Debates Contemporâneos em Paleoantropologia 2024

17/05 | Aula 1: Abertura e funcionamento do curso.

24/05 | Aula 2: Apresentação dos primeiros homininios. Os achados no Chade dos fósseis que serviram para descrever o *Sahelanthropus tchadensis*, com idade aproximada de 7 milhões de anos.

Textos para leitura:
An Ancestor to Call Our Own | Kate Wong
Brain Shape Confirms Controversial Fossil as Oldest Human Ancestor | Kate Wong
New Material of the Earliest Hominid from the Upper Miocene of Chad | Michel Brunet
Facelift Supports Skull's Status as Oldest Member of the Human Family | Ann Gibbons
Sahelanthropus tchadensis May Not Have Been a Habitual Biped | Roberto Sáez
Standing Up for the Earliest Bipedal Hominins | Daniel Lieberman

07/06 | Aula 3: O *Ardipithecus*, o *Australopithecus*, a mistura entre características do gênero humano e características da linhagem dos monos (apes).

Textos para leitura:
Fossils Upend Conventional Wisdom about Evolution of Human Bipedalism | Jeremy DeSilva
'Lucy's Baby' Suggests Famed Human Ancestor Had a Primitive Brain | Ann Gibbons
Long-Awaited Research on a 4.4-Million-Year-Old Hominid Sheds New Light on Last Common Ancestor | Katherine Harmon
How Humanlike Was "Ardi"? | Katherine Harmon
Was "Ardi" Not a Human Ancestor After All? New Review Raises Doubts | Katherine Harmon
A 3.8-Million-Year-Old Skull Reveals the Face of Lucy's Possible Ancestors | Bruce Bower

14/06 | Aula 4: As descobertas em Malapa, na África do Sul, de uma nova espécie: *Australopithecus sediba*. Suas características, volume cerebral, discussão sobre sua linhagem. Nova descoberta na África do Sul, o *Homo naledi*. Seus traços arcaicos e traços modernos. A surpreendente datação do *H. naledi*. As descobertas dos fósseis humanos mais antigos fora da África, na República da Geórgia. Os crânios de 1,75 milhão de anos de Dmanisi e a enorme diversidade morfológica apresentada.

Textos para leitura:
First of Our Kind | Kate Wong
Mystery Human | Kate Wong
Newest Member of Human Family is Surprisingly Young | Ann Gibbons
Meet the Frail, Small-Brained People Who First Trekked Out of Africa | Ann Gibbons
Our Ancestors May Have Left Africa Hundreds of Thousands of Years Earlier than Thought | Ann Gibbons

21/06 | Aula 5: O sítio de Shangchen, na China, e as ferramentas líticas que poderiam indicar uma saída humana da África bem antes do que se imaginava. Os problemas na datação de Shangchen. A descoberta no sítio Lomekwi, no Kenya. O material lítico de 3,3 milhões de anos. Se são ferramentas, quem teria feito os artefatos? O achado de uso do fogo há 1 milhão de anos na caverna de Wonderwerk, na África do Sul. O primeiro cozimento dos alimentos pelos humanos?

Textos para leitura:
What Kind of Hominin First Left Africa? | Scardia/Neves
The News Origins of Technology | Kate Wong
Humans Tamed Fire by 1 Million Years Ago | Kate Wong
The First Cookout | Kate Wong

28/06 | Aula 6: O aparecimento dos primeiros traços que caracterizam os Neandertais, em Sima de los Huesos, Atapuerca, Espanha. Expressões de comportamentos simbólicos atribuídos a Neandertais. O desaparecimento dos Neandertais. O cruzamento *sapiens* e neandertais. A presença de genes neandertais nas populações humanas atuais.

Textos para leitura:
Neandertal Lineage Began in a "Game of Thrones" World | Kate Wong
Twilight of the Neandertals | Kate Wong
Neandertal Minds | Kate Wong
Did Neandertals Think Like Us? | Kate Wong
Oldest Cave Paintings May Be Creations of Neandertals, Not Modern Humans | Kate Wong

05/07 | Aula 7: Novas datações de arte rupestre na Europa: Panel de las Manos, Caverna El Castilho, Espanha. O comportamento dos Neandertais rediscutido. O possível uso de penas como adorno por Neandertais. Caverna Gorham. A mais antiga gravura rupestre em Gibraltar.

Textos para leitura:
Caveman Couture: Neandertals Rocked Dark Feathers | Kate Wong
World's Oldest Engraving Upends Theory of Homo sapiens Uniqueness | Kate Wong
Ancient Engraving Strengthens Case for Sophisticated Neandertals | Kate Wong
Neandertals Turned Eagle Talons into Jewerly 130,000 Years Ago | Kate Wong
Early Dates for 'Neanderthal Cave Art' May Be Wrong | Aubert/Brumm

12/07 | Aula 8: A herança genética neandertal no homem moderno. 1% a 4% dos genes das pessoas de fora da África são de neandertais. Os genes relacionados a doenças e a características positivas que deles herdamos. O surgimento do pensamento simbólico. A revolução criativa do Paleolítico Superior. O fóssil mais antigo com alguns traços típicos do *Homo sapiens*.

Textos para leitura:
Oldest Homo sapiens Bones Found in Europe | Ann Gibbons
Did Neanderthals Make Art? | Bruce Hardy
Neandertal Genome Study Reveals That We Have a Little Caveman in Us | Kate Wong
Sex with Neandertals Introduced Helpful and Harmful DNA into Modern Human Genome | Kate Wong
World's Oldest Homo sapiens Fossils Found in Marocco | Ann Gibbons

19/07 | Aula 9: A descoberta de um pequeno homininio na Ilha de Flores com características muito primitivas, mas datação recente. O "efeito ilha" de encolhimento de mamíferos grandes. O anão *Homo floresiensis* seria a redução de qual homininio? Novas descobertas na Jordânia ajudam a explicar o floresiensis. As descobertas em Denisova, Rússia.

Textos para leitura:
The Morning of The Modern Mind | Kate Wong
Is This Indonesian Cave Painting the Earliest Portrayal of a Mythical Story? | Kate Wong
Fossils Hint at Long-Sougth Ancestor of Weirdest Human Species | Kate Wong
Rethinking the Hobbits of Indonesia | Kate Wong
How Islands Shrink People | Ann Gibbons

26/07 | Aula 10: Últimas notícias sobre os denisovanos, uma nova espécie do gênero *Homo* definida inicialmente a partir de DNA. Achados que podem dar aos denisovanos uma aparência física.

Textos para leitura:
No Bones About It: Ancient DNA from Siberia Hints at Previously Unknown Human Relative | Kate Wong
Ancient Skulls May Belong to Elusive Humans Called Denisovans | Ann Gibbons
Moderns Said to Mate with Late-Surviving Denisovans | Ann Gibbons
Ancient Jaw Gives Elusive Denisovans a Face | Ann Gibbons
'Dragon Man' May Be an Efusive Denisovan | Ann Gibbons

02/08 | Aula 11: As novas descobertas e polêmicas. O *Homo luzonensis*, quando os *sapiens* saíram da África. O *Homo naledi*.

Textos para leitura:
Philippine Fossils Add Surprising New Species to Human Family Tree | Kate Wong
Uma Outra Jornada para o sapiens | Rocha/Neves
This Small-Brained Human Species May Have Buried Its Dead, Controlled Fire and Made Art | Kate Wong
Possible New Human Species Found through 300,000-Year-Old Jawbone Fossil | Dyani Lewis

17/05 | Aula 1: Abertura e funcionamento do curso.

24/05 | Aula 2: Apresentação dos primeiros hominínios. Os achados no Chade dos fósseis que serviram para descrever o *Sahelanthropus tchadensis*, com idade aproximada de 7 milhões de anos.

Textos para leitura:
An Ancestor to Call Our Own | Kate Wong
Brain Shape Confirms Controversial Fossil as Oldest Human Ancestor | Kate Wong
New Material of the Earliest Hominid from the Upper Miocene of Chad | Michel Brunet
Facelift Supports Skull's Status as Oldest Member of the Human Family | Ann Gibbons
Sahelanthropus tchadensis May Not Have Been a Habitual Biped | Roberto Sáez
Standing Up for the Earliest Bipedal Hominins | Daniel Lieberman

AN ANCESTOR TO CALL OUR OWN

BY KATE WONG

Controversial new fossils could bring scientists closer than ever to the origin of humanity

POITIERS, FRANCE—Michel Brunet removes the cracked, brown skull from its padlocked, foam-lined metal carrying case and carefully places it on the desk in front of me. It is about the size of a coconut, with a slight snout and a thick brow visoring its stony sockets. To my inexpert eye, the face is at once foreign and inscrutably familiar. To Brunet, a paleontologist at the University of Poitiers, it is the visage of the lost relative he has sought for 26 years. "He is the oldest one," the veteran fossil hunter murmurs, "the oldest hominid."

Brunet and his team set the field of paleoanthropology abuzz when they unveiled their find last July. Unearthed from sandstorm-scoured deposits in northern Chad's Djurab Desert, the astonishingly complete cranium—dubbed *Sahelanthropus tchadensis* (and nicknamed Toumaï, which means "hope of life" in the local Goran language)—dates to nearly seven million years ago. It may thus represent the earliest human forebear on record, one who Brunet says "could touch with his finger" the point at which our lineage and the one leading to our closest living relative, the chimpanzee, diverged.

KAZUHIKO SANO

APE OR ANCESTOR? *Sahelanthropus tchadensis,* potentially the oldest hominid on record, forages in a woodland bordering Lake Chad some seven million years ago. Thus far the creature is known only from cranial and dental remains, so its body in this artist's depiction is entirely conjectural.

Less than a century ago simian human precursors from Africa existed only in the minds of an enlightened few. Charles Darwin predicted in 1871 that the earliest ancestors of humans would be found in Africa, where our chimpanzee and gorilla cousins live today. But evidence to support that idea didn't come until more than 50 years later, when anatomist Raymond Dart of the University of the Witwatersrand described a fossil skull from Taung, South Africa, as belonging to an extinct human he called *Australopithecus africanus,* the "southern ape from Africa." His claim met variously with frosty skepticism and outright rejection—the remains were those of a juvenile gorilla, critics countered. The discovery of another South African specimen, now recognized as *A. robustus,* eventually vindicated Dart, but it wasn't until the 1950s that the notion of ancient, apelike human ancestors from Africa gained widespread acceptance.

In the decades that followed, pioneering efforts in East Africa headed by members of the Leakey family, among others, turned up additional fossils. By the late 1970s the australopithecine cast of characters had grown to include *A. boisei, A. aethiopicus* and *A. afarensis* (Lucy and her kind, who lived between 2.9 million and 3.6 million years ago during the Pliocene epoch and gave rise to our own genus, *Homo*). Each was adapted to its own environmental niche, but all were bipedal creatures with thick jaws, large molars and small canines—radically different from the generalized, quadrupedal Miocene apes known from farther back on the family tree. To probe human origins beyond *A. afarensis,* however, was to fall into a gaping hole in the fossil record between 3.6 million and 12 million years ago. Who, researchers wondered, were Lucy's forebears?

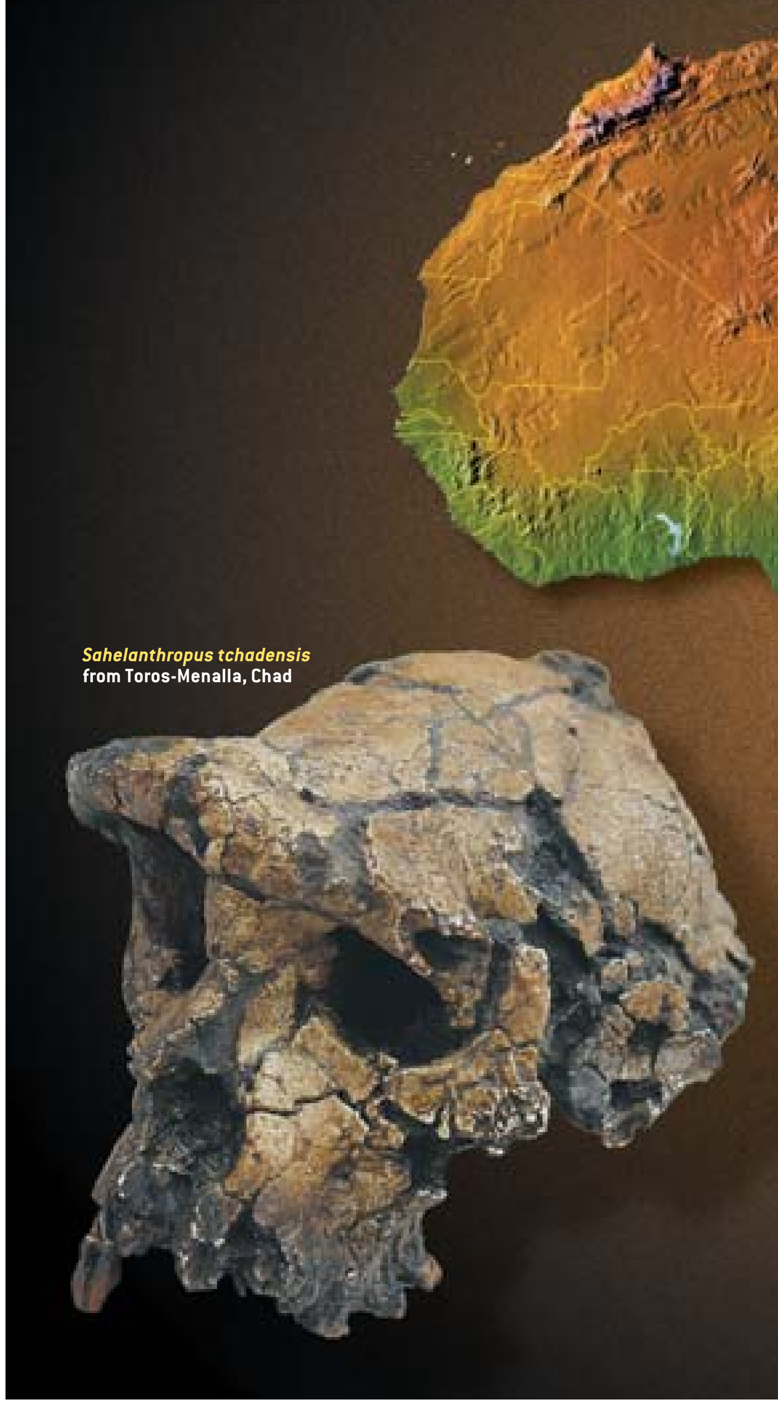
Despite widespread searching, diagnostic fossils of the right age to answer that question eluded workers for nearly two decades. Their luck finally began to change around the mid-1990s, when a team led by Meave Leakey of the National Museums of Kenya announced its discovery of *A. anamensis,* a four-million-year-old species that, with its slightly more archaic characteristics, made a reasonable ancestor for Lucy [see "Early Hominid Fossils from Africa," by Meave Leakey and Alan Walker; Scientific American, June 1997]. At around

Overview/*The Oldest Hominids*

- The typical textbook account of human evolution holds that humans arose from a chimpanzeelike ancestor between roughly five million and six million years ago in East Africa and became bipedal on the savanna. But until recently, hominid fossils more than 4.4 million years old were virtually unknown.
- Newly discovered fossils from Chad, Kenya and Ethiopia may extend the human record back to seven million years ago, revealing the earliest hominids yet.
- These finds cast doubt on conventional paleoanthropological wisdom. But experts disagree over how these creatures are related to humans—if they are related at all.

African Roots

RECENT FINDS from Africa could extend in time and space the fossil record of early human ancestors. Just a few years ago, remains more than 4.4 million years old were essentially unknown, and the oldest specimens all came from East Africa. In 2001 paleontologists working in Kenya's Tugen Hills and Ethiopia's Middle Awash region announced that they had discovered hominids dating back to nearly six million years ago (*Orrorin tugenensis* and *Ardipithecus ramidus kadabba,* respectively). Then, last July, University of Poitiers



Sahelanthropus tchadensis
from Toros-Menalla, Chad

paleontologist Michel Brunet and his Franco-Chadian Paleoanthropological Mission reported having unearthed a nearly seven-million-year-old hominid, called *Sahelanthropus tchadensis*, at a site known as Toros-Menalla in northern Chad. The site lies some 2,500 kilometers west of the East African fossil localities. "I think the most important thing we have done in terms of trying to understand our story is to open this new window," Brunet remarks. "We are proud to be the pioneers of the West."

Ardipithecus ramidus kadabba
from Middle Awash, Ethiopia

Orrorin tugenensis
from Tugen Hills, Kenya

PATRICK ROBERT *Corbis Sygma* (*Sahelanthropus tchadensis skull*); © 1999 TIM D. WHITE *Brill Atlanta\National Museum of Ethiopia* (*A. r. kadabba fossils*); GAMMA (*O. tugenensis fossils*); EDWARD BELL (*map illustration*)

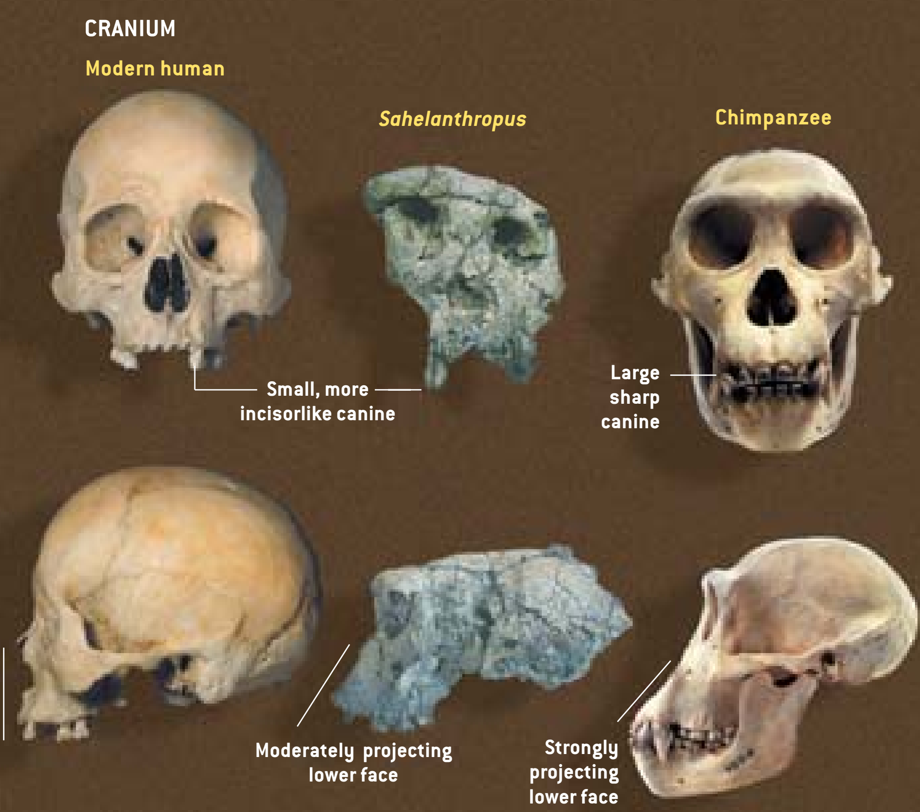
It is the visage of the lost relative he has sought for 26 years. ***"He is the oldest one,"*** *the veteran fossil hunter murmurs,* ***"the oldest hominid."***

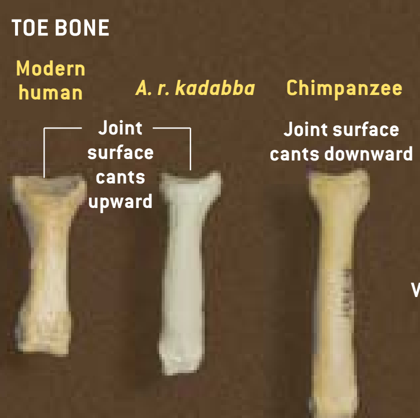
the same time, Tim D. White of the University of California at Berkeley and his colleagues described a collection of 4.4-million-year-old fossils from Ethiopia representing an even more primitive hominid, now known as *Ardipithecus ramidus ramidus*. Those findings gave scholars a tantalizing glimpse into Lucy's past. But estimates from some molecular biologists of when the chimp-human split occurred suggested that even older hominids lay waiting to be discovered.

Those predictions have recently been borne out. Over the past few years, researchers have made a string of stunning discoveries—Brunet's among them—that may go a long way toward bridging the remaining gap between humans and their African ape ancestors. These fossils, which range from roughly five million to seven million years old, are upending long-held ideas about when and where our lineage arose and what the last common ancestor of humans and chimpanzees looked like. Not surprisingly, they have also sparked vigorous debate. Indeed, experts are deeply divided over where on the family tree the new species belong and even what constitutes a hominid in the first place.

Anatomy of an Ancestor

KEY TRAITS link putative hominids *Ardipithecus ramidus kadabba, Orrorin* and *Sahelanthropus* to humans and distinguish them from apes such as chimpanzees. The fossils exhibit primitive apelike characteristics, too, as would be expected of creatures this ancient. For instance, the *A. r. kadabba* toe bone has a humanlike upward tilt to its joint surface, but the bone is long and curves downward like a chimp's does (which somewhat obscures the joint's cant). Likewise, *Sahelanthropus* has a number of apelike traits—its small braincase among them—but is more humanlike in the form of the canines and the projection of the lower face. (Reconstruction of the *Sahelanthropus* cranium, which is distorted, will give researchers a better understanding of its morphology.) The *Orrorin* femur has a long neck and a groove carved out by the obturator externus muscle—traits typically associated with habitual bipedalism, and therefore with humans—but the distribution of cortical bone in the femoral neck may be more like that of a quadrupedal ape.

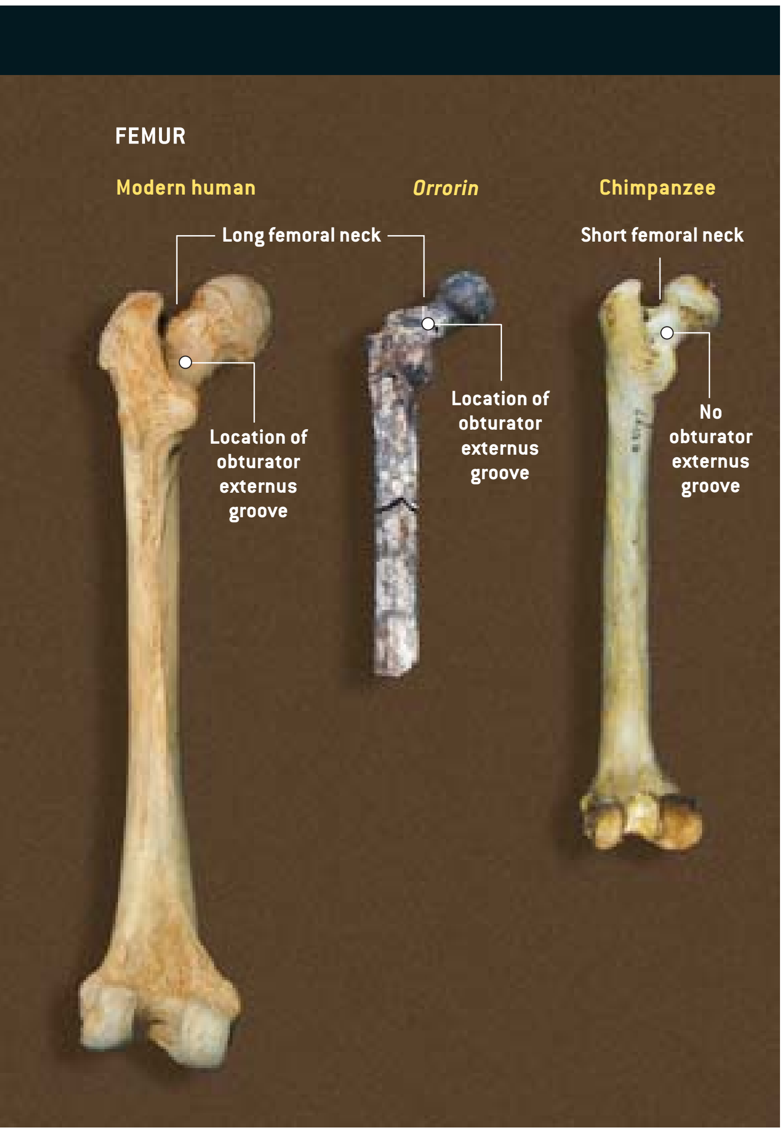




© C. OWEN LOVEJOY*Brill Atlanta* (*human,* A. r. kadabba *and chimpanzee toe bones*); CHRISTIAN SIDOR *New York College of Osteopathic Medicine* (*human skull and human femur*); MISSION PALÉOANTHROPOLOGIQUE FRANCO-TCHADIENNE (Sahelanthropus *skull*); © 1996 DAVID L. BRILL\DIVISION OF MAMMALS, NATIONAL MUSEUM OF NATURAL HISTORY, SMITHSONIAN INSTITUTION (*chimpanzee skull*); GAMMA (Orrorin *femur*); C. OWEN LOVEJOY *Kent State University* (*chimpanzee femur*)

Standing Tall

THE FIRST HOMINID CLUE to come from beyond the 4.4-million-year mark was announced in the spring of 2001. Paleontologists Martin Pickford and Brigitte Senut of the National Museum of Natural History in Paris found in Kenya's Tugen Hills the six-million-year-old remains of a creature they called *Orrorin tugenensis*. To date the researchers have amassed 19 specimens, including bits of jaw, isolated teeth, finger and arm bones, and some partial upper leg bones, or femurs. According to Pickford and Senut, *Orrorin* exhibits several characteristics that clearly align it with the hominid family—notably those suggesting that, like all later members of our group, it walked on two legs. "The femur is remarkably humanlike," Pickford observes. It has a long femoral neck, which would have placed the shaft at an angle relative to the lower leg (thereby stabilizing the hip), and a groove on the back of that femoral neck, where a muscle known as the obturator externus pressed against the bone during upright walking. In other respects, *Orrorin* was a primitive animal: its canine teeth are large and pointed relative to human canines, and its arm and finger bones retain adaptations for climbing. But the femur characteristics signify to Pickford and Senut that when it was on the ground, *Orrorin* walked like a man.



In fact, they argue, *Orrorin* appears to have had a more humanlike gait than the much younger Lucy did. Breaking with paleoanthropological dogma, the team posits that *Orrorin* gave rise to *Homo* via the proposed genus *Praeanthropus* (which comprises a subset of the fossils currently assigned to *A. afarensis* and *A. anamensis*), leaving Lucy and her kin on an evolutionary sideline. *Ardipithecus,* they believe, was a chimpanzee ancestor.

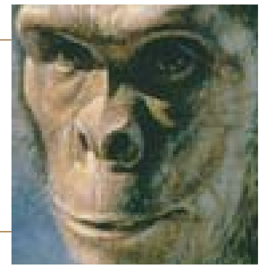
Not everyone is persuaded by the femur argument. C. Owen Lovejoy of Kent State University counters that published computed tomography scans through *Orrorin*'s femoral neck—which Pickford and Senut say reveal humanlike bone structure—actually show a chimplike distribution of cortical bone, an important indicator of the strain placed on that part of the femur during locomotion. Cross sections of *A. afarensis*'s femoral neck, in contrast, look entirely human, he states. Lovejoy suspects that *Orrorin* was frequently—but not habitually—bipedal and spent a significant amount of time in the trees. That wouldn't exclude it from hominid status, because full-blown bipedalism almost certainly didn't emerge in one fell swoop. Rather *Orrorin* may have simply not yet evolved the full complement of traits required for habitual bipedalism. Viewed that way, *Orrorin* could still be on the ancestral line, albeit further removed from *Homo* than Pickford and Senut would have it.

Better evidence of early routine bipedalism, in Lovejoy's view, surfaced a few months after the *Orrorin* report, when Berkeley graduate student Yohannes Haile-Selassie announced the discovery of slightly younger fossils from Ethiopia's Middle Awash region. Those 5.2-million- to 5.8-million-year-old remains, which have been classified as a subspecies of *Ardipithecus ramidus, A. r. kadabba,* include a complete foot phalanx, or toe bone, bearing a telltale trait. The bone's joint is angled in precisely the way one would expect if *A. r. kadabba* "toed off" as humans do when walking, reports Lovejoy, who has studied the fossil.

Other workers are less impressed by the toe morphology. "To me, it looks for all the world like a chimpanzee foot phalanx," comments David Begun of the University of Toronto, noting from photographs that it is longer, slimmer and more curved than a biped's toe bone should be. Clarification may come when White and his collaborators publish findings on an as yet undescribed partial skeleton of *Ardipithecus,* which White says they hope to do within the next year or two.

Differing anatomical interpretations notwithstanding, if either *Orrorin* or *A. r. kadabba* were a biped, that would not only push the origin of our strange mode of locomotion back by nearly 1.5 million years, it would also lay to rest a popular idea about the conditions under which our striding gait evolved. Received wisdom holds that our ancestors became bipedal on the African savanna, where upright walking may have kept the blistering sun off their backs, given them access to previously out-of-reach foods, or afforded them a better view above the tall

Humanity may have arisen more than a million years earlier than a number of molecular studies had estimated. More important, it may have originated in a different locale.



grass. But paleoecological analyses indicate that *Orrorin* and *Ardipithecus* dwelled in forested habitats, alongside monkeys and other typically woodland creatures. In fact, Giday WoldeGabriel of Los Alamos National Laboratory and his colleagues, who studied the soil chemistry and animal remains at the *A. r. kadabba* site, have noted that early hominids may not have ventured beyond these relatively wet and wooded settings until after 4.4 million years ago.

If so, climate change may not have played as important a role in driving our ancestors from four legs to two as has been thought. For his part, Lovejoy observes that a number of the savanna-based hypotheses focusing on posture were not especially well conceived to begin with. "If your eyes were in your toes, you could stand on your hands all day and look over tall grass, but you'd never evolve into a hand-walker," he jokes. In other words, selection for upright posture alone would not, in his view, have led to bipedal locomotion. The most plausible explanation for the emergence of bipedalism, Lovejoy says, is that it freed the hands and allowed males to collect extra food with which to woo mates. In this model, which he developed in the 1980s, females who chose good providers could devote more energy to child rearing, thereby maximizing their reproductive success.

The Oldest Ancestor?

THE PALEOANTHROPOLOGICAL community was still digesting the implications of the *Orrorin* and *A. r. kadabba* discoveries when Brunet's fossil find from Chad came to light. With *Sahelanthropus* have come new answers—and new questions. Unlike *Orrorin* and *A. r. kadabba,* the *Sahelanthropus* material does not include any postcranial bones, making it impossible at this point to know whether the animal was bipedal, the traditional hallmark of humanness. But Brunet argues that a suite of features in the teeth and skull, which he believes belongs to a male, judging from the massive brow ridge, clearly links this creature to all later hominids. Characteristics of *Sahelanthropus*'s canines are especially important in his assessment. In all modern and fossil apes, and therefore presumably in the last common ancestor of chimps and humans, the large upper canines are honed against the first lower premolars, producing a sharp edge along the back of the canines. This so-called honing canine-premolar complex is pronounced in males, who use their canines to compete with one another for females. Humans lost these fighting teeth, evolving smaller, more incisorlike canines that occlude tip to tip, an arrangement that creates a distinctive wear pattern over time. In their size, shape and wear, the *Sahelanthropus* canines are modified in the human direction, Brunet asserts.

At the same time, *Sahelanthropus* exhibits a number of apelike traits, such as its small braincase and widely spaced eye sockets. This mosaic of primitive and advanced features, Brunet says, suggests a close relationship to the last common ancestor. Thus, he proposes that *Sahelanthropus* is the earliest member of the human lineage and the ancestor of all later hominids, in-

WITNESS/GAMMA

HUNTING FOR HOMINIDS: Michel Brunet (*left*), whose team uncovered *Sahelanthropus,* has combed the sands of the Djurab Desert in Chad for nearly a decade. Martin Pickford and Brigitte Senut (*center*) discovered *Orrorin* in Kenya's Tugen Hills. Tim White (*top right*) and Yohannes Haile-Selassie (*bottom right*) found *Ardipithecus* in the Middle Awash region of Ethiopia.

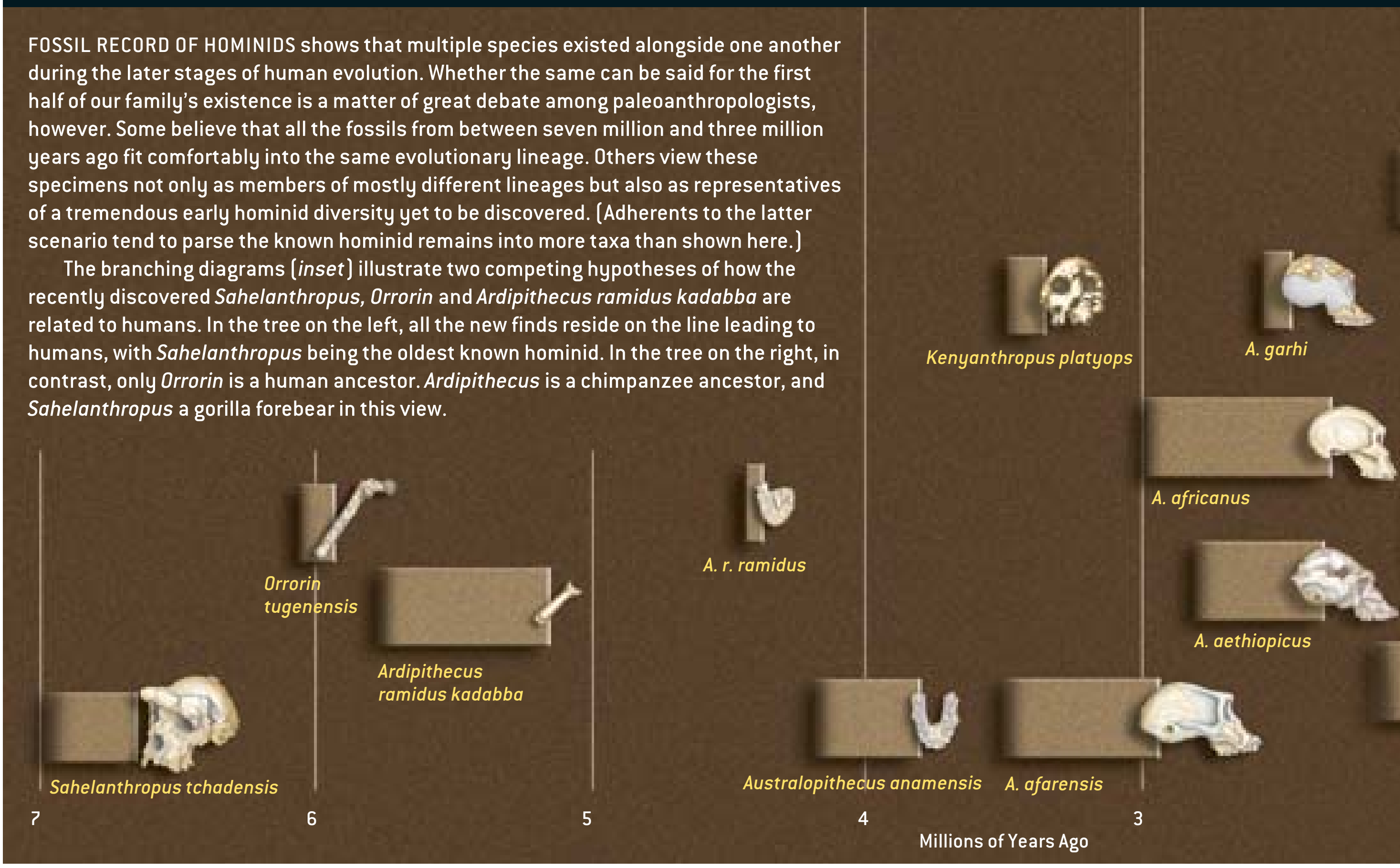
cluding *Orrorin* and *Ardipithecus*. If Brunet is correct, humanity may have arisen more than a million years earlier than a number of molecular studies had estimated. More important, it may have originated in a different locale than has been posited. According to one model of human origins, put forth in the 1980s by Yves Coppens of the College of France, East Africa was the birthplace of humankind. Coppens, noting that the oldest human fossils came from East Africa, proposed that the continent's Rift Valley—a gash that runs from north to south—split a single ancestral ape species into two populations. The one in the east gave rise to humans; the one in the west spawned today's apes [see "East Side Story: The Origin of Humankind," by Yves Coppens; Scientific American, May 1994]. Scholars have recognized for some time that the apparent geographic separation might instead be an artifact of the scant fossil record. The discovery of a seven-million-year-old hominid in Chad, some 2,500 kilometers west of the Rift Valley, would deal the theory a fatal blow.

Most surprising of all may be what *Sahelanthropus* reveals about the last common ancestor of humans and chimpanzees. Paleoanthropologists have typically imagined that that creature resembled a chimp in having, among other things, a strongly projecting lower face, thinly enameled molars and large canines. Yet *Sahelanthropus,* for all its generally apelike traits, has only a moderately prognathic face, relatively thick enamel, small canines and a brow ridge larger than that of any living ape. "If *Sahelanthropus* shows us anything, it shows us that the last common ancestor was not a chimpanzee," Berkeley's White remarks. "But why should we have expected otherwise?" Chimpanzees have had just as much time to evolve as humans have had, he points out, and they have become highly specialized, fruit-eating apes.

Brunet's characterization of the Chadian remains as those of a human ancestor has not gone unchallenged, however. "Why *Sahelanthropus* is necessarily a hominid is not particularly clear," comments Carol V. Ward of the University of Missouri. She and others are skeptical that the canines are as humanlike as Brunet claims. Along similar lines, in a letter published last October in the journal *Nature,* in which Brunet's team initially reported its findings, University of Michigan paleoanthropologist Milford H. Wolpoff, along with *Orrorin* discoverers Pickford and Senut, countered that *Sahelanthropus* was an ape rather than a hominid. The massive brow and certain features on the base and rear of *Sahelanthropus*'s skull, they observed, call to mind the anatomy of a quadrupedal ape with a difficult-to-chew diet, whereas the small canine suggests that it was a female of such a species, not a male human ancestor. Lacking proof that *Sahelanthropus* was bipedal, so their reasoning goes, Brunet doesn't have a leg to stand on. (Pickford and Senut further argue that the animal was specifically a go-

© 1998 DAVID L. BRILL *Brill Atlanta (top)*; GAMMA *(bottom left)*; © 1998 DAVID L. BRILL *Brill Atlanta (bottom left)*

Hominids in Time



FOSSIL RECORD OF HOMINIDS shows that multiple species existed alongside one another during the later stages of human evolution. Whether the same can be said for the first half of our family's existence is a matter of great debate among paleoanthropologists, however. Some believe that all the fossils from between seven million and three million years ago fit comfortably into the same evolutionary lineage. Others view these specimens not only as members of mostly different lineages but also as representatives of a tremendous early hominid diversity yet to be discovered. (Adherents to the latter scenario tend to parse the known hominid remains into more taxa than shown here.)

The branching diagrams (*inset*) illustrate two competing hypotheses of how the recently discovered *Sahelanthropus, Orrorin* and *Ardipithecus ramidus kadabba* are related to humans. In the tree on the left, all the new finds reside on the line leading to humans, with *Sahelanthropus* being the oldest known hominid. In the tree on the right, in contrast, only *Orrorin* is a human ancestor. *Ardipithecus* is a chimpanzee ancestor, and *Sahelanthropus* a gorilla forebear in this view.

ILLUSTRATIONS BY PATRICIA J. WYNNE AND CORNELIA BLIK

rilla ancestor.) In a barbed response, Brunet likened his detractors to those Dart encountered in 1925, retorting that *Sahelanthropus*'s apelike traits are simply primitive holdovers from its own ape predecessor and therefore uninformative with regard to its relationship to humans.

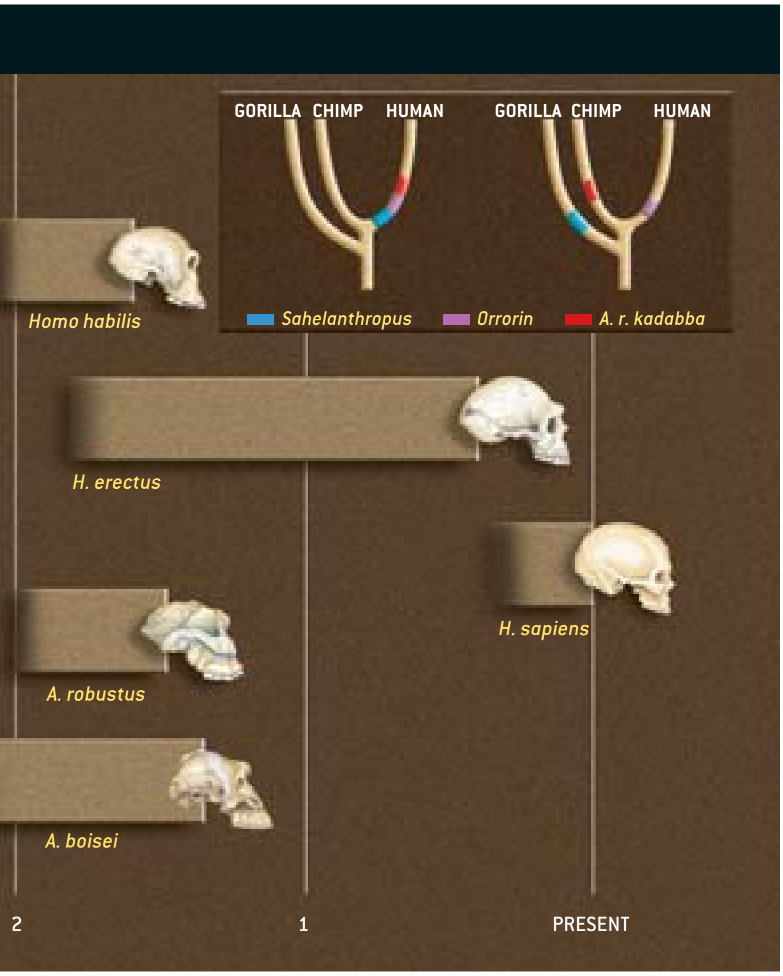
The conflicting views partly reflect the fact that researchers disagree over what makes the human lineage unique. "We have trouble defining hominids," acknowledges Roberto Macchiarelli, also at the University of Poitiers. Traditionally paleoanthropologists have regarded bipedalism as the characteristic that first set human ancestors apart from other apes. But subtler changes—the metamorphosis of the canine, for instance—may have preceded that shift.

