SPECIAL REPORT

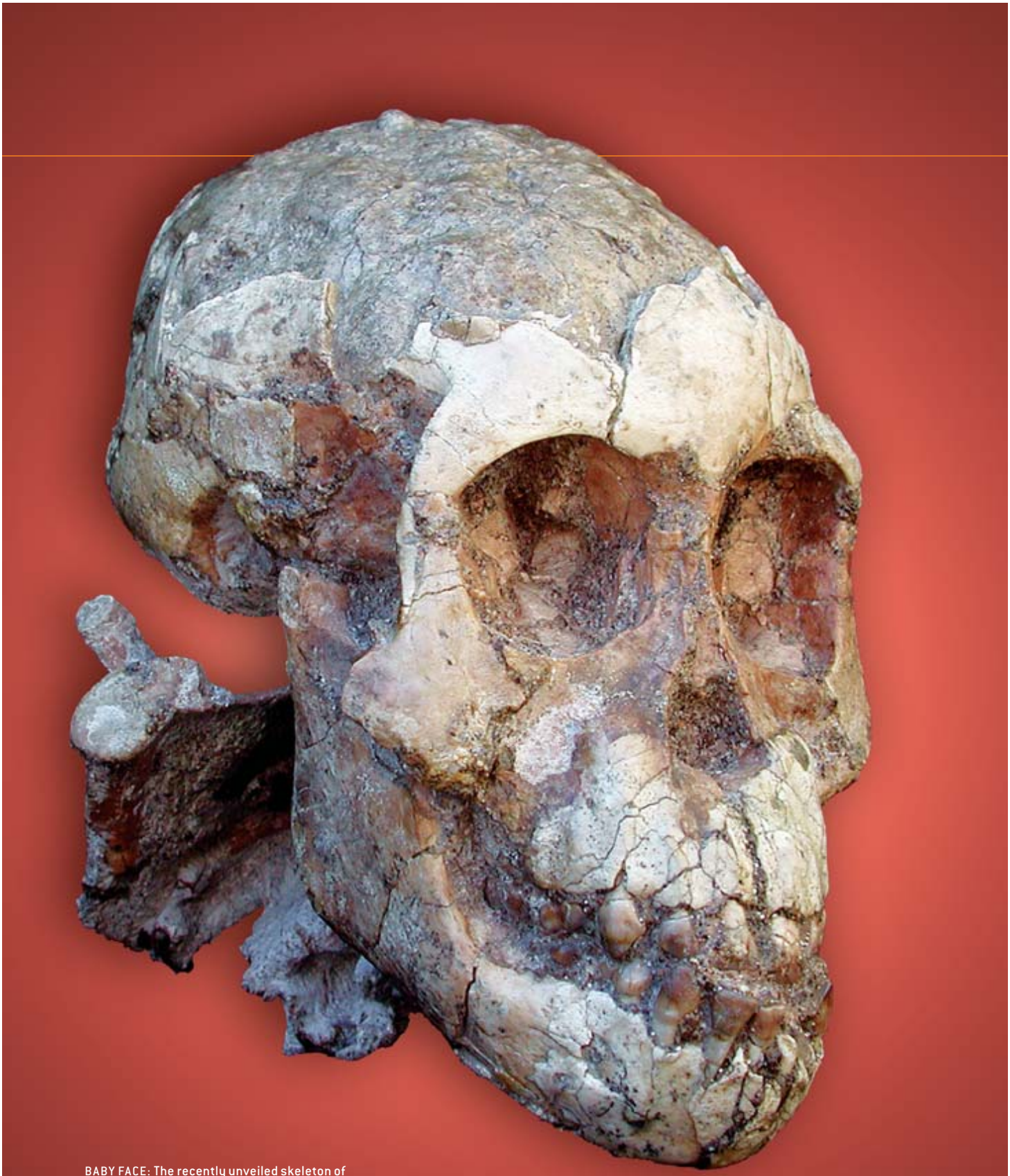
An earlier version of this story was posted on www.sciam.com. Readers were invited to send in their comments and questions, and scientists were asked to provide commentaries. That feedback helped to shape the article that follows.

