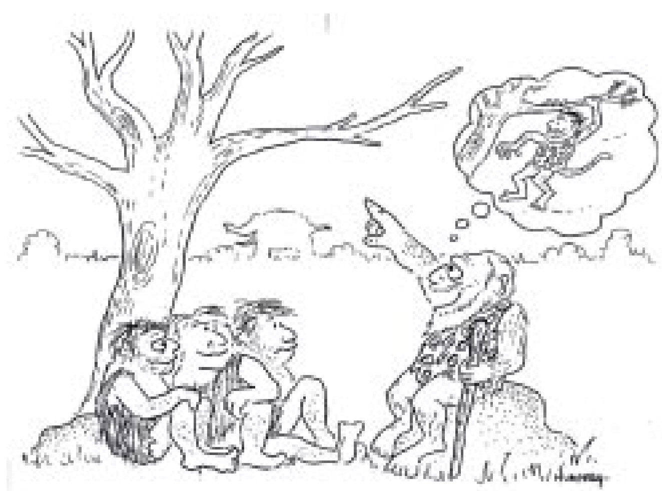

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