To understand how animals are related to one another, evolutionary biologists employ a method called cladistics, in which organisms are grouped according to shared, newly evolved traits. In short, creatures that have these derived characteristics in common are deemed more closely related to one another than they are to those that exhibit only primitive traits inherited from a more distant common ancestor. The first occurrence in the fossil record of a shared, newly acquired trait serves as a baseline indicator of the biological division of an ancestral species into two daughter species—in this case, the point at which chimps and humans diverged from their common ancestor—and that trait is considered the defining characteristic of the group.

Thus, cladistically "what a hominid is from the point of view of skeletal morphology is summarized by those characters preserved in the skeleton that are present in populations that directly succeeded the genetic splitting event between chimps and humans," explains William H. Kimbel of Arizona State University. With only an impoverished fossil record to work from, paleontologists can't know for certain what those traits were. But the two leading candidates for the title of seminal hominid characteristic, Kimbel says, are bipedalism and the transformation of the canine. The problem researchers now face in trying to suss out what the initial changes were and which, if any, of the new putative hominids sits at the base of the human clade is that so far *Orrorin, A. r. kadabba* and *Sahelanthropus* are represented by mostly different bony elements, making comparisons among them difficult.

How Many Hominids?

MEANWHILE THE ARRIVAL of three new taxa to the table has intensified debate over just how diverse early hominids were. Experts concur that between three million and 1.5 million years ago, multiple hominid species existed alongside one



another at least occasionally. Now some scholars argue that this rash of discoveries demonstrates that human evolution was a complex affair from the outset. Toronto's Begun—who believes that the Miocene ape ancestors of modern African apes and humans spent their evolutionarily formative years in Europe and western Asia before reentering Africa—observes that *Sahelanthropus* bears exactly the kind of motley features that one would expect to see in an animal that was part of an adaptive radiation of apes moving into a new milieu. "It would not surprise me if there were 10 or 15 genera of things that are more closely related to *Homo* than to chimps," he says. Likewise, in a commentary that accompanied the report by Brunet and his team in *Nature,* Bernard Wood of George Washington University wondered whether *Sahelanthropus* might hail from the African ape equivalent of Canada's famed Burgess Shale, which has yielded myriad invertebrate fossils from the Cambrian period, when the major modern animal groups exploded into existence. Viewed that way, the human evolutionary tree would look more like an unkempt bush, with some, if not all, of the new discoveries occupying terminal twigs instead of coveted spots on the meandering line that led to humans.

Other workers caution against inferring the existence of multiple, coeval hominids on the basis of what has yet been found. "That's *X-Files* paleontology," White quips. He and Brunet both note that between seven million and four million years ago, only one hominid species is known to have existed at any given time. "Where's the bush?" Brunet demands. Even at humanity's peak diversity, two million years ago, White says, there were only three taxa sharing the landscape. "That ain't the Cambrian explosion," he remarks dryly. Rather, White suggests, there is no evidence that the base of the family tree is anything other than a trunk. He thinks that the new finds might all represent snapshots of the *Ardipithecus* lineage through time, with *Sahelanthropus* being the earliest hominid and with *Orrorin* and *A. r. kadabba* representing its lineal descendants. (In this configuration, *Sahelanthropus* and *Orrorin* would become species of *Ardipithecus.*)

Investigators agree that more fossils are needed to elucidate how *Orrorin, A. r. kadabba* and *Sahelanthropus* are related to one another and to ourselves, but obtaining a higher-resolution picture of the roots of humankind won't be easy. "We're going to have a lot of trouble diagnosing the very earliest members of our clade the closer we get to that last common ancestor," Missouri's Ward predicts. Nevertheless, "it's really important to sort out what the starting point was," she observes. "Why the human lineage began is the question we're trying to answer, and these new finds in some ways may hold the key to answering that question—or getting closer than we've ever gotten before."

It may be that future paleoanthropologists will reach a point at which identifying an even earlier hominid will be well nigh impossible. But it's unlikely that this will keep them from trying. Indeed, it would seem that the search for the first hominids is just heating up. "The *Sahelanthropus* cranium is a messenger [indicating] that in central Africa there is a desert full of fossils of the right age to answer key questions about the genesis of our clade," White reflects. For his part, Brunet, who for more than a quarter of a century has doggedly pursued his vision through political unrest, sweltering heat and the blinding sting of an unrelenting desert wind, says that ongoing work in Chad will keep his team busy for years to come. "This is the beginning of the story," he promises, "just the beginning." As I sit in Brunet's office contemplating the seven-million-year-old skull of *Sahelanthropus,* the fossil hunter's quest doesn't seem quite so unimaginable. Many of us spend the better part of a lifetime searching for ourselves. SA

Kate Wong is a writer and editor for ScientificAmerican.com

MORE TO EXPLORE

Late Miocene Hominids from the Middle Awash, Ethiopia. Yohannes Haile-Selassie in *Nature,* Vol. 412, pages 178–181; July 12, 2001.

Extinct Humans. Ian Tattersall and Jeffrey H. Schwartz. Westview Press, 2001.

Bipedalism in *Orrorin tugenensis* Revealed by Its Femora. Martin Pickford, Brigitte Senut, Dominique Gommercy and Jacques Treil in *Comptes Rendus: Palevol,* Vol. 1, No. 1, pages 1–13; 2002.

A New Hominid from the Upper Miocene of Chad, Central Africa. Michel Brunet, Franck Guy, David Pilbeam, Hassane Taisso Mackaye et al. in *Nature,* Vol. 418, pages 145–151; July 11, 2002.

The Primate Fossil Record. Edited by Walter C. Hartwig. Cambridge University Press, 2002.

Brain Shape Confirms Controversial Fossil as Oldest Human Ancestor

Kate Wong April 4, 2013

Sahelanthropus tchadensis, also known as Toumaï, had a tiny brain, but one that had nonetheless undergone some reorganization toward the human condition. Image: Didier Descouens, via Wikimedia Commons

HONOLULU--A seven-million-year-old skull found in the Djurab Desert in Chad may indeed represent the earliest known member of the human family. Researchers unveiled the specimen back in 2002 and made quite a splash with their claim that the ancient fossil was our ancestor. They assigned it to a new species, Sahelanthropus tchadensis (nickname: Toumaï) and said it was very close to the point at which the human lineage diverged from that of our closest living relative, the chimpanzee. Critics, however, countered that the skull was probably an ape's instead of that of a hominin (a creature on the line leading to us), given its primitive features. But a new analysis of the skull—specifically, its braincase—supports the discoverers' claim that Toumaï is a hominin.

Thibaut Bienvenu of the Collège de France and his colleagues reconstructed Toumaï's endocast—a cast of the interior of the braincase, which reveals the shape of the brain. Because the fossil skull is distorted and filled with a highly mineralized matrix, they had to do their reconstruction virtually, which meant imaging it with 3D X-ray synchrotron microtomography and then feeding that data into a program that allowed them to remove the matrix and correct the distortion on screen.

The resulting virtual reconstruction of the endocast reveals that Toumaï had a cranial capacity of 378 cubic centimeters—consistent with earlier estimates. This puts it within the range of chimp cranial capacity. In comparison, modern humans have brains around three times larger than that. But though Toumaï's brain was apelike in its small size, it was apparently homininlike in other ways. In a presentation given on April 2 at the annual meeting of the Paleoanthropology Society, Bienvenu reported that the endocast shows strongly posteriorly projecting occipital lobes, a tilted brainstem, and a laterally expanded prefrontal cortex, among other hominin brain characteristics.

Previously, Michel Brunet of the Collège de France, whose team discovered Toumaï*, and his colleagues argued that Toumaï was a hominin on the basis of traits including his relatively small canine teeth, which are associated with reduced aggression, and the forward position of his foramen magnum (the spinal cord opening in the base of the skull), which is associated with upright walking. Both of these characteristics are considered hallmarks of humanity. But skeptics argued that other features, such as the hulking brow ridge and aspects of the rear and base of the skull, signaled that the fossil represents an ape. The endocast traits bolster the original interpretation.

Bienvenu said that Toumaï's endocast offers "a unique window on the first stage of human brain evolution" and shows evidence of brain reorganization toward the human condition well before brain size had begun to expand. He added that this early brain reorganization was probably a consequence of the shift to upright walking.

04/10/13 Posted updated to identify Brunet.

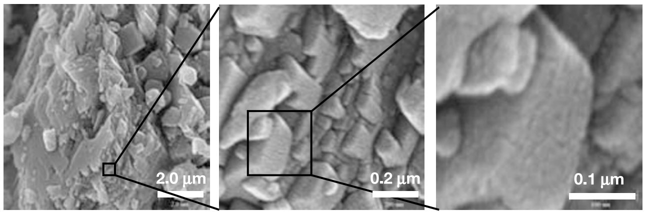


Figure 4 Scanning electron microscope images of untreated gouge from San Andreas gouge, with an order-of-magnitude resolution increase from left to right. The gouge samples were mounted onto colloidal graphite coating covering upper portions of platinum trays, and sputter-coated with gold–palladium under vacuum. Note the particles of 0.02–0.05 μm in the middle and right frames.

event. In such a case, the observed gouge zone 70–100 m wide was formed by 7,000–10,000 earthquakes, which is in agreement with estimates of recurrence intervals. Although the present observations on gouge energetics are in accord with some studies[30], they contradict common thought that gouge surface energy is a negligible component of earthquake energy balance[3,9]. If our conclusions are valid in general, they could explain, for example, the heat flow anomaly of the San Andreas fault system[6]. □

Methods

We employ a Beckman Coulter LS230 laser diffraction particle size analyser. Its 750-nm laser source and proprietary polarization intensity differential scattering (PIDS) technology provide detection limits of 0.04–2,000 μm. Spectrometry by laser diffraction does not discern between primary particles and agglomerates and is therefore sensitive to the degree of agglomeration inside the analyser[14,17]. Disaggregation is a time-dependent process that can occur over the course of days in silicate mineral suspensions[17]. Accordingly, gouge PSD measurements lasting up to 190 h were taken, during which progressive disaggregation could be discerned (Figs 2, 3). Initial sonication accelerated disaggregation but had no noticeable influence on the final PSD. Ultrafine particles might reagglomerate during the analysis[14], as indicated by the increased scatter in surface area at long times (Fig. 3b). Power-law disaggregation (Fig. 3) and recurring agglomeration/disaggregation during analysis indicates that PSD and surface area results are conservative estimates of primary gouge particle size and area produced by the seismic slip. Ultrafine particles could also have been lost as a result of Ostwald ripening and volatilization during sampling and handling.

The collected gouge samples were sealed at the site and stored in plastic bags. For the PSD measurements, tens of micrograms of sample were added to 25 ml of an aqueous surfactant solution (usually 1% analytical reagent grade sodium metaphosphate prepared with doubly distilled water) or methanol and then subjected for 30 min to a low-energy sonic bath. After an additional 30 min this slurry was added to the laser analyser containing 125 ml of the same solution. Measurements of the diffraction spectrum were performed with continuous circulation inside the analyser, and PIDS was used in all reported runs. Spectral analysis was performed with proprietary software using the Mie scattering model[14], with constants for the complex refractive index plus wavelength dependence for quartz[14] and an absorption coefficient of 0.01.

Received 4 December 2004; accepted 28 January 2005; doi:10.1038/nature03433.

1. Sammis, C. G., Osborne, R. H., Anderson, J. L., Banerdt, M. & White, P. Self-similar cataclasis in the formation of fault gouge. *Pure Appl. Geophys.* **124,** 53–78 (1986).
2. Marone, C. & Scholz, C. Particle-size distribution and microstructures within simulated fault gouge. *J. Struct. Geol.* **11,** 799–814 (1989).
3. Scholz, C. H. *The Mechanics of Earthquakes and Faulting* (Cambridge Univ. Press, London, 2002).
4. Dor, O., Reches, Z. & van Aswagen, G. in *Rockburst and Seismicity in Mines* Vol. 5 (eds van Aswegen, G., Durrheim, R. J. & Ortlepp, W. D.) 109–112 (South African Inst. of Mining and Metallurgy, Johannesburg, 2001).
5. Chester, F. M., Evans, J. P. & Biegel, R. L. Internal structure and weakening mechanisms of the San-Andreas Fault. *J. Geophys. Res. Solid Earth* **98,** 771–786 (1993).
6. Zoback, M. D., Hickman, S. & Ellsworth, W. San Andreas Fault observatory at depth. ⟨http://www.icdp.gfzpotsdam.de/html/sites/sanandreas/objectives/proposal.html⟩ (2002).
7. Ben-Zion, Y. & Sammis, C. G. Characterization of fault zones. *Pure Appl. Geophys.* **160,** 677–715 (2003).
8. Sleep, N. H. & Blanpied, M. L. Creep, compaction, and the weak rheology of major faults. *Nature* **359,** 687–692 (1992).
9. Olgaard, D. & Brace, W. The microstructure of gouge from a mining-induced seismic shear zone. *Int. J. Rock Mech. Mining Sci.* **20,** 11–19 (1983).
10. Steacy, S. J. & Sammis, C. G. An automaton for fractal patterns of fragmentation. *Nature* **353,** 250–252 (1991).
11. An, L. J. & Sammis, C. G. Particle-size distribution of cataclastic fault materials from southern California—a 3-d study. *Pure Appl. Geophys.* **143,** 203–227 (1994).
12. Kanamori, H. Mechanics of earthquakes. *Annu. Rev. Earth Planet. Sci.* **22,** 207–237 (1994).
13. Brune, J. N. Fault-normal dynamic unloading and loading: an explanation for 'nongouge' rock powder and lack of fault-parallel shear bands along the San Andreas Fault. *Eos* **8,** 47 (2001).
14. Xu, R. *Particle Characterization: Light Scattering Methods* (Kluwer Academic, Dordrecht, 2000).
15. Gregg, S. J. & Sing, K. S. W. *Adsorption, Surface Area and Porosity* (Academic, London, 1982).
16. Dewers, T. A., Wilson, B. & Reches, Z. Scaling particle size in fault gouge: Variable fractal dimension or non-fractal distribution? *Eos* **84,** NG12C-06 (2003).
17. Franco, F., Perez-Maqueda, L. A. & Perez-Rodriguez, J. L. The effect of ultrasound on the particle size and structural disorder of a well-ordered kaolinite. *J. Colloid Interface Sci.* **274,** 107–117 (2004).
18. Evans, J. P. & Chester, F. M. Fluid–rock interaction in faults of the San-Andreas System—Inferences from San-Gabriel fault rock geochemistry and microstructures. *J. Geophys. Res.* **100,** 13007–13020 (1995).
19. Wilson, B. *Meso- and Micro-structural Analysis of the San Andreas Fault at Tejon Pass, California.* Thesis, Univ. Oklahoma, Norman (2004).
20. Smith, B. & Dandwell, D. Coulomb stress accumulation along the San Andreas Fault system. *J. Geophys. Res.* **108,** 2296 (2003).
21. McGarr, A., Spottiswoode, S. M., Gay, N. C. & Ortlepp, W. D. Observations relevant to seismic driving stress, stress drop, and efficiency. *J. Geophys. Res.* **84,** 2251–2261 (1978).
22. Ogasawara, H., Yanagidani, Y. & Ando, M. (eds) *Seismogenic Process Monitoring* (Balkema, Rotterdam, 2002).
23. Ortlepp, W. D. *Rock Fracture and Rockbursts* (South Africa Institute of Mining and Metallurgy, Monograph series M9, 1997).
24. Hochella, M. F. Jr & Banfield, J. F. in *Chemical Weathering Rates of Silicate Minerals* (eds White, A. F. & Brantley, S. L.) 353–406 (Mineralogical Society of America, Washington DC, 1995).
25. Poliakov, A. N. B., Dmowska, R. & Rice, J. R. Dynamic shear rupture interactions with fault bends and off-axis secondary faulting. *J. Geophys. Res.* **107,** 2295 (2002).
26. Li, V. C. in *Fracture Mechanics of Rocks* (ed. Atkinson, B. K.) 351–428 (Academic, London, 1987).
27. Yund, R. A., Blanpied, M. L., Tullis, T. E. & Weeks, J. D. Amorphous material in high strain experimental fault gouges. *J. Geophys. Res.* **95,** 15589–15602 (1990).
28. Reches, Z. & Dewers, T. A. Gouge formation by dynamic pulverization during earthquakes. *Earth Planet. Sci. Lett.* (submitted).
29. Grady, D. E. & Kipp, D. E. Geometric statistics and dynamic fragmentation. *J. Appl. Phys.* **58,** 1210–1222 (1985).
30. Reches, Z. Mechanisms of slip nucleation during earthquakes. *Earth Planet. Sci. Lett.* **170,** 475–486 (1999).

Acknowledgements We thank the US National Science Foundation and the Southern California Earthquake Center for supporting this research.

Authors' contributions All authors contributed equally to this work.

Competing interests statement The authors declare that they have no competing financial interests.

Correspondence and requests for materials should be addressed to Z.R. (reches@ou.edu).

New material of the earliest hominid from the Upper Miocene of Chad

Michel Brunet[1], Franck Guy[1,2], David Pilbeam[2], Daniel E. Lieberman[2], Andossa Likius[3], Hassane T. Mackaye[3], Marcia S. Ponce de León[4], Christoph P. E. Zollikofer[4] & Patrick Vignaud[1]

[1]*Laboratoire de Géobiologie, Biochronologie et Paléontologie Humaine, CNRS UMR 6046, Faculté des Sciences, Université de Poitiers, 40 Avenue du Recteur Pineau, 86022 Poitiers Cedex, France*
[2]*Peabody Museum, Harvard University, 11 Divinity Avenue, Cambridge, Massachusetts 02138, USA*
[3]*Université de N'Djamena, BP 1117, N'Djamena, Tchad*
[4]*Anthropologisches Institut/MultiMedia Laboratorium, Universität Zürich-Irchel, Winterthurerstrasse 190, 8057 Zürich, Switzerland*

Discoveries in Chad by the Mission Paléoanthropologique Franco-Tchadienne have substantially changed our understanding of early human evolution in Africa[1–3]. In particular, the TM 266 locality in the Toros-Menalla fossiliferous area yielded a nearly complete cranium (TM 266-01-60-1), a mandible, and several isolated teeth assigned to *Sahelanthropus tchadensis*[3] and biochronologically dated to the late Miocene epoch (about 7 million years ago). Despite the relative completeness of the TM 266 cranium, there has been some controversy about its morphology and its status in the hominid clade[4,5]. Here we describe new dental and mandibular specimens from three Toros-Menalla (Chad) fossiliferous localities (TM 247, TM 266 and TM 292) of

the same age[6]. This new material, including a lower canine consistent with a non-honing C/P_3 complex, post-canine teeth with primitive root morphology and intermediate radial enamel thickness, is attributed to *S. tchadensis*. It expands the hypodigm of the species and provides additional anatomical characters that confirm the morphological differences between *S. tchadensis* and African apes. *S. tchadensis* presents several key derived features consistent with its position in the hominid clade close to the last common ancestor of chimpanzees and humans.

The upper Miocene vertebrate localities from the Toros-Menalla fossiliferous area discovered by the Mission Paléoanthropologique Franco-Tchadienne in the Mega-Chad basin, are north of the 16th parallel, 150 km west of the Koro-Toro australopithecine localities[1,2,7]. The faunal assemblage from TM 266 is found in the Anthracotheriid Unit, so named because it contains a very common, large anthracotheriid, *Libycosaurus petrochii*[6]. The mammalian fauna from the Anthracotheriid Unit, which includes a primitive suid, *Nyanzachoerus syrticus*, and a primitive loxodont elephant, contains more primitive taxa than the Lukeino fauna (Kenya, dating from 6 Myr ago)[8] and is more similar to the fauna from the lower Nawata Formation of Lothagam (Kenya, 6.5–7.4 Myr ago)[9]. The Anthracotheriid Unit assemblage indicates a mosaic of landscapes[6] probably resembling that of the present-day Okavango Delta (Botswana). Previous collecting in TM 266 uncovered a cranium, TM 266-01-60-1, as well as two mandibular fragments and several isolated teeth assigned to *Sahelanthropus tchadensis*[3]. Because of the age of this earliest hominid taxon (the term hominid is used here for convenience to denote all taxa that are closer to humans than chimpanzees, and does not connote any taxonomic scheme[3]; similarly, australopithecine is used as a generic term *sensu lato* to refer to all Pliocene hominid taxa that do not belong to the genera *Ardipithecus* and *Homo*), it is important to evaluate and expand the hypodigm to test hypotheses about its systematic relationships. Additional information that expands the *Sahelanthropus tchadensis* hypodigm comes from recent discoveries of new hominid material from TM 266 and from two new sites, TM 247 and TM 292, also in the Anthracotheriid Unit. These three sites are within a small area (0.73 km^2). The new specimens (Table 1) consist of two lower jaws (Figs 1, 2) and the crown of a right P^3 (Fig. 3).

TM 292-02-01 (Fig. 1) is a partial mandible fragment lacking the left and right corpus posterior to M_2. The cortical bone is well preserved except in the antero-medial lower part of the symphyseal region, and in the alveolar process in the region of the incisors. The left I_2, C_1, M_1 and M_2 roots and right I_1–I_2, P_3 and M_1–M_2 roots are preserved. The crowns of the left M_1, M_2 and the right M_1 are partly preserved, and the crown of the left canine is well preserved (Fig. 1g, h). TM 247-01-02 (Fig. 2) is a fragmentary right mandibular corpus. All the roots are well preserved; the crowns of P_3–M_1 are partly preserved but are missing in M_2–M_3. The corpus of the TM 292-02-01 fragment is more gracile (maximum corpus breadth at M_1, perpendicular to corpus height, is 14.5 mm) than that of the previously discovered TM 266-02-154-1 specimen[3] (maximum corpus breadth at M_1 is 20.0 mm) as well as the newly discovered TM 247-01-02 (corpus breadth at M_1 is 16.1 mm), although this is a minimum estimate because the cortical bone surface has been eroded on the buccal side of the corpus. TM 292-02-01 and TM 247-01-02 each have a single, large mental foramen located at mid-corpus below P_4. The anterior margin of the symphysis in TM 292-02-01 is vertical (Fig. 1c, d) with the rather damaged inferior part sloping posteriorly. The planum alveolare of the symphysis is about 45° relative to the alveolar plane of the corpus. The inferior and superior transverse tori are weakly developed (superior is larger), and delimit a shallow genioglossal fossa with a large genioglossal foramen.

Among the mandibular teeth, only the lower left canine and P_4 of TM 292-02-01 (Fig. 1e, g) are sufficiently well preserved to be described in detail. The canine crown, which is small with an asymmetrical outline in occlusal view at the cervix level (maximum mesiodistal length is 10.0 mm, and buccolingual width is 8.5 mm), is broken apically and worn distally. The wear pattern of the lower canine indicates that occlusion of the upper canine was solely against the large distal tubercle that projects lingually. This pattern of occlusion is clearly marked by a grooved wear strip on the distal

Table 1 **New specimens of *Sahelanthropus tchadensis***

Specimen number	Collected	Element	Discoverer
TM 292-02-01 (Fig. 1)	2002	Mandibular fragment	MPFT
TM 247-01-02 (Fig. 2)	2001	Right mandibular corpus fragment	MPFT
TM 266-01-462 (Fig. 3)	2001	Right P^3	MPFT

MPFT, Mission Paléoanthropologique Franco-Tchadienne.

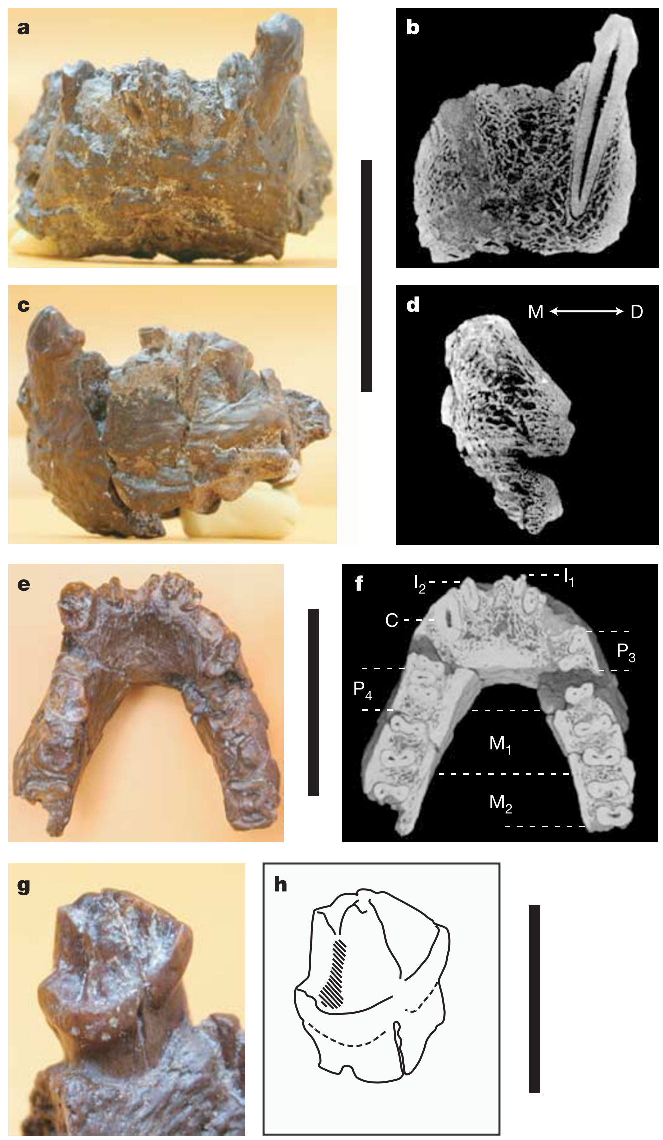


Figure 1 Lower jaw (TM 292-02-01) assigned to *Sahelanthropus tchadensis*. **a**, Frontal view. **b**, Left canine posterior coronal computed tomography (CT) scan (flipped horizontally) (scanner, University Museum, Tokyo, Japan). **c**, Left buccal view. **d**, Symphysis midsagittal CT scan (M, mesial; D, distal) (scanner, University Museum, Tokyo, Japan). **e**, Occlusal view. **f**, Three-dimensional reconstruction with axial CT scan; root pattern shown is taken just below the cervix (synchrotron, ESRF, Grenoble, France). **g**, **h**, Left canine disto-lingual view (**g**) and drawing (**h**) showing the location of the distal wear strip and indentation. Scale bar, 4 cm (**a**–**f**); 1 cm (**g**, **h**).

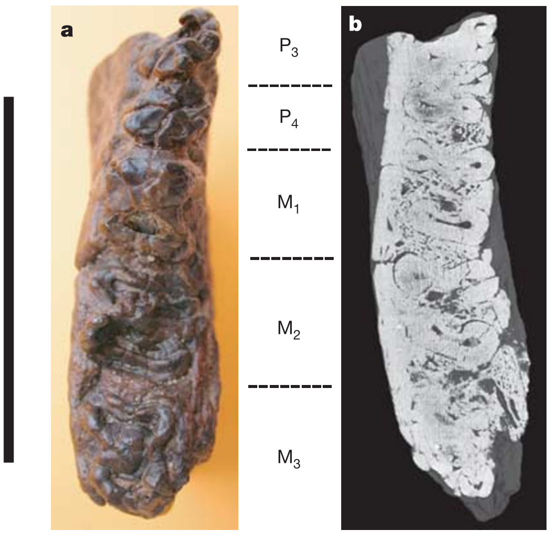


Figure 2 Right lower jaw (TM 247-01-02) assigned to *Sahelanthropus tchadensis*. **a**, Occlusal view. **b**, Three-dimensional reconstruction with axial computed tomography scan, root pattern shown is taken just below the cervix (synchrotron, ESRF, Grenoble, France). Scale bar, 4 cm.

enamel surface that terminates in an indentation on the occlusal surface of the distal shelf-like tubercle (Fig. 1g, h). TM 292-02-01 is therefore consistent with the absence of a functional C/P_3 honing complex in *S. tchadensis*[3]. The crown of the canine is short, yet its root is surprisingly long (Fig. 1b). Both the mesial and distal crown shoulders (Fig. 1g, h) are very low relative to the cervix. In contrast to the configuration in *Ardipithecus kadabba*[10,11] (Fig. 1b), the mesial shoulder is only slightly more apical than the distal shoulder. A distinct marginal ridge is present on the mesiolingual surface.

The subrectangular P_4 of TM 292-02-01 has a maximum mesiodistal length of 8.0 mm, with a distolingually well-developed talonid; the elongated partly preserved trigonid has a distinct distally positioned metaconid (Fig. 1e).

TM 266-01-462 (Fig. 3) is a right P^3 lacking roots and a portion of the distal intercuspal crown. Dimensions of the P^3 are 13.0 mm (buccolingual) and about 7.3 mm (minimum mesiodistal at paracone). The occlusal crown outline is oval with a slight concavity on its mesial surface below the marginal ridge. The mesial enamel surface shows a well-delimited interproximal canine wear facet below the mesial marginal ridge, confirming the lack of a diastema between C_1 and P_3. The mesial marginal ridge is above mid-crown level. In addition, the TM 266-01-462 premolar is bicuspid with a tall, conical paracone, and a smaller, lower protocone that is more mesially located than the paracone. Both cusps are slightly worn, with the tip of the paracone showing a small area of dentine exposure. The P^3 presents a mesio-cervical enamel extension on the steeply sloping buccal surface. The small anterior fovea is mesial to the transverse crest of the paracone and bordered by a moderately thick mesial marginal ridge that slopes downwards buccally. The paracone has a prominent, rounded transverse crest extending slightly mesially to the median groove between the two cusps. The mesially facing triangular portion of the occlusal surface present in African apes and *Ardipithecus ramidus* is absent[12].

The maximum radial enamel thickness measured from micro computed tomography scans of the P^3 (TM 266-01-462, protocone and paracone), upper right M^2 and M^3 (TM 266-01-60-1, paracone, protocone and hypocone) and the right P_4 (TM 266-02-154-1, protoconid) ranges from 1.2 to 1.9 mm. The lower buccal and upper lingual cusps tend to have thicker enamel (1.4–1.9 mm) than the lower lingual and upper buccal cusps (1.2–1.6 mm). The postcanine

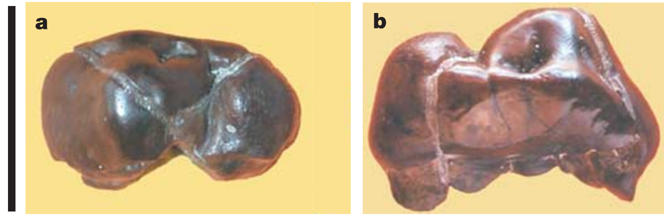


Figure 3 Right upper P^3 (TM 266-01-462) assigned to *Sahelanthropus tchadensis*. **a**, Occlusal view. **b**, Mesial view. Scale bar, 1 cm.

cuspal enamel thickness in these *S. tchadensis* specimens is therefore intermediate between published values for chimpanzees and australopithecines[12].

The new material presented here is important for several reasons. First, the fossils add substantially to the holotype cranium, TM 266-01-60-1, which is remarkable in its completeness and preservation. The *S. tchadensis* hypodigm now includes a minimum of six individuals (a maximum of nine) from three sites in a small area of the Anthracotheriid Unit. Second, these new fossils now permit a more complete and reliable understanding of this earliest known hominid taxon. *S. tchadensis* shares major derived features with other recognized hominids that are consistent with its position in the hominid clade, close to the last common ancestor of chimpanzees and humans. In the dentition these anatomical characters are a non-honing C/P_3 complex; no diastema between C and P_3; a vertical symphysis with weak transverse tori; canines with a small crown and long root, a lower canine crown with a large distal tubercule, both shoulders being very low; an upper P^3 with a steeply sloping buccal surface; postcanine teeth with maximum radial enamel thickness intermediate between chimpanzees and australopithecines; and bulbous, slightly crenulated postcanine occlusal morphology. All the hominid mandibular premolar specimens from Toros-Menalla have the same root pattern, with two roots and three separate pulp canals in each premolar (one mesial and two distal) retaining the presumed primitive condition for the *Pan*/*Homo* clade[13] (Figs 1f and 2b).

The anatomical characters of the new material of *S. tchadensis*, such as a lower canine crown with a distinct mesial marginal ridge and a distal grooved wear strip ending on a large distal tubercle (a feature consistent with the absence of a honing C/P_3 complex), confirm the morphological differences of the Chadian species from African apes, and its morphological affinities with the hominid clade. Although the new fossils provide valuable data, the nearly complete cranium TM 266-01-60-1 remains a key specimen for *S. tchadensis* that is older than any other Late Upper Miocene hominid so far known[10,11,14]. Identifiable derived features of *S. tchadensis*[3] are a face with an anteroposteriorly short premaxilla, an anteriorly positioned foramen magnum linked to a short basioccipital and a sub-horizontal nuchal plane, a downward lipping of the nuchal crest, and a non-honing C/P_3 complex. Post-mortem plastic deformation of the TM 266 cranium has precluded further detailed analysis[4]. However, a virtual three-dimensional reconstruction of the TM 266 cranium (presented in ref. 15) provides additional morphological information for the more precise evaluation of its systematic position with respect to the extant great apes and to other known hominid taxa, and for testing hypotheses about key aspects of its behaviour, particularly its mode of locomotion. □

Received 17 September 2004; accepted 26 January 2005; doi:10.1038/nature03392.

1. Brunet, M. *et al.* The first Australopithecine 2,500 kilometres west of the Rift Valley (Chad). *Nature* **378,** 273–275 (1995).
2. Brunet, M. *et al.* *Australopithecus bahrelghazali*, une nouvelle espèce d'Hominidé ancien de la région de Koro Toro (Tchad). *C. R. Acad. Sci. Paris* **322,** 907–913 (1996).
3. Brunet, M. *et al.* A new hominid from the Upper Miocene of Chad, Central Africa. *Nature* **418,** 145–151 (2002).

4. Wolpoff, M., Senut, B., Pickford, M. & Hawks, J. *Sahelanthropus* or '*Sahelpithecus*'? *Nature* **419,** 581–582 (2002).
5. Brunet, M. *et al.* *Sahelanthropus* or '*Sahelpithecus*'? (Reply). *Nature* **419,** 582 (2002).
6. Vignaud, P. *et al.* Geology and palaeontology of the Upper Miocene Toros-Menalla hominid locality, Djurab Desert, Northern Chad. *Nature* **418,** 152–155 (2002).
7. Brunet, M. *et al.* Tchad: un nouveau site à Hominidés Pliocène. *C. R. Acad. Sci. Paris* **324,** 341–345 (1997).
8. Deino, A. L., Tauxe, L., Monaghan, M. & Hill, A. Ar^{40}/Ar^{39} geochronology and paleomagnetic stratigraphy of the Lukeino and lower Chemeron Formations at Tabarin and Kapcheberek, Tugen Hills, Kenya. *J. Hum. Evol.* **42,** 117–140 (2002).
9. MacDougall, I. & Feibel, C. in *Lothagam the Dawn of Humanity in Eastern Africa* (eds Leakey, M. G. & Harris, J. M.) 43–64 (Columbia University Press, New York, 2003).
10. Haile-Selassie, Y., Suwa, G. & White, T. Late Miocene teeth from Middle Awash, Ethiopia, and early hominid dental evolution. *Science* **303,** 1503–1505 (2004).
11. Haile-Selassie, Y. Late Miocene hominids from the Middle Awash, Ethiopia. *Nature* **412,** 178–181 (2001).
12. White, T. D., Suwa, G. & Asfaw, B. *Australopithecus ramidus*, a new species of hominid from Aramis, Ethiopia. *Nature* **371,** 306–312 (1994).
13. Wood, B. A., Abbott, S. A. & Uyttershaut, H. Analysis of the dental morphology of Plio-Pleistocene hominids. IV. Mandibular postcanine root morphology. *J. Anat.* **156,** 107–139 (1988).
14. Senut, B., Pickford, M., Gommery, D., Mein, P. & Cheboi, K. First hominid from the Miocene (Lukeino Formation, Kenya). *C. R. Acad. Sci. Paris* **332,** 137–144 (2001).
15. Zollikofer, C. P. E. *et al.* Virtual cranial reconstruction of *Sahelanthropus tchadensis*. *Nature* doi: 10.1038/nature03397 (this issue).

Acknowledgements We thank the Chadian Authorities (Ministère de l'Éducation Nationale de l'Enseignement Supérieur et de la Recherche, Université de N'djaména, CNAR), the Ministère Français de l'Éducation Nationale (Faculté des Sciences, Université de Poitiers), the Ministère de la Recherche (CNRS: Département SDV & ECLIPSE), the Ministère des Affaires Étrangères (DCSUR, Paris and SCAC, N'Djamena) to the Région Poitou-Charentes, the American School of Prehistoric Research, the RHOI (co-Principal Investigators F. C. Howell and T. D. White), the Armée Française, MAM and Epervier for logistical support; the scanner staff of the University Museum, the University of Tokyo (microCT scanning, G. Suwa); to the ESRF, Grenoble (W. G. Stirling, General Director, A. Bravin and C. Nemoz, ID 17); many colleagues and friends for their help, especially G. Suwa for enamel thickness measurements, P. Tafforeau for ESRF three-dimensional scan reconstructions; T. D. White for discussions; all the other members of the Mission Paléoanthropologique Franco-Tchadienne (MPFT) who joined us for field missions; S. Riffaut and X. Valentin for technical support; and G. Florent and C. Noël for administrative guidance at the MPFT.

Competing interests statement The authors declare that they have no competing financial interests.

Correspondence and requests for materials should be addressed to M.B. (michel.brunet@univ-poitiers.fr).

Virtual cranial reconstruction of *Sahelanthropus tchadensis*

Christoph P. E. Zollikofer[1], Marcia S. Ponce de León[1], Daniel E. Lieberman[2], Franck Guy[2,3], David Pilbeam[2], Andossa Likius[4], Hassane T. Mackaye[4], Patrick Vignaud[3] & Michel Brunet[3]

[1] *Anthropologisches Institut/MultiMedia Laboratorium, Universität Zürich-Irchel, Winterthurerstrasse 190, 8057 Zürich, Switzerland*
[2] *Peabody Museum, Harvard University, 11 Divinity Avenue, Cambridge, Massachusetts 02138, USA*
[3] *Laboratoire de Géobiologie, Biochronologie et Paléontologie Humaine, CNRS UMR 6046, Faculté des Sciences, Université de Poitiers, 40 Avenue du Recteur Pineau, 86022 Poitiers Cedex, France*
[4] *Université de N'Djamena, BP 1117, N'Djamena, Tchad*

Previous research in Chad at the Toros-Menalla 266 fossiliferous locality (about 7 million years old) uncovered a nearly complete cranium (TM 266-01-60-1), three mandibular fragments and several isolated teeth attributed to *Sahelanthropus tchadensis*[1–3]. Of this material, the cranium is especially important for testing hypotheses about the systematics and behavioural characteristics of this species, but is partly distorted from fracturing, displacement and plastic deformation. Here we present a detailed virtual reconstruction of the TM 266 cranium that corrects these distortions. The reconstruction confirms that *S. tchadensis* is a hominid and is not more closely related to the African great apes[4,5]. Analysis of the basicranium further indicates that *S. tchadensis* might have been an upright biped, suggesting that bipedalism was present in the earliest known hominids, and probably arose soon after the divergence of the chimpanzee and human lineages.

Primary distortion in TM 266-01-60-1 results from morphological discontinuities along major cracks between the left and right sides of the face, between the supraorbital torus and the zygomatics, between the left and right posterior cranial vault including the nuchal plane and basioccipital, and along a coronally oriented crack between left frontal and temporoparietal portions of the vault (Fig. 1; also see Fig. 1 in ref. 1). However, anatomical continuity is well preserved in the sagittal and parasagittal planes, particularly between the face, the neurocranium and the basicranium. Anatomical continuity in the basicranium extends from the basisphenoid to the nuchal plane and within each of the cranial units delimited by major cracks, as evident from matching fracture lines between adjacent parts. Plastic deformation resulting in left–right asymmetry is noticeable in the maxilla. The fossil is barely affected by expanding matrix distortion[6], and no missing regions need to be estimated to reconstruct its original form.