AN EXTRAORDINARY NEW HUMAN FOSSIL RENEWS DEBATE OVER THE EVOLUTION OF UPRIGHT WALKING

LUCY'S BABY

BY KATE WONG

The arid badlands of Ethiopia's remote Afar region have long been a favorite hunting ground for paleoanthropologists. Many hominins—the group that includes all the creatures in the human line since it branched away from that of the chimps—once called it home. The area is perhaps best known for having yielded "Lucy," the 3.2-million-year-old skeleton of a human ancestor known as *Australopithecus afarensis*. Now researchers have unveiled another incredible *A. afarensis* specimen from a site called Dikika, just four kilometers from where Lucy turned up. But unlike Lucy, who was well into adulthood by the time she died, the new fossil is that of an infant, one who lived 3.3 million years ago (and yet has nonetheless been dubbed "Lucy's baby").



BABY FACE: The recently unveiled skeleton of a juvenile *Australopithecus afarensis* nicknamed Selam is more complete than even the well-known Lucy fossil. And whereas much of Lucy's face is missing, Selam's is exquisitely preserved.

No other hominin skeleton of such antiquity—including Lucy—is as complete as this one. Moreover, as the earliest juvenile hominin ever found, the Dikika child provides an unprecedented opportunity to study growth processes in our ancient relatives. "If Lucy was the greatest fossil discovery of the 20th century," says Donald C. Johanson of Arizona State University, who unearthed the famed fossil in 1974, "then this baby is the greatest find of the 21st thus far."

Bundle of Joy

IT WAS THE AFTERNOON of December 10, 2000, when fossil hunters led by Zeresenay Alemseged, now at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, spotted the specimen. Only part of its tiny face was visible; most of the rest of the skeleton was entombed in a melon-size block of sandstone. But "right away it was clear it was a hominin," Alemseged recollects, noting the smoothness of the brow and the small size of the canine teeth, among other humanlike characteristics. Further evaluation, however, would have to wait until the fossil was cleaned—a painstaking process in which the cementlike matrix is removed from the bone almost grain by grain with dental tools.

> "You don't just magically flip some evolutionary switch somewhere and transmute a quadruped into an upright-walking bipedal human."
>
> —*Donald C. Johanson*

It took Alemseged five years to expose key elements of the child's anatomy; many more bones remain obscured by the sediment. Still, the find has already surrendered precious insights into a species that most researchers believe gave rise to our own genus, *Homo*. Alemseged and his colleagues described the fossil and its geologic and paleontological context in two papers published in the September 21 *Nature*. And at a press conference held in Ethiopia to announce the discovery, they christened the child Selam—"peace" in several Ethiopian languages—in hopes of encouraging harmony among the warring tribes of Afar.

The skeleton, judged to be that of a three-year-old girl, consists of a virtually complete skull, the entire torso, and parts of the arms and legs. Even the kneecaps—no larger than macadamia nuts—are preserved. Many of the bones are still in articulation. Hominin fossils this complete are incredibly rare, and ones of infants are rarer still because their bones are that much more fragile. Indeed, the next oldest skeleton of a juvenile that is comparably intact is a Neandertal baby dating to around 50,000 years ago.

Walking vs. Climbing

THE EXCEPTIONAL PRESERVATION of Selam, as well as that of other animals found at the site, indicates to team geologist Jonathan G. Wynn of the University of South Florida that her body was buried shortly after death by a flood event. Whether she perished in the flood or before it is unknown.

Although she was only three when she died, Selam already possessed the distinctive characteristics of her species. Her projecting snout and narrow nasal bones, for example, readily distinguish her from another ancient youngster, the so-called Taung child from South Africa, who was a member of the closely related *A. africanus* species. And her lower jaw resembles mandibles from Hadar, the site where Lucy and a number of other *A. afarensis* individuals were found.