A high-resolution computed tomography scan was used to create a digital representation of the TM 266 cranium that was disassembled along major cracks, cleaned of adhering matrix with the use of digital filtering, and then reconstructed virtually with two different established protocols (see Methods). The reconstruction, illustrated in Fig. 2, was evaluated with three independent tests. First, the face and neurobasicranial complex, which were reconstructed separately, fitted together at multiple points in an approximately coronal plane along the superior and lateral margins of the post-orbital region. Second, the reconstructed morphology was assessed a posteriori against an anatomical constraint not considered during the virtual reconstruction. In all mammals including primates, the posterior maxillary (PM) plane is approximately perpendicular relative to the neutral horizontal axis (NHA) of the orbits[7]. PM orientation was estimated by a plane that passes, in lateral projection, from the maxillary tuberosities through the pterygopalatine fossae[8]. In the TM 266 reconstruction, this plane is about 89° relative to the NHA (estimated from the orbital margins and the partly preserved medial walls). As a third test, the TM 266 reconstruction was compared with three-dimensional shape variability in a comparative African ape/fossil hominid sample (see Methods). We performed a generalized least-squares superimposition[9] of the symmetrized landmark configurations[10] of all specimens and calculated the minimum form change necessary to transform the TM 266 reconstruction to the closest possible hypothetical *Pan* and *Gorilla* cranial forms with the use of the 99% probability density borders as a minimum-distance criterion (Fig. 3). Figure 3a–c shows this procedure for the first three PCs, which account for more than 58% of the total shape variability. To account for allometric shape effects, all shape PCs were regressed against centroid size to obtain a common allometric shape score[11] (Fig. 3d). The isolated fragments of the TM 266 cranium were then positioned to fit the calculated three-dimensional landmark configurations of the closest-possible *Pan* and *Gorilla* shapes (Fig. 3e). The resulting '*Pan*-like' and '*Gorilla*-like' morphologies are anatomically infeasible, involving overlap between neurocranial fragments and disruption of anatomical continuity between neighbouring facial fragments. Although the cranial morphology of TM 266-01-60-1 cannot be reconstructed to fall within the size–shape

PALEOANTHROPOLOGY

Facelift Supports Skull's Status as Oldest Member of the Human Family

For paleoanthropologists seeking the roots of humanity, a striking skull discovered among the shifting sand dunes of the Djurab Desert of Chad in 2001 was a dramatic find, offering the first glimpse of a primate alive at the dawn of humankind. But although the nearly 7-million-year-old skull was introduced as that of the oldest known hominid, rivals soon argued that it looked more like a gorilla ancestor than a human (*Science*, 12 July 2002, p. 171). Now the skull of *Sahelanthropus tchadensis*, nicknamed Toumai, is back in headlines again. It appears in *Nature* this week with two new looks—a three-dimensional virtual reconstruction and a clay bust on the cover, a nod to creation myths that humans were made of clay.

Fresh fossils of teeth and jaw fragments plus a state-of-the-art analysis of the virtual skull show that Toumai is indeed a hominid, or a member of the lineage that includes humans and our ancestors but not other apes, argues paleontologist Michel Brunet of the University of Poitiers, France, leader of the team that discovered Toumai. The new analysis also suggests that *Sahelanthropus* might have walked upright, a traditional marker of being a hominid. "It is quite clear Toumai is a hominid," says Brunet. "It is not a gorilla."

Family portraits? A computer reconstruction (*above*) suggests that Toumai (reconstructed in clay, *right*) is the oldest known human ancestor.

Other researchers applaud the sophistication of the reconstruction, performed by a team led by neurobiologist Christoph Zollikofer of the University of Zurich (UZ), Switzerland. "What a facelift! This beautiful reconstruction is the outcome of high technology combined with a deep understanding of anatomy," says Tel Aviv University paleoanthropologist Yoel Rak. But some caution that although the new evidence helps build the case that Toumai was a hominid, its identity is far from certain. "I'd be happy to put it down as [a very early] hominid," says anatomist Fred Spoor of University College London. "But it's a time we know so little about that I am still skeptical."

Brunet took the skull to Zollikofer and UZ anthropologist Marcia Ponce de Leon, known for their sophisticated high-resolution computed tomography scans and analyses. The skull had been crushed under a sand dune and distorted, and the researchers were able to erase the ravages of time in the computer, using three-dimensional computer graphics tools to rebuild it piece by piece. The resulting face is taller, with a bit more snout than seen in the original.

Zollikofer and Ponce de Leon then identified 39 landmarks on the skull, which they used to compare it directly with the skulls of fossil hominids, two chimpanzee species, and gorillas. They found that the shape of Toumai's skull "falls exactly within the hominids," says Zollikofer. No matter how they tried, they could not force the pieces of the skull to fit into the shape of a chimpanzee or gorilla skull without deforming it grossly. "It is impossible to reconstruct Toumai as an ape," he says.

Several researchers find the virtual evidence compelling. "I was worried about the distortion, but they are great at building virtual reconstructions that test hypotheses about how these fossils looked," says anthropologist John Kappelman of the University of Texas, Austin.

The reconstruction also revealed new evidence that suggests *Sahelanthropus* walked upright. A virtual line from the top to the bottom of Toumai's eye orbit makes roughly a right angle with another virtual plane at the base of the skull. That right angle is also seen in humans, reflecting that the head sits directly atop a vertical spine when walking upright. The angle between the planes is much smaller in the quadrupedal apes studied, reflecting that the head sits in front of a more horizontal ▶

CREDITS: M.P.F.T. (ARTIST'S RECONSTRUCTION: E. DAYNES)

ScienceScope

Hubble Relief

Finally, some good news for the Hubble Space Telescope. NASA engineers say that they can run Hubble on two gyroscopes rather than the three now operating. Space agency managers hope that turning off one gyro could extend Hubble's life by 6 months or more without affecting the quality of science returned. That could mean more time to revisit Hubble—either by shuttle or by robot—for an overhaul. Science chief Al Diaz says he will decide soon whether to turn off a gyro; currently, no repair visit is on the books, and the telescope is expected to die in late 2007 or early 2008.

NASA also says there is good news on the robotic servicing front. Engineers told *Science* that they have a plan to install two sets of three gyroscopes within an instrument now waiting on Earth to be installed in Hubble. With new gyros and new batteries, they say, Hubble could continue to operate for well over a decade. But incoming Administrator Michael Griffin likely will revisit the servicing issue. Griffin's Senate confirmation hearing is slated for 12 April.

–ANDREW LAWLER

Bay State Passes Stem Cell Bill

Massachusetts legislators overwhelmingly passed measures last week that explicitly allow research cloning, or somatic cell nuclear transfer (SCNT). The action promises to "put the state firmly in support of SCNT and other embryonic stem cell research," says Kevin Casey, director of government relations at Harvard University.

The state House and Senate have yet to agree on specifics of the final measure, which also would outlaw reproductive cloning. Republican Governor Mitt Romney opposes research cloning, but the bills passed by well over the two-thirds majority needed to override his promised veto. Senate president Robert Travaglini (D) has indicated that another bill is in the works that would earmark as much as $100 million to fund the research.

Harvard stem cell researcher George Daley is thrilled about what he calls "a real victory for science." Efforts to inform legislators helped, says Daley, who demonstrated nuclear transfer to a state senator. "I think this made it quite clear to him that SCNT is not about cloning babies," he says.

–CONSTANCE HOLDEN

neck, explains co-author Daniel Lieberman of Harvard University. Thus the team concludes that *Sahelanthropus* "might" have been bipedal. "I'm the first to say you need postcranial fossils to be 100% sure, but it's darned hard to think how Toumai could not have walked upright," says Lieberman.

However, others caution that skulls don't walk upright by themselves, and that lower limbs are needed to prove this hallmark trait. Until Brunet and his colleagues describe postcranial fossils, paleoanthropologist Milford Wolpoff of the University of Michigan, Ann Arbor, sees Toumai as an ape, citing what he calls apelike features in the base of the neck.

More fossils also are needed to settle the question of how *Sahelanthropus* is related to later hominids. "There is still insufficient fossil evidence to determine whether there were one, two, or more hominid species lineages between 5 [million] and 7 million years ago in Africa," says paleoanthropologist Tim White of the University of California, Berkeley.

Brunet declines to comment on reports that his team has also discovered a partial thighbone, but he adds cryptically: "Surely postcranials will be coming in the future. I will be very, very surprised if it is not bipedal."

–Ann Gibbons

PALEOCLIMATOLOGY

Cosmic Dust Supports a Snowball Earth

Answering questions about Earth's climate of more than half a billion years ago can be a challenge—even questions as stark as whether land and sea were completely coated by ice from pole to pole. Indeed, the revival of the Snowball Earth hypothesis almost 7 years ago has bogged down of late, as paleoclimatologists have failed to turn up unequivocal evidence that ice enrobed our planet.

But on page 239 of this issue, a group of geochemists offers a new snowball marker: the element iridium, which continually rains down on us from space. They say they found so much iridium deposited at the end of a glaciation 635 million years ago that the planet must have been frozen pretty much solid for 12 million years straight. "I think this is a very exciting discovery," says geochemist Frank Kyte of the University of California, Los Angeles. Like any new tool, iridium needs some more work, but "I'm sure it will invoke a lot of discussion."

This isn't iridium's first appearance as a timekeeper. But geochemists Bernd Bodiselitsch and Christian Koeberl of the University of Vienna, Austria, and their colleagues took a new tack when they analyzed 44 elements including iridium along three cores drilled by copper miners in Zambia and the Democratic Republic of the Congo. Bodiselitsch and his colleagues figured that on an iced-over world, the iridium-rich meteoritic dust that rains onto Earth would accumulate until the snowball ended in a sudden meltdown, as climate modelers believe would happen. All the iridium accumulated in the ice would then be deposited in a single, thin layer of marine sediment. The more iridium deposited at the end of a snowball, the longer the snowball had gone on.

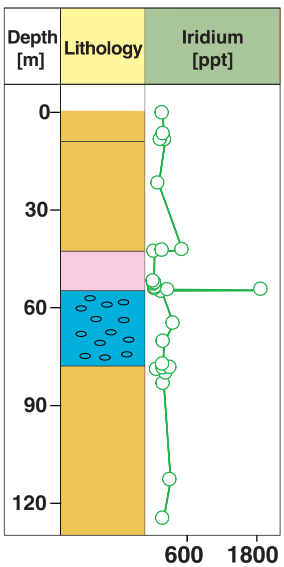
In the first few centimeters of sediment laid down on top of glacial sediments, Bodiselitsch and colleagues indeed found sharp spikes in the abundance of iridium. A spike showed up in all three cores at the end of the Marinoan glaciation about 635 million years ago and in two cores at the end of the earlier Sturtian glaciation about 710 million years ago. The iridium could conceivably have been homegrown—from a volcanic eruption or concentrated from crustal rock by some geochemical process—but several other elements were present in proportions typical of meteorites, not the crust. And the proportion of iridium to some other elements suggested that geochemical processing had not concentrated the iridium, they concluded. If meteoritic material was falling to Earth 635 million years ago at anything like the rate it has during the past 80 million years, the group calculates, the Marinoan glaciation lasted 12 million years, give or take 3 million years.

If the Marinoan ice age managed to save up 12 million years' worth of extraterrestrial iridium, it must have iced over the entire planet, researchers agree. The alternative to Snowball Earth has been Slushball Earth (*Science*, 26 May 2000, p. 1316). Rather than pole-to-pole ice, some paleoclimate modelers have suggested that Marinoan glaciation might have left tropical oceans ice-free and still produced glacial deposits near equatorial continents. But a slushball would have melted down within something like a million years as volcanoes belching carbon dioxide fueled a growing greenhouse. "It's hard to see what would keep a slushball around for 10 [million] or 20 million years," says climate modeler Raymond Pierrehumbert of the University of Chicago. And even if a slushball did last, its glaciers—unlike those of a snowball—would continually flow down to the sea, steadily depositing iridium, not producing a spike of it.

Geochemists are excited but naturally cautious. "Iridium is a strong indicator of extraterrestrial material," says Bernhard Peucker-Ehrenbrink of the Woods Hole Oceanographic Institution in Massachusetts. "However, it is just one of a series of useful tracers." He and others, he expects, will be pursuing other extraterrestrial tracers such as isotopes of helium and of osmium to test the claim of a Snowball Earth. Prompting such testing "is what good, interesting, provocative papers should do," he says.

–Richard A. Kerr

The ice was all around? A true Snowball Earth would have coated the globe with ice.



No accident. The discovery of a spike of cosmic iridium (green line) at the end of an ancient ice age (top of blue glacial sediments) suggests that ice covered the planet.

CREDITS (TOP TO BOTTOM): PHOTOS.COM; ADAPTED FROM BERND BODISELITSCH *ET AL.*

Nutcracker Man

Divulgando la investigación sobre evolución humana | Outreaching the human evolution research

NOVIEMBRE 7, 2020 DE ROBERTO SÁEZ

Sahelanthropus tchadensis may not have been a habitual biped

In many texts, when depicting the human evolutionary tree, the *S. tchadensis* cranium is often claimed to be consistent with being biped, mainly driven by the foramen magnum position. Habitual bipedalism is a key feature for taxa to be included in the hominin clade, yet some specific characteristics of the bipedal locomotion can differ from those of modern humans. The case of *Sahelanthropus* is important because the age of its fossils (6-7 million years) approximately matches the time that our branch of the primate family tree diverged from the ancestors of chimpanzees and gorillas. We only know *Orrorin tugenensis* as another hominin candidate in such chronology. There are three femoral remains of *Orrorin*, but until now the *Sahelanthropus* femur had not yet been published, and this is a major skeletal element to understand bipedalism.

What hominin taxa at that time could be a direct ancestor of living humans is a very difficult question to face. The Late Miocene fossil record is really small and makes impossible to sort ancestors from non-ancestral close relatives.

In this context, a new paper (R. Macchiarelli et al, 2020) focuses on the study of the partial left femur TM 266-01-063 found in July 2001 at Toros-Menalla, Chad. This is the same location where the *Sahelanthropus tchadensis* holotype was recovered also in 2001: the cranium TM 266-01-060-1. What five key ideas does the new femur bring, according the analysis of overall shape differences by Macchiarelli et al?

1) Yes, the femur can likely be assigned to *S. tchadensis*.

We are most confident that the TM 266 femoral shaft belongs to a hominid sensu lato. It could sample a hominid hitherto unrepresented at Toros-Menalla, but a more parsimonious working hypothesis is that it belongs to S. tchadensis.

2) This femur is very different from the *Orrorin tugenensis* femur, another early hominin normally considered as habitual biped.

The differences between TM 266 and the O. tugenensis partial femur BAR 1002’00 are substantial and are consistent with maintaining at least a species level distinction between S. tchadensis and O. tugenensis.

(https://nutcrakerman.files.wordpress.com/2020/11/femurstchadensis-1.png)
The partial femur TM 266-01-063 from Toros-Menalla, Chad, in anterior (a), posterior (b), medial (c), and lateral (d) views. Scale bar = 2 cm. Credit: R. Macchiarelli, A. Bergeret-Medina, D. Marchi et al. (2020)

3) But actually, *S. tchadensis* may not have been a habitual biped!

If the TM 266 femoral shaft belongs to S. tchadensis, we cannot be confident that the latter was a habitual biped. Based on our analyses, the TM 266 partial femur lacks any feature consistent with regular bouts of terrestrial bipedal travel; instead, its gross morphology suggests a derived Pan-like bauplan.

4) If the TM 266 femur can be added to the hypodigm of *S. tchadensis*, the conclusions could be important to actually stop considering *S. tchadensis* as an early hominin.

The lack of clear evidence that the TM 266 femur is from a hominid that was habitually bipedal further weakens the already weak case for S. tchadensis being a stem hominin.

It is possible that S. tchadensis is a stem hominin with some reduction of the canine and loss of the honing complex, but without the femoral adaptations to terrestrial bipedalism that are seen in A. afarensis and O. tugenensis. If there is compelling evidence that S. tchadensis is a stem hominin, then bipedalism can no longer be seen as a requirement for inclusion in the hominin clade.

5) A hominin, a panin, or neither? A potential third way for *Sahelanthropus*.

Being a stem hominin or a stem panin, or their most recent common ancestor, may not be the only options for S. tchadensis. It is probable that during the late Miocene and the early Pliocene, there was a modest adaptive radiation of African hominids that includes taxa that are neither hominins nor panins as defined previously. Any such extinct groups are likely to include taxa with novel morphology or with novel combinations of morphology we also see in hominins or panins. Given the mix of inferred primitive and inferred derived features in S. tchadensis, we suggest it could belong to a group that has no living representative.

If we treat the hominin status of S. tchadensis, or any other enigmatic taxon, as a given and not a hypothesis, we run the risk of adding further confusion to a picture that is already complicated and less easy to resolve.

BUT In a new preprint (under review as of Feb-21), Franck Guy and colleagues analyse the original materials of the same left femur and two antimeric ulnae. Based on each features they tackle and the functional signals found, they argue that *S. tchadensis* was indeed bipedal.

References:

- *R. Macchiarelli, A. Bergeret-Medina, D. Marchi et al. (2020) (https://doi.org/10.1016/j.jhevol.2020.102898). Nature and relationships of Sahelanthropus tchadensis. Journal of Human Evolution 149 | Front image: The partial femur TM 266-01-063 (left) in anterior (a), posterior (b), medial (c), and lateral (d) views compared with the CT-based reconstruction of BAR 1002'00 (Puymerail, 2011, 2017, based on a record kindly made available by B. Senut and M. Pickford).*
- *F. Guy et al. (2020) (https://doi.org/10.21203/rs.3.rs-69453/v1). Postcranial evidence of late Miocene hominin bipedalism in Chad. Preprint is under consideration at a Nature Portfolio Journal.*

Further information: Toumaï, esperanza de vida (https://nutcrackerman.com/2014/12/02/toumai-esperanza-de-vida/) | Nutcracker Man

Esta entrada fue publicada en Actualidad y etiquetada Early hominin, Miocene, Sahelanthropus tchadensis. Guarda el enlace permanente.

2 pensamientos en "*Sahelanthropus tchadensis may not have been a habitual biped*"

Eduardo Adarve | **noviembre 7, 2020 en 19:58**

Hola Roberto, interesante texto, como todos los tuyos.
Según explicas, es posible que S. tchadensis sea el ancestro común de humanos y chimpancés ¿hasta ahora qué especie es la considerada como el ancestro común?¿O. tugenensis u otra especie?.
Saludos. Eduardo.

Responder

Roberto Sáez | **noviembre 8, 2020 en 16:49**

Hola Eduardo. Supongo que te refieres a las opciones para S. tchadensis, como perteneciente al linaje de homininos, de chimpancés, o a un linaje antepasado común a los dos anteriores. En el artículo se propone explorar la idea de que pertenezca a otro linaje distinto, del que no quedan representantes vivos. Encontrar el Último Ancestro Común de humanos y chimpancés sigue siendo el «santo grial» de la paleoantropología. Y no solo ya encontrarlo, sino caracterizarlo: ¿cómo era su locomoción?, ¿tenía ya dentición reducida? Además, ¿dónde hay que buscarlo? Parece que todo apunta a África, pero prácticamente solo conocemos el este y el sur. ¿Puede ser el UAC originario del centro o del oeste, donde es casi imposible encontrar fósiles? En cuanto a Orrorin tugenensis, es una pena no tener fósiles del cráneo. Por ahora su probable bipedación le otorga su encaje entre los homininos.

Responder

News & views

Palaeontology

Standing up for the earliest bipedal hominins

Daniel E. Lieberman

A leg bone and two arm bones of a hominin from Chad suggest that, seven million years ago, around the time that the human and chimpanzee lineages split, early hominins were bipedal but were also able to climb trees. **See p.94**

What set the human lineage on a separate path from chimpanzees sometime between ten million and six million years ago? The first scientists to study the origins of our species speculated that brain enlargement led the way in driving human evolution. However, nearly a century's worth of fossil discoveries in Africa instead point to the ability to walk on two legs (bipedalism), and perhaps a slightly lower-quality diet compared with that of chimpanzees, as the first distinguishing features of the earliest hominins (species more closely related to humans than to chimpanzees)[1]. Even so, much about the first hominins and why they evolved remains mysterious. Was the last common ancestor of humans and chimpanzees similar to a chimpanzee, a gibbon, a monkey or something completely different? And did bipedalism evolve before, during or after the split between humans and chimpanzees? On page 94, Daver *et al.*[2] present fossil evidence that helps to address some of these questions.

There are almost no fossils unambiguously recognizable as being the immediate ancestors of chimpanzees or the other living African great apes. The best available evidence to address some of the key open questions has instead come from the oldest known hominin species (Fig. 1). These include *Ardipithecus ramidus*, dated to 4.3 million to 4.5 million years ago; *Ardipithecus kadabba*, dated to 5.2 million to 5.8 million years ago; *Orrorin tugenensis*, dated to about 6 million years ago; and, last but not least, *Sahelanthropus tchadensis*, dated to about 7 million years ago. *Sahelanthropus* was previously known from only a partial cranium, a few jaw fragments and some teeth[3]. Daver and colleagues describe three more fossils attributed to *Sahelanthropus*: a partial leg bone (femur) and two arm bones (ulnae), the characteristics of which suggest that this species not only walked on two feet but also climbed trees.

Sahelanthropus was discovered in Chad in 2001, and immediately caused considerable excitement. It was not only about one million years older than any other known hominin species, but was also found 2,500 kilometres away from the closest known hominin fossils in eastern Africa. The cranium of the specimen, nicknamed Toumaï (meaning 'hope of life' in the local Daza language), had a chimpanzee-like brain volume of between approximately 360 and 390 cubic centimetres. Compared with chimpanzees, *Sahelanthropus* has slightly larger molar teeth with thicker enamel, smaller upper canine teeth that don't sharpen themselves against the lower premolar teeth and a slightly flatter face[4] — characteristics that are similar to those of later hominin species.

Perhaps the most exciting feature that Toumaï shares with other hominins is the anatomy of the skull opening (foramen magnum) at the base of the skull where the spine connects and the spinal cord emerges. The foramen magnum of four-legged animals is typically located towards the back of the skull and is oriented

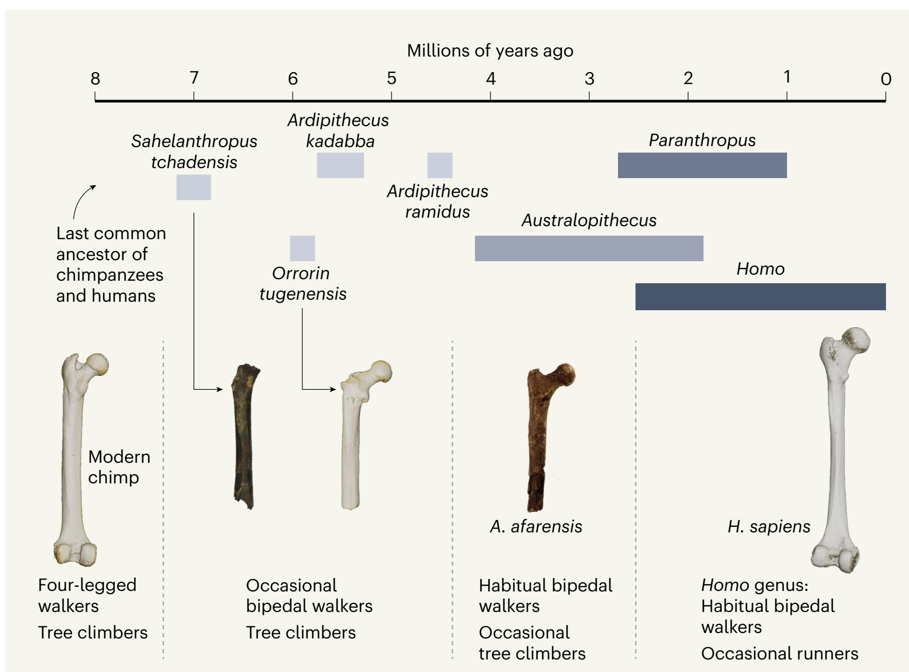


Figure 1 | The evolution of bipedalism. Hominins (species more closely related to humans than to chimpanzees) evolved from an ancestor shared with African great apes (such as chimpanzees and gorillas), which move by walking on four legs and climbing trees. *Sahelanthropus tchadensis* is the oldest known hominin species. It has features that suggest it was an occasional bipedal walker, including leg-bone characteristics (too subtle to see on the scale of this femur image) that Daver *et al.*[2] report. The authors indicate that arm bones (not shown) of this species were adapted for tree climbing. A similar mix of adaptations for occasional bipedal walking and tree climbing characterizes early hominins of the genus *Orrorin* and *Ardipithecus*. Species of the genus *Australopithecus* were comparatively more effective habitual bipedal walkers, but retained adaptations for climbing trees. Species in the genus *Homo* have numerous adaptations for effective bipedal walking and for running, but have lost most adaptations for tree-climbing. Femur images are not shown at their relative scale (images, apart from that of *Australopithecus afarensis,* are from ref. 2; *A. afarensis* image: Daniel E. Lieberman). Note that the *Sahelanthropus* femur is missing joints at the end of the bone, which would have provided insights into how this species moved.

backwards, whereas in *Sahelanthropus* it is positioned near the middle of the skull and is oriented downwards[5]. Combined with the horizontal angle of the back of the skull where the neck muscles attach, a downwards-oriented foramen magnum provides strong evidence that, like bipeds, *Sahelanthropus* balanced its head on a vertical neck[6].

The hominin status of *Sahelanthropus* is controversial. In addition to debates about the geological age of the fossil material, and reservations about the cranium's reconstruction, researchers have speculated that *Sahelanthropus*'s similarities to hominins are just comparable characteristics that evolved independently[7]. This is an important critique, because independent similarities can and do evolve among closely related species, a phenomenon known as convergence. That bipedalism evolved more than once among apes is thought by many to be unlikely, but requires further testing. Hypotheses of bipedalism have previously been questioned[8,9] for extinct species of ape, such as *Oreopithecus* and *Danuvius*.

Some scientists have reserved judgement on whether *Sahelanthropus* was a biped because of the absence of supporting evidence from parts of the body other than the skull, such as the pelvis, femur or feet. And to add to the controversy, such potentially relevant evidence was known to exist but was unavailable to researchers. When the *Sahelanthropus* cranial material was discovered in 2001, a femur and ulna were also retrieved, together with thousands of other fossils. It was not until three years later that the femur was recognized as probably belonging to a hominin by researchers unaffiliated with the team working on *Sahelanthropus*, and an account of the femur's discovery was published[10] in 2009. A subsequent analysis argued that the femur's shape was more similar to that of apes than to that of known bipedal hominins, although this assessment was based on just a few measurements of the femur and on 2D photographs[11].

The ulna found in 2001 and another discovered in 2003 were subsequently recognized as being those of hominins. Given all of this uncertainty and controversy, Daver and colleagues' analysis of the *Sahelanthropus* femur and ulnae is of considerable interest. But don't expect a full resolution just yet, because the femur consists mostly of a shaft that doesn't have the joints at either end (Fig. 1) that would provide most of the information needed to infer *Sahelanthropus*'s posture and how it walked.

Nevertheless, the authors have squeezed as much information as possible from the fossil data, focusing on features that they suggest are consistent with bipedalism. First, as is characteristic of bipedal hominins, the base of the femur's neck seems to be oriented slightly towards the front of the body and is flattened. The upper part of the femur is also slightly flattened, and the sites at which the gluteal muscles insert are fairly robust and human-like. In addition, the cross-sectional shape of the femur at several locations falls within the range expected for hominins. This feature is indicative of a femur that shows resistance to the sideways-bending forces that are characteristic of those encountered by bipedal hominins.

The researchers also point to traces of a bony ridge called a calcar femorale, a region of dense bone thought to buttress the upper femur from the forces produced by walking upright. However, this feature is not necessarily diagnostic of bipedalism[12].

Whatever you might think about the femur, the ulnae are unquestionably chimpanzee-like and are clearly well adapted to climbing trees. In addition to being short, the bones have highly curved shafts, indicating the presence of powerful forearm muscles that could flex the elbow during climbing. The elbow joints are also ape-like, with a shape that would be able to cope with high forces while flexed – a position typical for tree climbing that is mechanically challenging.

The *Sahelanthropus* femur doesn't have 'smoking-gun' traces of bipedalism, but it looks more like that of a bipedal hominin than that of a quadrupedal ape. When considered in conjunction with the orientation of the foramen magnum, which is compatible only with bipedalism, it seems reasonable to infer that *Sahelanthropus* was some type of biped and that, like later hominins such as *A. ramidus*, it was also well adapted to climbing trees. A few million years after *Sahelanthropus* and *Ardipithecus*, another genus of hominin – *Australopithecus* – evolved to be highly effective walkers while retaining many adaptations necessary for climbing trees. It was in only the human genus, *Homo*, that hominins lost the adaptations needed for moving through the trees as they became runners. That said, we know little else about the gait of *Sahelanthropus*. A mixed repertoire of walking and climbing makes sense given that *Sahelanthropus* lived near a lake with woodland adjacent to it.

It bears repeating that, apart from bipedalism and slightly more hominin-like teeth and face, many *Sahelanthropus* features are similar to those of a chimpanzee. This resemblance makes sense if the last common ancestor of humans and chimpanzees was chimpanzee-like[1] and *Sahelanthropus* evolved very soon after humans and chimpanzees diverged. But these and other inferences are sure to remain the subject of much debate, especially until more fossils are found to fill the evolutionary record, not just of humans, but also of chimpanzees.

Daniel E. Lieberman is in the Department of Human Evolutionary Biology, Harvard University, Cambridge, Massachusetts 02138, USA.
e-mail: danlieb@fas.harvard.edu

From the archive

Assessing how pollution affects mental health, and praise for a museum's efforts to educate children about science.

50 years ago

Relationships between pollution and health have for long been the subject of debate and study. The effect of air pollution on respiratory diseases, the contribution of poor sanitation to the spread of diseases such as cholera ... have all been discussed in the scientific and popular Press. But what of the effects of pollution on mental health? ... According to a study carried out for the National Institute of Mental Health, such questions have received at best only scant attention, and much more research is required not only on the physiological effects of pollutants on the central nervous system, but also on the mental stresses and strains of living in a degraded environment.
From *Nature* 1 September 1972

100 years ago

The direct educational work accomplished by museums in the United States is a perpetual source of shame to us in this country ... [M]uch is being done in some of our own museums ... but have we anything to compare with what is described in ... the journal of the American Museum of Natural History? ... [T]he American Museum ... has 869 nature-study collections to be lent to any public school in greater New York. There are two motor cars and a motor cycle to deliver slides and collections. Each messenger visits from twenty to forty schools a day. The American Museum is about to erect a special School Service building ... where from three to five thousand children daily may be taken care of properly ... The American Museum has its own Department of Education ... In the same way the Brooklyn Botanical Garden has its Curator of Elementary Education ... [W]hy is it that the Americans have got so far ahead of us on these lines? ... [T]o a large extent it is because Americans are not ashamed of having an ideal and of talking about it. They do not mind saying what they are going to do, and they make the utmost of everything that they have done.
From *Nature* 2 September 1922

1. Pilbeam, D. R. & Lieberman, D. E. in *Chimpanzees and Human Evolution* (eds Muller, M. N., Wrangham, R. W. & Pilbeam, D. R.) 22–141 (Belknap, 2017).
2. Daver, G. *et al. Nature* **609**, 94–100 (2022).
3. Brunet, M. *et al. Nature* **418**, 145–151 (2002).
4. Guy, F. *et al. Proc. Natl Acad. Sci. USA* **102**, 18836–18841 (2005).
5. Zollikofer, C. P. *et al. Nature* **434**, 755–759 (2005).
6. Lieberman, D. E. *The Evolution of the Human Head* (Harvard Univ. Press, 2011).
7. Wood, B. & Harrison, T. *Nature* **470**, 347–352 (2011).
8. Russo, G. A. & Shapiro, L. J. *J. Hum. Evol.* **65**, 253–265 (2013).
9. Williams, S. A., Prang, T. C., Meyer, M. R., Russo, G. A. & Shapiro, L. J. *Nature* **586**, E1–E3 (2020).
10. Beauvilain, A. & Watté, J.-P. *Bull. Soc. Geol. Normandie* **96**, 19–26 (2009).
11. Macchiarelli, R., Bergeret-Medina, A., Marchi, D. & Wood, B. *J. Hum. Evol.* **149**, 102898 (2020).
12. Cazenave, M., Kivell, T. L., Pina, M., Begun, D. R. & Skinner, M. M. *J. Hum. Evol.* **167**, 103183 (2022).

The author declares no competing interests.
This article was published online on 24 August 2022.

Biophysics

A phase transition for chromosome transmission

Kazuhiro Maeshima

An analysis of chromosomes during mitotic cell division reveals that DNA and associated histone proteins condense through a process called phase transition, which helps them to resist the pushing forces involved in mitosis. **See p.183**

The faithful transmission of matching copies of DNA from a dividing mother cell to its two daughters requires the DNA to be tightly compacted. This process is fundamental to the mitotic cell divisions needed for an organism's development and maintenance, but the underlying physical principles of chromosome compaction remain unclear. Schneider *et al.*[1] provide evidence on page 183 that a key aspect of accurate chromosome transmission is condensation into a more solid-like state through a process called phase transition.

The packaging of DNA into the condensed, rod-like shape characteristic of mitotic chromosomes involves multiple levels of organization. On a local scale, negatively charged DNA is wrapped around positively charged histone proteins to form bead-like structures called nucleosomes that are linked by DNA 'strings' – this irregularly folded, beads-on-a-string structure is known as chromatin[2]. Long tails on the histones, enriched with positive charges, bind to nearby nucleosomes and mediate nucleosome–nucleosome contacts, thus compacting the chromosomes. On a larger scale, a ring-like protein complex called condensin forms an axis around which chromatin packs in loops to form a compact, rod-like shape[3].

Separating these tightly packaged mitotic chromosomes into daughter cells involves two opposing forces. First, fibres called microtubules pull the two sister chromosomes apart. Second, other microtubules make contact with the chromosome arms and push them in the opposite direction through a 'polar ejection' force (Fig. 1a)[4]. These two forces first align chromosomes around the centre of the cell and then accurately divide them into two daughters. Condensins are known to confer the mechanical stability needed for chromosomes to remain intact despite being pulled[5]. Do they also confer mechanical resistance to the polar ejection force, or is another factor involved?

Schneider *et al.* first showed that chromosomes remained resistant to the polar ejection force even when condensin was depleted (Fig. 1b). The authors confirmed that, as previously observed[6], the mitotic-chromatin density (an indicator of compaction state) was similar in condensin-depleted and control cells. However, they also found that chromosomes in the condensin-depleted cells adopted abnormal shapes.

The authors therefore investigated another possible factor – 'deacetylation' of the histone tail. Acetyl groups can modify histones, changing the physical properties of local chromatin through loss of positive charges in histone tails and so loss of nucleosome–nucleosome contacts. Histone tails are deacetylated in mitotic chromosomes[7], leading to a greater increase in nucleosome–nucleosome contacts and subsequent global chromatin compaction. Could this deacetylation explain how mechanical resistance to polar ejection forces is obtained?

Schneider *et al.* treated human cells with a drug called trichostatin A (TSA), which inhibits the histone deacetylase enzymes that remove acetyl groups from histones. As expected, TSA treatment led to histone-tail hyperacetylation,

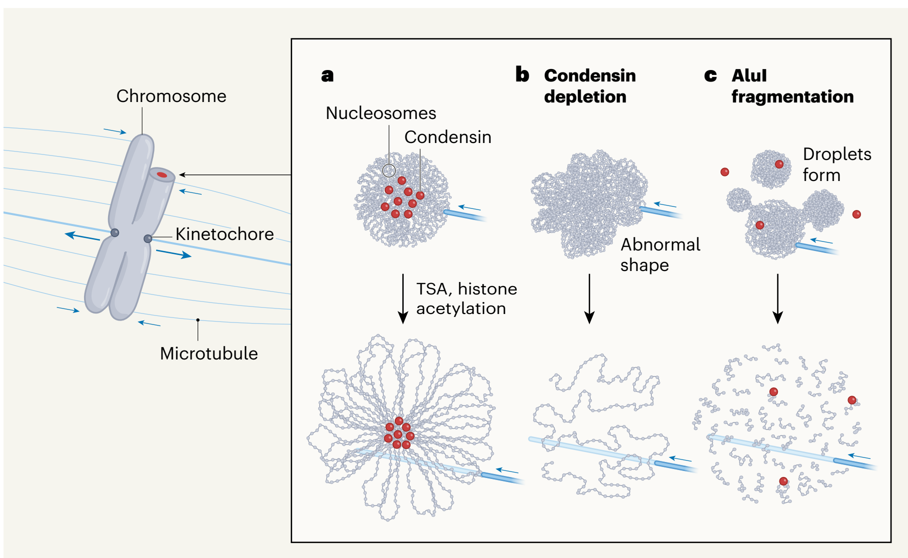


Figure 1 | Resisting pushing forces during mitotic cell division. a, Chromosomes undergoing mitosis form a rod-like shape, with an axis of condensin protein at the centre, surrounded by nucleosomes (bead-like complexes of DNA wrapped around histone proteins). Fibres called microtubules attach to kinetochore structures to pull halves of the chromosome to opposite poles of the dividing cell, and other microtubules push the chromosome arms in the opposite direction (the polar ejection force). Proper chromosome separation requires that the chromosome arms resist the polar ejection force, preventing microtubules from penetrating them. Schneider *et al.*[1] show that an absence of acetyl groups on histone tails is key to this resistance. Treatment with the drug trichostatin A (TSA), which induces histone acetylation, leads to puncturing of the chromosome surface by microtubules. **b**, When condensin was depleted, chromosomes adopted an abnormal shape, but resisted the polar ejection force until treated with TSA. **c**, When DNA was fragmented using an enzyme called AluI, round bodies formed and fused to one another like liquid droplets. A stiff surface still prevented microtubules from penetrating the round bodies, but TSA treatment dissolved these bodies.

07/06 | Aula 3: O *Ardipithecus*, o *Australopithecus*, a mistura entre características do gênero humano e características da linhagem dos monos (apes).

Textos para leitura:

Fossils Upend Conventional Wisdom about Evolution of Human Bipedalism | Jeremy DeSilva
'Lucy's Baby' Suggests Famed Human Ancestor Had a Primitive Brain | Ann Gibbons
Long-Awaited Research on a 4.4-Million-Year-Old Hominid Sheds New Light on Last Common Ancestor | Katherine Harmon
How Humanlike Was "Ardi"? | Katherine Harmon
Was "Ardi" Not a Human Ancestor After All? New Review Raises Doubts | Katherine Harmon
A 3.8-Million-Year-Old Skull Reveals the Face of Lucy's Possible Ancestors | Bruce Bower

scientificamerican.com

Fossils Upend Conventional Wisdom about Evolution of Human Bipedalism

Jeremy DeSilva

22–28 minutos

Long before our ancestors evolved large brains and language, even before they tamed fire or made stone tools, they started doing something no mammal had done before: walking on two legs. Skeletal adaptations for traveling upright are evident in fossils of the very oldest hominins—members of the human family—which date to between seven million and five million years ago. Moving on two legs rather than four set the stage for subsequent evolutionary changes in our lineage. It allowed our predecessors to expand their home ranges and diversify their diets, and it transformed the way we give birth and parent our children. This peculiar mode of locomotion was foundational to virtually all the other characteristics that make humans unique.

In the iconic representation of human evolution, a procession of ancestors starting with a chimplike creature ambling on all fours gives way to a series of ever more erect forebears, culminating in a fully upright *Homo sapiens* striding triumphantly on two legs. First popularized in the 1960s, the March of Progress, as this image and its variants are known, has decorated countless books, T-shirts, bumper stickers and coffee mugs.

But paleoanthropological discoveries made over the past two decades are forcing scientists to redraw this traditional, linear imagery. We now know that various hominin species living in different environments throughout Africa, sometimes contemporaneously, evolved different ways to walk on two legs. The emergence of bipedalism kicked off a long phase of rampant evolutionary riffing on this form of locomotion. Our modern stride was not predetermined, with each successive ancestor marching closer to a particular end goal (evolution has no plans, after all). Rather it's one of many forms of upright walking that early hominins tried out—and the version that ultimately prevailed.

Mysterious Footprints

They didn't want to get hit by a flying lump of elephant poop. Who would? So paleontologists Kay Behrensmeyer and Andrew Hill, who were visiting archaeologist Mary Leakey's fossil site of Laetoli in Tanzania, hopped into a gully to take cover and gather more ammunition for the game of elephant dung dodgeball that had spontaneously broken out. It was July 24, 1976, the day of one of the most serendipitous discoveries in the history of paleoanthropology.

Hill and Behrensmeyer scanned the ground for dung but instead spotted fossilized elephant footprints and raindrop impressions hardened in an exposed layer of volcanic ash that fell 3.66 million years ago. A truce was called in the dung fight, and the others came to marvel at what had been found. Fossils speak broadly about an organism; fossil footprints capture precious snapshots of moments in time for long-extinct animals.

For the next few weeks Leakey and her team explored an area they called Site A, brushing aside overlying sediment to reveal thousands of footprints, mostly made by small antelopes and hares but also from ancient elephants, rhinoceroses, giraffes, large cats, birds and even a beetle. Hoping to find hominins in the mix, Leakey told the group to be on the lookout for bipedal footprints. Maybe they'd get lucky. That September they did. Peter Jones and Philip Leakey discovered five consecutive footprints made by something traveling on two, rather than four, legs. A hominin? Maybe, but the footprints were strangely shaped, and whatever made them had cross-stepped, moving the left foot over the right like a model on a runway rather than walking in the usual human way. The Site A bipedal trackway was a mystery.

Fossil footprints from Laetoli, Tanzania, show that two different hominin species walked bipedally in this area 3.66 million years ago. The Site G trackway (*bottom*) is thought to have been made by *Australopithecus afarensis*. The Site A trackway (*top*) was made by a different, as yet unidentified hominin. Credit: Jeremy DeSilva (*top*); John Reader/Science Source (*bottom*)

Two years later two other members of Leakey's team, Paul Abell and Ndibo Mbuika, discovered another bipedal trackway two kilometers west of Site A at a location dubbed Site G. Two or three, perhaps even four, individuals had walked stride for stride through the muddy ash, leaving 69 stunningly humanlike footprints. Most scholars agree these tracks were made by *Australopithecus afarensis*—Lucy's species—fossils of which have been found at Laetoli. The Site G tracks were decidedly different from the ones at Site A, however. If a hominin made the tracks at Site G, then what kind of creature made the bipedal trackway at Site A?

In the mid-1980s University of Chicago anthropologist Russ Tuttle took a crack at solving this mystery. After comparing the shape of the Site A footprints with those made by unshod humans, chimpanzees, and circus bears trained to walk on two legs, Tuttle concluded that the prints were either made by a second species of hominin that roamed Laetoli during the Pliocene epoch or made by a bipedally walking bear. Perhaps because a linear view of the evolution of human bipedalism was the dominant paradigm, other researchers embraced the bear hypothesis. As a result, whereas the Site G hominin footprints were exhaustively studied and became world-famous, the footprints at Site A fell into obscurity.

Three decades passed before anyone focused on them again.

Dartmouth College, where I teach anthropology, is a small liberal arts school in New Hampshire nestled in a valley between that state's White Mountains and the Green Mountains of Vermont. Although the school is only two hours by car from metro Boston, its motto is *vox clamantis in deserto*, which translates to "a voice crying out in the wilderness." Large swaths of sugar maples provide an ample supply of syrup, the famous Appalachian Trail abuts the campus, and bears—a lot of bears—live in the surrounding woods.

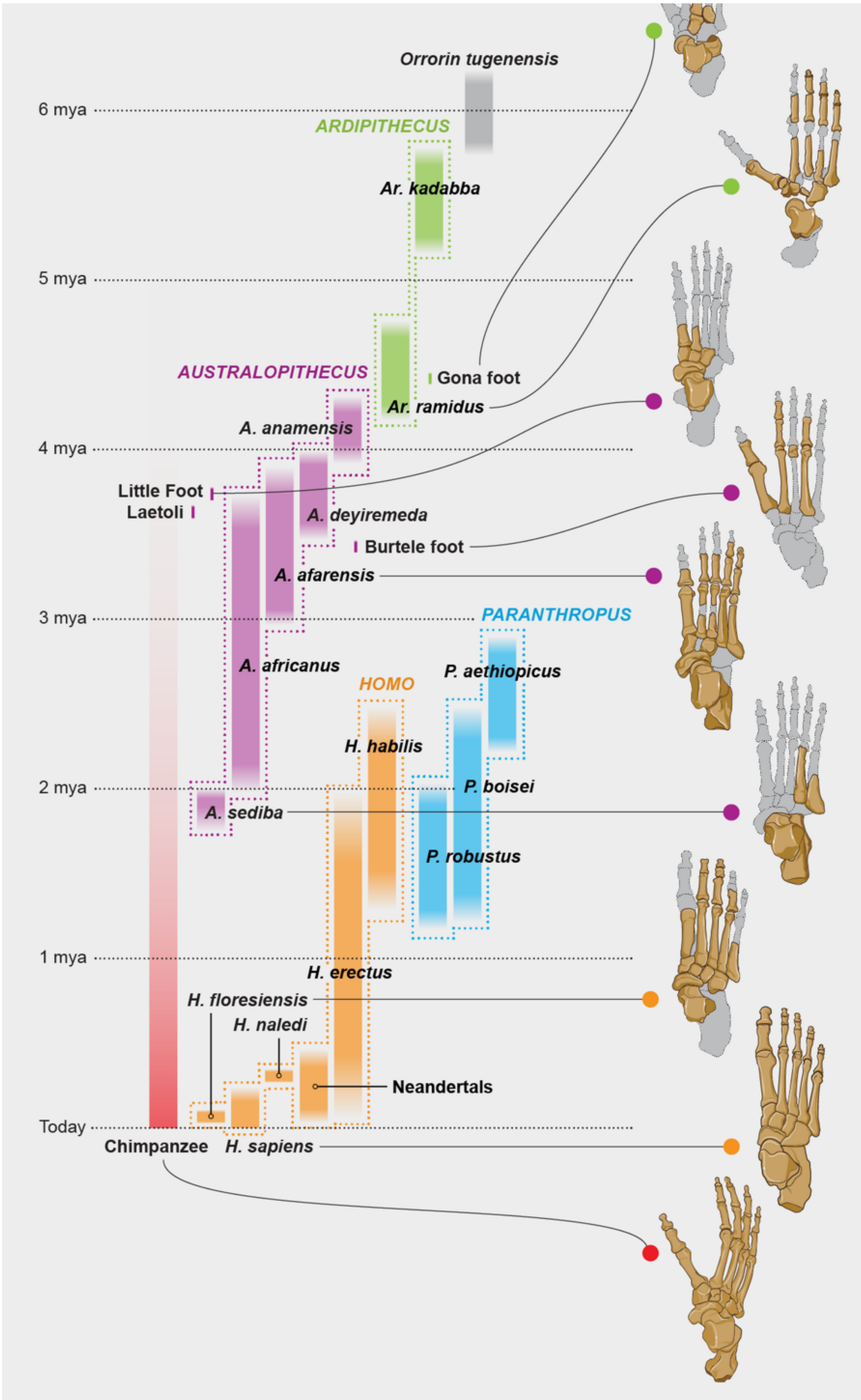
In 2017 my then graduate student Ellison McNutt, who is now a professor of anatomy at Ohio University, and I teamed up with local black bear expert Ben Kilham to collect footprints from cubs whose feet were similar in size to the tracks at Laetoli Site A. Using maple syrup and applesauce to tempt them, we persuaded the young bears to rear up on their hind legs and amble through an experimental trackway filled with mud. To our surprise, their footprints and gait mechanics were no match for Site A. Bears' heel impressions are narrow, and their steps are widely spaced because their hip and knee anatomy causes them to wobble back and forth when walking bipedally. We started to have our doubts about the bear hypothesis.

More than 40 years have passed since the discovery of the Site A trackway. In that time, seasonal rains have slowly washed sediment from the barren hills at Laetoli, exposing tens of thousands of fossils. Teams led by Charles Musiba of the University of Colorado Denver, Terry Harrison of New York University and Denise Su of Arizona State University have recovered many of these fossils. We know from other sites that an extinct bear called *Agriotherium* did roam Africa during the Pliocene, but not one of the animal fossils these teams have recovered at Laetoli is from a bear. Someone needed to take another look at the bipedal tracks at Site A. But those same seasonal rains that gift us fossil bones and footprints also have the erosive power to take them away. We had assumed the Site A bipedal footprints were long gone. Thankfully, we were wrong.

In 2019 Musiba and I traveled to Laetoli and used Mary Leakey's detailed drawings like a treasure map to identify the precise location where the mysterious bipedal footprints should be. Then we began to dig. After several days Tanzanian team member Kallisti Fabian called to us, "*Mtu*"—the Swahili word for "human." He had found the footprints. The rains had not destroyed them but had covered and preserved all five of them with a layer of fine sediment. Using tongue depressors and thick-bristled brushes, we fully cleaned the prints, revealing never before seen details of the toe impressions, which we captured with high-resolution, 3-D laser scans unavailable to our colleagues working in the 1970s. The heel impressions of the Site A footprints are large, and the big toe is the dominant digit, as it is in humans and our ape cousins. This was no bear. A hominin made these tracks. But which hominin?

Walk These Ways

Upright walking was long thought to have evolved in linear, sequential fashion, with each successive ancestor looking more like us in posture and stride. But discoveries made over the past two decades have upended that view. Paleoanthropologists now know that for most of the time over which humans have been evolving, multiple hominin species with different ways of walking upright overlapped in time and space. For example, three hominin species belonging to three different genera—*Paranthropus*, *Australopithecus* and *Homo*—all roamed South Africa's Cradle of Humankind region two million years ago, each with a distinct gait. Some hominins, such as *Australopithecus sediba* and *Homo naledi*, even possessed adaptations to life in the trees long after other hominins were fully committed to life on the ground.



Credit: Dino Pulerà (*foot illustrations*) and Jen Christiansen

Walk on a sandy beach, and you are sure to see a variety of *H. sapiens* footprints—small, flat prints made by a toddler next to the long, arched prints of her mother, for instance. Modern humans come in all shapes and sizes, and so do our feet. Almost certainly, the same was also true for *A. afarensis.* Maybe the footprints at Sites A and G were showing normal variation within a single species of hominin. If so, the small size of the Site A footprints might indicate they were made by a child of Lucy's species. That's what I originally hypothesized, anyway.

Footprint expert Kevin Hatala of Chatham University, who helped to discover and analyze 1.55-million-year-old *Homo erectus* footprints at Ileret, Kenya, joined our team, and together we compared the shape of the Site A footprints with the best-preserved footprints from Site G and another trackway discovered in 2015 at Site S, along with hundreds of footprints made by humans and chimpanzees. The differences we observed did not fit within the range of variation among footprints from people of all ages today.

We found that the Site A footprints had a shape that was as different from the Site G and S prints as a chimpanzee's footprints are from yours and mine. That's not to say the Site A footprints were just like a chimpanzee's, only that they were very different in shape from those of Lucy's species. Compared with those presumed *A. afarensis* footprints at Sites G and S, the Site A footprints were short and wide, the big toe stuck out to the side a bit, and there was some evidence the walkers had a more flexible middle portion of the foot.

In our paper describing these findings, published last December in the journal *Nature*, we claimed that not only were the Site A footprints from a hominin, but they also were evidence of a second species at Laetoli. As is expected in science, not all of our colleagues have fully embraced our interpretation. Some think we just found another *A. afarensis* footprint trail. But it is worth repeating that the Site A footprints were so different from the Site G *Australopithecus* prints that our field was convinced for decades that they were made by a bear.

It seems to me that shortly after ash fell from the sky 3.66 million years ago, two kinds of hominins, walking on slightly different feet in slightly different ways, moved north toward the Olduvai Basin in Tanzania, perhaps in search of water. Because it is thought that the footprint layer at Laetoli captures at most a few days of activity, this is the best evidence we have that different Pliocene hominin species not only were contemporaries but shared the same landscape. How they interacted—if at all—is anyone's guess at this point.

Compared with the Laetoli Site G footprint (*top*), presumably made by *A. afarensis*, the Site A print (*bottom*) is short and wide; the big toe sticks out to the side. Credit: John Reader/Science Source (*top*); Jeremy DeSilva (*bottom*)

Fossil Feet

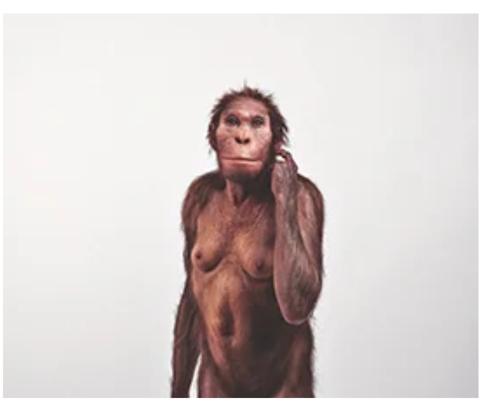
The rediscovery of the Laetoli Site A footprints and our conclusion that they were made by a second species are the latest additions to a growing body of evidence that the evolution of upright walking was a lot less linear, more complex and more interesting than we once thought. The other evidence comes not from footprints but from fossils of the hominins themselves. Isolated foot bones are rare in the human fossil record, and foot skeletons are even more elusive. So it is exciting that in the past two decades, paleoanthropologists searching in Africa's Great Rift Valley and in caves in South Africa have quadrupled the number of fossils from the only part of a biped's body usually in direct contact with the ground. Many of these new discoveries sample a pivotal period in human evolution, between five million and three million years ago, when our ancestors were becoming committed upright walkers. In 2017 McNutt and I teamed up with Bernhard Zipfel, a former podiatrist-turned paleoanthropologist at the University of the Witwatersrand in South Africa, to make sense of these finds.

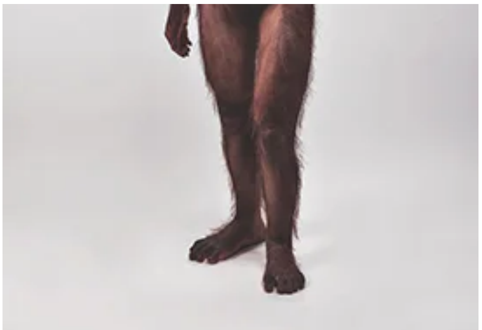
Specifically, we sought to evaluate the received wisdom about the evolution of bipedalism in light of the new fossil evidence. According to the traditional view, hominins started out with a chimplike foot built for grasping tree branches. This foot evolved into a transitional foot capable of both grasping and walking, as seen in the fossil known as [Ardi](), a member of *Ardipithecus ramidus* that lived in Aramis, Ethiopia, 4.4 million years ago. Fast forward to Lucy, the *A. afarensis* individual who lived in Hadar, Ethiopia, some 3.2 million years ago, whose foot has a big heel and a stiff midfoot that were better adapted to life on the ground. With the emergence of our own genus, *Homo*, roughly a million years later, the foot became even better suited to terrestrial locomotion, evolving shorter toes and a high arch.

Decades after the discovery of the Site A tracks at Laetoli, researchers returned to study the tracks again. Although seasonal rains tend to erode footprints, in this case they covered them with a protective layer of sediment. Credit: Shirley Rubin

After studying all the foot fossils carefully curated in museums throughout Africa, we noticed a very different pattern emerging from our data. As bipedalism evolved in our earliest ancestors, there was a burst of evolutionary experimentation that resulted in different hominins having different foot forms. We identified five different foot morphs, possibly indicating five distinct ways of walking upright, in the two-million-year interval we studied. Between the chronological bookends of Ardi and Lucy are three other uniquely shaped feet. The first belongs to an Ardi-type creature, about the same age as that fossil, from Gona, Ethiopia; the second comes from a 3.67-million-year-old hominin from Sterkfontein, South Africa, dubbed “Little Foot”; and the third is a strikingly primitive foot from a site called Burtele in Woranso-Mille, Ethiopia, that dates to 3.4 million years ago. Although all five of these hominin feet exhibit both apelike and humanlike features, these traits occur in a completely different combination in each foot and do not follow the predicted pattern of becoming less apelike and more humanlike over time.

Like an ancient version of the story of Cinderella, perhaps one of these recently discovered feet will fit the mysterious hominin footprints at Laetoli Site A and reveal the identity of the track maker. We’ll see as we continue to explore these early stages of our evolutionary history.





Multiple styles of upright walking continued to evolve even after the emergence of species with our modern human gait. *Australopithecus sediba* (*top*) had adaptations to both terrestrial and arboreal locomotion; tiny *Homo floresiensis* (*bottom*) had large, flat feet that might have required taking small, high steps. Credit: S. Entressangle and Elisabeth Daynes/Science Source (*top*); Sebastien Plailly and Elisabeth Daynes/Science Source (*bottom*)

Sustained Diversity

Intriguingly, the pattern of locomotor diversity is not limited to these early chapters of human evolution. Take, for instance, [Australopithecus sediba](). Rivaling the elephant dung fight in the lore of fortuitous paleoanthropological discoveries, this nearly two-million-year-old hominin was discovered in 2008 by then nine-year-old Matthew Berger. He literally stumbled over a rock containing a hominin clavicle and lower jaw while surveying for fossils at the site of Malapa Cave in South Africa's Cradle of Humankind with his father, paleoanthropologist Lee Berger of the University of the Witwatersrand. In the months that followed, Berger and his team excavated the fossil-bearing cave walls and discovered two partial skeletons of a new species they called *A. sediba.* Berger invited me to study the foot and leg fossils shortly after I had completed my Ph.D.

I was shocked by what I saw. The shapes of the bones were all wrong. For a hominin of this time period, the heel bone was too apelike, and the midfoot, ankle, knee, hip and lower back showed strange traits in both skeletons. In isolation, these bones were bizarre. But in concert, they told the story of a hominin with a peculiar way of walking, one that was similar to that of humans today who hyperpronate, or excessively transfer weight to the inside of their foot. This gait can lead to joint pathologies in modern people, but Berger and I and our colleagues interpreted the peculiarly shaped bones of *A. sediba* as anatomical solutions to the problems modern humans face when they walk in this manner. In other words, we think this species was adapted to walk in this way. Why? The shoulders and arms of *A. sediba* indicate that it climbed trees, and its teeth preserve microscopic traces of plant cells derived from leaves, fruit and bark—evidence that this species frequently fed in trees. This way of walking was the compromise for a hominin well adapted for life in two worlds, navigating between the trees and the ground—long after other hominin species had fully committed to terrestrial life.

A. sediba was not the only hominin walking around southern Africa two million years ago. In 2020 a team of researchers led by Andy Herries of La Trobe University in Australia reported newly discovered fossils from the Drimolen Cave system, also in the

Cradle of Humankind area. These fossils came from two other hominin species: the large-toothed *Paranthropus robustus* and the much more humanlike *H. erectus.* In other words, three different kinds of hominins from three different genera—*Homo, Paranthropus* and *Australopithecus*—were coexisting.

We know from a partial skeleton discovered in the 1980s along the western side of Lake Turkana in Kenya that *H. erectus* had a body form nearly identical to that of humans living today. Footprints on the eastern side of the lake confirm that these hominins walked like us. *H. erectus*—the likely ancestor to the lineage that led to our own species, *H. sapiens*—would have peered across its territory and seen two other bipeds from two different genera, *Australopithecus* and *Paranthropus.* Given the different shapes of their foot and leg bones, I think these hominins all had different styles of walking.

The pattern of diverse walking styles persisted even after *Australopithecus* and *Paranthropus* went extinct. As recently as 60,000 years ago, by which point *H. sapiens* was well established, the small human species *Homo floresiensis*, nicknamed the Hobbit, roamed its island home of Flores in Indonesia on relatively giant, flat feet and short legs with small joints. I wonder if the resulting gait would include the short steps and high knee drive of a person in snowshoes.

Perhaps gait differences helped hominins determine whether a group foraging in the distance belonged to their own species or another. And if gait did reveal the distant foragers to be from their same species, could the observers tell whether the other individuals were friends and family or strangers? Knowing the answer could have been the difference between avoiding conflict and inviting it. Gait, it turns out, is more than a means of getting from point A to point B.

Open Questions

Many questions remain about the evolution of bipedalism. We still do not know why upright walking was selectively advantageous for our earliest ancestors and extinct relatives. Hypotheses abound. In 1809 French naturalist Jean-Baptiste Lamarck speculated that humans evolved upright walking to see over tall grass. Six decades later Charles Darwin surmised that walking on two legs freed the hands to use tools. Other scholars have since proposed that it allowed our ancestors to gather and carry food or to wade through shallow water. Still others argue that it offered a more energetically efficient means of traveling between scattered resources. It seems to me, though, that efforts to identify *the* reason bipedalism evolved are a fool's errand. Instead I think it's possible—maybe even probable—that bipedalism evolved multiple times at the base of the hominin family tree, perhaps for different reasons, in different hominins living in slightly different environments throughout Africa. The diversity of foot forms found in Pliocene fossil sites across the continent supports such a scenario.

The fossil record of apes from the Miocene epoch (23 million to 5.3 million years ago) highlights other unknowns. Paleoanthropologists working in Africa have struggled to find ape fossils from this all-important time period when hominins diverged from other apes. But their counterparts in southern Europe have turned up an impressive collection of bones from apes that used to live in Spain, France, Germany, Greece, Italy, Hungary and Turkey. Judging from their hands, arms, backs, hips and legs, these European apes didn't knuckle-walk like a chimpanzee. Instead some of them may have been able to move on two legs more often and more efficiently than modern African apes do. Depending on where these ancient apes—such as the 11.6-million-year-old *Danuvius guggenmosi* from Germany, first announced in 2019—fit into the family tree, it is even possible that the ape from which the ancestors of humans, chimpanzees and gorillas split was not a knuckle-walker at all but more upright, using hand-assisted bipedalism to "walk" through the trees. In that case, the unique hominin adaptation would be not bipedal walking per se but rather bipedal walking *on the ground*. If more fossils continue to support this hypothesis, then rudimentary bipedalism might turn out not to be a new form of locomotion at all; it may be an old one co-opted for a new environment as our ancestors shifted from an arboreal to a terrestrial existence.

This idea is controversial and in need of further testing. The challenge is that paleoanthropologists have yet to unearth fossil foot or leg bones from Africa during the key time period when the lineages that would eventually lead to humans, chimpanzees and gorillas were beginning to diverge, between 12 million and seven million years ago. To fill in that gap, we rely on the anatomy of those ancient apes from southern Europe. In a way, it is like trying to figure out what your great-grandmother looked like by studying tattered black-and-white photographs of your 19th-century cousins three times removed. They'll provide some clues but not the full picture. We'll see how this hypothesis holds up in the decades to come as more fossils are recovered from sites around the Mediterranean and in Africa. For now, though, the very beginnings of upright walking remain shrouded in mystery.

Once our ancestors got moving on two legs, they kept on walking, and that journey has continued right up to today. In a lifetime, the average person will take about 150 million steps—enough to circle Earth three times. We stroll, stride, plod, traipse, amble, saunter, shuffle, tiptoe, lumber, tromp, lope, strut and swagger. After walking all over someone, we might be asked to walk a mile in their shoes. Heroes walk on water, and geniuses are walking encyclopedias. But rarely do we humans *think* about walking. It has become, you might say, pedestrian. The fossils, however, reveal something else entirely. Walking is anything but ordinary. Instead it is a complex, convoluted evolutionary experiment that began with humble apes taking their first steps in Miocene forests and eventually set hominins on a path around the world.

‘Lucy’s baby’ suggests famed human ancestor had a primitive brain

By Ann GibbonsApr. 1, 2020 , 2:10 PM

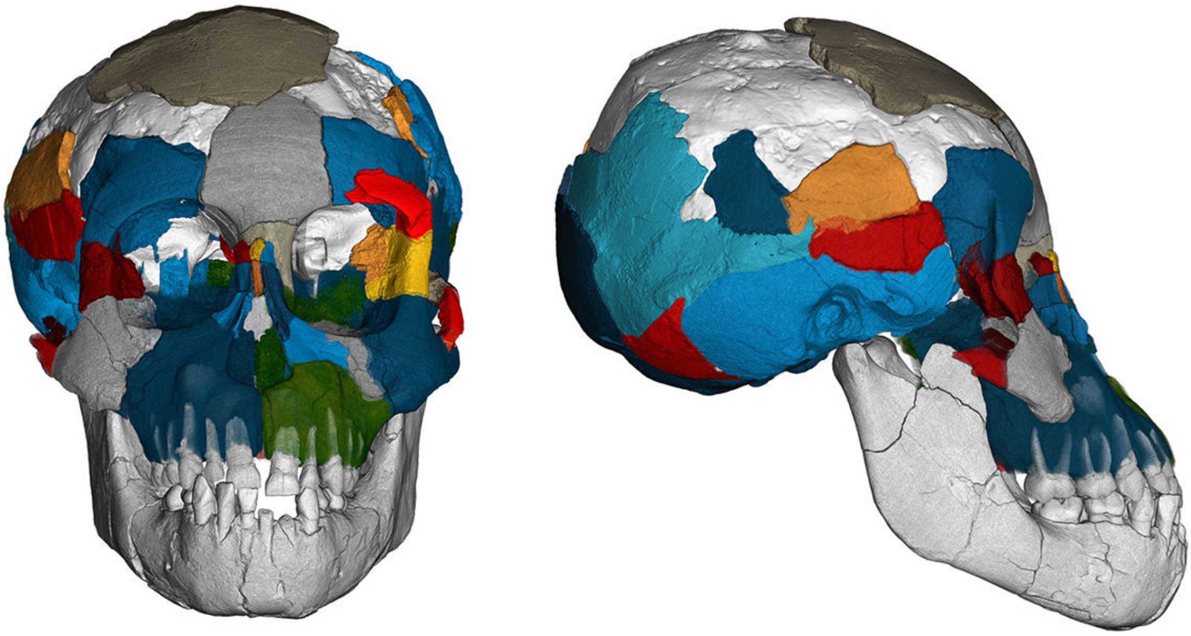
‘Lucy’s baby’ suggests famed human ancestor had a primitive brain

In 1974, the world was stunned by the discovery of “Lucy,” the partial skeleton of a human ancestor that walked upright—and still spent time in the trees—3.2 million years ago. Later discoveries revealed her species, scattered throughout eastern Africa, had brains bigger than chimpanzees. But a new study of an ancient toddler finds that the brains of Lucy’s kind were organized less like those of humans and more like those of chimps. That suggests the brains of our ancestors expanded *before* they reorganized in the ways that let us engage in more complex mental behaviors such as making tools and developing language. The remains also suggest Lucy's species had a relatively long childhood—similar to modern humans—and that they would have needed parenting longer than their chimp relatives.

Anthropologists have made much of the fact that adult members of Lucy's species—*Australopithecus afarensis*—had skulls 20% larger than a chimpanzee's. Researchers have long debated what this meant for their brain power. Had the brains of these early hominins, or members of the human family, already reorganized by the time their kind was walking upright in Africa and—perhaps—hafting sharp stone tools 2.9 million to 3.9 million years ago? "There's been a big debate about when the reorganization of the brain took place in the hominin lineage," says University of Chicago paleoanthropologist Zeresenay Alemseged.

To test this idea, an international team of paleoanthropologists used a synchrotron in Grenoble, France, to take super–high-resolution images of the deformed skull and teeth of an *A. afarensis* toddler, known as the Dikika child, which Alemseged discovered in Ethiopia in 2000.

The team zoomed in on the inside of the skull, where the brain leaves an imprint. They found that a fold in the tissue at the back of the brain, called the lunate sulcus, was in the same position as in a chimp, not a human brain where its position may have had some impact on complex mental function. Other features also showed "the brain imprint of *A. afarensis* is completely apelike," says paleoanthropologist Philipp Gunz of the Max Planck Institute for Evolutionary Anthropology. Gunz spent 7 years doing the 3D reconstruction of the skull of Dikika and six other adult and juvenile members of the species.



High-resolution images of a toddler *Australopithecus afarensis* suggest its brain was organized like that of a chimpanzee.

Philipp Gunz/MPI EVA Leipzig

The team also painstakingly counted growth lines on the Dikika child's teeth and found that it was 2.4 years old at the time of death. Its brain volume was about 275 milliliters, the same as for a chimp of the same age. A second skull was of similar age and size; both suggest *A. afarensis*'s brain grew at about the same rate as a chimp's, the team reports today in *Science Advances*. To reach its adult brain size, *A. afarensis* therefore must have had a longer period of brain growth—or childhood—which is a hallmark of later humans, including us.

Those longer childhoods demand that mothers or other caretakers invest more energy in raising their offspring. "This suggests that a longer childhood emerged way before [our genus] *Homo*," Alemseged says.

The new reconstructions of the Dikika skull are "exceptional," says paleoanthropologist Steven Leigh of the University of Colorado, Boulder, who was not part of the study. But evolutionary neuroscientist Chet Sherwood of George Washington University cautions that because the study is based on skulls of only two juveniles and five adults, “one needs to be cautious.” And recent studies question how much differences on the surface of the brain actually correspond with rewiring of the brain and real functional change in different species, says neuroscientist and anthropologist Katerina Semendeferi of the University of California, San Diego. Nevertheless, both think the reconstructions are spectacular. And, Sherwood adds, these fossils are so rare that they’re “worth pursuing as much as possible.”

Subscribe

SCIENTIFIC AMERICAN

Cart 2 | My Account | Stay Informed

EVOLUTION

Long-Awaited Research on a 4.4-Million-Year-Old Hominid Sheds New Light on Last Common Ancestor

Fifteen years in the making, a dossier of papers on "Ardi" published in *Science* suggest that like humans, chimpanzees have undergone substantial evolutionary change

By Katherine Harmon on October 1, 2009

The first full analysis of a 4.4-million-year-old early human paints a clearer picture of what the last common ancestor of humans and chimpanzees may have looked like, which is not, after all, that much like a chimp at all. The ancient *Ardipithecus ramidus* ("Ardi", as the most complete female specimen is known) is described in 11 research papers published online today in *Science*. The prodigious research effort combines Ardi's fossils with those from many other *Ar. ramidus* individuals—both male and female—found near the Awash River in the Afar Rift region of Ethiopia.

Ar. ramidus, although likely millions of years more recent than the so-called missing link between chimpanzees and humans, represents "coming as close as we've ever come to that last common ancestor," Tim White of the University of California, Berkeley, one of the studies' lead authors, said in a recorded interview for *Science*.

Ardi is, in fact, "so rife with anatomical surprises, that no one could have imagined it without direct fossil evidence," wrote C. Owen Lovejoy, a professor of anthropology at Kent State University in Ohio, and his colleagues in a summary of one of the papers.

Among the surprises: Ardi's jaw and limbs show she was a forest-dwelling omnivore, not a fruit-eater like today's chimps or an open savanna–dweller like other early hominids. Ardi had a brain about the size of a modern chimp's relative to body size (about a third the size of a modern human's). And *Ar. ramidus*'s foot is strikingly unlike that of a modern chimpanzee, the authors of another paper (led by Lovejoy) explain.

For a primitive cousin who likely stood at only about 120 centimeters and weighed about 50 kilograms, Ardi is likely to make a big impact in the field of paleoanthropology. For instance, Ardi's physical form also has implications for many other ancient animals, including the controversial six-million- to seven-million-year-old *Sahelanthropus tchadensis*, discovered in Chad in 2001. The similarities in skull size and shape among these two species now has prompted the researchers of one of the new papers (led by Gen Suwa, a professor at the University of Tokyo) to conclude that *S. tchadensis* was, indeed, an early hominid, rather than a female ape as others have suggested.

Slide Show: Images of Ardi

Fragile fossils

First announced 15 years ago with only scant tooth and jaw fragments, *Ar. ramidus* had remained a relative paleoanthropological secret amidst growing literature on other early hominids, such as the well-known Lucy, a 3.2-million-year-old *Australopithecus afarensis*.

For the new papers, an international team of researchers assembled and described the more than 110 pieces of Ardi's skeleton, including portions of the skull, hands, feet, arms, legs and pelvis, and those of other *Ar. ramidus* specimens and surrounding plants and animals.

"It's an amazing amount of material," says Carol Ward, an associate professor and integrative anatomy specialist at the University of Missouri–Columbia (M.U.). "That in itself is astonishing."

The recovery efforts themselves took some "heroic efforts," says Brian Richmond, of George Washington University's Center for the Advanced Study of Hominid Paleobiology (CASHP), in Washington, D.C. Poorly fossilized, many of the bones would crumble with a normal human touch, so they were carefully removed, cast and scanned.

Long before the fossils were unearthed, they sustained quite a bit of damage, leaving the skull and the pelvis crushed and distorted. Close study and computer modeling helped researchers put the pieces back together, but, Richmond notes, "it takes a substantial amount of reconstruction," and a bit of guesswork to assemble the body—and movements—of a creature long extinct.

By hand or by foot

Perhaps one of the biggest questions that remains in the field of human evolution is how the modern two-legged gait came to be, and Ardi complicates some common assumptions made in the past by anthropologists.

Today's chimpanzees and gorillas get around on the ground by walking on the hind feet and the knuckles of their hands, leaving many to speculate that early humans may well have done the same. "It has long been assumed that our hands must have evolved from hands like those of African apes," Lovejoy and his co-authors wrote in one paper summary. Other early specimens have lacked sufficient hand bones to establish if they were transitioning from knuckle walking, note the authors of one of the papers.

The more complete hands of Ardi, however, throw another wrench into this theory. The stiff but strong hands of modern great apes are well-adapted to navigating life in the treetops. Humans, however, have weaker but more flexible hands, allowing for better dexterity and tool use. The hands of *Ar. ramidus* were indeed strong enough to hang from tree branches but don't show any indication of knuckle-walking, and in some ways they may have been more flexible than our own, Lovejoy and co-authors note.

So does that mean that Ardi was walking on two legs? By the time Lucy came along about 3.2 million years ago, her cadre was already fairly well-adapted to bipedal walking (although not quite so well as modern humans). The researchers suggest that Ardi was, in fact, an upright walker and that "*Ar. ramidus* could walk without shifting its center of mass from side to side," a hallmark of latter hominids, wrote Lovejoy and his colleagues.

M.U.'s Ward is not convinced that Ardi was quite as steady on her feet as the authors suggest. After examining some of the figures, Ward notes that the specimen's knees may actually have been spaced farther apart, making Ardi less able to flow from one foot to another without making the large adjustment of body weight.

She is not alone in her skepticism. "There is precious little to indicate that it was an upright walker," Richmond says, which actually surprised him, noting that there is other evidence of bipedality going back some four million years ago (work on fossils of *Orrorin tugenensis* even suggests bipedality going back some six million years). He also cites the lack of a knee joint as an unknown key to the species's locomotion capabilities.

Its hips do, however, appear to be moderately adjusted to accommodate some upright walking. But they were not as similar to modern human hips as those of *Australopithecus*. And the feet, although more primitive than a chimpanzee's, "certainly would have been capable of bipedal walking," Richmond says, although the presence of a large grasping toe and other aspects make it less well-suited to getting around upright.

Perhaps more fossil evidence will help to clarify the path from the tree branch to the savannah, but in the meantime, Ardi has brought some welcome new evidence to the field, Ward notes. "The question is no longer, 'Why did our ancestors stand upright?'" she says. "It's, 'Why did they never drop down on all fours when they came out of the trees?'"

Forest dweller

Challenging long-held assumptions about where—and why—early humans dropped down from the trees and stretched their legs, *Ar. ramidus* appears to have lived not in a savanna but in a forest.

Previous excavation of early humans has often been in areas in which ancient deluges had mixed various biomes and layers together, providing a convoluted picture of each individual's original environment, U.C. Berkeley's White et al. wrote in one of the new papers. Ethiopia's Afar Rift location, however, had experienced no such archaic amalgamation, providing paleoanthropologists with a clearer picture of Ardi's world.

Analysis of the area's geology and other nearby fossils revealed ancient fig and hackberry trees as well as new species of mammals and birds. These findings, along with the dearth of grassland-dwelling species, such as the larger hoofed species found elsewhere, led the authors of one of the papers (led by Giday WoldeGabriel, a geologist at Los Alamos National Laboratory in New Mexico) to propose that the area "was humid and cooler than it is today, containing habitats ranging from woodlands to forest patches," they wrote in a summary.

Given that they did inhabit a largely wooded area, however, means that ground-based travel was probably secondary, Ward says. "The most important way of getting around for these animals was climbing trees." Nevertheless, it raises questions as to why these animals may have started perambulating upright before later hominids moved onto the grasslands, whereas ancestors of chimpanzees and other great apes eventually retreated deeper into the forest.

Social speculations

What can the outlines of Ardi's frame reveal about the daily lives of this species?

Researchers found an important indicator in the canine teeth from male *Ar. ramidus* specimens. Modern male chimpanzees and gorillas have long, sharp canine teeth, which they use in fights with other males to obtain female mates. *Ar. ramidus*—and to an even lesser extent, humans—don't have such fearsome teeth. In the papers, Lovejoy suggests that this may be a sign of the absence of such male-to-male competition and aggression over female mates and perhaps an indication that the males were starting to be more involved in the rearing process.

These ancient *Ar. ramidus* males also appear to have been nearly the same size of the females, another indication that they likely had a different social system than modern chimpanzees, whose aggression-based hierarchy had long been the foil for early hominids.

As White noted in his interview, the absence of these two key gender differences seems to be “signaling a new social structure.”

Others in the field agree that these two signatures are likely indicators of a different type of mating system than the one seen in modern African apes. However, recreating the details of a social system purely on fossil evidence is tricky, if not impossible, says Michael Plavcan, an associate professor of Anthropology at the University of Arkansas in Fayetteville. Some new world monkeys, for example also show little sexual body size or canine tooth dimorphism and pair off for life—“the family counsel’s animal of the year,” says Plavcan—others, with similar characteristics are, he explains, “intensely promiscuous.”

Next steps

Like any significant scientific discovery, *Ar. ramidus* raises more questions than it answers. "It's going to keep generations of students busy," CASHP's Richmond says of the research. It will also likely usher in a change in the common understanding that modern humans descended directly from chimpanzees—as popularized by the illustrated "quadrupedal monkey to upright man" sequence. Accepting the new view of human evolution that the Ardi analyses suggest, says Ward, will mean "tearing that [depiction] up and throwing it out the window."

This new evidence calls into question many assumptions that have been made about *Homo sapiens*'s assumed privileged evolution. Indeed, if anything, Ardi reveals that chimpanzees, too, have been on quite an evolutionary odyssey in the past seven million to 10 million years.

It also points the way toward more work outside of Ardi's clan. "This just highlights the need for more research to find the last common ancestor of chimpanzees and humans," Richmond says. "Ultimately we want to know where we first came from and what were the factors that let us take our unique steps toward humanity," he says. But the fossil record will have to be the final arbitrator. "I think at this point it's premature to make conclusions about the common ancestor without having evidence," he says.

Indeed, even White noted that it is still too early to say for sure exactly how these evolutionary lines are related and how the hominids came to start walking upright.

The analysis of Ardi gives new poignancy to the notion, set forth nearly 150 years ago by Charles Darwin and Thomas Huxley, that there was likely a common ancestor quite different from both modern humans and great apes. Darwin knew, White noted in the recorded interview that, "the only way we're really going to know what this last common ancestor looked like is to go and find it."

ABOUT THE AUTHOR(S)

Katherine Harmon

Recent Articles

What's in Your Wiener? Hot Dog Ingredients Explained

The Puzzle of Pancreatic Cancer: How Steve Jobs Did Not Beat the Odds—but Nobel Winner Ralph Steinman Did

Are Zombie Bees Infiltrating Your Neighborhood?

READ THIS NEXT

Long-Awaited Research on a 4.4-Million-Year-Old Hominid Sheds New Light on Last Common Ancestor

Observations

Was "Ardi" not a human ancestor after all? New review raises doubts

By Katherine Harmon on February 16, 2011

Genetic findings often underscore the notion that organisms with similar-looking body parts aren't always close evolutionary relatives. Wings for flying or sharp teeth for ripping into food can be the result of convergent evolution, in which natural selection results in similar-looking solutions to problems faced by different species—whether they are distantly or closely related.

Teasing apart the origins of shared features in closely related species is especially tricky, especially when DNA clues are not available. So when researchers spy skeletal similarities in the fossil record, they might be led to believe that species "are more closely related than they really are," wrote the authors of a new review paper. For example, rather than indicating a direct link to modern humans, the familiar features of some purported human ancestors, including *Ardipithecus ramidus*, might be explained by convergent evolution.

"We could actually place *Ardipithecus* in a lineage that's unrelated to humans," Terry Harrison, of the Center for the Study of Human Origins at New York University and co-author of the paper, said in a podcast with *Nature* (*Scientific American* is part of Nature Publishing Group).

The 4.4-million-year-old "Ardi" might have split off from the main stems of the ancient ape family tree before the last common ancestor linking humans and chimps, which is thought to have lived between eight million and four million years ago, Harrison and Bernard Wood, of George Washington University's Center for the Advanced Study of Hominid Paleobiology, noted in their new review paper, published online February 16 in *Nature*.

"I think it's equally likely, or perhaps even preferable, that it is an ancestral form or an early representative of the African great ape" group—that "it's not necessarily uniquely linked to humans," Harrison said of *Ardipithecus* in the podcast.

Some of the most solid evidence for Ardi being included in the hominin branch is her small canine teeth. But the researchers are quick to point out that other ancient non-hominin species, including *Oreopithecus* and *Ouranopithecus*, also came to have reduced canine teeth, "presumably as a result of parallel shifts in dietary behavior in response to changing ecological conditions," the researchers suggest in their article. "Thus, these changes are in fact, not unique to hominins."

The placement of a hole at the base of the skull, known as the foramen magnum, also might suggest Ardi as an upright walker, and thus perhaps a solid hominin. But in looking to other apes, "this feature is more broadly associated with differences in head carriage and facial length, rather than uniquely with bipedalism," Wood and Harrison note. Some extinct primates, such as *Oreopithecus bambolii*, evolved outside of the human line but nevertheless possessed similarly hominin-like traits, which, the authors write, "encourage researchers to generate erroneous assumptions about evolutionary relationships."