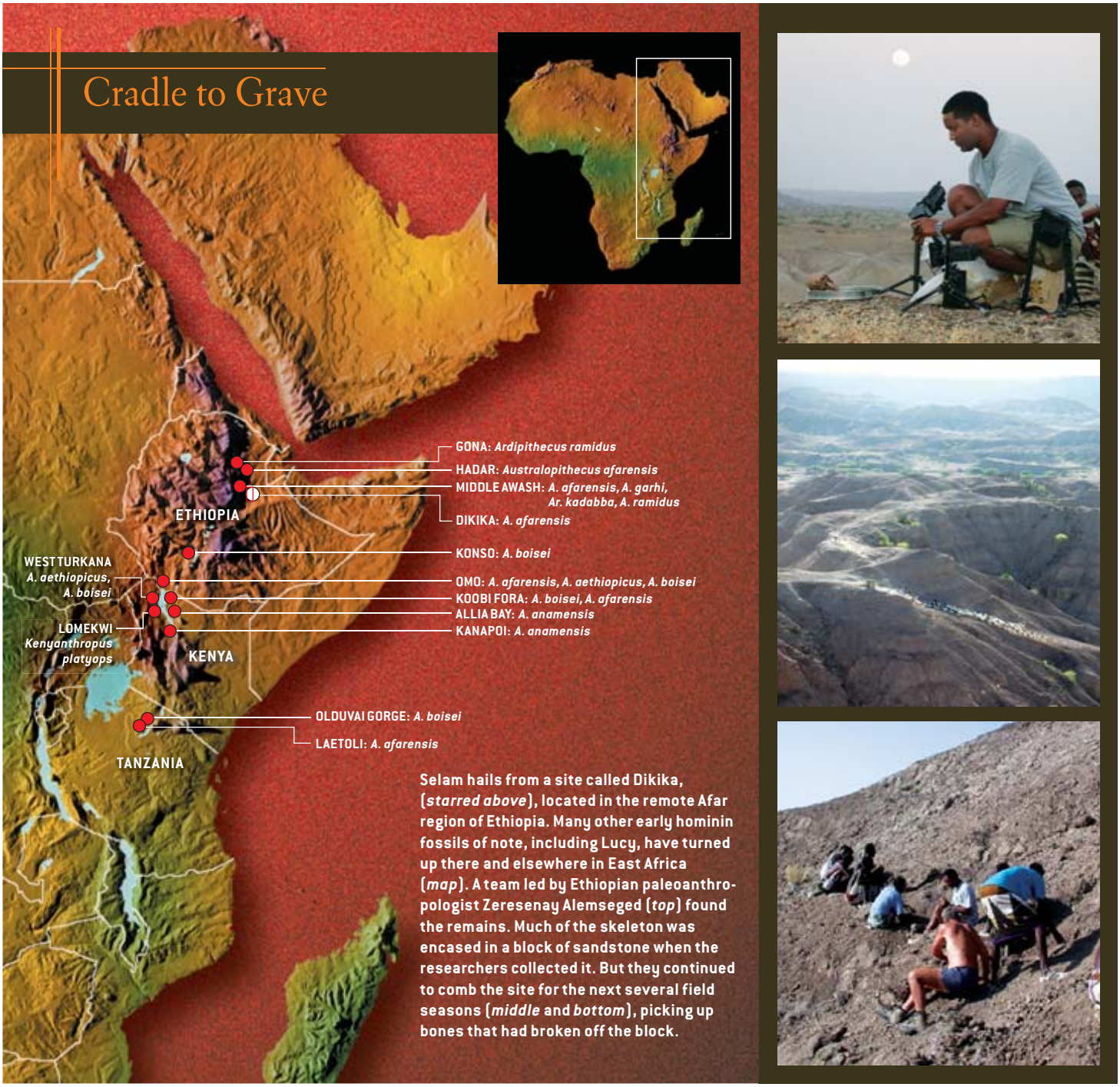
Selam also exhibits the same mash-up of traits in her postcranial skeleton that has long vexed scientists interested in how *A. afarensis* moved around the landscape. Scholars agree that *A. afarensis* was a creature that got around

Overview/*The Earliest Child*

- Researchers working in northeastern Ethiopia have found the remains of a baby *Australopithecus afarensis*, a species believed to be ancestral to our own.
- Some 3.3 million years old, the spectacularly complete skeleton is the earliest child in the human fossil record.
- Preserving bones never before known for *A. afarensis*, the specimen is raising questions about how our ancestors became bipedal.
- The Dikika infant may also illuminate the order in which other body parts changed over the course of human evolution.