Wood and Harrison draw parallels to the decades-old case of the short-faced, small-canined *Ramapithecus punjabicus*, which was initially thought to be a hominin but later shown to be a female *Sivapithecus*, a relative of orangutans.

Part of the problem in trying to understand the ancestral ties among extinct species derives from assumptions about what the last common ancestor of humans and great apes looked like, including the classic fallacy that our predecessors looked like modern chimpanzees. "It is simplistic to assume that only hominins have undergone significant evolutionary change since the most recent common ancestor," Wood and Harrison note in their article. Key features, such as small canine teeth, that we take to be indicative of changing behavior in hominins, could have been useful in other far different primate lines as well. "It would be rash simply to assume that those features are immune from" convergent evolution, conclude the authors. They argue for "an alternative and perhaps more prudent" line of thinking that the path that led to humans was likely less "ladder-like" and rather "more bushy," full of evolutionary dead ends that branched out and died off before the human stem had taken hold. Such a model also suggests that finds such as *Ardipithecus* should not be thought of as human until more evidence is uncovered.

Tim White, of the University of California, Berkeley, and one of the lead authors on the 2009 Ardi papers, called the new article a "six page illustrated op-ed piece" in the *Nature* podcast. He maintains that "whole functional complexes"—not just individual characteristics—that were described in his team's papers link Ardi to humans "to the exclusion of the great apes."

Wood and Harrison do not dismiss *Ardipithecus* as a possible human ancestor, but they note that, "it remains to be seen how many of these alleged hominin synaphomorphies will withstand close scrutiny." They encourage other paleoanthropologists to "acknowledge the potential shortcomings of their data when it comes to generating hypotheses about relationships," and accept that with current fossil evidence and analysis, we might not be able to know for sure whether or not Ardi was a hominin.

"Fossils don't come with their birth certificates attached—they don't come with prognostications of their future," *Nature* editor Henry Gee, who edited the article, said in the podcast. "It's up to us to draw those inferences from the fossils."

Image of human and other primate skulls courtesy of Wikimedia Commons

ABOUT THE AUTHOR(S)

Katherine Harmon

Recent Articles

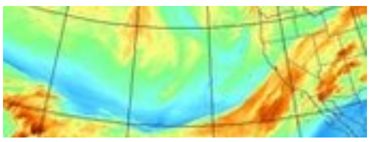
What's in Your Wiener? Hot Dog Ingredients Explained

Are Zombie Bees Infiltrating Your Neighborhood?

Major Flooding Inundates Drought-Stricken Colorado Cities

LATEST NEWS

Turkey Creates Its First Space Agency



Warning Scale Unveiled for Dangerous Rivers in the Sky

A 3.8-million-year-old skull reveals the face of Lucy's possible ancestors

The fossilized hominid skull illuminates the earliest-known Australopithecus species

Bruce Bower August 28, 2019 at 1:00 pm

A 3.8-million-year-old fossil of a hominid skull (right) offers hints about what the individual looked like (artist's reconstruction, left).

L-R: Matt Crow/Cleveland Museum of Natural History, John Gurche (facial reconstruction); Dale Omori/Cleveland Museum of Natural History

In a remarkable evolutionary windfall, fossil hunters have discovered neatly fitting halves of a nearly complete, 3.8-million-year-old hominid skull. This unexpected specimen shines some light on poorly understood, early members of the human evolutionary family.

The East African skull, which turned up at Ethiopia's Woranso-Mille site, has been classified as *Australopithecus anamensis*. It is the oldest known species in a hominid genus that includes *Australopithecus afarensis*, known best for Lucy's 3.2-million-year-old partial skeleton (*SN: 10/28/14*).

The research team, led by paleoanthropologist Yohannes Haile-Selassie of the Cleveland Museum of Natural History, describes its analysis of the skull in two papers published online August 28 in *Nature*.

"This specimen provides the first glimpse of the face of *Australopithecus anamensis*," Haile-Selassie said during an Aug. 27 news conference. The skull, which is slightly larger than a modern adult human's fist, also includes the first good example of an *A. anamensis* braincase.

For early-hominid investigators, "this is the specimen we have been waiting for," says paleoanthropologist Carol Ward of the University of Missouri in Columbia. Ward was not part of the Woranso-Mille team.

Until now, *A. anamensis* fossils consisted only of partial upper and lower jaws, isolated teeth, a braincase fragment and some lower-body bones (*SN: 2/18/15*). Those specimens, previously unearthed in Kenya and Ethiopia, date to between 4.2 million and 3.9 million years ago.

Then, on February 10, 2016, a member of the Woranso-Mille team noticed the lower part of a hominid skull protruding from eroding sediment. Later that day, Haile-Selassie found the braincase lying on the ground about three meters from the initial find. Soil sieving produced additional skull fragments.

Paleoanthropologist Yohannes Haile-Selassie holds a nearly complete *Australopithecus anamensis* skull shortly after its discovery at an Ethiopian site.Cleveland Museum of Natural History

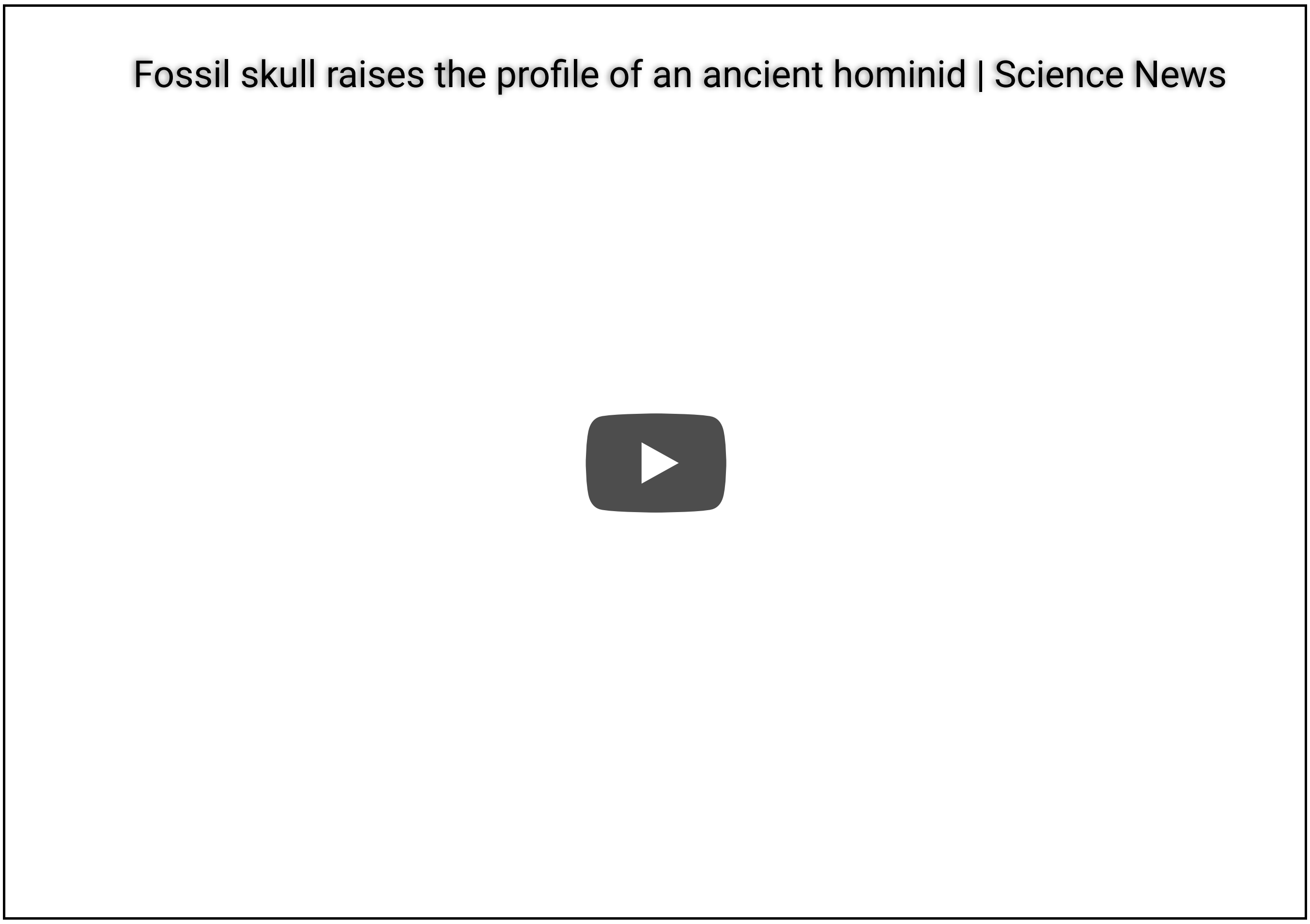
Geoscientist Beverly Saylor of Case Western Reserve University in Cleveland led an effort to date the fossil by estimating the ages of nearby volcanic rock layers. Known reversals of Earth's magnetic field in Woranso-Mille sediment also aided dating.

Geologic evidence indicated that the fossil *A. anamensis* individual had been covered in sandy deposits where a river entered a lake. The surrounding region was largely dry, but included some forested areas. Volcanic eruptions occasionally blanketed the lake and its surroundings.

A digital reconstruction of the Woranso-Mille skull helped to establish its species. The braincase displays features, such as a long, narrow shape and a roughly chimpanzee-sized brain, similar to those of even older proposed hominids such as *Sahelanthropus tchadensis* and *Ardipithecus ramidus* (*SN: 2/16/11*). In contrast, forward-projecting cheek bones recall those of later hominids, such as 2.5-million-year-old *Paranthropus aethiopicus*. That species belonged to an African line of big-jawed, small-brained creatures that died out around 1 million years ago. It's hard to know whether these shared traits evolved independently, or if the traits signal an evolutionary relationship.

Further comparisons connected the Woranso-Mille skull to earlier *A. anamensis* finds. Many of the skull's features differ from those of Lucy's kind, Haile-Selassie says. For instance, *A. anamensis* possessed a sloping face, unlike the flat faces of *A. afarensis*.

Crucially, the Woranso-Mille skull differs enough from an approximately 3.9 million-year-old hominid forehead bone discovered in East Africa in 1981 to assign that older find, known as the Belohdelie frontal, to *A. afarensis*, Haile-Selassie contends. If so, *A. anamensis* — now placed at between 4.2 million and 3.8 years ago — and Lucy's kind — dating to between 3.9 million and 3 million years ago — overlapped for at least 100,000 years. That scenario contradicts an earlier hypothesis that *A. anamensis* evolved directly into Lucy's kind, with the earlier species disappearing as it morphed into its descendant species (*SN: 4/12/06*).



A discovery at an Ethiopian desert site of a nearly complete, 3.8-million-year-old *Australopithecus anamensis* skull is letting researchers reconstruct what the ancient individual looked like and its relationship to Lucy's species.

A large *A. anamensis* group might have become isolated from its species-mates and then evolved into an early version of *A. afarensis*, Haile-Selassie speculates. In that case, other *A. anamensis* groups would have coexisted for a while with Lucy's species.

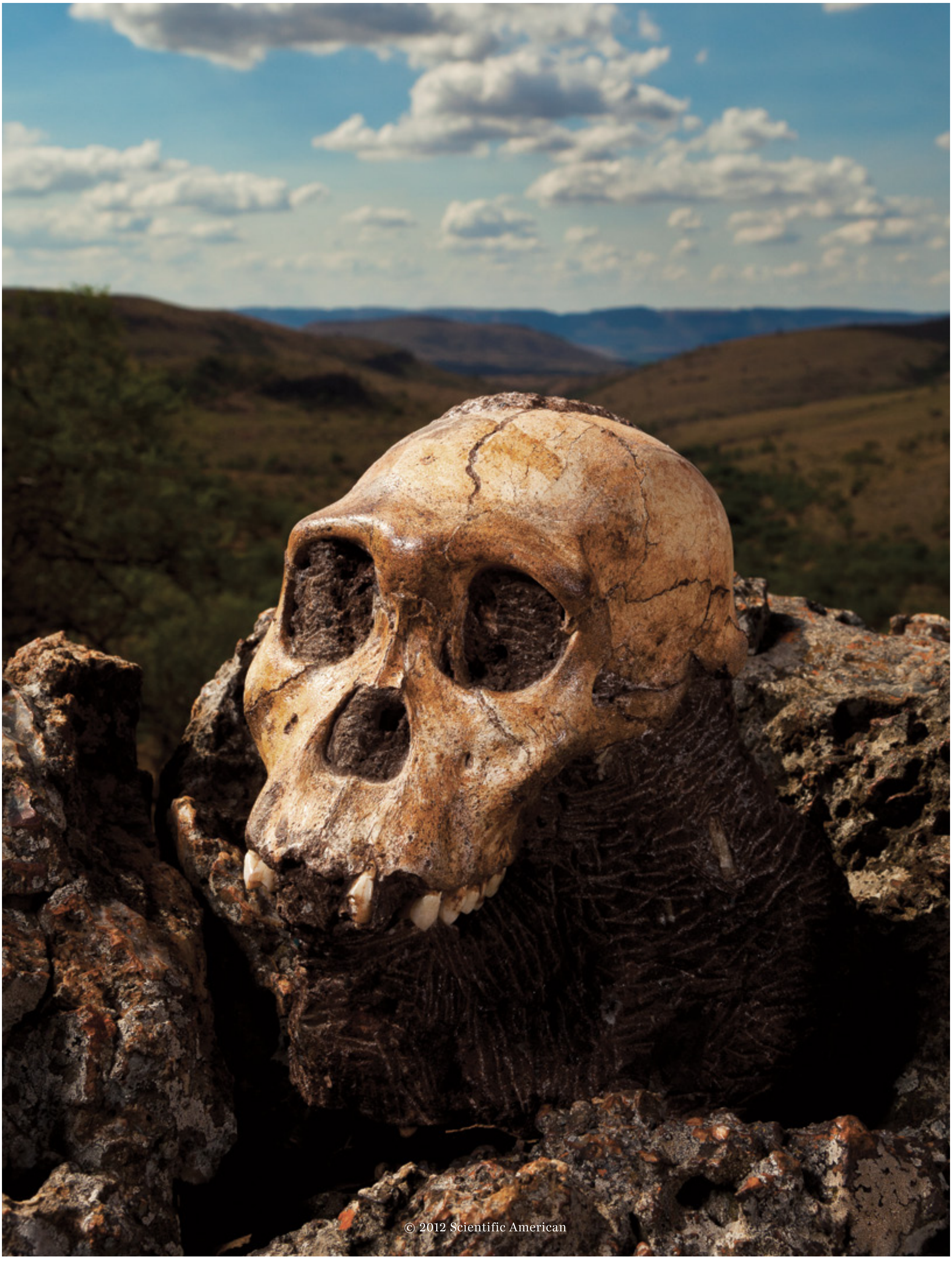
While the newly discovered skull "fills a critical gap in *Australopithecus* evolution," the evolutionary status of the Belohdelie frontal remains unknown, says paleoanthropologist William Kimbel of Arizona State University's Institute of Human Origins in Tempe. More *A. anamensis* skulls are needed to assess whether the Belohdelie frontal displays traits more typical of that species or of Lucy's kind, Kimbel says.

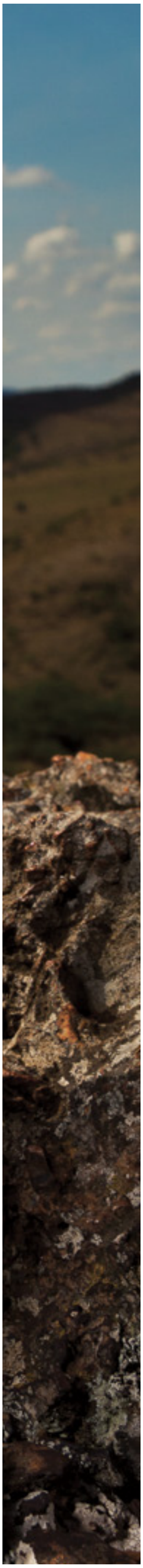
Paleoanthropologist Berhane Asfaw of Rift Valley Research Service in Addis Ababa, Ethiopia, agrees. Asfaw described the Belohdelie frontal in a 1987 paper. Frontal bone shapes vary considerably in Lucy's species, which includes four partial skulls, he says. "And we don't know what kind of face the Belohdelie frontal had."

In all its largely intact glory, the Woranso-Mille skull highlights how little is known about the relationship between *A. anamensis* and Lucy's kind, Ward says.

14/06 | Aula 4: As descobertas em Malapa, na África do Sul, de uma nova espécie: *Australopithecus sediba*. Suas características, volume cerebral, discussão sobre sua linhagem. Nova descoberta na África do Sul, o *Homo naledi*. Seus traços arcaicos e traços modernos. A surpreendente datação do *H. naledi*. As descobertas dos fósseis humanos mais antigos fora da África, na República da Geórgia. Os crânios de 1,75 milhão de anos de Dmanisi e a enorme diversidade morfológica apresentada.

Textos para leitura:
First of Our Kind | Kate Wong
Mystery Human | Kate Wong
Newest Member of Human Family is Surprisingly Young | Ann Gibbons
Meet the Frail, Small-Brained People Who First Trekked Out of Africa | Ann Gibbons
Our Ancestors May Have Left Africa Hundreds of Thousands of Years Earlier than Thought | Ann Gibbons





BRENT STIRTON *Getty Images*

HUMAN EVOLUTION

First of Our Kind

Sensational fossils from South Africa spark debate over how we came to be human

By Kate Wong

IN BRIEF

The origin of our genus, *Homo,* is one of the biggest mysteries facing scholars of human evolution.

Based on the meager evidence available, scientists have surmised that *Homo* arose in East Africa, with Lucy's species, *Australopithecus afarensis,* giving rise to the founding member of our lineage, *Homo habilis.*

Recently discovered fossils from a site northwest of Johannesburg, South Africa, could upend that scenario. The fossils represent a previously unknown species of human with an amalgam of australopithecine and *Homo* traits that suggest to its discoverers that it could be the ancestor of *Homo.*

NEW HUMAN SPECIES from South Africa—*Australopithecus sediba*—has been held up as the ancestor of our genus, *Homo.*

SOMETIME BETWEEN THREE MILLION AND TWO million years ago, perhaps on a primeval savanna in Africa, our ancestors became recognizably human. For more than a million years their australopithecine predecessors—Lucy and her kind, who walked upright like us yet still possessed the stubby legs, tree-climbing hands and small brains of their ape forebears—had thrived in and around the continent's forests and woodlands. But their world was changing. Shifting climate favored the spread of open grasslands, and the early australopithecines gave rise to new lineages. One of these offshoots evolved long legs, toolmaking hands and an enormous brain. This was our genus, *Homo,* the primate that would rule the planet.

For decades paleoanthropologists have combed remote corners of Africa on hand and knee for fossils of *Homo*'s earliest representatives, seeking to understand the details of how our genus rose to prominence. Their efforts have brought only modest gains—a jawbone here, a handful of teeth there. Most of the recovered fossils instead belong to either ancestral australopithecines or later members of *Homo*—creatures too advanced to illuminate the order in which our distinctive traits arose or the selective pressures that fostered their emergence. Specimens older than two million years with multiple skeletal elements preserved that could reveal how the *Homo* body plan came together eluded discovery. Scientists' best guess is that the transition occurred in East Africa, where the oldest fossils attributed to *Homo* have turned up, and that *Homo*'s hallmark characteristics allowed it to incorporate more meat into its diet—a rich source of calories in an environment where fruits and nuts had become scarce. But with so little evidence to go on, the origin of our genus has remained as mysterious as ever.

Lee Berger thinks he has found a big piece of the puzzle. A paleoanthropologist at the University of the Witwatersrand in Johannesburg, South Africa, he recently discovered a trove of fossils that he and his team believe could revolutionize researchers' understanding of *Homo*'s roots. In the white-walled confines of room 210 at the university's Institute for Human Evolution, he watches as Bernard Wood of George Washington University paces in front of the four plastic cases that have been removed from their fireproof safe and placed on a table clothed in royal blue velvet. The foam-lined cases are open, revealing the nearly two-million-year-old fossils inside. One holds pelvis and leg bones. Another contains ribs and vertebrae. A third displays arm bones and a clavicle. And a fourth houses a skull. On a counter opposite the table, more cases hold a second partial skeleton, including a nearly complete hand.

Wood, a highly influential figure in the field, pauses in front of the skull and leans in for a closer look. He strokes his beard as he considers the dainty teeth, the grapefruit-size braincase. Straightening back up, he shakes his head. "I'm not often at a loss for words," he says slowly, almost as if to himself, "but wow. Just wow."

Berger grins. He has seen this reaction before. Since he unveiled the finds in 2010, scientists from all over the world have been flocking to his lab to gawk at the breathtaking fossils. Based on the unique anatomical package the skeletons present, Berger and his team assigned the remains to a new species, *Australopithecus sediba*. They furthermore propose that the combination of primitive *Australopithecus* traits and advanced *Homo* traits evident in the bones qualifies the species for a privileged place on the family tree: as the ancestor of *Homo*. The stakes are high. If Berger is right, paleoanthropologists will have to completely rethink where, when and how *Homo* got its start—and what it means to be human in the first place.

THE ROAD NOT TAKEN

IN THE MIDDLE of the rock-strewn dirt road that winds through the John Nash Nature Reserve, Berger brings the Jeep to a halt and points to a smaller road that branches right. For 17 years he had made the 40-kilometer trip northwest from Johannesburg to the 9,000-hectare parcel of privately owned wilderness and driven past this turnoff, continuing along the main road, past the resident giraffes and warthogs and wildebeests, to a cave he was excavating just a few kilometers away called Gladysvale. In 1948 American paleontologists Frank Peabody and Charles Camp came to this area to look for fossils of hominins (modern humans and their extinct relatives) on the advice of famed South African paleontologist Robert Broom, who had found such fossils in the caves of Sterkfontein and Swartkrans, eight kilometers away. Peabody suspected that Broom had intentionally sent them on a wild goose chase, so unimpressed was he with the sites here. Little did Berger or the expeditioners before him know that had they only followed this smaller path—one of

1

2

3

LEE BERGER (*left*) and Meshack Kgasi (*right*) inspect the miners' pit at the Malapa site, where Berger discovered *Australopithecus sediba* (*1*). Blocks of concretelike calcified clastic sediment dislodged by miners will be CT-scanned to see if they contain fossils (*2*). View captures the valleys in and around the Malapa area, northwest of Johannesburg in South Africa (*3*).

BRENT STIRTON *Getty Images*

several miners' tracks used in the early 1900s to cart the limestone that built Johannesburg from quarries out to the main road—they would have made the discovery of a lifetime.

Berger, now 46 years old, never imagined he would find something like *A. sediba*. Although he thought *Homo* might have had roots in South Africa instead of East Africa, he knew the odds of making a big find were slim. Hominin fossils are extremely rare, so "you don't have any expectations," he reflects. What is more, he was focused on the so-called Cradle of Humankind, an already intensively explored region whose caves had long been yielding australopithecines generally considered to be more distantly related to *Homo* than the East African australopithecines seemed to be. And so Berger continued to toil at Gladysvale day after day, year after year. Because he found little in the way of hominins among the millions of animal fossils there—just scraps of a species called *A. africanus*—he busied himself with another goal: dating the site. A critical problem with interpreting the South African hominin fossils was that scientists had not yet figured out how to reliably determine how old they were. In East Africa, hominin fossils come from sediments sandwiched between layers of volcanic ash that blanketed the landscape during long-ago eruptions. Geologists can ascertain how old an ash layer is by analyzing its chemical "fingerprint." A fossil that originates from a layer of sediment that sits in between two volcanic ashes is thus intermediate in age between those two ashes. The cave sites in the Cradle of Humankind lack volcanic ashes. Through his 17 years of trial and error at Gladysvale, however, Berger and his colleagues hit on techniques that circumvented the problem of not having ash to work with.

Those techniques would soon come in very handy. On August 1, 2008, while surveying the reserve for potential new fossil sites in the area that he had identified using Google Earth, Berger turned right on the miners' track he had passed by for 17 years and followed it to a three- by four-meter hole in the ground blasted by the miners. Eyeballing the site, he found a handful of animal fossils—enough to warrant a trip back for a closer look. He returned on August 15 with his then nine-year-old son, Matthew, and dog, Tau. Matthew took off into the bush after Tau, and within minutes he shouted to his father that he had found a fossil. Berger doubted it was anything important—probably just an antelope bone—but in a show of fatherly support, he made his way over to inspect the find. There, protruding from a dark hunk of rock nestled in the tall grass by the corpse of a lightning-struck tree, was the tip of a collarbone.

As soon as Berger laid eyes on it, he knew it belonged to a hominin. In the months that followed he found more of the clavicle's owner, along with another partial skeleton, 20 meters away in the miners' pit. To date, Berger and his team have recovered more than 220 bones of *A. sediba* from the site—more than all the known early *Homo* bones combined. He christened the site *Malapa,* meaning "homestead" in the local Sesotho language. Using the approaches honed at Gladysvale, the geologists on Berger's team would later date the remains with remarkable precision to 1.977 million years ago, give or take 2,000 years.

A PATCHWORK PREDECESSOR

THAT THE MALAPA FOSSILS include so many body parts is important because it means they can offer unique insights into the order in which key *Homo* traits appeared. And what they show very clearly is that quintessentially human features did not necessarily evolve as a package deal, as was thought. Take the pelvis and the brain, for example. Conventional wisdom holds that the broad, flat pelvis of australopithecines evolved into the bowl-shaped pelvis seen in the bigger-brained *Homo* to allow delivery of babies with larger heads. Yet *A. sediba* has a *Homo*-like pelvis with a broad birth canal in conjunction with a teeny brain—just 420 cubic centimeters, a third of the size of our own brain. This combination shows brain expansion was not driving the metamorphosis of the pelvis in *A. sediba*'s lineage.

Not only do the *A. sediba* fossils mingle old and new versions of general features, such as brain size and pelvis shape, but the pattern repeats at deeper levels, like an evolutionary fractal. Analysis of the interior of the young male's braincase shows that the brain, while small, possessed an expanded frontal region, indicating an advanced reorganization of gray matter; the adult female's upper limb pairs a long arm—a primitive holdover from a tree-dwelling ancestor—with short, straight fingers adapted to making and using tools (although the muscle markings on the bones attest to powerful, apelike grasping capabilities). In some instances, the juxtaposition of old and new is so improbable that had the bones not been found joined together, researchers would have interpreted them as belonging to entirely different creatures. The foot, for instance, combines a heel bone like an ancient ape's with an anklebone like *Homo*'s, according to Malapa team member Bernard Zipfel of the University of the Witwatersrand. It is as if evolution was playing Mr. Potato Head, as Berger puts it.

The extreme mosaicism evident in *A. sediba,* Berger says, should be a lesson to paleoanthropologists. Had he found any number of its bones in isolation, he would have classified them differently. Based on the pelvis, he could have called it *H. erectus.* The arm alone suggests an ape. The anklebone is a match for a modern human's. And like the blind men studying the individual parts of the elephant, he would have been wrong. "*Sediba* shows that one can no longer assign isolated bones to a genus," Berger asserts. That means, in his view, finds such as a 2.3-million-year-old upper jaw from Hadar, Ethiopia, that has been held up as the earliest trace of *Homo* cannot safely be assumed to have belonged to the *Homo* line.

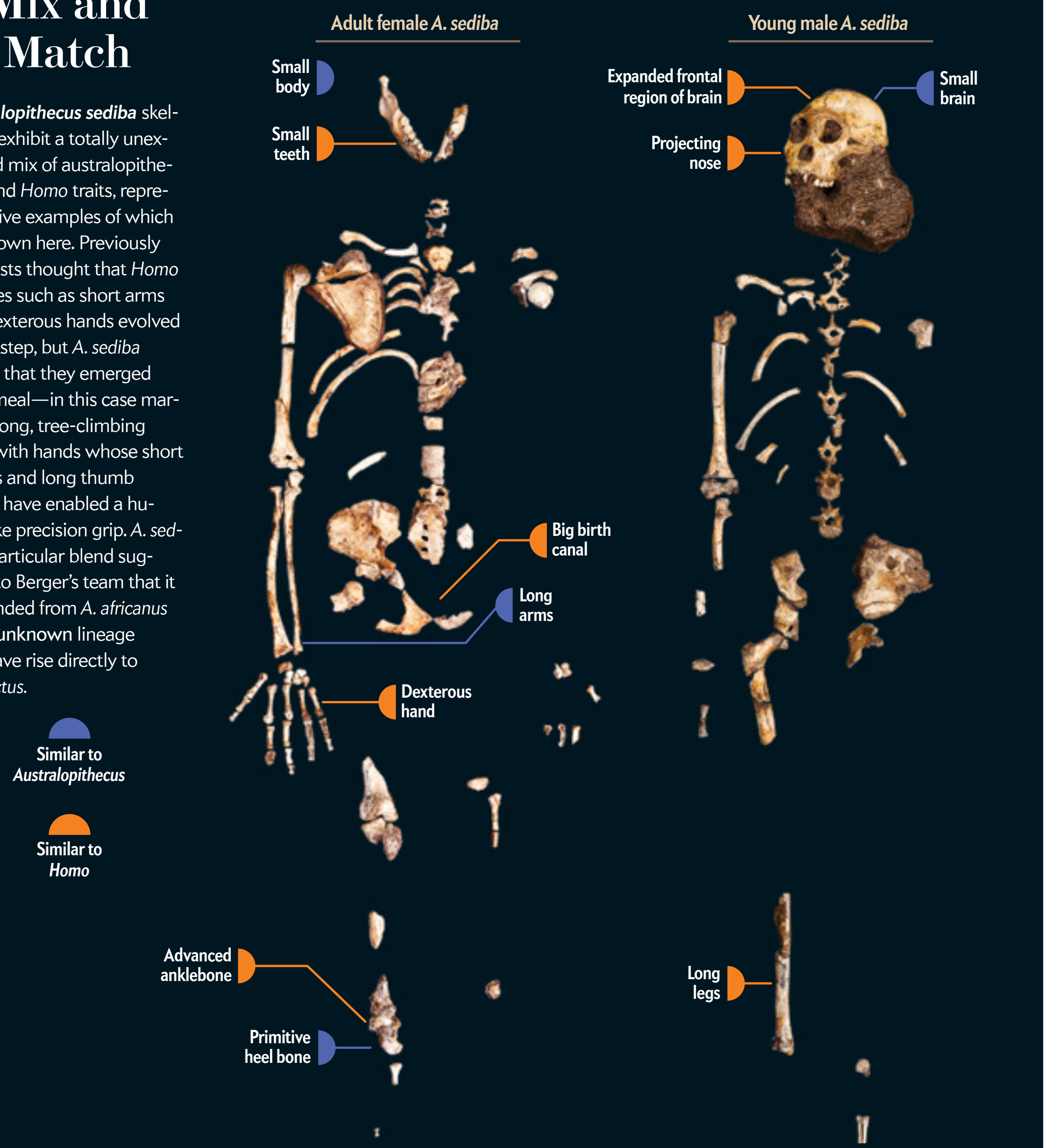
Taking that jaw out of the running would make *A. sediba* older than any of the well-dated *Homo* fossils but still younger than *A. afarensis,* putting it in pole position for the immediate ancestor of the genus, Berger's team contends. Furthermore, considering *A. sediba*'s advanced features, the researchers propose that it could be specifically ancestral to *H. erectus* (a portion of which is considered by some to be a different species called *H. ergaster*). Thus, instead of the traditional view in which *A. afarensis* begat *H. habilis,* which begat *H. erectus,* he submits that *A. africanus* is the likely ancestor of *A. sediba,* which then spawned *H. erectus.*

If so, that arrangement would relegate *H. habilis* to a dead-end side branch of the human family tree. It might even kick *A. afarensis*—long considered the ancestor of all later hominins, including *A. africanus* and *Homo*—to the evolutionary curb, too. Berger points out that *A. sediba*'s heel is more primitive than that of *A. afarensis,* indicating that *A. sediba* either underwent an evolutionary reversal toward a more primitive heel or that it descended from a different lineage than the one that includes *A. afarensis* and *A. africanus*—one that has yet to be discovered.

"In the South, we have a saying: 'You dance with the girl you

Mix and Match

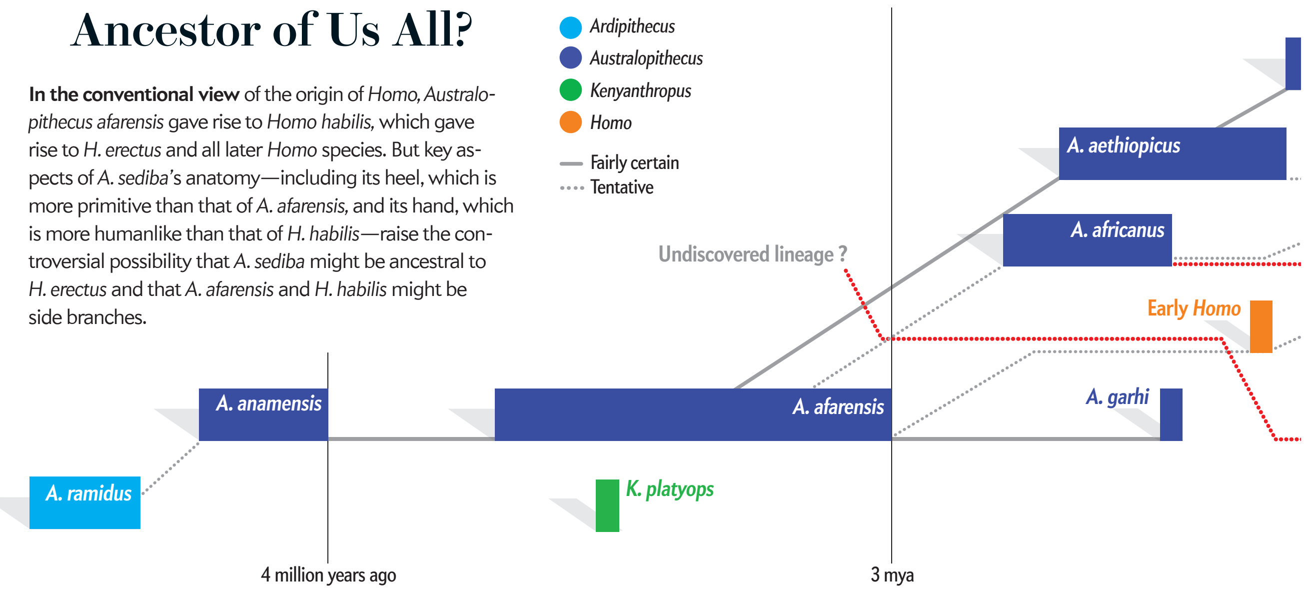
Australopithecus sediba skeletons exhibit a totally unexpected mix of australopithecine and *Homo* traits, representative examples of which are shown here. Previously scientists thought that *Homo* features such as short arms and dexterous hands evolved in lockstep, but *A. sediba* shows that they emerged piecemeal—in this case marrying long, tree-climbing arms with hands whose short fingers and long thumb would have enabled a humanlike precision grip. *A. sediba*'s particular blend suggests to Berger's team that it descended from *A. africanus* or an unknown lineage and gave rise directly to *H. erectus.*



BRENT STIRTON *Getty Images*

Ancestor of Us All?

In the conventional view of the origin of *Homo, Australopithecus afarensis* gave rise to *Homo habilis,* which gave rise to *H. erectus* and all later *Homo* species. But key aspects of *A. sediba*'s anatomy—including its heel, which is more primitive than that of *A. afarensis,* and its hand, which is more humanlike than that of *H. habilis*—raise the controversial possibility that *A. sediba* might be ancestral to *H. erectus* and that *A. afarensis* and *H. habilis* might be side branches.



brought,' " quips Berger, who grew up on a farm in Sylvania, Ga. "And that is what paleoanthropologists have been doing" in trying to piece together the origin of *Homo* from the fossils that have turned up in East Africa. "Now we have to recognize there is more potential out there," he states. Maybe the East Side story of human origins is wrong. The traditional view of South Africa's oldest hominin fossils is that they represent a separate evolutionary experiment that ultimately fizzled out. *A. sediba* could turn the tables and reveal, in South Africa, another lineage, the one that ultimately gave rise to humankind as we know it (indeed, *sediba* is the Sesotho word for "fountain" or "wellspring").

William Kimbel of Arizona State University, who led the team that found the 2.3-million-year-old jawbone in Ethiopia, is having none of it. The idea that one needs a skeleton to classify a specimen is a "nonsensical argument," he retorts. The key is to find pieces of anatomy that contain diagnostic traits, he says, and the Hadar jaw has features clearly linking it to *Homo,* such as the parabolic shape formed by its tooth rows. Kimbel, who has seen the Malapa fossils but not studied them in depth, finds their *Homo*-like traits intriguing, although he is not sure what to make of them. He scoffs at the suggestion that they are directly ancestral to *H. erectus,* however. "I don't see how a taxon with a few characteristics that look like *Homo* in South Africa can be the ancestor [of *Homo*] when there's something in East Africa that is clearly *Homo* 300,000 years earlier," he declares, referring to the jaw.

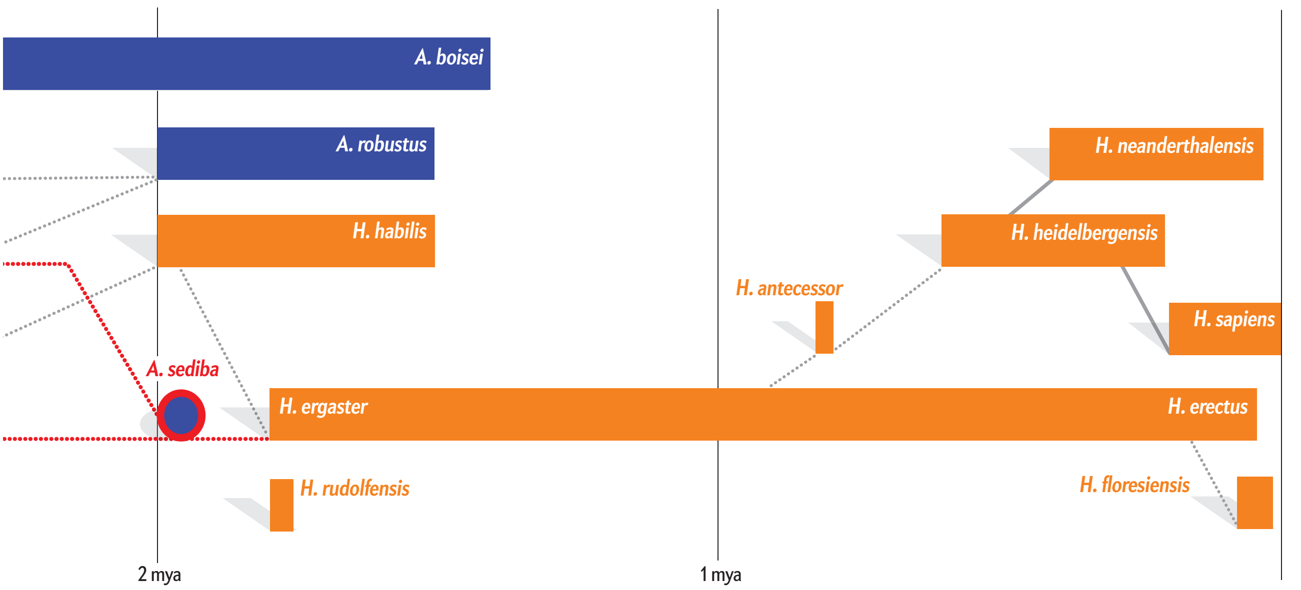
Kimbel is not alone in rejecting the argument for *A. sediba* as the rootstock of *Homo*. "There are too many things that do not fit, particularly the dates and geography," comments Meave Leakey of the Turkana Basin Institute in Kenya, whose own research has focused on fossils from East Africa. "It is much more likely that the South African hominins are a separate radiation that took place in the south of the continent."

René Bobe of George Washington University says that if the *A. sediba* remains were older—say, around 2.5 million years old—they might make for a plausible *Homo* ancestor. But at 1.977 million years old, they are just too primitive in their overall form to be ancestral to fossils from Kenya's Lake Turkana region that are just a tad younger yet have many more indisputable *Homo* traits. Berger counters that *A. sediba* almost certainly existed as a species before the Malapa individuals. Bobe and others maintain that such information is not currently known. "Paleoanthropologists tend to think of the fossils they find as being in a key position within the [hominin] phylogenetic tree, and in many cases that's unlikely to be the situation," Bobe observes. From a statistical standpoint, "if you have [hominin] populations distributed across Africa, evolving in complex ways, why would the one you find be the ancestor?"

Berger has found a sympathetic ear in Wood, who says Berger is "absolutely right" that *A. sediba* demonstrates that isolated bones do not predict what the rest of the animal looks like. *A. sediba* shows that the combinations of traits evident from previous fossil discoveries do not exhaust the possibilities, Wood remarks. But he does not endorse the suggestion that *A. sediba* is the ancestor of *Homo*. "There are not many characters linking it to *Homo,*" he notes, and *A. sediba* may have evolved those traits independently from the *Homo* lineage. "I just think *sediba* has got too much to do in order to evolve into [*erectus*]," Wood says.