NATIONAL MUSEUM OF ETHIOPIA, ADDIS ABABA (*preceding page*)

Cradle to Grave



Selam hails from a site called Dikika, (*starred above*), located in the remote Afar region of Ethiopia. Many other early hominin fossils of note, including Lucy, have turned up there and elsewhere in East Africa (*map*). A team led by Ethiopian paleoanthropologist Zeresenay Alemseged (*top*) found the remains. Much of the skeleton was encased in a block of sandstone when the researchers collected it. But they continued to comb the site for the next several field seasons (*middle* and *bottom*), picking up bones that had broken off the block.

EDWARD BELL (*map*); DENNÉ REED *University of Texas at Austin* (*top and bottom*); JONATHAN G. WYNN *University of St. Andrews* (*middle*)

capably on two legs. But starting in the 1980s, a debate erupted over whether the species was also adapted for life in the trees. The argument centered on the observation that whereas the species has clear adaptations to bipedal walking in its lower body, its upper body contains a number of primitive traits better suited to an arboreal existence, such as long, curved fingers for grasping tree branches. One camp held that *A. afarensis* had made a full transition to terrestrial life and that the tree-friendly features of the upper body were just evolutionary baggage handed down from an arboreal ancestor. The other side contended that if *A. afarensis* had retained those traits for hundreds of thousands of years, then tree climbing must have still formed an important part of its locomotor repertoire.

Like her conspecifics, Selam has legs built for walking and fingers built for climbing. But she also brings new data to the controversy in the form of two shoulder blades, or scapulae—

Spectacular Skeleton

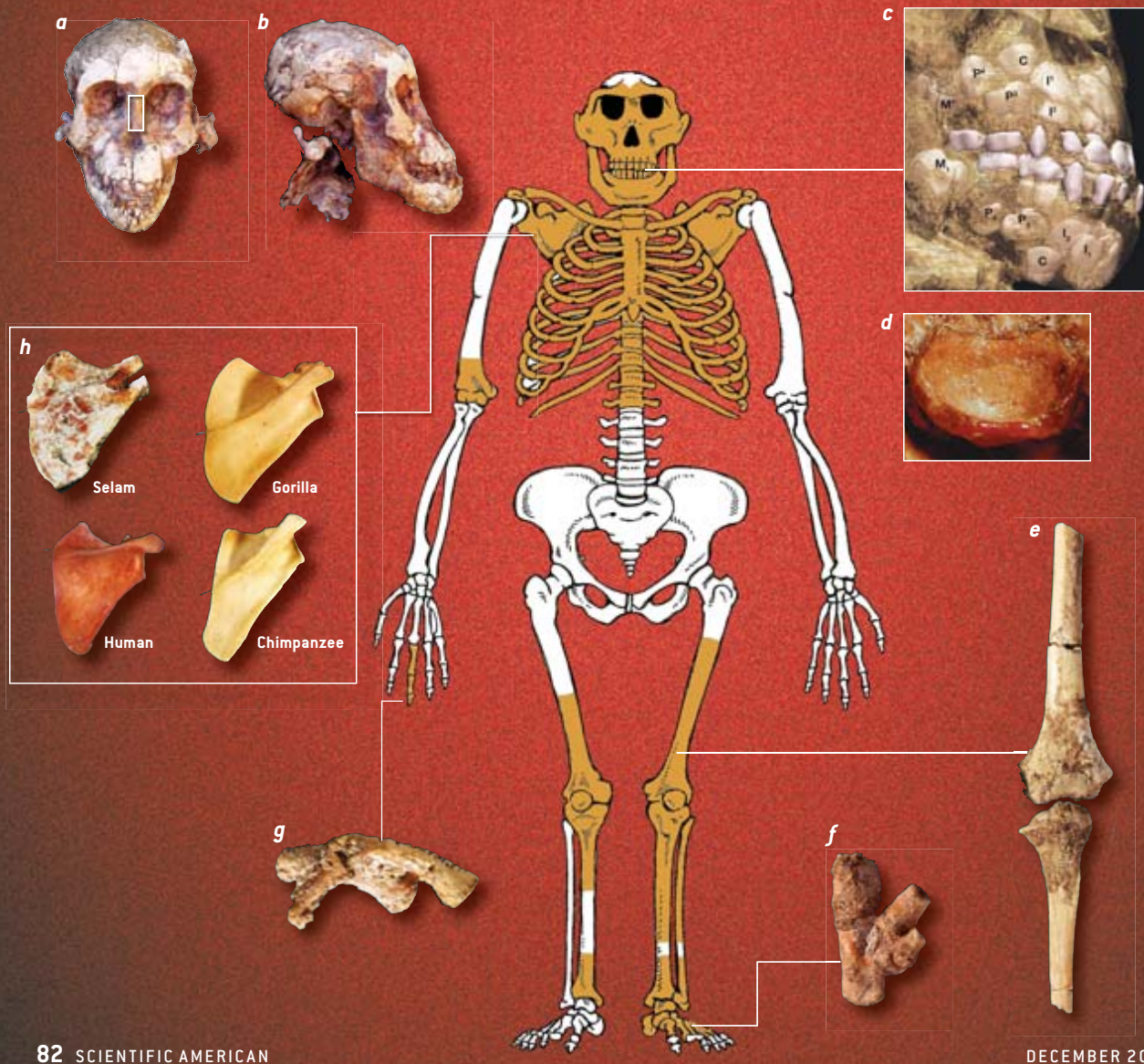
Selam is one of the most complete early hominin skeletons ever found, although many of the bones are still at least partially obscured by sandstone. In the drawing below, based on an adult *A. afarensis,* the bones believed to be present in the new specimen are shaded in gold.

Features of Selam's face, including the small, narrow nasal bones (*a*), identify her as *A. afarensis,* as opposed to the closely related *A. africanus.* Although much of the braincase is missing, the fossil preserves a natural sandstone endocast, or impression of the interior of the skull (*b*). The apparent brain size hints that *A. afarensis* may have had delayed brain growth relative to chimps, which is a characteristic of modern humans.

Computed tomography revealed that in addition to having a full set of milk teeth, the child had permanent teeth waiting to come in (*c*). The remains also include a delicate bone known as the hyoid (*d*), which helps to anchor the tongue and the voice box. It is only the second hominin hyoid ever found—the first came from a 60,000-year-old Neandertal skeleton. Its morphology suggests that *A. afarensis* had a chimplike voice box.

Like other *A. afarensis* individuals, Selam has a number of traits in her leg bones (*e*) and foot bones (*f*) that indicate she walked bipedally on the ground. Her heel, for example, exhibits a humanlike wideness. But her upper body seems partly adapted for life in the trees. She has long, curved fingers (*g*) that would have aided in grasping tree branches. And the socket of her shoulder blade, or scapula (*h*), faces upward like an ape's, rather than to the side like a human's.

The scapula is a bone of contention, however. According to the discoverers, it looks most like that of a gorilla. But critics charge that the bone is actually rather humanlike, particularly in the relative proportions of the depressed areas for muscle attachment on either side of the ridge that divides the blade.



PATRICIA J. WYNNE (*illustration*); FROM "A JUVENILE EARLY HOMININ SKELETON FROM DIKIKA, ETHIOPIA," BY ZERESENAY ALEMSEGED ET AL., IN *NATURE*; VOL. 443, SEPTEMBER 21, 2006 (*all bones*)

What readers want to know

In an earlier version of this article, posted on our Web site, we invited readers to submit any questions they had about Selam. Kate Wong answered their questions in the blog. An edited selection of those exchanges follow.