Resolution of the issue of where *A. sediba* belongs in our family tree is hampered by the lack of a clear definition of the genus *Homo*. Coming up with one, however, is a taller order than it might seem. With so few specimens from the transition period, and most of them being scraps, identifying those features that first distinguished *Homo* from its australopithecine forebears—those traits that made us truly human—has proved challenging. The skeletons from Malapa expose just how vexing the situation is: they are so much more complete than any early *Homo* specimen that it is very difficult to compare them with anything. "*Sediba* may force us to come up with a definition," Berger says.

Graphic by Jen Christiansen



ALL IN THE DETAILS

WHATEVER THE POSITION of the Malapa fossils in the family tree, they are poised to provide researchers with the most detailed portrait yet of an early hominin species, in part because they make up multiple individuals. In addition to the juvenile male and the adult female, the two most complete specimens, Berger's team has collected bones representing another four individuals, including a baby. Populations are incredibly rare in the human fossil record, and the individuals at Malapa have the added benefit of peerless preservation. Hominin bones that virtually never survive the ravages of deep time have turned up here: a paper-thin shoulder blade, the delicate sliver that is the first rib, pea-size finger bones, vertebrae with spiny projections intact. And a number of bones that were previously known only from fragments are complete. Before the discovery of Malapa, paleoanthropologists did not have a single complete arm from an early hominin, meaning that the limb lengths that are used to reconstruct such essential behaviors as locomotion are estimates. Even Lucy—the most complete hominin of such antiquity back when she was found in 1974—is missing significant chunks of her arm and leg bones. In the adult female from Malapa, in contrast, virtually the entire upper limb is preserved—from shoulder blade to hand. Only the very last digits of some of her fingers and some wristbones are missing, and Berger expects to find those—and the rest of the bones of both skeletons when he excavates the site (thus far the team has only collected bones visible from the surface, rather than systematically digging for buried material). From this evidence, researchers will be able to reconstruct how *A. sediba* matured, how it moved around the landscape and how members of the population varied from one another, among other things.

It is not only the bones that promise to tell new tales. Malapa has also yielded some other materials that could literally flesh out researchers' understanding of *A. sediba*. Paleontologists have long thought that during the fossilization process, all of an organism's organic components—such as skin, hair, organs, and so forth—are lost to decomposition, leaving behind only mineralized bone. But when Berger saw a CT scan of the skull of the young male, he noticed a place on the crown where there appeared to be an air space between the surface of the fossil and the contour of the actual bone. Examining the spot more closely, he observed a distinctive pattern on the surface that looked like the structural components of skin. He is now conducting extensive tests to determine whether the odd-looking patch on the male's crown and another on the female's chin—and similar patches on antelope bones from the site—are in fact skin.

Preserved skin, if confirmed as such, could reveal *A. sediba*'s coloring and the density and patterning of its hair. Such evidence could also show the distribution of sweat glands—information that would provide insights into how well the species was able to regulate its body temperature, which in turn would have affected how active it was. Sweat glands could additionally offer clues to brain evolution: an effective means of keeping cool was a prerequisite for the emergence of large brain size—a trademark characteristic of *Homo*—because brains are temperature-sensitive. And if organic material is present, Berger might even be able to obtain DNA from the remains. Currently the oldest hominin DNA to have been sequenced is 100,000-year-old DNA from a Neandertal. But because the preservation conditions at Malapa were apparently exceptional, Berger has some hope of getting genetic information from the much older *A. sediba* specimens. In that event, scientists might be able to determine whether the adult female and young male really were mother and son, as has been suggested, and how, if at all, the other hominins at the site fit in. Moreover, such a discovery would prompt researchers at other early hominin sites to test for DNA, which, if successful, could settle debates over how the various hominin species were related.

SYNCHROTRON X-RAY SCANNING of the skull of the young male *A. sediba* enabled detailed reconstruction of the brain (*pink*), which exhibits advanced reorganization in the frontal lobes despite being little larger than a chimpanzee's brain.

COURTESY OF PAUL TAFFOREAU ESRF

Preservation of organic remains would be a first in hominin paleontology, and the Malapa team knows it will need extraordinary evidence to persuade the research community of such a claim. Thus far, however, the test results support the hypothesis, and Berger thinks the odds are very good that future analyses will bear it out. After all, similar claims have been made for organic material from dinosaur bones, and those are tens of millions of years older than the Malapa fossils. Organic preservation in hominin assemblages might even be fairly common, he suggests—it is just that no one ever thought to look for it.

Another thing no one thought to look for in a hominin this old? Tartar. The surfaces of the young male's molar teeth bear dark brown stains. Fossil preparators typically clean off the teeth when readying hominin remains for study. But it occurred to Berger that the stains might actually be the same gunk we modern humans fend off with toothbrushes and pilgrimages to the dentist. Ancient tartar would provide valuable insights into the evolution of the hominin diet.

Previous studies of what early humans ate have looked at carbon isotope ratios in teeth, which can indicate whether an animal dined on so-called C3 plants, such as trees and shrubs, or C4 plants, such as certain grasses and sedges—or, in the case of carnivorous species, preyed on animals that ate those plant foods—or some combination thereof over its lifetime. Such evidence is indirect and nonspecific. Tartar, in contrast, is the remnants of the food itself. The team is currently studying tiny silica crystals called phytoliths that are embedded in the tartar. Phytoliths come from plants, and some plants make species-specific forms of the crystals. Studies of these phytoliths can thus reveal exactly which kinds of plants an animal ate just before it died. By analyzing the isotope ratios, phytoliths and wear marks on *A. sediba*'s teeth that can signal whether an animal was chewing harder or softer foods in the weeks before it perished, the team should be able to glean a wealth of subsistence data. And because the researchers have bones from *A. sediba* individuals across a range of developmental stages, they might even be able to figure out what babies ate versus adult fare, for instance.

In a review paper published in *Science* last October, Peter S. Ungar of the University of Arkansas and Matt Sponheimer of the University of Colorado at Boulder observed that recent analyses have hinted at unexpected diversity and complexity in the diets of our predecessors. Whereas *Ardipithecus ramidus,* one of the earliest putative hominins, dined primarily on C3 foods, as savanna chimpanzees do, other early African hominins appear to have eaten a mix of C3 and C4 foods. One species, *Paranthropus robustus,* even ate a mostly C4 diet, as Thure Cerling of the University of Utah and his colleagues reported last June in the *Proceedings of the National Academy of Sciences USA*. Scientists will no doubt be eager to see where on the dietary spectrum *A. sediba* falls and how that picture fits with emerging clues about the paleoenvironment at Malapa, which appears to have included an abundance of grasses and trees. Perhaps the dietary evidence will shine a light on how *A. sediba* was using that dexterous hand, with its apparent adaptations to tool use—and, by the same token, whether it used its long, apelike arms to forage in the trees.

END OF DAYS

THE FINAL DAYS of the Malapa hominins appear to have been grim ones. Possible drought conditions may have made water hard to come by. Berger suspects that the hominins, desperate for a drink, may have tried to climb down into the then 30- to 50-meter-deep underground cavern at Malapa to access a shallow pool of freshwater and, in so doing, tumbled to their deaths. Perhaps the boy fell in first, and the adult female—maybe his mother—tried to rescue him only to fall in herself. A menagerie of other beasts, from antelopes to zebras, met the same fate, becoming entombed alongside the hominins for posterity.

Intriguingly, geologic evidence from the site indicates that the fossil assemblage at Malapa formed right around the same time that the earth was undergoing a geomagnetic reversal—a mysterious event in which the planet's polarity flips and magnetic north becomes magnetic south. The timing raises the question of whether the reversal somehow played a role in the demise of these creatures.

Scientists know very little about why reversals occur and whether they precipitate environmental change. Some geologists have suggested that these events could conceivably wreak ecological havoc—by compromising the magnetic field that shields organisms from deadly radiation, for example, or by confusing the internal navigation systems of migratory birds and other animals that use the earth's magnetic field to orient themselves. As one of the only places in the world that has a terrestrial record of a reversal and a collection of fossils from the same time, Malapa could offer rare insights into what happens when the planet's poles trade places.

Other evidence might throw additional light on their deaths. The fossilized bones of a pregnant antelope and her fetus from Malapa could help scientists pinpoint the time of year that the hominins died to within a couple weeks: antelopes give birth within a very narrow interval in the spring, and analysis of the fetus should allow researchers to figure out how far along the antelope was before she died. Meanwhile traces of maggots and carrion beetles that set on the hominins after death could reveal how long the bodies were exposed before the cave's flowing sediments buried them.

In a sense, the work on *A. sediba* has only just begun. "You're walking all over hominin fossils," Berger tells visitors to Malapa on an austral spring morning in late November. They are standing on the rocky ground between the tree where Matthew found the clavicle and the mining pit where Berger found its owner. Climbing down into the pit, he points onlookers to bits of fossils peeking out of the rock and awaiting collection. The awestruck guests crane to glimpse an infant's arm bone, the lower jaw of a false saber-toothed cat, the area that appears to contain the rest of the young male's skeleton. Just by gathering remains exposed by the miners and the occasional rainstorm, the team has amassed one of the largest fossil hominin samples on record. Once the researchers begin excavating the roughly 500-square-meter site, Berger knows they will find more bones—many more. Extensive planning is under way to erect a structure to protect the site from the elements and serve as a state-of-the-art field laboratory for when they begin the formal excavation later this year, which will probe beyond the miners' leavings into the undisturbed parts of the deposit. Meanwhile, in the Malapa block lab at the University of the Witwatersrand, chunks of rock blasted from the miners' pit fill floor-to-ceiling shelves. Researchers will peer into the rocks with a CT scanner to look for hominin bones, including the adult female's missing skull.

So vast are Malapa's riches that Berger could probably spend the rest of his career working on them. Yet already he is thinking about where he wants to go next. *A. sediba* "has taught me that we really need a better record—and it's out there," he warrants. The mapping project that led Berger to Malapa identified more than three dozen new fossil sites in the Cradle alone that could potentially harbor hominin remains. He is lining up researchers to dig the most promising of those spots. Berger himself has his sights set farther afield. The Congo and Angola, among other places, have cave formations similar to the ones in the Cradle and have never been searched for hominin fossils, he observes. Perhaps there, in paleoanthropological terra incognita, he will find another unexpected emissary from the dawn of humankind that will rewrite the story of our origins once again. SA

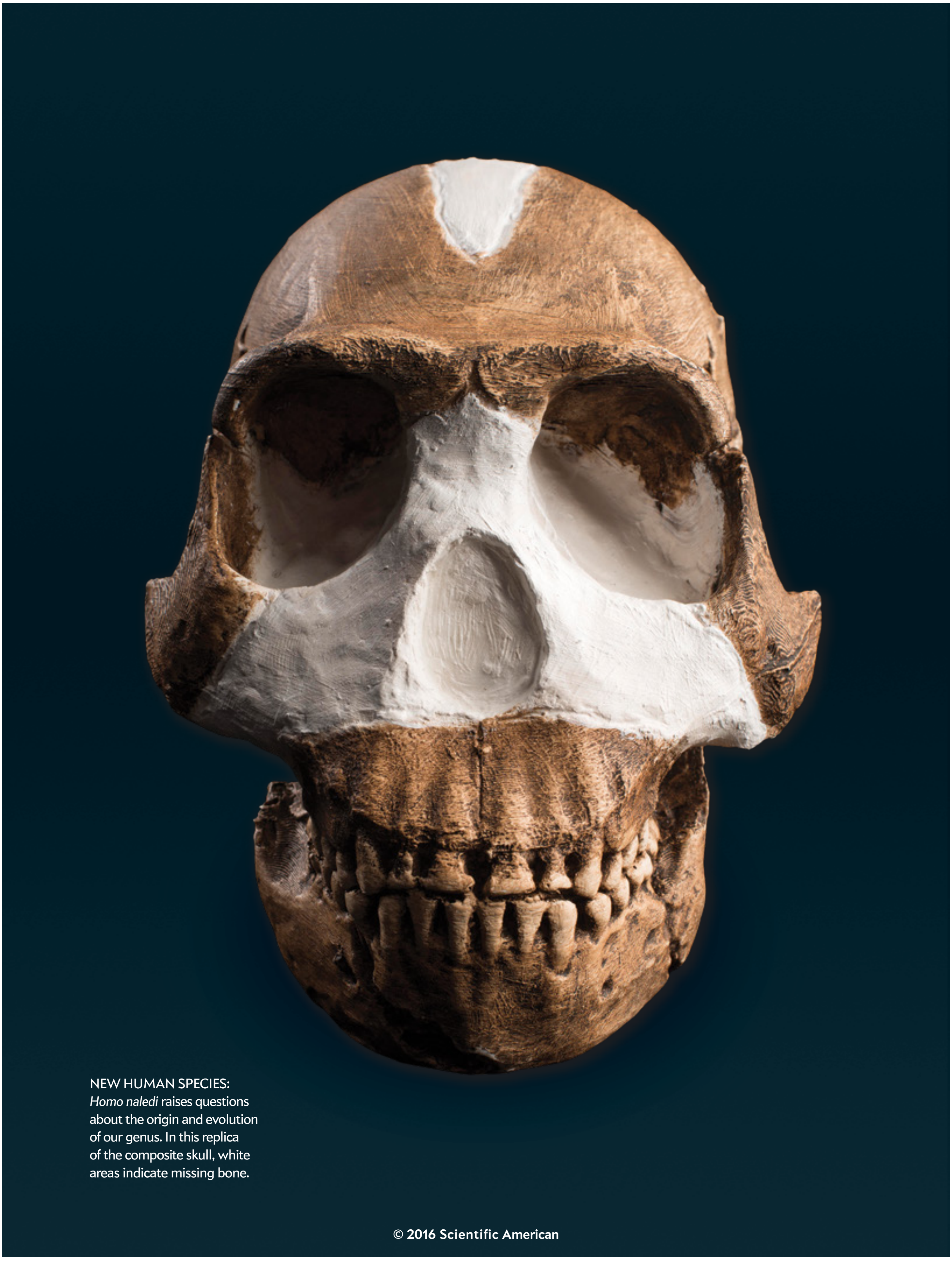
Kate Wong *is a senior editor at* Scientific American.

MORE TO EXPLORE

Australopithecus sediba: A New Species of *Homo*-like Australopith from South Africa. Lee R. Berger et al. in *Science,* Vol. 328, pages 195–204; April 9, 2010.

The September 9, 2011, issue of *Science* contains five research papers on details of *A. sediba*'s anatomy and age.

SCIENTIFIC AMERICAN ONLINE
View photographs and video of *A. sediba* at ScientificAmerican.com/apr2012/sediba



NEW HUMAN SPECIES: *Homo naledi* raises questions about the origin and evolution of our genus. In this replica of the composite skull, white areas indicate missing bone.

EVOLUTION

MYSTERY HUMAN

An astonishing trove of fossils has scientists, and the media, in a tizzy over our origins

By Kate Wong

IN BRIEF

In 2013 cavers discovered a trove of enigmatic fossils deep inside an underground cave system known as Rising Star near Johannesburg, South Africa.

Over the course of two expeditions scientists recovered more than 1,550 specimens belonging to at least 15 individuals from the site.

Last September researchers unveiled the discovery to great fanfare, announcing that the bones represent a new species, *Homo naledi*, that calls into question long-standing ideas about the rise of *Homo*.

Critics have raised concerns about the recovery and analysis of the fossils.

Kate Wong is a senior editor at *Scientific American.*

IN THE BRAND-NEW FOSSIL VAULT at the University of the Witwatersrand, Johannesburg, in South Africa, shelf space is already running out. The glass-doored cabinets lining the room brim with bones of early human relatives found over the past 92 years in the many caves of the famed Cradle of Humankind region, just 40 kilometers northwest of here. The country's store of extinct humans has long ranked among the most extensive collections in the world. But recently its holdings doubled with the discovery of hundreds of specimens in a cave system known as Rising Star. According to paleoanthropologist Lee Berger and his colleagues, who unearthed and analyzed the remains, they represent a new species of human—*Homo naledi,* for "star" in the local Sotho language—that could overturn some deeply entrenched ideas about the origin and evolution of our genus, *Homo.*

HOLE IN THE GROUND: Fossils of *Homo naledi* were found in a cave in South Africa's Cradle of Humankind.

Berger is camera-ready in a brown leather blazer and set to give his spiel to the dozen or so journalists, including me, gathered around him in the vault in late 2015. He directs the visitors' attention to the six black carrying cases—originally made to hold assault rifles—arrayed on tables around the room. Each contains a dizzying assortment of fossils nestled in its foam-lined interior. In the cabinets along the back wall, more *H. naledi* bones fill dozens of clear plastic containers labeled "cranial fragments," "pelvis," "radius." Berger reaches into case number two, which holds the crown jewels of the Rising Star assemblage—the group of bones that defines the species—and lifts out an upper jaw and a lower jaw. He carefully holds them one atop the other and displays the matched pair with a practiced flourish so that everyone gets a good look. The crowd murmurs appreciatively, pens scribble, camera shutters click, flashes pop. And he glides on to the next specimen, fielding questions, posing for photographs and encouraging the visitors to snap selfies with the vault's celebrity charges.

Just a few decades ago the sum total of fossils belonging to our extinct human relatives, also called hominins, could fit in a desk drawer. Those destitute days are long gone. Scientists have since amassed more evidence of the evolutionary history of the human family than of many other animal groups, including our closest living relatives, the great apes. As a result, they now know, for example, that humanity's roots reach back at least seven million years and that for much of that time our ancestors shared the planet with other hominins.

Yet they still have much to learn. Some chapters of the human story are completely unknown from the fossil record; others have been drafted on the basis of evidence so scanty that they are little more than speculation. And so even though the fossil record of humans is vastly bigger than it once was, it is still imperfect enough that new discoveries often alter scientists' understanding of the details of humanity's past—sometimes significantly so.

The Rising Star fossils are the latest to rock the paleoanthropology establishment. Berger and his team argue that *H. naledi* could illuminate the long-sought roots of *Homo* and revamp the human family tree. What is more, the researchers suggest, this creature, which had a brain the size of an orange, engaged in ritual behavior previously attributed exclusively to much brainier hominins—a finding that could upend the prevailing wisdom linking cognitive sophistication to large brain size.

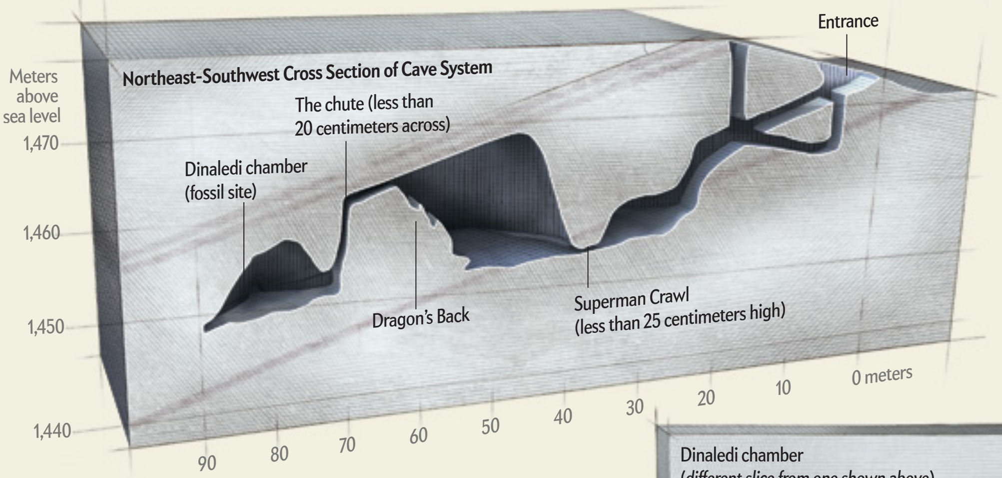
Some critics have dismissed these claims outright. Others have greeted them with uncharacteristic reticence. One major stumbling point for many is that the age of the bones is unknown. They could be more than four million years old or less than 100,000 years old. The lack of a date is not the only concern weighing on outside observers, however. The way the fossils were unearthed, analyzed and revealed to the rest of the world has vexed some of the field's leading scholars, who charge that Berger and his colleagues rushed the job and prioritized publicity over

PRECEDING PAGES: ISTOCKPHOTO (*pushpins*); COURTESY OF JOHN HAWKS *University of Wisconsin–Madison* AND UNIVERSITY OF THE WITWATERSRAND (*all other photographs*)

LOCATION

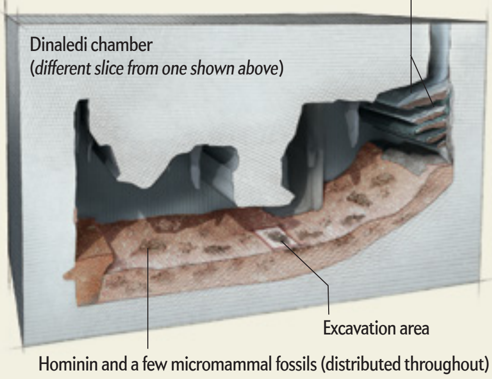
Chamber of Bones

Cavers discovered the fossils of the new human species *Homo naledi* in an underground cave known as Rising Star, just outside Johannesburg, South Africa (*right*). The bones come from the so-called Dinaledi chamber, which sits 30 meters below the surface. To reach it, excavators had to undertake steep climbs and squeeze through tight passages (*below*). *H. naledi* may have taken similar pains to get there: researchers think it may have been intentionally disposing of its dead in the chamber (*inset*), and although geologists are still working to understand how the cave evolved over time, they have yet to identify other plausible routes into the chamber.



Strange Circumstances

An apparent absence of large animal species other than *H. naledi* in the chamber is one of the clues that led the discovery team to hypothesize that the hominins were disposed of there as part of a mortuary custom, as opposed to, say, getting washed in during a flood or dragged in by a hungry carnivore. When the bodies were placed there is unknown, however. Scientists can often estimate the age of hominin remains by looking to associated bones of animal species that are known to have lived during a particular interval or by dating the surrounding rock. Rising Star not only lacks such animal remains, but the nearby flowstone is contaminated with clay, making it difficult to date.



SOURCE: "GEOLOGICAL AND TAPHONOMIC CONTEXT FOR THE NEW HOMININ SPECIES *HOMO NALEDI* FROM THE DINALEDI CHAMBER, SOUTH AFRICA," BY PAUL H.G.M. DIRKS ET AL., IN ELIFE, ARTICLE NO. 09561; PUBLISHED ONLINE SEPTEMBER 10, 2015

science. In a field known for its fierce rivalries, heated debate over new finds is the norm. But there is more on the line in the row over the Rising Star remains than a few egos. How scientists respond to this discovery in the longer term could set a new course in the quest for human origins, changing not only the questions they ask but the ways in which they attempt to answer them.

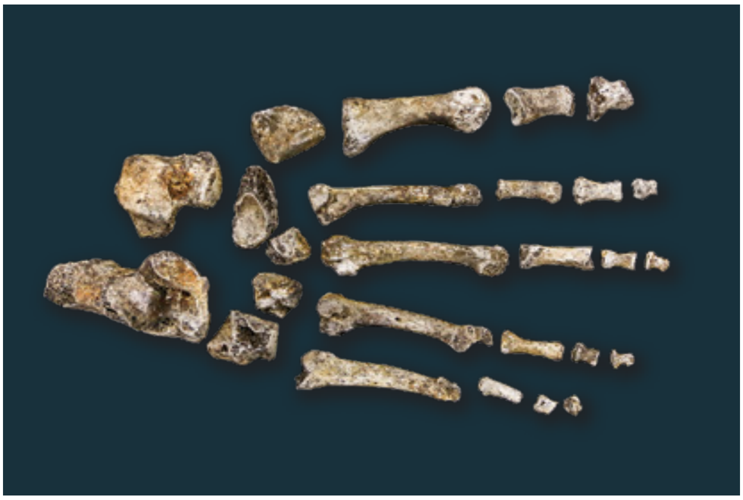
CHAMBER OF SECRETS

IN A WAY, it was a set of grainy photographs shown to Berger on October 1, 2013, that sparked this spectacle. Berger had hired geologist Pedro Boshoff to search the Cradle for new hominin sites. Over the years miners and fossil hunters had combed the region many times over. But Berger had good reason to think there was more to find. Five years earlier his then nine-year-old son had stumbled across bones of a previously unknown member of the human family, *Australopithecus sediba,* right in the middle of the Cradle.

Now Boshoff and local cavers Rick Hunter and Steven Tucker had found what appeared to be human bones littering the floor of an extremely difficult-to-reach chamber 30 meters down in the Rising Star cave system, just a few kilometers from the spot where Berger and his son had found *A. sediba*. The explorers had not collected any of the material, but they had taken pictures. As soon as Berger saw them, he knew the bones were important. They had features that clearly differed from those of anatomically modern humans—*Homo sapiens*. And there were lots of them, enough to represent a skeleton.

Berger immediately began making plans to recover the remains. There was a problem, though. He was not going to be able to collect them himself. The route from the cave entrance to the chamber that held the bones contained passages far too narrow to accommodate Berger's broad frame or that of most of his scientist colleagues for that matter. Widening these passages would disrupt the integrity of the cave and possibly damage the bones—

Illustration by José Miguel Mayo



a nonstarter, as far as he was concerned. So he put out a call on Facebook for skinny scientists who had experience caving and excavating old remains and who could come to Johannesburg on short notice to mount an expedition in exchange for little more than a plane ticket and the promise of adventure.

Five weeks after Boshoff showed him the tantalizing photographs, Berger had selected his team of excavators—all women, coincidentally—to carry out the difficult, dangerous work of recovering the bones from the chamber, as well as a crew to support the team's efforts; he developed a protocol for collecting the material and documenting exactly where in the chamber each piece of bone came from; and he established a group of senior scientists to oversee the excavation via closed-circuit television and to identify, log and store the specimens as they came out. He also had a plan for how to publicize the endeavor—a full-bore media blitz, carried out in partnership with *National Geographic* and *NOVA,* that would include live tweets and daily blogs, radio interviews and video clips posted from the field, as well as a TV documentary that would air at a later date, after the remains were eventually published. On November 10, cameras rolling, the excavators crawled, climbed and wriggled their way into the pitch-dark chamber and began the recovery effort.

Marina Elliott was the first scientist to enter the chamber. "I didn't know what to expect, but I was excited," she recalls when I accompany her to the Rising Star site. It is high noon on a bright, hot austral summer's day, and outside the cave the wind carries the sound of cars whizzing past on the nearby freeway. But inside the cave it is dim and cool and hushed—the stillness of age. A shaft of light from a natural opening in the ground above bathes the craggy interior, giving it the air of a place of worship.

The serenity of this part of the cave belies the danger farther in, however. Elliott shines her flashlight down one of the corridors, illuminating a perforated curtain of limestone. Behind that wall lies the first of the squeeze points on the route into the fossil chamber, she explains—the Superman Crawl, a tunnel that the women had to negotiate belly to ground and one arm outstretched. The journey did not get easier from there. The jagged Dragon's Back loomed ahead, followed by a 12-meter-long, vertical chute less than 20 centimeters (eight inches) across that opened into the chamber of bones.

But their efforts were richly rewarded. There were bones everywhere—much more than the single skeleton Berger had expected to salvage. Over the next 21 days Elliott and her colleagues hauled out 1,200 specimens. A second, shorter expedition in March 2014 yielded several hundred more. In total, the team recovered more than 1,550 bones and bone fragments of at least 15 individuals—including infants, tweens, young adults and old-timers—from an area the size of a card table. All told it is one of the largest single assemblages of hominin fossils ever found. And the team only scratched the surface. More bones, possibly thousands more, remain in the chamber.

A STAR IS BORN

WITH SAFE AFTER SAFE stuffed with hominin fossils, Berger and his colleagues now faced the daunting prospect of assessing them. Even before the researchers began their formal assessment, while the bones were still coming out of the ground, the find had an air of mystery about it. For one thing, the bones appeared to have a weird combination of primitive and modern traits. For another, no animal remains apart from those of a few small birds and rodents had turned up in the chamber along with the hominin bones. Larger animals such as monkeys, antelopes and hyenas, almost always accompany hominin fossils, particularly those found in underground caves. The absence of such species at Rising Star demanded explanation.

Berger recruited an army of 35 early-career researchers to help describe the fossils over the course of a monthlong workshop in Johannesburg in May 2014. For most of these people—many still working on their Ph.D.s—it was a rare opportunity to work on new fossils, as opposed to studying material that had already been characterized by other, more seasoned scientists. They worked in groups organized by body part: skull, hand, teeth, spine, hip, leg, foot, and so forth.

When they pooled their findings, a startling picture emerged of a tall, slender hominin with upper limbs built for climbing and using tools, lower limbs built for upright striding and a tee-

HEAD TO TOE: Vast Rising Star fossil assemblage includes rare foot bones (*far left*) and multiple leg bones (*near left*). Though fragmentary, the fossils are beautifully preserved and can in some instances be attributed to the same individual, as is the case for the lower jaw and skull fragments above.

ny brain. It is "a really, really strange creature," Berger says.

On a Friday afternoon in December, senior team member John Hawks of the University of Wisconsin–Madison takes me back to the vault to point out some of the salient aspects of the Rising Star remains. The rest of his colleagues are still outside enjoying beer and barbecue at the department holiday party, but Hawks is in his element here among the bones. He bustles around the room, setting the fossil cases out on the tables and selecting replicas of other hominin specimens from the vault's vast collection for comparison.

The skull alone is a mishmash of traits associated with various hominin species. It would have held a brain measuring just 450 to 550 cubic centimeters—as small as that of primitive *Australopithecus afarensis,* best known from the 3.2-million-year-old Lucy skeleton, found in 1974 in Ethiopia. Yet the shape of the skull evokes the more humanlike *Homo erectus*. The teeth resemble those of *Homo habilis,* one of the most primitive members of our genus, in the way they increase in size from the front of the tooth row to the back. But overall the teeth are small, and the molars have simple crowns with fewer, lower cusps—traits associated with later *Homo*.

The bones below the head echo the mix-and-match theme. The upper limb pairs a shoulder and fingers adapted to climbing with a wrist and palm built for manipulating stone tools—an activity that was not thought to become important to hominins until after they had abandoned life in the trees and evolved large, inventive brains. And the lower limb marries a Lucy-like hip joint to a foot that is virtually indistinguishable from our own. Researchers have been operating under the assumption that the signature features of *Homo*—such as a toolmaking hand, big brain and small teeth—evolved in concert. "*Sediba* and *naledi* show that things we thought we evolved together did not," Hawks asserts.

This unprecedented combination of primitive and modern features is not the only distinctive thing about *H. naledi*. The fossils also have traits never before seen in a member of the human family. Hawks plucks one of the finger bones out of its foam cutout. It is the first metacarpal, the bone in the palm that sits below the thumb, and when he displays it next to the same bone from *H. sapiens,* the difference is stark. The shaft of its first metacarpal is smooth, thick and broad for its entire length. *H. naledi*'s, in contrast, is narrow at the base and broad at the top, with a sharp crest running along its shaft and thin wings of bone on the sides. The femur bears unique traits, too, as do other elements.

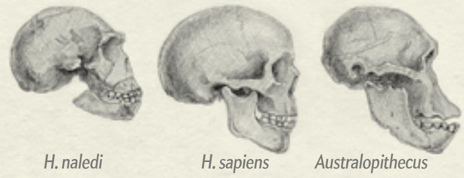
To Berger and his colleagues, the novel combination of australopithecine and *Homo* characteristics, along with the presence of unique traits, easily justified assigning the Rising Star fossils to a new hominin species. Although the researchers have yet to establish the age of the fossils, in their paper announcing the find, published last September in the online open-access journal eLife, they proposed that, given its primitive features compared with early *Homo* species such as *H. habilis* and *H. erectus, H. naledi* might be older than two million years and stem from the base of the genus *Homo*. If so, the discovery would be a major coup: the origin of *Homo* is arguably the biggest unsolved mystery in all of human evolution because fossils transitional between the australopithecines, with their many apelike traits, and later *Homo,* with its modern body plan, are exceedingly rare and mostly scraps. Scientists have been eager to elucidate which hominin species founded the *Homo* branch of the hominin family tree and how the traits in the modern human body plan evolved with new discoveries.

Berger's team did not stop at saying the find could bear on the origin of *Homo,* however. It argued that the unexpected mix of traits evident in *H. naledi* implies that isolated fragments cannot be used to understand the evolutionary relationships of fossil humans, because the part cannot predict the whole—fighting words to those researchers who have interpreted isolated bones as the earliest evidence of the *Homo* lineage.

Perhaps even more provocative than the team's ideas about what *H. naledi* means for understanding hominin relationships

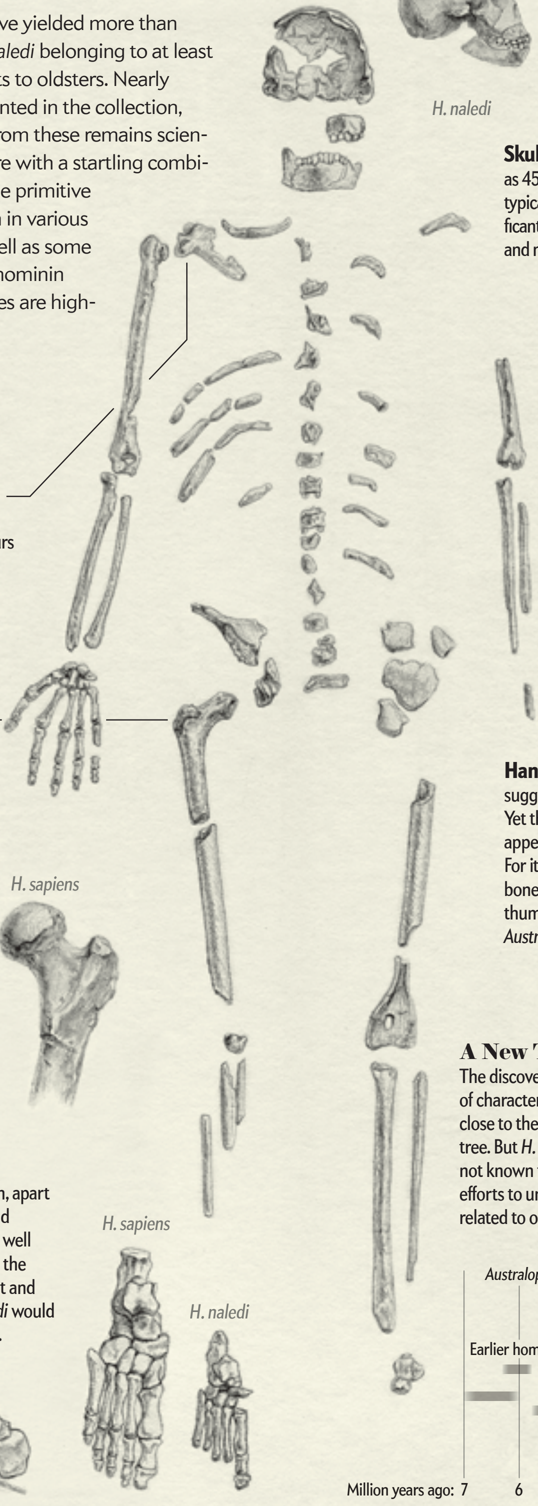
A Novel Mix

The excavations at Rising Star have yielded more than 1,550 fossil specimens of *Homo naledi* belonging to at least 15 individuals ranging from infants to oldsters. Nearly every bone in the body is represented in the collection, many of them more than once. From these remains scientists have reconstructed a creature with a startling combination of traits associated with the primitive australopithecines and traits seen in various species in our genus, *Homo,* as well as some traits not known from any other hominin species. Examples of these features are highlighted in the diagram below.

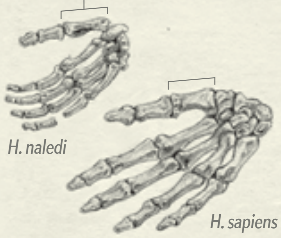


Skull of *H. naledi* housed a brain as small as 450 cubic centimeters—a size that is typical for australopithecines but significantly smaller than the brains of *H. sapiens* and most other members of *Homo.*

Teeth are primitive in the way they increase in size from front to back. Overall they are small, and the molars have comparatively simple cusps—both traits of later *Homo* species.

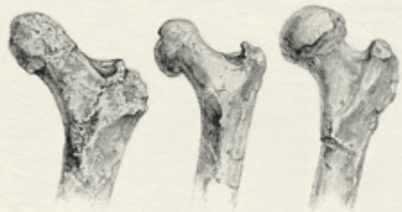


Shoulder socket faces up like an ape's or australopithecine's rather than out to the side like ours does. This upward orientation is an adaptation to climbing trees.

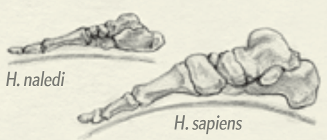


Hand has strongly curved fingers, suggesting that *H. naledi* climbed in trees. Yet the wrist and palm look modern and appear to be adapted to manipulating tools. For its part *H. naledi's* first metacarpal, the bone in the palm below the lowermost thumb bone, looks neither *Homo*-like nor *Australopithecus*-like and is utterly unique.

Femur has a small head and long neck compared with the large head and small neck seen in the *Homo sapiens* femur. These features suggest that *H. naledi's* hip worked like an australopithecine's.



Foot is remarkably like our own, apart from the slightly curved toes and somewhat lower arch, and thus well adapted to upright striding. But the combination of this modern foot and the primitive hip means *H. naledi* would have walked differently from us.



A New Twig in Our Tree

The discovery team argues that *H. naledi's* particular mix of characteristics suggests that the species originated close to the origin of *Homo*—a coveted spot in the family tree. But *H. naledi* preserves parts of the anatomy that are not known for other early *Homo* species, complicating efforts to understand how these extinct hominins are related to one another—and to us.

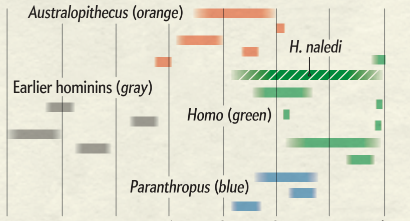


Illustration by Portia Sloan Rollings, Graphic by Jen Christiansen is how it interpreted *H. naledi*'s behavior. In their attempts to figure out how the hominins ended up in the chamber, the researchers considered a number of mechanisms known to account for hominin accumulations at other sites, including the possibility that their bones had washed into the cave system during a flood or that large carnivores had dragged them there to eat. Yet the available evidence did not match any of those explanations. Floodwaters, for instance, would have surely carried the remains of other animals into the chamber, too. And carnivores would have left behind telltale tooth marks on the bones. All things considered, the team concluded, the likeliest explanation was that *H. naledi* had intentionally deposited the bodies in the chamber.

The hominins would have had to go to considerable lengths to do so. Although the team geologists do not yet know exactly how the Rising Star cave system formed and changed over time, they have found only one entrance to the bone chamber—the one the excavators squeezed through to recover the fossils. If that was indeed the only entrance, then whoever disposed of the dead would have had to, at minimum, scale the 20-meter spine of the Dragon's Back to reach the opening of the chute that opens into the chamber. From there they could have either crawled down the chute with the bodies or just dumped them in and let them slide into the chamber below. And if the route into the chamber was always pitch-dark, as the team thinks it was, then the hominins may have required an artificial light source to find their way in. The suggestion was that tiny-brained *H. naledi* not only had a mortuary ritual but mastery of fire.

Ensconced in a leather club chair in the sitting area of his office, coffee mug in hand, Berger launches into a discussion of what the Rising Star find means for human evolution. It's 7:30 in the morning, but the blinds are drawn, and the lights are low. Between the animal hide rugs decorating the floor and the jazz warbling from a vintage-style turntable, the room feels more like a gentleman's hunting lodge than a work space. "There is no age at which [the find] is not disruptive," he exults. If it is old, then critical physical and behavioral traits may have emerged at the root of our genus or earlier, rather than in later *Homo*. Really old *H. naledi* could even oust the australopithecines from the line leading to us, according to Berger. If, on the other hand, the fossils are young, researchers are going to have to reconsider which species left behind the cultural remains at key archaeological sites across Africa.

It may be *H. naledi* originated millions of years ago and managed to persist across the ages unchanged, like a coelacanth, overlapping with other *Homo* species, including *H. sapiens,* for a time. Perhaps it invented some of the cultural traditions archaeologists have traditionally assumed originated with our kind, Berger says. Possibly *H. naledi* interbred with our ancestors and contributed DNA to the modern human gene pool, like Neandertals and Denisovans did.

CASTING ASPERSIONS

WHEN THE TEAM published its papers announcing the discovery in eLife last September, the world went wild for *H. naledi*. Seemingly every media outlet on the planet covered the find. Even the *Onion* joined the bandwagon, running a doctored image of a lachrymal Berger with a story entitled "Tearful Anthropologists Discover Dead Ancestor of Humans 100,000 Years Too Late." Yet underneath that tidal wave of public enthusiasm runs a current of discontent among some of paleoanthropology's elite. No one disputes that the find is important—a cave full of human fossils is extraordinary—but the team's approach to recovering, describing and interpreting the bones has raised eyebrows.