How was Selam's age at death assessed? —Stephen
A: Selam's age was estimated based on her apparent stage of dental development. Using comparable data from African apes, the researchers judged her to be about three years old when she died. But *Australopithecus afarensis* no doubt had a developmental schedule that differed from that of chimps and gorillas, so this is only an educated guess.

How was sex determined? —Debra Martin
A: The skeleton is believed to be that of a female based on computed tomographic measurements of the fully formed permanent tooth crowns still embedded in the jaws. When compared with measurements of teeth from *A. afarensis* individuals from the sites of Hadar, Laetoli and Maka, the Dikika child's teeth grouped closely with those of confirmed females.

What is the uncertainty of the measurement of the age of a fossil like Selam? What technology is used? —Juan Moreira
A: Diana C. Roman of the University of South Florida dated the fossil by ascertaining the ages of the layers of volcanic ash around Selam. One layer was deposited before the child died; the other was deposited some time after she died. By interpolating the position of the fossil relative to those two layers, Roman determined that the fossil was between 3.31 million and 3.35 million years old—an uncertainty of 40,000 years.

Has there been an x-ray or similar imaging done to determine what might remain? —Theresa Meade
A: The bones in the sandstone block are thought to have all been at least partly revealed, although it is possible there are some small bones buried in there. So it looks like it is really mostly a question of how complete the bones that have been partially cleaned are. The skull was subjected to CT scanning, which revealed the permanent teeth, as well as the morphology of the inner ear. But I don't know if the rest of the specimen was scanned.

What's the big deal? We know that our ancestors had to come down out of the trees sometime. Kids nowadays have a predilection for climbing trees, too. (Maybe an unconscious link to an arboreal past?) —Matthew T.
A: The question is to what extent *A. afarensis* was adapted for terrestriality. No one is suggesting that *A. afarensis* could not get up into a tree under any circumstances—as you correctly point out, humans can still do that—the debate is over whether it was adapted to do so. It's a big deal because bipedalism is a hallmark of human evolution, so paleoanthropologists are eager to understand the details of how it emerged.

Are there any plant or animal fossils associated with* A. afarensis *finds that would indicate what kind of environment they lived in? —Traveler
A: The animal fossils found at Dikika indicate that the child inhabited a moist, mosaic environment composed of woodlands and grasslands, with permanent water nearby. This is very similar to the environment in which Lucy and other representatives of *A. afarensis* lived.

What does the animal have to gain from being able to engage in endurance running? —Donald McMiken
A: Endurance running has been hypothesized to have given early humans a leg up (if you will) in hunting or scavenging, by allowing them to wear the prey out or reach the carcass faster, respectively.

bones previously unknown for this species. According to Alemseged, her scapulae look most like those of a gorilla. The upward-facing shoulder socket is particularly apelike, contrasting sharply with the laterally facing socket modern humans have. This orientation, Alemseged says, may have facilitated raising the hands above the head—something primates do when they climb. (Although gorillas do not climb as adults, they do spend time in the trees as youngsters.)

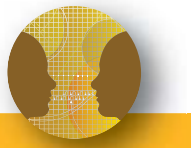
Further hints of arboreal tendencies reside in the baby's inner ear. Using computed tomographic imaging, the team was able to glimpse her semicircular canal system, which is important for maintaining balance. The researchers determined that Selam's semicircular canals are similar to those of African apes and *A. africanus*. This, they suggest, could indicate that *A. afarensis* was not as fast and agile on two legs as we modern humans are. It could also mean that *A. afarensis* was limited in its ability to decouple the movements of its head and torso, a feat that seems to play a key role in endurance running in our own species.

The conclusion that *A. afarensis* was a bipedal creature with an upper body at least partly adapted for life in the trees echoes what Jack T. Stern, Jr., of Stony Brook University and his colleagues wrote years ago in their reports on Lucy and her contemporaries. "I was happy to

see that this paper suggests I might have been right," Stern comments. Johanson agrees that the case for a partly arboreal *A. afarensis* is stronger than it once was. "Early on I was a staunch advocate of strict terrestrial bipedalism in *afarensis*," he remarks. But taking more recent findings into consideration, Johanson says, "it's not out of the realm of possibility that they were still exploiting some of the arboreal habitats for getting off the ground at night and sleeping up there or going back to familiar food sources."

A combination of walking and climbing would fit neatly with the picture that is emerging from studies of the environments of early hominins, including Selam. Today Dikika is an expanse of dusty hills dotted with only the occasional tree or shrub. But 3.3 million years ago, it was a well-watered delta flanked by forests, with some grasslands nearby. "In this context, it is not surprising to have an 'ape' that spends time in the trees and on the ground," comments project member René Bobe of the University of Georgia.

Not everyone is persuaded by the arboreal argument. C. Owen Lovejoy of Kent State University disputes the claim that Selam's scapula looks like a gorilla's. "It's primitive, but it's really more humanlike than gorillalike," he remarks. Lovejoy, a leading proponent of the idea that *A. afarensis* was a dedicated biped, maintains that the forelimb features that are typically held up as indicators that *A. afarensis* spent time in the trees only provide "evidence that the animal has an arboreal history." The discovery of the famed Laetoli footprints in 1978 closed the debate, he states. The trail did not show a prehensile big toe, without which, Lovejoy says, *A. afarensis* simply could not move about effectively in the trees.



What the experts are saying

We polled the experts for their thoughts on the discovery of Selam. Their views are encapsulated here. Go to www.sciam.com/ontheweb for the full comments.

JOHN HAWKS of the University of Wisconsin–Madison wonders whether Selam spells the end of a hotly contested hominin genus. In 2001 paleoanthropologists announced that they had found a fairly complete skull and some jaws and teeth at a site called Lomekwi in Kenya. They assigned the 3.5-million-year-old remains to a new genus of hominin, *Kenyanthropus.* Skeptics counter that the fossils are instead a regional variant of *A. afarensis.* It is an obvious sample with which to compare Selam. But oddly enough, no mention of *Kenyanthropus* appears in the formal description of the child.

RALPH L. HOLLOWAY of Columbia University hopes that the brain endocast will show enough details in the so-called Broca's regions and the occipital region to reveal a posterior placement of the lunate sulcus, a curved depression in the brain's surface. This would indicate a definite reorganizational pattern of the cerebral cortex toward a more humanlike rather than chimplike or gorillalike pattern.

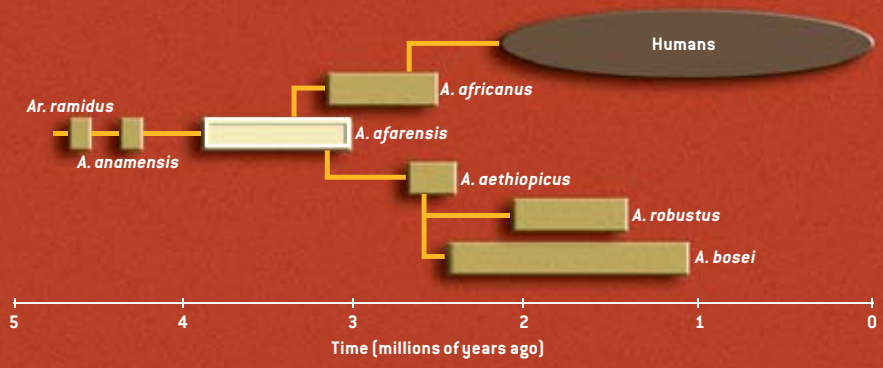
C. OWEN LOVEJOY of Kent State University makes the case that rather than reopening the debate over whether *A. afarensis* was a dedicated biped or whether it also spent some time in the trees, the Dikika child firmly closes it in favor of the species being strictly bipedal. Although the shoulder blade bears some resemblances to the gorilla shoulder blade, it actually shows some striking similarities with the human shoulder blade. Also, the fact that the youngster already had curved fingers at age three suggests that this is an inherited, primitive characteristic—as opposed to the individual having developed curved fingers as a result of grasping tree branches, which is what the arborealists envision.