Berger is no stranger to side eye from his academic peers. Telegenic and silver-tongued, he hooked up with *National Geographic* early in his career. The relationship brought research funding, bylines and television appearances. Yet he had found few fossils, and his scientific papers and popular writings met with accusations of sloppy scholarship and grandstanding from some of paleoanthropology's most respected figures, including Tim White of the University of California, Berkeley, and Bernard Wood of George Washington University.

Berger's discovery of *A. sediba* in 2008 raised his scientific profile. Even his harshest critics conceded that the find, which included two largely complete skeletons dated to 1.98 million years ago, was spectacular. But many did not agree with his interpretation of it. Berger had long contended that South Africa was being overlooked in favor of East Africa in the search for *Homo*'s origin. *A. sediba,* with its mosaic of australopithecine and *Homo* traits, seemed to offer a means of potentially rooting *Homo* in South Africa. The problem was that the oldest fossils attributed to *Homo* were East African specimens older than *A. sediba*. Berger argued that fossil fragments like the ones from East Africa that were being held up as the earliest *Homo* could no longer be assigned to one taxon or another because his skeletons, with their surprising combination of traits, showed the whole was not inferable from the part. His peers largely rejected that claim.

With *H. naledi,* Berger doubled down on the public outreach and on those controversial ideas about *Homo*'s origin and fragmentary fossils. It did not take critics long to loose their arrows. White told his university's alumni association magazine, *California,* that the Rising Star fossils looked like primitive *H. erectus,* not a new species. White is best known for his discoveries of hominin fossils in Ethiopia, including those of 2.4-million-year-old *Australopithecus garhi,* which he and Berhane Asfaw of the Rift Valley Research Service and their colleagues said were from the right time and place to be ancestral to *Homo*. He further accused the Rising Star team of damaging fossils during excavation and rushing its findings to publication. Later, in a scathing blog post for the *Guardian,* White warned of the dangers of mixing science and showmanship. "We are witnessing portions of science collapsing into the entertainment industry," he wrote.

White is not the only one with concerns. Carol Ward of the University of Missouri cautions that although the quantity of fossils is stunning, their significance remains unknown. She emphasizes the importance of determining the age of the bones: "When we know how old they are, then we can tell you what they mean for human evolution but not until then."

Ward also has misgivings about the paper describing the fossils, noting that it did not include sufficient data about how they compare with other relevant fossils for outside scientists to be able to evaluate many of the team's claims. Nor did the paper contain a phylogenetic analysis—basically a study in which a computer program compares traits across a group of organisms and thereby reconstructs the members' evolutionary relationships—which could reveal where *H. naledi* fits in the human family tree. "There seems to be a great desire [on the part of the authors] for it to be related to the origins of *Homo,*" she observes, but in the absence of a detailed phylogeny or a date, no one can know if it is.

Many researchers stand by the thinking that, based on present evidence, *Homo* debuted in East Africa. Last March, months before the details of *H. naledi* were released, Brian Villmoare of the University of Nevada, Las Vegas, Kaye Reed of Arizona State University and their colleagues announced their discovery of a 2.8-million-year-old piece of lower jaw from the site of Ledi-Geraru in northeastern Ethiopia that they say is the earliest known representative of our genus. The jaw has clear hallmarks of *Homo,* they observe, as well as traits transitional between *Australopithecus* and *Homo*. Without a date, the *H. naledi* fossils cannot unseat the Ledi-Geraru jaw as the oldest evidence of our lineage, in Reed's view, nor does she accept the argument made by Berger, Hawks and their colleagues, that isolated fragments of anatomy cannot be reliably assigned to one taxonomic group or another. "I have a good date at 2.8, and there are features of *Homo,*" she maintains.

GETTING A GRIP: Hand of *H. naledi* is the most complete one known for an extinct human species.

Part of the reason paleoanthropologists disagree on which fossils herald the dawn of *Homo* is that they are divided over what constitutes *Homo* in the first place. *H. naledi* "highlights an ongoing debate about how to define *Homo,* both for things we have pieces of and things we have more of," comments Susan Antón of New York University, an expert on early members of our genus. Sorting *Homo* from *Australopithecus* is "a very messy thing for everyone right now, and different people have different philosophies about how to make that distinction." She and her collaborators have been defining it on the basis of traits found in the cranium, jaws and teeth. Others have argued that the distinction between the two has to be based on the bones below the head—the postcrania, as they are termed—because they reflect the major adaptive changes hominins underwent as they transitioned from wooded environments to open ones. But those postcranial bones are largely unknown for early *Homo* species. The Rising Star fossils are "an embarrassment of riches," Antón remarks. But the mosaic of traits gives mixed signals, and Berger's team did not explicitly state how it defines *Homo* and why. "We have a lot more talking to do," she says of the field.

Yet even if the Rising Star remains do constitute a new *Homo* species and even if they turn out to be more than two million years old, those facts alone may not be enough to sway the skeptics toward the notion that *H. naledi* was on or near the line leading to us. George Washington University's Wood suspects that the bones represent a relic population that might have evolved its odd traits in relative isolation. "South Africa is a cul-de-sac at the bottom of the African continent," he says. "My guess is gene exchange in this cul-de-sac was probably not as common as it was in East Africa, where you have a lot more potential for homogenization, with genes coming in from southern and central Africa." Wood points to another weird species of *Homo*—the small-brained, small-bodied *Homo floresiensis* that persisted on the island of Flores in Indonesia long after *H. sapiens* originated in Africa—as another example of such a relic population.

The suggestion that small-brained *H. naledi* was ritually disposing of its dead has likewise met with resistance. "It would be quite radical," says archaeologist Alison Brooks of George Washington University. The practice is widely thought to be exclusive to the much larger-brained anatomically modern humans and possibly Neandertals and only became commonplace after 100,000 years ago. "I don't want to rule it out entirely that [the Rising Star researchers] are right," Brooks adds, "but I just think it is so far out there that they really need a higher standard of proof."

In fact, some of the discovery team members themselves struggled with the idea that *H. naledi* was deliberately disposing of its dead in that underground chamber, if only for logistical reasons. "It's hard to get in there with my backpack, never mind dragging a body," Elliott reflects. "But we spent two years trying to find an alternative and couldn't."

If *H. naledi* did in fact transport the dead to the chamber, its behavior need not necessarily reflect cognitive sophistication, however. Travis Pickering of the University of Wisconsin–Madison, who has worked in the Cradle of Humankind for the past 20 years, agrees that intentional disposal of the remains by other hominins is the most sensible explanation for how the bones got into the remote chamber. But "whether that means *Homo naledi* was a rather culturally advanced species with well-developed mortuary practices or simply an atavistic one that had the sense not to cohabit with rotting corpses is currently unanswerable," he comments.

EYE ON THE PRIZE

BERGER DISMISSES THE DETRACTORS, noting that they have made their comments strictly in the popular press and on social media, not in the rigorous forum of a scientific journal. "Their evidence stops at their mouths," he says. Staunchly defending the care with which the team excavated the fossils, he explained in a public post on Facebook that the damage on the bones was already there when Rising Star team members first arrived on the scene. Berger presumes it resulted from unknown amateur cavers who had explored the chamber before them and stepped on the bones. The excavators were able to work quickly, he says, because "we didn't have a lot of problems other teams have." At other sites, fossils are

SCIENTIFIC AMERICAN ONLINE Learn more about *Homo naledi* at ScientificAmerican.com/mar2016/naledi typically encased in rock. Excavation and cleaning of such fossils are typically extremely laborious and time-consuming. But at Rising Star the fossils were simply lying in damp earth that brushed away easily. And unlike other teams, which are small and conduct their research in distant locales six to eight weeks a year, Berger's is large and based in Johannesburg, so it can work at the site or in the vault any time. If you look at the Rising Star work in terms of person-hours logged in the time between discovery and publication, "it's as much as anyone else has done," he insists.

As for White's suggestion that the fossils belong to primitive *H. erectus,* not a new species, "he disagrees with everything except the ones he basically has named," Berger quips. Assigning the *naledi* remains to *H. erectus* would mean that *erectus* had more variation than is seen in our own species, which is improbable, in his view. More to the point, *H. naledi* has unique traits not seen in any other hominin. "If we're going to be evolutionary biologists, the argument stops there," Berger declares. "Frankly I'm surprised [people] aren't arguing that it's a new genus," rather than merely a new species.

Asked about dating the Rising Star fossils, Berger says the geologists are working on it and will get the timing down eventually. But he maintains that the date will not change their understanding of how *H. naledi* is related to other members of the human family. Although *H. naledi* has some key traits of *Homo,* the overall package is in some ways more primitive than that of *H. habilis* and, for that matter, that of the Ledi-Geraru jaw that currently holds the title of oldest *Homo* fossil. No matter what age the Rising Star fossils turn out to be, they imply that *H. naledi*'s branch of the family tree sprouted before these other branches did. If the fossils are young, then they represent a late population of this species.

Why, then, didn't the team include a phylogeny in the paper announcing the fossils as a new species? To figure out how organisms are related to one another, evolutionary biologists use a method called cladistics that sorts taxa into groups based on novel characteristics they share with their last common ancestor but not earlier ones. The catch is, the method works best when the characteristics are observable in all the organisms in question.

Where fossils are concerned, meeting that requirement is easier said than done because they vary widely in the traits they preserve. In paleoanthropology, researchers have tended to base their cladistic analyses on traits found in skulls and teeth; skulls because they vary widely in form in hominins and thus historically were thought to be particularly useful for defining species and teeth because they are the most common elements in the hominin fossil record. Bones from the rest of the skeleton are not always found in association with skulls or teeth, so it can be difficult to assign them to a species that is defined by cranial or dental remains. Moreover, a skeletal element that is known in one species is often missing in another.

Indeed, some of *H. naledi*'s key elements—including its nearly complete sets of hand and foot bones—are only partly represented in the fossil record of other *Homo* species, such as *H. erectus* and *H. habilis,* if they are even represented at all. Lacking corresponding parts with which to compare them, the researchers could not conduct a cladistic analysis of *H. naledi* that factored in its many postcranial traits of interest. With that course of comparison closed off to them, the researchers ran an analysis based on skull and dental traits. But some of the test results did not make logical sense, suggesting that *H. naledi,* with its many primitive traits, is more closely related to *H. sapiens* than to the much older *H. erectus*. To Berger, that finding underscores that trees based on data from one anatomical region, such as the head or teeth, are unreliable.

Berger remains certain that *H. naledi* will shake up scientists' understanding of human evolution one way or another. But he is not asking his peers to take his word for it. In a departure from the usual way of doing things in paleoanthropology, which has a reputation for secrecy where access to fossils is concerned, he instituted an explicit policy for the Rising Star remains that makes them available to any researcher who applies to see them. And on the day they published the eLife papers, the researchers released free three-dimensional scans of critical bones on MorphoSource, a digital repository for anatomical data, allowing visitors to print their own 3-D replicas of the specimens. The data resolution is not yet high enough for the purposes of carrying out original research, but "it's good enough to check what we're saying," Berger says.

"It's such an overwhelming positive that people are getting access; the complaints are just noise," observes David Strait of Washington University in St. Louis. He notes that in 2000, White wrote a prominent editorial in which he asserted that, given the intense public interest in human origins, paleoanthropologists have a special duty to get things right. "That's completely wrong," Strait asserts. "Of course, we should try to do things well, but science should operate by falsifying possibilities. We narrow down the possible truths to get a better idea of what happened in the past, and there is always the possibility for new data to emerge that change everyone's thinking." By making the fossils available to other researchers, Strait says, Berger has given those scientists who disagree with him an avenue to test their ideas against his: "The field moves forward only if people can study the stuff."

In the meantime, with or without the opposition's approval, work will continue apace at Rising Star. The geologists are busy reconstructing the history of the cave, the excavators are recovering more fossils from the chamber, the molecular biologists will attempt to extract DNA from the bones. And the fossil hunters are seeking new leads. "[*Homo naledi*] should launch the greatest age of exploration there ever was," Berger declares with characteristic zeal. If it doesn't, maybe the team's next find will: he reveals that his explorers have already made additional progress on that front. Pressed for more detail, Berger demurs, other than to say with a sly grin that they have located "more than one" new site that has set his heart to racing like Rising Star did when he first saw those grainy photographs. The show will go on. SA

MORE TO EXPLORE

***Homo naledi,* a New Species of the Genus *Homo* from the Dinaledi Chamber, South Africa.** Lee R. Berger et al. in eLife, Article No. 09560. Published online September 10, 2015.

Geological and Taphonomic Context for the New Hominin Species *Homo naledi* from the Dinaledi Chamber, South Africa. Paul H.G.M. Dirks et al. in eLife, Article No. 09561. Published online September 10, 2015.

FROM OUR ARCHIVES

First of Our Kind. Kate Wong; April 2012.

scientificamerican.com/magazine/sa

PALEOANTHROPOLOGY

Newest member of human family is surprisingly young

Archaic species may have coexisted with our ancestors

By **Ann Gibbons**

Just as a high-profile expedition to retrieve fossils of human ancestors from deep within a cave system in South Africa was getting underway in 2013, two spelunkers pulled aside paleoanthropologist Lee Berger. They had found what looked like an ancient thigh bone in a completely different cave. "Can we go get it?" they asked.

Berger was overseeing a team of 60 people, some of whom were 18 meters below ground gathering fossils. "This was day two. Lives were in danger. This was the beginning of my hair turning really white," says Berger, of the University of the Witwatersrand in Johannesburg, South Africa. "I said 'No, and don't tell anyone. I don't want anyone distracted.'"

But on the last day of the expedition, which retrieved 1500 fossils of a mysterious new species of hominin named *Homo naledi*, Berger gave the spelunkers the go-ahead. They came back with the thigh bone plus photos of a skull poking out of the dirt in a second chamber of the cave system. "I couldn't believe it," Berger says.

He and his team present the nearly complete new cranium plus 131 *H. naledi* fossils from the second cave in a series of papers in *eLife* this week. The new fossils reinforce a picture of a small-brained, small-bodied creature, which makes the dates reported in one paper all the more startling: 236,000 to 335,000 years ago. That means a creature reminiscent of much earlier human ancestors such as *H. habilis* lived at the same time as modern humans were emerging in Africa and Neandertals were evolving in Europe. "This is astonishingly young for a species that still displays primitive characteristics found in fossils about 2 million years old," says paleoanthropologist Chris Stringer of the Natural History Museum in London.

First announced in 2015, *H. naledi* was a puzzle from the start. Fossils from 15 individuals, including fragile parts of the face that are preserved in the new skull, show that the species combines primitive traits such as a small brain, flat midface, and curving fingers with more modern-looking features in its teeth, jaw, thumb, wrist, and foot. Berger's team put it in our genus, *Homo*.

But where it really fit in our family tree "hinged on the date," says paleoanthropologist William Kimbel of Arizona State University in Tempe. Dating cave specimens is notoriously difficult because debris falling from cave walls or ceilings can mix with sediments around a fossil and skew the dates. And these fossils likely were moved over time by rising and falling groundwater, so identifying the sediments where they were originally buried is a challenge, says geologist Paul Dirks of James Cook University in Townsville, Australia. He enlisted 19 other scientists and several labs to independently test samples using several methods. They dated cave formations deposited atop the fossils using a technique called optically stimulated luminescence, which provided a minimum age of 236,000 years for the fossils. The radioactive decay of uranium in three teeth of *H. naledi* provided a maximum age of 335,000 years.

Spelunkers found this ancient skull in a new cave system, giving *Homo naledi* a nearly complete face.

PHOTO: UNIVERSITY OF THE WITWATERSRAND/JOHN HAWKS

Geochronologist Warren Sharp of the Berkeley Geochronology Center in California cautions that the maximum age may be off if the team didn't accurately estimate how much uranium the teeth absorbed from groundwater over time. But Dirks points out that the results from several methods all point to fairly recent dates. "There is a little play in the upper limit, but it certainly isn't going to shift to 1 million years," he says.

National Geographic leaked the dates in a brief Q&A with Berger in April, but without presenting the evidence. Now that he has seen the scientific paper, geochemist Henry Schwarcz of McMaster University in Hamilton, Canada, calls the dating effort "an impressive tour de force."

The recent dates suggest that like the 60,000- to 100,000-year-old fossils of tiny *H. floresiensis* (the "Hobbit") found on an Indonesian island, *H. naledi* was a "twig off the mainstream of *Homo*—some little relic of a relatively archaic population," Kimbel says. It was "a lineage that existed for 1 million years or more and we missed it," says co-author John Hawks, a paleoanthropologist at the University of Wisconsin in Madison.

Researchers remain skeptical, however, of some of Berger's other claims, such as that *H. naledi* might have made Middle Stone Age tools found in the region. That would imply surprising sophistication for such a small-brained hominin. "Yes, that hand could make and use tools," says paleoanthropologist Bill Jungers of the State University of New York in Stony Brook. But he agrees with paleoanthropologist Rick Potts of the National Museum of Natural History in Washington, D.C., who says the idea is a nonstarter because no tools, fire, or other signs of culture have been found in association with any *H. naledi* fossils.

Ditto for the claim that *H. naledi* purposefully buried the bodies of its dead in both caves, or that it might have acquired some of its modern traits by mating with other early members of *Homo*. "It's just sheer speculation," Kimbel says.

Berger says the search for stone tools and other evidence to test whether *H. naledi* was capable of modern symbolic behavior is his top priority. "We're going after all these critical questions—is there fire in there, is there DNA?" he says. His team began new forays into the caves last week. ■

he ancient residents of Dmanisi had brains one-third to one-half the size of modern humans'. © KEN GARRETT

Meet the frail, small-brained people who first trekked out of Africa

By **Ann Gibbons** | Nov. 22, 2016 , 9:00 AM

On a promontory high above the sweeping grasslands of the Georgian steppe, a medieval church marks the spot where humans have come and gone along Silk Road trade routes for thousands of years. But 1.77 million years ago, this place was a crossroads for a different set of migrants. Among them were saber-toothed cats, Etruscan wolves, hyenas the size of lions—and early members of the human family.

Here, primitive hominins poked their tiny heads into animal dens to scavenge abandoned kills, fileting meat from the bones of mammoths and wolves with crude stone tools and eating it raw. They stalked deer as the animals drank from an ancient lake and gathered hackberries and nuts from chestnut and walnut trees lining nearby rivers. Sometimes the hominins themselves became the prey, as gnaw marks from big cats or hyenas on their fossilized limb bones now testify.

"Someone rang the dinner bell in gully one," says geologist Reid Ferring of the University of North Texas in Denton, part of an international team analyzing the site. "Humans and carnivores were eating each other."

> **What was it that allowed them to move out of Africa without fire, without very large brains? How did they survive?**
>
> *Donald Johanson, Arizona State University*

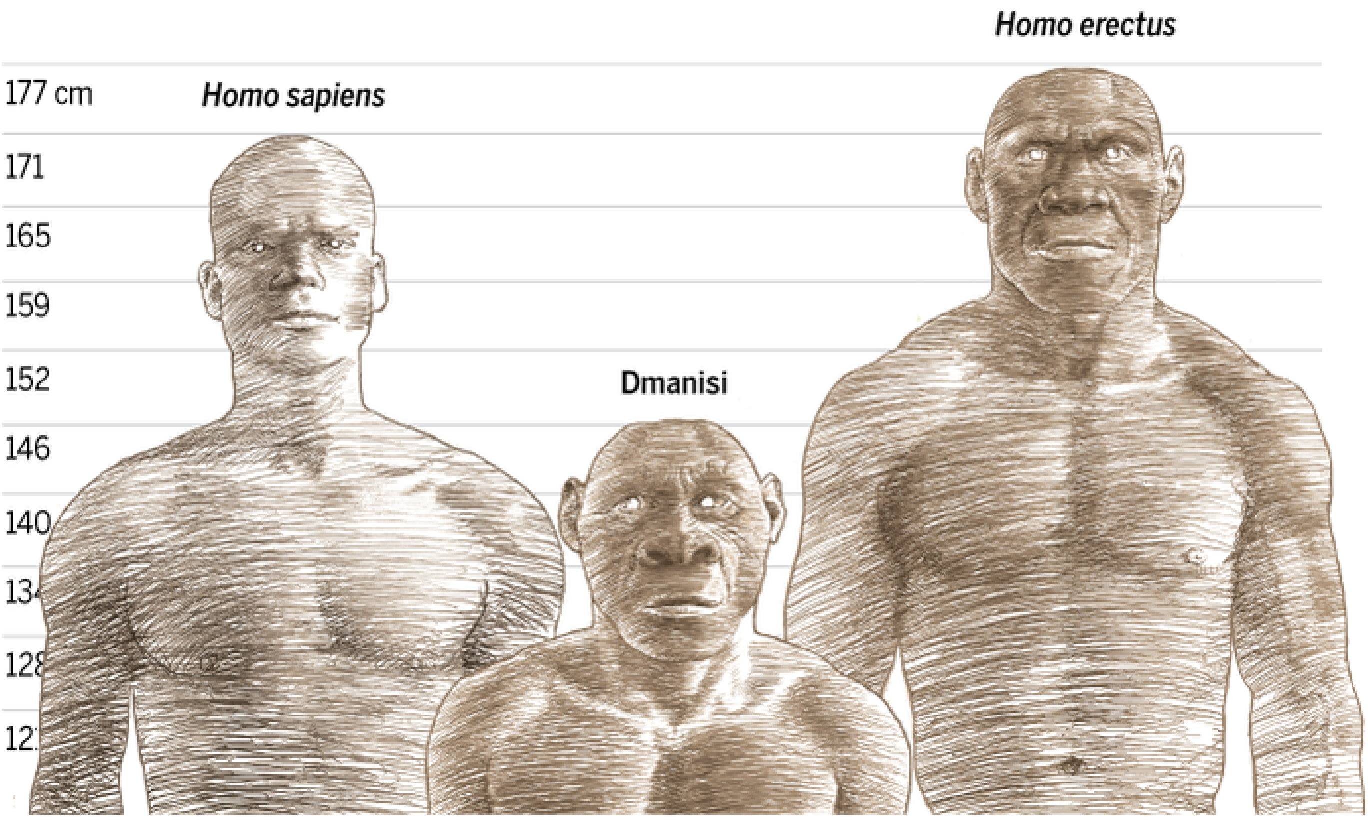
This is the famous site of Dmanisi, Georgia, which offers an unparalleled glimpse into a harsh early chapter in human evolution, when primitive members of our genus *Homo* struggled to survive in a new land far north of their ancestors' African home, braving winters without clothes or fire and competing with fierce carnivores for meat. The 4-hectare site has yielded closely packed, beautifully preserved fossils that are the oldest hominins known outside of Africa, including five skulls, about 50 skeletal bones, and an as-yet-unpublished pelvis unearthed 2 years ago. "There's no other place like it," says archaeologist Nick Toth of Indiana University in Bloomington. "It's just this mother lode for one moment in time."

Until the discovery of the first jawbone at Dmanisi 25 years ago, researchers thought that the first hominins to leave Africa were classic *H. erectus* (also known as *H. ergaster* in Africa). These tall, relatively large-brained ancestors of modern humans arose about 1.9 million years ago and soon afterward invented a sophisticated new tool, the hand ax. They were thought to be the first people to migrate out of Africa, making it all the way to Java, at the far end of Asia, as early as 1.6 million years ago. But as the bones and tools from Dmanisi accumulate, a different picture of the earliest migrants is emerging.

By now, the fossils have made it clear that these pioneers were startlingly primitive, with small bodies about 1.5 meters tall, simple tools, and brains one-third to one-half the size of modern humans'. Some paleontologists believe they provide a better glimpse of the early, primitive forms of *H. erectus* than fragmentary African fossils. "I think for the first time, by virtue of the Dmanisi hominins, we have a solid hypothesis for the origin of *H. erectus*," says Rick Potts, a paleoanthropologist at the Smithsonian Institution's National Museum of Natural History in Washington, D.C.

The trail of the little people

Short and small-brained, even compared with classic *Homo erectus*, the Dmanisi people or their immediate ancestors emerged from Africa and migrated thousands of kilometers into Asia.



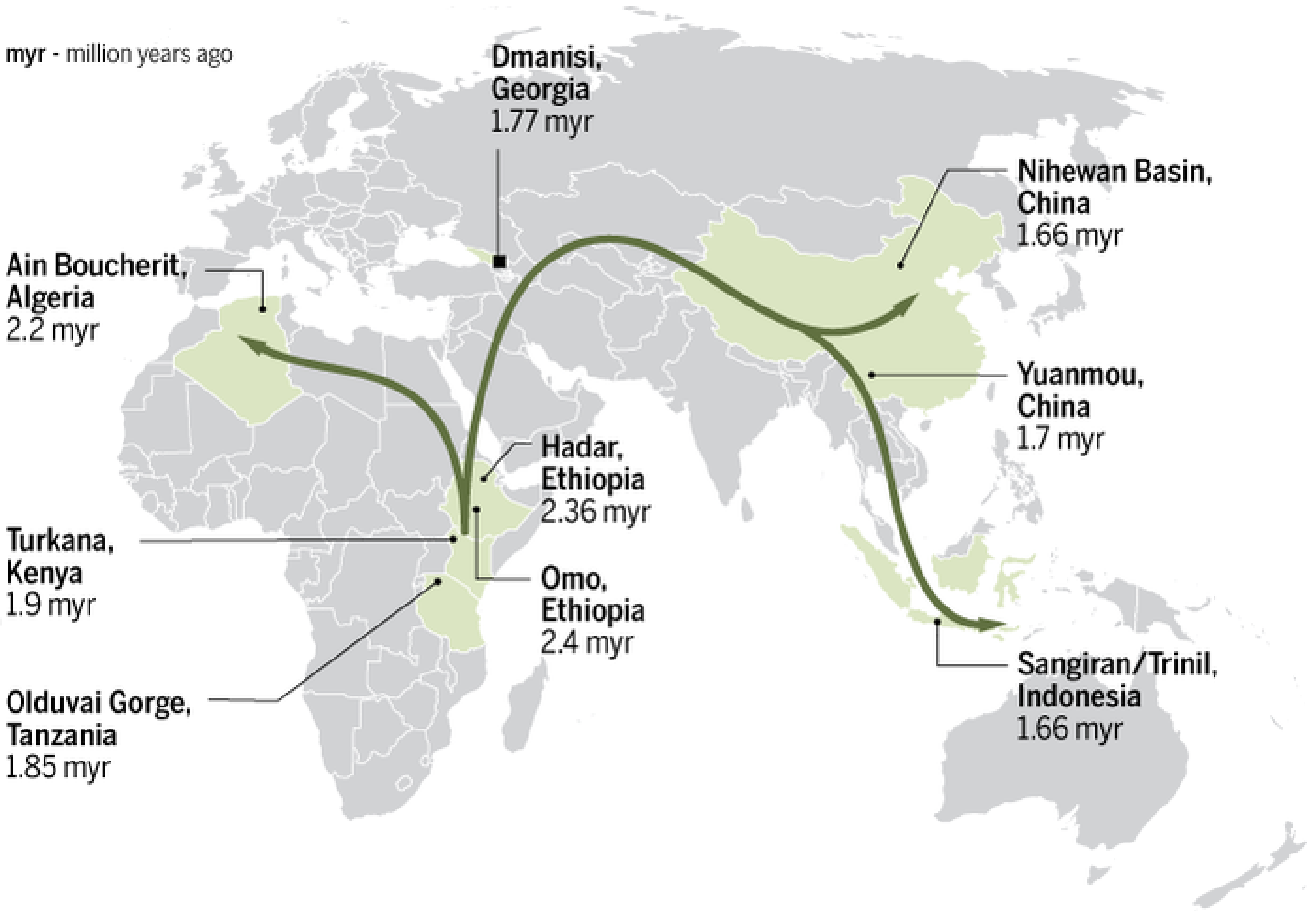
GARVIN GRULLÓN

This fall, paleontologists converged in Georgia for "Dmanisi and beyond," a conference held in Tbilisi and at the site itself from 20–24 September. There researchers celebrated 25 years of discoveries, inspected a half-dozen pits riddled with unexcavated fossils, and debated a geographic puzzle: How did these primitive hominins—or their ancestors—manage to trek at least 6000 kilometers from sub-Saharan Africa to the Caucasus Mountains? "What was it that allowed them to move out of Africa without fire, without very large brains? How did they survive?" asks paleoanthropologist Donald Johanson of Arizona State University in Tempe.

They did not have it easy. To look at the teeth and jaws of the hominins at Dmanisi is to see a mouthful of pain, says Ann Margvelashvili, a postdoc in the lab of paleoanthropologist Marcia Ponce de León at the University of Zurich in Switzerland and the Georgian National Museum in Tbilisi. Margvelashvili found that compared with modern hunter-gatherers from Greenland and Australia, a teenager at Dmanisi had dental problems at a much younger age—a sign of generally poor health. The teen had cavities, dental crowding, and hypoplasia, a line indicating that enamel growth was halted at some point in childhood, probably because of malnutrition or disease. Another individual suffered from a serious dental infection that damaged the jawbone and could have been the cause of death. Chipping and wear in several others suggested that they used their teeth as tools and to crack bones for marrow. And all the hominins' teeth were coated with plaque, the product of bacteria thriving in their mouths because of inflammation of the gums or the pH of their food or water. The dental mayhem put every one of them on "a road to toothlessness," Ponce de León says.

To the ends of earth

By following a trail of stone tools and fossils, researchers have traced possible routes for the spread of early *Homo* out of Africa to the far corners of Asia, starting about 2 million years ago.



GARVIN GRULLÓN

They did, however, have tools to supplement their frail bodies. Crude ones—but lots of them. Researchers have found more than 15,000 stone flakes and cores, as well as more than 900 artifacts, in layers of sediments dating from 1.76 million to 1.85 million years ago. Even though *H. erectus* in East Africa had invented hand axes, part of the so-called Acheulean toolkit, by 1.76 million years ago, none have been found here at Dmanisi. Instead, the tools belong to the "Oldowan" or "Mode 1" toolkit—the first tools made by hominins, which include simple flakes for scraping and cutting and spherical choppers for pounding. The Oldowan tools at Dmanisi are crafted out of 50 different raw materials, which suggests the toolmakers weren't particularly selective. "They were not choosing their raw material—they were using everything," says archaeologist David Zhvania of the Georgian National Museum.

That simple toolkit somehow enabled them to go global. "They were able to adjust their behavior to a wide variety of ecological situations," Potts says. Perhaps the key was the ability to butcher meat with these simple tools—if hominins could eat meat, they could survive in new habitats where they didn't know which plants were toxic. "Meat eating was a big, significant change," says paleoanthropologist Robert Foley of the University of Cambridge in the United Kingdom.

Even with their puny stone flakes, "these guys were badass," competing for meat directly with large carnivores, Toth says. At the meeting, he pointed to piles of cobblestones near the entrance of an ancient gully, which suggest the hominins tried to fend off (or hunt) predators by stoning them.

Simple stone flakes, like those removed from this core, enabled the Dmanisi hominins to butcher meat. MALKHAZ MACHAVARIANI, © THE GEORGIAN

They set their own course as they left Africa. Researchers had long thought that *H. erectus* swept out of their native continent in the wake of African mammals they hunted and scavenged. But all of the roughly 17,000 animal bones analyzed so far at Dmanisi belong to Eurasian species, not African ones, according to biological anthropologist Martha Tappen of the University of

Minnesota in Minneapolis. The only mammals not of Eurasian origin are the hominins—"striking" evidence the hominins were "behaving differently from other animals," Foley says.

Perhaps venturing into new territory allowed the hominins to hunt prey that would not have known to fear and flee humans, suggests paleoanthropologist Robin Dennell of the University of Exeter in the United Kingdom. Tappen calls that an "intriguing new idea" but thinks it should be tested. Checking the types of animal bones at other early Homo fossil sites out of Africa could show whether the mix of prey species changed when hominins colonized a new site, supporting a "naïve prey" effect.

Whatever impelled them, the migrants left behind a trail of tools that have enabled researchers to trace their steps out of Africa. There, the oldest stone tools, likely fashioned by the first members of early Homo, such as small-brained *H. habilis*, date reliably to 2.6 million years ago in Ethiopia (and, possibly, 3.3 million years in Kenya). New dates for stone tools and bones with cutmarks at Ain Boucherit, in the high plateau of northeastern Algeria, suggest that hominins had crossed the Sahara by 2.2 million years ago when it was wetter and green, according to archaeologist Mohamed Sahnouni of the National Centre for Research on Human Evolution in Burgos, Spain. His unpublished results, presented at the Dmanisi meeting, are the earliest evidence of a human presence in northern Africa.

The next oldest tools are those from Dmanisi, at 1.85 million years old. The trail of stone tools then hopscotches to Asia, where Mode 1 toolkits show up by nearly 1.7 million years ago in China and 1.6 million in Java, with *H. erectus* fossils. "We pick up little fractions of a current" of ancient hominin movements, Foley says.

Now the site of a medieval church, the promontory at Dmanisi has been a crossroads for humans and animals for at least 1.8 million years. KEN GARRETT

The identity of the people who dropped these stone breadcrumbs is a mystery that has only deepened with study of the Dmanisi fossils. The excavation team has classified all the hominins at the Georgia site as *H. erectus*, but they are so primitive and variable that researchers debate whether they belong in *H. erectus*, *H. habilis*, a separate species, *H. georgicus*—or a mix of all three, who may have inhabited the site at slightly different dates.

A new reanalysis of the Dmanisi skulls presented at the meeting added fuel to this debate by underscoring just how primitive most of the skulls were. Using a statistics-based technique to compare their shape and size with the skulls of many other hominins, Harvard University paleoanthropologist Philip Rightmire found that only one of the Dmanisi skulls—at 730 cubic centimeters—fits "comfortably within the confines of *H. erectus*." The others—particularly the smallest at 546 cc—cluster more closely with *H. habilis* in size.

Nor did the Dmanisi hominins walk just like modern humans. A new analysis of cross sections of three toe bones found that the cortical bone—the dense outer layer—wasn't buttressed in the same way as it is in the toes of modern humans. When these hominins "toed off," the forces on their toes must have been distributed differently. They may have walked a bit more like chimps, perhaps pushing off the outside edge of their foot more, says Tea Jashashvili of the University of Southern California in Los Angeles and the Georgian National Museum.

"If there are so many primitive traits, why are they calling it *H. erectus*?" asks Ian Tattersall, a paleoanthropologist at the American Museum of Natural History in New York City. "People are avoiding the question of what *H. erectus* is. Every time new stuff comes up, they're enlarging the taxon to fit new stuff in." Foley ventures: "I haven't the slightest idea of what *H. erectus* means."

Fossils and scientists mingle at the Georgian National Museum in Tbilisi. MIRIAN KILADZE, © THE GEORGIAN NATIONAL MUSEUM

Indeed, *H. erectus* now includes the 1-million-year-old type specimen from Trinil on the island of Java as well as fossils from South Africa, East Africa, Georgia, Europe, and China that span roughly 300,000 to 1.9 million years. "They're putting everything into *H. erectus* over huge geographical distances, essentially spread throughout the whole world, and over a vast number of years," Johanson says.

Yet no other species matches the Dmanisi specimens better, Rightmire says. For example, the shapes of their dental palate and skulls match those of *H. erectus*, not *H. habilis*. And the variation in skull size and facial shape is no greater than in other species, including both modern humans or chimps, says Ponce de León—especially when the growth of the jaw and face over a lifetime are considered.

Though the fossils' small stature and brains might fit best with *H. habilis*, their relatively long legs and modern body proportions place them in *H. erectus*, says David Lordkipanidze, general director of the Georgian National Museum and head of the Dmanisi team. "We can't forget that these are not just heads rolling around, dispersing around the globe," Potts adds. Like Rightmire, he thinks the fossils represent an early, primitive form of *H. erectus*, which had evolved from a *H. habilis*–like ancestor and still bore some primitive features shared with *H. habilis*.

Regardless of the Dmanisi people's precise identity, researchers studying them agree that the wealth of fossils and artifacts coming from the site offer rare evidence for a critical moment in the human saga. They show that it didn't take a technological revolution or a particularly big brain to cross continents. And they suggest an origin story for first migrants all across Asia: Perhaps some members of the group of primitive *H. erectus* that gave rise to the Dmanisi people also pushed farther east, where their offspring evolved into later, bigger-brained *H. erectus* on Java (at the same time as *H. erectus* in Africa was independently evolving bigger brains and bodies). "For me, Dmanisi could be the ancestor for *H. erectus* in Java," says paleoanthropologist Yousuke Kaifu of the National Museum of Nature and Science in Tokyo.

In spite of the remaining mysteries about the ancient people who died on this windy promontory, they have already taught researchers lessons that extend far beyond Georgia. And for that, Lordkipanidze is grateful. At the end of a barbecue in the camp house here, he raised a glass of wine and offered a toast: "I want to thank the people who died here," he said.

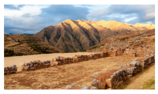
Posted in: **Africa**, **Archaeology**, **Evolution**, **Human Evolution**
doi:10.1126/science.aal0416

Ann Gibbons

Ann is a contributing correspondent for *Science*.
Twitter

More from News

Airport construction threatens unexplored archaeological sites in Peru



Rise in size of African families may be tied to less schooling

Mysterious human relatives moved into 'penthouse' Siberian cave 100,000 years earlier than thought

Got a tip?

How to contact the news team

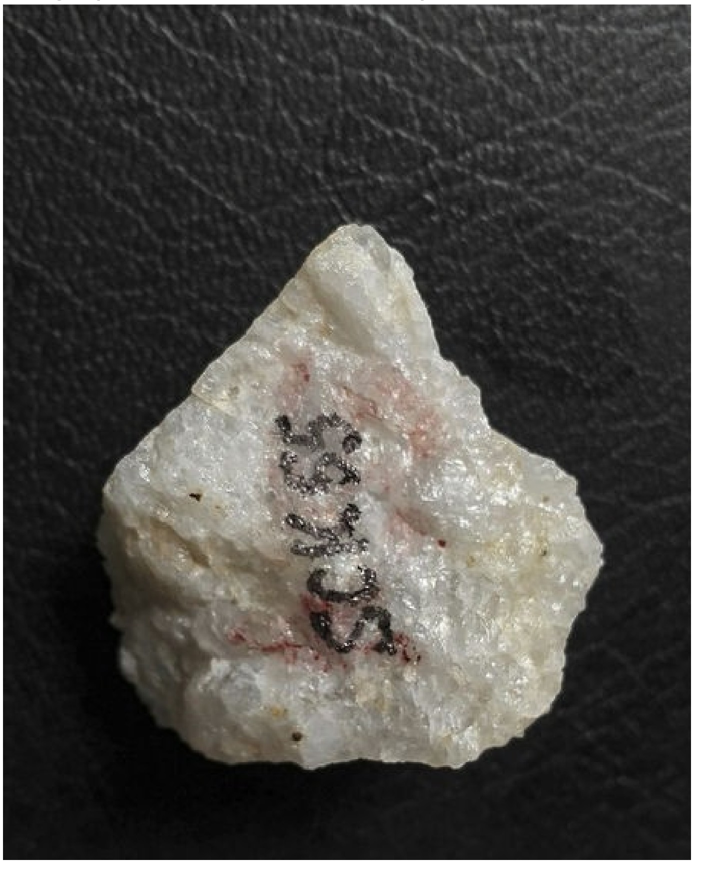
Our ancestors may have left Africa hundreds of thousands of years earlier than thought

By Ann Gibbons Jul. 11, 2018.

More than 2 million years ago, our ancestors were already world travelers, trekking all the way from Africa to Asia, according to stone tools found on a cliff face in north-central China. The age of the tools suggests that the forebears of modern humans left Africa at least 250,000 years earlier than thought; it also supports a minority view that a key human ancestor, *Homo erectus*, may have originated in Asia, not in Africa.

Until now, the oldest evidence of human ancestors outside of Africa was in Dmanisi, Georgia. Here, fossils of short people thought to be early *H. erectus* date back to about 1.85 million years—just after the species appears in Africa. The oldest evidence of early human activity in China and Indonesia has been fossils and stone tools that date to 1.5 million to 1.7 million years ago, including a skullcap of *H. erectus* from a site just 4 kilometers south of the newly dated tools. This trail of stones and bones has suggested that after the earliest members of our own genus *Homo* appeared about 2.8 million years ago in Ethiopia, they didn't leave until 2 million years ago or so—and made it to eastern Asia even later.

Now, evidence from the site of Shangchen, in the Loess Plateau approximately 1200 kilometers southwest of Beijing, is shaking up that view. On the steep cliff faces of a gully at Shangchen, a Chinese team unearthed 96 stone points, flakes, and cores that were probably used to carve up animal bones or to smash them open for marrow. Antelope, deer, and pig bones were found with the tools.



The same team, led by geologist Zhaoyu Zhu of the Guangzhou Institute of Geochemistry at the Chinese Academy of Sciences, spent years nailing down dates for the layers of sediments in which the tools were embedded. The sediments at Shangchen lack volcanic minerals, which provide the gold standard for radiometric dating methods and are plentiful in Africa. Instead, the researchers used paleomagnetic dating—which detects known reversals in Earth's magnetic field that are recorded in ancient rock—and found that the stone tools range in age from 1.6 million to 2.1 million years ago.

This indicates hominins—the family that includes humans and our ancestors—got out of Africa at least a quarter of a million years earlier than thought, and occupied Shangchen on and off for more than 850,000 years, the team reports today in *Nature*.