RENÉ BOBE of the University of Georgia observes that one of the many important aspects of this fossil is that its geologic and paleontological context can be studied in detail. Dikika reveals hominin adaptations and environments that existed just before major climatic changes led to the ice ages, before *Homo* made its first appearance in the fossil record and before the earliest known stone tools. In Selam's day, Dikika was largely a lush, forested place. But by the time *Homo erectus* emerged, a little less than two million years ago, grasslands were much more prominent.

WILLIAM E. H. HARCOURT-SMITH of the American Museum of Natural History argues that features of Selam's upper limbs and inner ear are strong evidence that *A. afarensis* was partly arboreal. It will be very interesting, he says, to see whether analyses of her foot reveal that she was able to move her big toe so as to grasp branches. In his view, the first obligate bipeds were early members of our own genus, *Homo.*

An Ancient Ancestor

***A. afarensis* (*reconstruction at right*) is but one of many australopithecine species known to science. Researchers disagree about exactly how these species are related to one another, but most presume that *A. afarensis* was a precursor to our own genus (*below*).**



MELISSA THOMAS (*timeline*); AMERICAN MUSEUM OF NATURAL HISTORY, NEW YORK (*reconstruction*)

A Hodgepodge Hominin

EXPERTS MAY DISAGREE over the functional significance of Selam's apelike skeletal characteristics, but they concur that different parts of the hominin body were undergoing selection at different times. *A. afarensis* is "a good example of mosaic evolution," Johanson states. "You don't just magically flip some evolutionary switch somewhere and transmute a quadruped into an upright-walking bipedal human." It looks like natural selection is selecting for bipedalism in the lower limbs and pelvis first, and things that are not really used in bipedal locomotion, such as arms and shoulders, change at a later stage, he says. "We're getting to know more and more about the sequence of changes" that produced a terrestrial biped from a tree-dwelling, apelike creature.

Analysis of Selam's skull hints at a similarly piecemeal metamorphosis. The shape of the hyoid—a delicate, rarely preserved bone that helps to anchor the tongue and the voice box—indicates that *A. afarensis* had air sacs in its throat, which suggests that the species possessed an apelike voice box. Conversely, the child's brain shows a subtle sign of humanity. By studying the fossil's natural sandstone endocast, an impression of the braincase, Alemseged's team ascertained that Selam had attained only 65 to 88 percent of the adult brain size by the age of three. A chimp of comparable age, in contrast, has reached more than 90 percent of its adult brain size. This raises the tantalizing possibility that *A. afarensis* experienced a more humanlike pattern of brain growth.

More fossils are needed to discern whether the new skeleton is representative of *A. afarensis* infants, and scientists are doubtless eager to recover remains of other *A. afarensis* children of different ages—if they ever can—to see how they compare. But the little girl from Dikika still has more secrets to spill. "I think the impact of this specimen will be in its information of the growth and development of *Australopithecus*, not only for individual body parts but for rates of development among structures within one individual," observes Carol V. Ward of the University of Missouri–Columbia.

For his part, Alemseged estimates that it will take him several more years to finish removing the sandstone from Selam's bones. Once he does, however, he will be able to reconstruct nearly the entire body of an *A. afarensis* three-year-old—and begin to understand what growing up australopithecine was all about. SA

Kate Wong is editorial director of ScientificAmerican.com

MORE TO EXPLORE

New Look at Human Evolution. Special edition. *Scientific American,* Vol. 13, No. 2; 2003.

Becoming Human: Evolution and the Rise of Intelligence. Special edition. *Scientific American,* Vol. 16, No. 2; 2006.

Geological and Palaeontological Context of a Pliocene Juvenile Hominin at Dikika, Ethiopia. Jonathan G. Wynn et al. in *Nature,* Vol. 443, pages 332–336; September 21, 2006.

A Juvenile Early Hominin Skeleton from Dikika, Ethiopia. Zeresenay Alemseged et al. in *Nature,* Vol. 443, pages 296–301; September 21, 2006.

From Lucy to Language. Donald Johanson and Blake Edgar. Simon & Schuster, 2006.

Extended coverage of *Lucy's Baby*—including more interviews, commentaries and photographs—can be found at ***www.sciam.com/ontheweb***