"The dates are convincing," says geochronologist Andrew Roberts of the Australian National University in Canberra, who was not part of the team. Geoarchaeologist Reid Ferring of the University of North Texas in Denton, who dated the Dmanisi site, says the paper makes a "good case for occupations older than Dmanisi."

Another key finding is that the new dates show that "already before 2 million years, hominins were able to cope with a range of environmental conditions," says archaeologist Wil Roebroeks of Leiden University in the Netherlands, who is not a member of the team. During the long span of occupations at Shangchen, which is about the same latitude as Kabul, the climate fluctuated from warm and wet to cold and dry. "They must have been freezing their buns off," adds paleoanthropologist Rick Potts of the Smithsonian Institution's National Museum of Natural History in Washington, D.C.

The early dates suggest hominins were already remarkably adaptable by 2.1 million years ago—even though they had not yet evolved the even bigger brains, long legs, or more advanced tools like hand axes seen in later humans. Although the identity of these early globetrotters is unknown, the new dates raise the possibility that *H. erectus* wasn't the first hominin to leave Africa. Chinese and Georgian scholars have long argued that a more primitive species of hominin got out of Africa and gave rise to *H. erectus* in Asia. And now, these early tools show hominins were in China far before *H. erectus* appeared in Africa—and early enough for a new species to evolve. In fact, "*H. erectus* may have evolved in Eurasia and migrated to Africa," Ferring says.

Posted in: **Archaeology**
doi:10.1126/science.aau7506

21/06 | Aula 5: O sítio de Shangchen, na China, e as ferramentas líticas que poderiam indicar uma saída humana da África bem antes do que se imaginava. Os problemas na datação de Shangchen. A descoberta no sítio Lomekwi, no Kenya. O material lítico de 3,3 milhões de anos. Se são ferramentas, quem teria feito os artefatos? O achado de uso do fogo há 1 milhão de anos na caverna de Wonderwerk, na África do Sul. O primeiro cozimento dos alimentos pelos humanos?

Textos para leitura:
What Kind of Hominin First Left Africa? | Scardia/Neves
The News Origins of Technology | Kate Wong
Humans Tamed Fire by 1 Million Years Ago | Kate Wong
The First Cookout | Kate Wong

Received: 26 March 2020 | Revised: 19 May 2020 | Accepted: 5 August 2020
DOI: 10.1002/evan.21863

ISSUES

Evolutionary Anthropology ISSUES, NEWS, AND REVIEWS WILEY

What kind of hominin first left Africa?

Giancarlo Scardia[1] | Walter A. Neves[2] | Ian Tattersall[3] | Lukas Blumrich[2]

[1]Universidade Estadual Paulista (UNESP), Instituto de Geociências e Ciências Exatas, Rio Claro, Brazil

[2]Universidade de São Paulo (USP), Instituto de Estudos Avançados, São Paulo, Brazil

[3]Division of Anthropology, American Museum of Natural History, New York, New York

Correspondence
Giancarlo Scardia, Universidade Estadual Paulista (UNESP), Instituto de Geociências e Ciências Exatas, Rio Claro SP 13506-900, Brazil.
Email: giancarlo.scardia@unesp.br

Funding information
Conselho Nacional de Desenvolvimento Científico e Tecnológico, Grant/Award Number: 302127/2015-1; Fundação de Amparo à Pesquisa do Estado de São Paulo, Grant/Award Numbers: 2013/22631-2, 2016/04809-7; Wenner-Gren Foundation, Grant/Award Number: 8991

Abstract

Recent discoveries of stone tools from Jordan (2.5 Ma) and China (2.1 Ma) document hominin presence in Asia at the beginning of the Pleistocene, well before the conventional Dmanisi datum at 1.8 Ma. Although no fossil hominins documenting this earliest Out of Africa phase have been found, on chronological grounds a pre-*Homo erectus* hominin must be considered the most likely maker of those artifacts. If so, this sheds new light on at least two disputed subjects in paleoanthropology, namely the remarkable variation among the five Dmanisi skulls, and the ancestry of *Homo floresiensis*.

KEYWORDS

early Pleistocene, *Homo floresiensis*, *Homo georgicus*, Out of Africa

1 | INTRODUCTION

In the conventional paleoanthropological narrative *Homo erectus*, first documented in Java, was the first hominin to exit Africa and enter Eurasia. As currently articulated, this scenario depends heavily on evidence from the Georgian site of Dmanisi, where five skulls and some associated postcrania, dated to ca. 1.8 million years (Ma),[1] have been allocated to *H. erectus*.[2] Under this reasoning, the first appearance of *H. erectus* in Asia soon followed its first appearance in Africa, currently dated at ca. 2 Ma in South Africa.[3]

Recent discoveries of stone tools in Jordan[4] and in China[5] date back to 2.5 and 2.1 Ma, respectively, and suggest a new and starkly different picture. On a purely chronological basis, these dates push the first Out of Africa event back by 700 thousand years, strongly suggesting that a pre-*erectus* hominin must have been involved in this expansion. In this note we present a short summary of recent discoveries in Jordan and China and discuss how this new evidence sheds light on at least two widely disputed subjects in paleoanthropology, namely the remarkable variation among the five Dmanisi skulls, and the ancestry of *Homo floresiensis*.

Since the early 1980s, the Dawqara Formation in the Zarqa Valley, Jordan, has been known for the occurrence of cores and flakes artifacts within its fluvial sediments.[6] Early findings were confirmed by surveys in the late 1990s, when *Mammuthus meridionalis*, *Equus* cf. *tabeti*, and *Bos primigenius* were also reported in the upper part of the Dawqara Fm.[7] The Zarqa Valley was then revisited between 2013 and 2016 by a Brazilian-Italian team, with the aim of providing a robust chronostratigraphic framework for the several artifact-bearing sites.

Three major fluvial terraces are observed at the confluence between the Zarqa River and its tributary the Dulayl. The highest (oldest) of these lies 40–50 m above the modern river, and it consists of fluvial sediments belonging to the Dulayl (at the bottom) and Dawqara (at the top) formations, respectively, the two separated by a basaltic lava flow. The top of the Dawqara Fm is capped by a thick caliche produced by pedogenic processes. Megafaunal remains are encountered throughout the succession,[4,7] but stone tools have been found only above the basalt layer, within the Dawqara Fm. Artifacts occur at several stratigraphic levels, suggesting an almost continuous hominin occupation of the Zarqa Valley during the deposition of the Dawqara Fm.[4] Techno-typologically, the lithic assemblage of Dawqara is composed of pebble-cores and flakes.

Age estimates of the Dawqara Fm have been obtained by integrating $^{40}Ar/^{39}Ar$ on basalt (2.52 ± 0.01 Ma), U–Pb laser ablation on caliche (1.98 ± 0.2 Ma), and magnetostratigraphy. The results from these independent dating methods are in mutual agreement, and pin down the deposition of the Dawqara Fm to the period between 2.52 Ma and the Matuyama-Olduvai geomagnetic reversal at 1.95 Ma.[8] By linear interpolation, the artifact-bearing stratigraphic levels have been dated to 2.48, 2.24, 2.16, 2.06, and 1.95 Ma, respectively.[4]

Far to the east, in China, the Loess Plateau is a large layered deposit of wind-blown dust deposited during the last 2.6 Ma by winter monsoon winds. As loess is mostly composed of fine-grained sediments (silt, 2–62 μm), pebble- to cobble-sized stone tools are easily identified; and, in 2018, artifacts dating by magnetostratigraphy from 2.1 to 1.3 Ma were reported.[5] These results provide independent support for the claim of artifacts as old as 2.2 Ma from the Longgupo Cave,[9] the chronology of which is provided by combined electron spin resonance (ESR) and uranium series dating methods. Like the Dawqara assemblage, the Chinese Plateau lithic assemblage also consists of pebble-cores and flakes.

The evidence collected in these two Asian regions during the last few years is composed of a large sample size, especially in the Jordan case, including features (e.g., dominant noncortical cores and flakes, bulbar scars) that allow it to be classified as "anthropological origin probable, natural origin improbable," according to Shea's[10,11] criteria for recognizing anthropic agency in stone artifact assemblages. This lithic evidence thus documents an initial exit of hominins from Africa at around 2.5 Ma, and to their presence in China by 2.1 Ma. No fossil hominins documenting this earliest Out of Africa phase have been found either in Jordan or in China, leaving Dmanisi as still the oldest hominin fossil site outside Africa.

2 | DMANISI FOSSILS

Dmanisi has been systematically explored by a Georgian-led team since 1993. The age of the site is well bracketed between 1.85 and 1.78 Ma,[1] and five hominin crania (Figure 1) have been found at the site, along with a pebble-cores and flakes lithic industry interpreted as Oldowan.[2] These skulls vary considerably in morphology, and the species names attributed to them have varied wildly. The situation became even more complicated following the discovery of the extremely distinctive Skull 5 in 2005.[12,13] For some, including the Georgian team, the latest conclusion is that all five skulls can be ascribed to one single population, to which an unprecedented quadrinomen was given: *Homo erectus ergaster georgicus*.[12] In contrast, for others a more primitive hominin, or more likely two hominin species—if not two genera—are represented at Dmanisi.[14,15,16] For those who espouse a single variable lineage at this locality, the extreme morphological diversity in the sample is explained by what would be a highly unusual combination of biological age differences, sexual dimorphism, and facial remodeling due to tooth loss and other dental pathologies.[2,17]

The Dmanisi team described the five hominin skulls from the site as having a combination of primitive (*habilis*-like) and derived (*erectus*-like) traits. As Rightmire et al.[1] put it, "it is becoming clear that the Caucasus hominins share features with African *Homo habilis* but had not yet evolved a full suite of the characters diagnostic of later *H. erectus*" (p. 12). For instance, cranial capacity ranges between 546 and 730 cm^3, well below the average of 904 cm^3 found in specimens often attributed to *H. erectus*.[18] Some other characteristics that allegedly revealed a mosaic of primitive and derived traits included brow ridges that are only moderately thickened, and a supra-orbital sulcus that is minimal but associated with a very marked post-orbital constriction. The occipital is flexed, but a transverse torus is not uniformly present, while the face is prognathic with a relatively massive midface. Lordkipanidze et al.[19] similarly reported that the postcranial anatomy of the Dmanisi hominins showed a surprising mosaic of primitive and derived features. Primitive features included small body size and an absence of humeral torsion, while derived ones included body proportions similar to modern humans and lower limb structure suggesting this form was already an obligate biped. All in all, Lordkipanidze et al.[19] concluded that "the first hominin species currently known from outside Africa did not possess the full suite of derived locomotor traits apparent in African *H. erectus* and later hominins" (p. 309). Still, a major problem in all of this is that (just as at

FIGURE 1 The five hominin crania from Dmanisi, from left to right: Skull 1 (D2280), Skull 2 (D2282), Skull 3 (D2700), Skull 4 (D3444), and Skull 5 (D4500). Courtesy of the Georgian National Museum [Color figure can be viewed at wileyonlinelibrary.com]

Dmanisi) nothing known from Africa bears the cranial apomorphies that define the *H. erectus* holotype from Java. What is more, something rather similar appears to apply to *H. habilis*, which has never been adequately defined in morphological terms. Indeed, this African "species" is essentially a taxonomic wastebasket into which a motley assortment of hominin fossils dating between ca. 2.5 and 1.8 Ma has been rather heedlessly tossed, so that the more informal "early *Homo*" might be a preferable term for this grouping.[20] Despite this needless complication, and in agreement with evidence from Jordan and China, the heterogeneity we see at Dmanisi can be much more easily interpreted if we invoke a member of the "early *Homo*" group as the first hominin to leave Africa and as the ancestor of the Dmanisi hominins. Accepting that Skull 5 (the mandible of which would more properly be the holotype of *Homo georgicus*) is entirely distinctive from everything else at Dmanisi, we prefer to ascribe the remaining four skulls to another species, which is not *H. erectus*, since none of them has any of the apomorphies of the Trinil holotype. Neither it is clear, for similar reasons, that the remaining Dmanisi individuals are appropriately referred to *Homo ergaster* (a.k.a. "African *H. erectus*"). Indeed, it is still an open question whether those four skulls might actually belong to more than one species.

3 | FLORES FOSSILS

On the other side of Asia, the discoveries at Liang Bua cave, Flores (Indonesia), remain controversial to this day. Brown et al.[21] described the remains of a short-statured hominin (LB1), including a cranium, a mandible and some postcranial elements. Additional bones of LB1 were discovered later, together with another mandible (LB6) and skeletal remains from 5 to 7 different individuals.[22] The distinctive features of these fossils, including short stature (106 cm), a small cranial capacity (417 cm^3 as measured by Falk et al.[23]) and a mix of features seen in both australopiths and *Homo*,[24] were thought by the discoverers to be distinctive enough to describe a new species, *H. floresiensis*. The Liang Bua remains were recently dated to between 98 and 67 ka,[25] apparently antedating the presence of *Homo sapiens* on the island. The picture was, and still is, very complex, with a lot of open questions. The lack of a connection between Flores and the neighboring continent, for example, suggests that these small-brained hominins had developed some form of ocean navigation capability.[26] The complexity of the artifacts found at Liang Bua also raised questions about the identity of their makers.[27] Interestingly, observations on the LB1 endocast suggested that the species may have had relatively high cognitive capabilities.[23] But the most intriguing question of all concerns the origin of this unusual form. From the very beginning three different interpretations were heatedly debated: that the bones represent anatomically modern humans with genetic or metabolic disorders[28,29]; that the new species is derived by dwarfing from the Asian *H. erectus*[30,31,32]; or that *H. floresiensis* is descended from an earlier lineage of *Homo*.[33,34]

The various pathologies suggested in defense of the first hypothesis have all been convincingly dismissed.[31,35] Microcephaly, for example, has been rejected in multiple analyses,[36,37,38] as has Down Syndrome.[33,39] What is more, the description of new and similar skeletal remains from Mata Menge, Flores, has finally confirmed the validity of *H. floresiensis* as a distinctive anatomical entity.[40] These findings suggest a complex hominin evolutionary history for Flores, since the

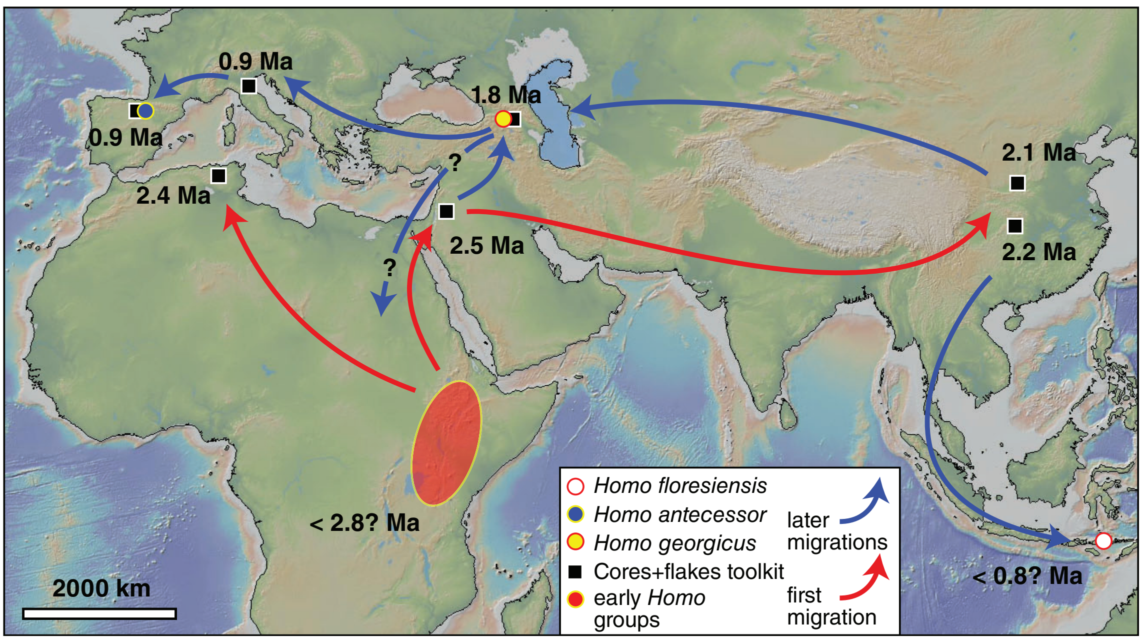


FIGURE 2 Tentative scenario for the first Out of Africa expansion at ca. 2.5 Ma according to the recent findings from Jordan and China, and later migrations stemming from the early *Homo* lineage. See text for discussion and references [Color figure can be viewed at wileyonlinelibrary.com]

island has been inhabited at least since ca. 700 ka, leading up to the extinction of the "hobbit-like" hominin around ca. 50 ka.[41]

The biggest question, however, remains open: did *H. floresiensis* derive from *H. erectus* through dwarfing (via an unusually intense "island effect"), or did it descend from a more primitive, smaller-bodied, hominin? Some studies of the cranium and dentition of LB1,[30,42] of its endocast,[43] of its calvaria,[44] and of the mandibular fragment and teeth,[40] have favored the hypothesis that *H. floresiensis* is descended from *H. erectus*. However, as noted by Gómez-Robles,[45] the traits that point away from *H. erectus* and to a more primitive ancestor come mostly from the postcranial remains, which were not included in the abovementioned analyses. The study of the external cranial morphology of LB1 by Gordon et al.[46] agrees with the hypothesis that *H. erectus* and *H. floresiensis* shared a common ancestor, but the authors hint that LB1 may be more similar in morphology to *H. habilis* than to *H. erectus*. A much more comprehensive phylogenetic analysis was carried out by Argue et al.[34] who supported previous findings[24,36] that *H. floresiensis* is more likely a sister either to *H. habilis* alone, or to the clade that includes *H. habilis*, *H. erectus*, *H. ergaster*, and *H. sapiens*.

The main objection to the Argue group's hypotheses has been the lack of archeological evidence for a pre-*erectus* hominin dispersal from Africa.[45] But at 2.5 and 2.1 Ma, respectively, the stone tools from Jordan and China may resolve this issue. If what we may—for lack of a better term, and in the absence of a morphologically coherent definition for our own genus—describe as "early *Homo*" was actually the first hominin to leave Africa, we would have a ready explanation for the more primitive, more australopith-like features of its descendant *H. floresiensis*—including the latter's short stature and archaic body proportions (relatively long arms vs. legs). As, indeed, we would also have for the Oldowan characteristics of its associated lithic industry.[47,48,49]

4 | CONCLUSIONS

In the light of recent findings, then, we propose the following tentative scenario to account for the diversity of extinct hominins found outside Africa (Figure 2). Namely, that something which on account of our inadequate current taxonomic framework we have to call "early *Homo*" differentiated in Africa, possibly as early as 2.8 Ma.[50] Subsequently, one or more members of this group reached the Mediterranean fringe[51] and spread Out of Africa at 2.5 Ma. After successfully expanding over Asia, at least one of those hominins (but likely more, as argued by those advocating diversity at Dmanisi) gave rise to new species that reached the Caucasus by around 1.8 Ma, and thence Europe by ca. 0.9 Ma[52,53,54] and maybe back to Africa.[55] The eastward expansion (or occupation) in Asia of small-bodied and archaically-proportioned hominins continued, possibly in multiple waves; and, by ca. 0.8 Ma, representatives of this group had penetrated as far as insular southeast Asia, where *H. floresiensis* ultimately emerged as the result of a mild "island effect." *H. erectus* probably also differentiated in eastern Asia,[56] but that is another story.

ACKNOWLEDGMENTS

Research funded by FAPESP (2013/22631-2; 2016/04809-7), the Wenner-Gren Foundation (8991), and CNPq (302127/2015-1). We thank A. Margvelashvili for the photo of the five hominin crania from Dmanisi and C.J. Lepre for helpful comments. Constructive comments on the manuscript by J.J. Shea and an anonymous reviewer are also appreciated.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

ORCID

Giancarlo Scardia https://orcid.org/0000-0003-3710-7197
Ian Tattersall https://orcid.org/0000-0002-0640-8248

REFERENCES

[1] Ferring R, Oms O, Agustí J, et al. 2011. Earliest human occupations at Dmanisi (Georgian Caucasus) dated to 1.85–1.78 ma. Proc Natl Acad Sci 108:10432–10436.
[2] Rightmire GP, Margvelashvili A, Lordkipanidze D. 2019. Variation among the Dmanisi hominins: multiple taxa or one species? Am J Phys Anthropol 168:481–495.
[3] Herries AIR, Martin JM, Leece AB, et al. 2020. Contemporaneity of *Australopithecus*, *Paranthropus*, and early *Homo erectus* in South Africa. Science 368:eaaw7293.
[4] Scardia G, Parenti F, Miggins D, Gerdes A, Araujo A, Neves W. 2019. Chronologic constraints on hominin dispersal outside Africa since 2.48 Ma from the Zarqa Valley, Jordan. Quat Sci Rev 219:1–19.
[5] Zhu Z, Dennell R, Huang W, et al. 2018. Hominin occupation of the Chinese loess plateau since about 2.1 million years ago. Nature 559:608–611.
[6] Besançon J, Copeland L, Hours F, Macaire J-J, Sanlaville P. 1984. The lower and middle Paleolithic in the upper Zarqa/Khirbet Samra area of northern Jordan: 1982-83 survey results. Annu Depart Antiquit Jordan 25:91–143.
[7] Parenti F, Al-Shiyab AH, Santucci E, Kafafi Z, Palumbo G. 1997. Early Acheulean stone tools and fossil faunas from the Dauqara formation, upper Zarqa Valley, Jordanian plateau. In: Gebel HGK, Kafafi Z, Rollefson GO, editors. The prehistory of Jordan II. Perspectives from 1997, Berlin: Ex oriente. p 7–22.
[8] Gradstein FM, Ogg JG, Schmitz M, Ogg G, editors. 2012. The geologic time scale 2012, Amsterdam: Elsevier.
[9] Han F, Bahain J-J, Deng C, et al. 2017. The earliest evidence of hominid settlement in China: Combined electron spin resonance and uranium series (ESR/U-series) dating of mammalian fossil teeth from Longgupo cave. Quat Int 434:75–83.
[10] Shea JJ. 2010. Stone age visiting cards revisited: A strategic perspective on the lithic technology of early hominin dispersal. In: Fleagle JG, Shea JJ, Grine FE, Baden AL, Leakey RE, editors. Out of Africa I, vertebrate paleobiology and paleoanthropology, Netherlands, Dordrecht: Springer. p 47–64.
[11] Shea J. 2020. How to read stone tools. In: Prehistoric stone tools of eastern Africa: A guide, Cambridge: Cambridge University Press. p 41–66.
[12] Lordkipanidze D, Ponce de León MS, Margvelashvili A, et al. 2013. A complete skull from Dmanisi, Georgia and the evolutionary biology of early *Homo*. Science 342:326–331.
[13] Rightmire GP, Ponce de León MS, Lordkipanidze D, Margvelashvili A, Zollikofer CPE. 2017. Skull 5 from Dmanisi: Descriptive anatomy, comparative studies, and evolutionary significance. J Hum Evol 104:50–79.

[14] Martinón-Torres M, Bermúdez de Castro JM, Gómez-Robles A, et al. 2007. Dental evidence on the hominin dispersals during the Pleistocene. Proc Natl Acad Sci 104:13279–13282.
[15] Neves WA, Bernardo DV. 2011. The first hominin of Europe. Rev Arqueol 24:102–110.
[16] Schwartz JH, Tattersall I, Chi Z. 2014. Comment on "a complete skull from Dmanisi, Georgia, and the evolutionary biology of early *Homo*". Science 344:360.
[17] Margvelashvili A, Zollikofer CPE, Lordkipanidze D, Peltomäki T, Ponce de León MS. 2013. Explaining variation of the Dmanisi mandibles. Proc Natl Acad Sci 110:17278–17283.
[18] Rightmire GP. 2004. Brain size and encephalization in early to mid-Pleistocene *Homo*. Am J Phys Anthropol 124:109–123.
[19] Lordkipanidze D, Jashashvili T, Vekua A, et al. 2007. Postcranial evidence from early *Homo* from Dmanisi, Georgia. Nature 449:305–310.
[20] Antón SC, Potts R, Aiello LC. 2014. Evolution of early *Homo*: an integrated biological perspective. Science 345:1236828.
[21] Brown P, Sutikna T, Morwood MJ, et al. 2004. A new small-bodied hominin from the late Pleistocene of Flores, Indonesia. Nature 431: 1055–1061.
[22] Morwood MJ, Brown P, Jatmiko, et al. 2005. Further evidence for small-bodied hominins from the late Pleistocene of Flores, Indonesia. Nature 437:1012–1017.
[23] Falk D, Hildebolt C, Smith K, et al. 2005. The brain of *Homo floresiensis*. Science 308:242–245.
[24] Argue D, Morwood M, Sutikna T, Jatmiko, Saptomo WE. 2009. *Homo floresiensis*: A cladistic analysis. J Hum Evol 57:623–629.
[25] Sutikna T, Tocheri MW, Morwood MJ, et al. 2016. Revised stratigraphy and chronology for *Homo floresiensis* at Liang Bua in Indonesia. Nature 532:366–369.
[26] Neves W, Diniz-Filho JAF. 2018. O Hobbit da Ilha de Flores: implicações para a evolução humana. Ciência e Cultura 70:56–59.
[27] Martin RD, MacLarnon AM, Phillips JL, Dussubieux L, Williams PR, Dobyns WB. 2006. Comment on "the brain of LB1, *Homo floresiensis*". Science 312:999.
[28] Henneberg M, Thorne A. 2004. Flores human may be a pathological *Homo sapiens*. Before Farm 4:2–4.
[29] Henneberg M, Eckhardt RB, Chavanaves S, Hsü KJ. 2014. LB1 from Flores, Indonesia, exhibits Down syndrome. Proc Natl Acad Sci 111: 11967–11972.
[30] Kaifu Y, Baba H, Sutikna T, et al. 2011. Craniofacial morphology of *Homo floresiensis*: Description, taxonomic affinities, and evolutionary implication. J Hum Evol 61:664–682.
[31] Van Heteren AH. 2013. Is LB1 diseased or modern? A review of the proposed pathologies. Gene 528:12–20.
[32] Diniz-Filho J, Raia P. 2017. Island rule, quantitative genetics and brain-body size evolution in *Homo floresiensis*. Proc R Soc B 284: 20171065.
[33] Baab KL, Brown P, Falk D, et al. 2016. A critical evaluation of the Down syndrome diagnosis for LB1, type specimen of *Homo floresiensis*. PLoS One 11(6):e0155731.
[34] Argue D, Groves CP, Lee MSY, Jungers WL. 2017. The affinities of *Homo floresiensis* based on phylogenetic analyses of cranial, dental, and postcranial characters. J Hum Evol 107:107–133.
[35] Aiello LC. 2010. Five years of *Homo floresiensis*. Am J Phys Anthropol 142:167–179.
[36] Argue D, Donlon D, Groves C, Wright R. 2006. *Homo floresiensis*: microcephalic, pygmoid, *Australopithecus* or *Homo*? J Hum Evol 51: 360–374.
[37] Falk D, Hilderbolt C, Smith K, et al. 2007. Brain shape in human microcephalics and *Homo floresiensis*. Proc Natl Acad Sci 104(6): 2513–2518.
[38] Falk D, Hildebolt C, Smith K, et al. 2009. LB1's virtual endocast, microcephaly, and hominin brain evolution. Journal of Human Evolution 57:597–607.
[39] Westaway MC, Durband AC, Groves CP, Collard M. 2015. Hobbit did not have Down syndrome. Proc Natl Acad Sci 112:604–605.
[40] Van den Bergh GD, Kaifu Y, Kurniawan I, et al. 2016. *Homo floresiensis*-like fossils from the early middle Pleistocene of Flores. Nature 534:245–248.
[41] Sutikna T, Tocheri MW, Faith JT, et al. 2018. The spatio-temporal distribution of archaeological and faunal finds at Liang Bua (Flores, Indonesia) in light of the revised chronology for *Homo floresiensis*. J Hum Evol 124:52–74.
[42] Kaifu Y, Kono RT, Sutikna T, Saptomo WE, Awe RD. 2015. Unique dental morphology of *Homo floresiensis* and its evolutionary implications. PLoS One 10(11):0141614.
[43] Kubo D, Kono RT, Kaifu Y. 2013. Brain size of *Homo floresiensis* and its evolutionary implications. Proc R Soc B 280:1–8.
[44] Zeitoun V, Barriel V, Widianto H. 2016. Phylogenetic analysis of the calvaria of *Homo floresiensis*. C R Palevol 15:555–568.
[45] Gómez-Robles A. 2016. The dawn of *Homo floresiensis*. Nature 534: 188–189.
[46] Gordon AD, Nevell L, Wood B. 2008. The Homo floresiensis cranium (LB1): size, scaling, and early Homo affinities. Proc Natl Acad Sci 105:4650–4655.
[47] Brown P, Maeda T. 2009. Liang Bua *Homo floresiensis* mandibles and mandibular teeth: a contribution to the comparative morphology of a new hominin species. J Hum Evol 57:571–596.
[48] Moore MW, Brumm A. 2009. *Homo floresiensis* and the African Oldowan. In: Hovers E, Braun DR, editors. Interdisciplinary approaches to the Oldowan. Vertebrate paleobiology and paleoanthropology, Dordrecht: Springer.
[49] Moore MW, Sutikna T, Jatmiko, Morwood MJ, Brumm A. 2009. Continuities in stone flaking technology at Liang Bua, Flores, Indonesia. J Hum Evol 57:503–526.
[50] Villmoare B, Kimbel WH, Seyoum C, et al. 2015. Early *Homo* at 2.8 Ma from Ledi-Geraru, Afar, Ethiopia. Science 347:1352–1355.
[51] Sahnouni M, Parés JM, Duval M, et al. 2018. 1.9-million- and 2.4-million-year-old artifacts and stone tool–cutmarked bones from Ain Boucherit, Algeria. Science 362:1297–1301.
[52] Carbonell E, Bermúdez de Castro JM, Parés JM, et al. 2008. The first hominin of Europe. Nature 452:465–470.
[53] Muttoni G, Scardia G, Kent DV, et al. 2011. First dated human occupation of Italy at ~0.85 Ma during the late early Pleistocene climate transition. Earth Planet Sci Lett 307:241–252.
[54] Muttoni G, Scardia G, Kent DV. 2018. Early hominins in Europe: the Galerian migration hypothesis. Quat Sci Rev 180:1–29.
[55] Dennell RW, Roebroeks W. 2005. An Asian perspective on early human dispersal from Africa. Nature 438:1099–1104.
[56] Wood B. 2011. Did early Homo migrate "out of" or "in to" Africa? Proc Natl Acad Sci 108:10375–10376.

AUTHOR BIOGRAPHIES

Giancarlo Scardia is a geologist, paleomagnetist, and Professor at the São Paulo State University, Brazil. His main research interests include the chronology of early hominin dispersal episodes in Asia and Europe.

Walter Neves is an evolutionary anthropologist currently associated with the Institute of Advanced Studies at University of São Paulo, Brazil. He has been coordinator of the archeological fieldwork in Zarqa Valley, Jordan. His last book, entitled *The origin of meaning: A paleoanthropological approach*, is coming out of the press in 2020.

Ian Tattersall is a paleoanthropologist, systematist, and emeritus curator at the American Museum of Natural History in New York City. His most recent books (both with Rob DeSalle) are *The Accidental Homo* *sapiens: Genetics, Behavior, and Free Will* (Pegasus, 2019), and *A Natural History of Beer* (Yale, 2019).

Lukas Blumrich is a science journalist writing about human evolution, and graduate student of Medical Sciences at the University of São Paulo.

How to cite this article: Scardia G, Neves WA, Tattersall I, Blumrich L. What kind of hominin first left Africa? *Evolutionary Anthropology*. 2020;1–6. https://doi.org/10.1002/evan.21863

ARCHAEOLOGY

THE NEW ORIGINS OF TECHN

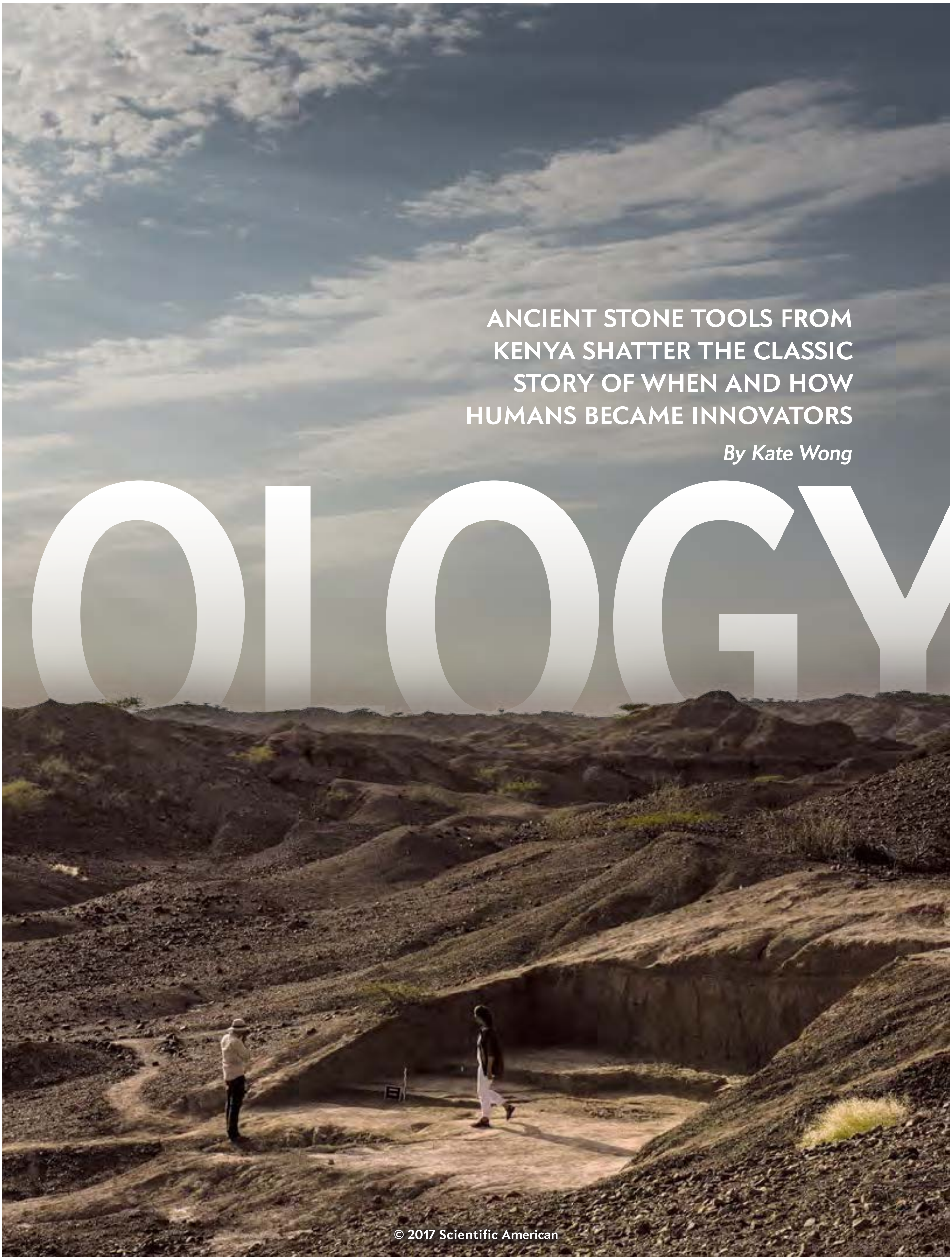
ARCHAEOLOGISTS at a site in northwestern Kenya called Lomekwi 3 have unearthed the oldest stone tools in the world.

Photographs by Andrew Renneisen

OLOGY

ANCIENT STONE TOOLS FROM KENYA SHATTER THE CLASSIC STORY OF WHEN AND HOW HUMANS BECAME INNOVATORS

By Kate Wong



The desert badlands on the northwestern shores of Kenya's Lake Turkana offer little to the people who live there. Drinking water is elusive, and most of the wild animals have declined to near oblivion. The Turkana scrape by as pastoralists, herding goats, sheep, cattle, donkeys and the occasional camel in the hot, arid countryside. It is a hard life. But millions of years ago the area brimmed with freshwater, plants and animals. It must have been paradise for the human ancestors who settled here.

Kate Wong is a senior editor at *Scientific American.*

Sonia Harmand has come to this region to study the legacy these ancestors left in stone. Harmand is an archaeologist at Stony Brook University. She has an intense gaze and a commanding presence. On a hazy July morning Harmand sits at a small, wood folding table, scrutinizing a piece of rock. It is brownish-gray, about the size of her pinkie fingernail, and utterly unremarkable to the untrained eye. But it is exactly what she has been looking for.

Nearby 15 workers from Kenya, France, the U.S. and England are digging their way into the side of a low hill. They tap hammers against chisels to chip away at the buff-colored sediments, searching for any bits of rock that could signal ancient human activity. At the top of the hill, the workers' water bottles hang like Christmas ornaments on the thorny branches of an acacia tree; the early breeze will keep their contents cool a little longer before the heat of the day sets in. By afternoon the air temperature will top 100 degrees Fahrenheit, and the excavation floor, windless and sun-cooked, will live up to its nickname: the Oven.

In 2015 Harmand and her husband, Jason Lewis, a paleoanthropologist at Stony Brook, announced that their team had discovered 3.3-million-year-old stone tools at this site, which is called Lomekwi 3. They were the oldest stone tools ever found by far—so old that they challenged a cherished theory of human evolution. The scientists want to learn who made the tools and why. But they also have a more immediate task: unearthing more evidence that the tools are, in fact, as old as they appear.

The fragment in Harmand's hand is the first evidence of ancient stone-tool production the researchers have recovered since they got here. It is a piece of debris produced by knapping—the act of striking one rock against another to produce a sharp-edged flake. Small and light, the fragment implies that the site has not been disturbed by flowing water in the millions of years since. That fact, in turn, supports the argument that the Lomekwi 3 tools come from this ancient sedimentary layer and not a younger one. Now that the excavators have hit the artifact-bearing level of the site, they must proceed with care. "*Pole pole,*" Harmand instructs them in Swahili. Slowly, slowly.

2

Paleoanthropologists have long viewed stone-tool production as one of the defining characteristics of the *Homo* genus and the key to our evolutionary success. Other creatures use tools, but only humans shape hard materials such as rock to suit their purposes. Moreover, humans alone build on prior innovations, ratcheting up their utility—and complexity—over time. "We seem to be the only lineage that has gone fully technological," says Michael Haslam of the University of Oxford. "It isn't even a crutch. It's like an addition to our bodies."

The conventional wisdom holds that our techno dependence began to form during a period of global climate change between three million and two million years ago, when Africa's woodlands transformed into savanna grasslands. Hominins, members of the human family, found themselves at a crossroads. Their old food sources were vanishing. They had to adapt or face extinction. One lineage, that of the so-called robust australopithecines, coped by evolving huge molars and powerful jaws to process the tougher plant foods available in grassland environments. Another—the larger-brained *Homo*—invented stone

IN BRIEF

A traditional view of human evolution holds that stone-tool technology originated with members of our genus, *Homo,* as an adaptation to shifting climate.

In this scenario, that adaptation quickly helped to establish a feedback loop that dramatically expanded brain size and technological prowess in our lineage.

Recently discovered stone tools from Kenya that date to 3.3 million years ago—long before the oldest known *Homo* fossils—have overturned this scenario.

WORKERS DIG into the side of a hill at Lomekwi 3 in July 2016, looking for artifacts (*1*). They sift each bucket of sediment they remove, hoping to recover even the smallest fragments of interest (*2*). Every pebble is studied for signs of human modification.

tools that gave it access to a wide variety of food sources, including the animals that grazed on these new plants. With the rich stores of calories from meat, *Homo* could afford to fuel an even bigger brain, which could then invent new and better tools for getting still more calories. In short order, a feedback loop formed, one that propelled our brain size and powers of innovation to ever greater heights. By one million years ago the robust australopithecines disappeared, and *Homo* was well on its way to conquering the planet.

The Lomekwi tools have smashed that scenario to pieces. Not only are they too old to belong to *Homo,* but they also predate the climate shift that supposedly kindled our ancestors' drive to create. And without any cut-marked bones or other signs of butchery at the site, it is not at all certain that the tools were used to process animal foods. What is more, such a vast expanse of time separates the Lomekwi tools from the next oldest implements on record that it is impossible to connect them to the rest of humanity's technological endeavoring, suggesting that the advent of stone tools was not necessarily the watershed moment that experts have always envisioned it to be.

These new discoveries have scientists scrambling to figure out when and how our predecessors acquired the cognitive and physical traits needed to conceptualize and fashion stone tools and to pass their craft to the next generation. If multiple lineages made tools from rock, researchers will need to rethink much of what they thought they knew about the origins of technology and how it shaped our branch of the family tree.

DAWN BREAKS GENTLY IN THE BUSH—A SLOW brightening of sky, a creeping swell of birdsong—and the team's campsite, on the bank of a dry riverbed about a mile from Lomekwi 3, comes to life. By 6:30 A.M. the workers emerge from their tents and head to the makeshift dining table for breakfast, walking along a gravel path lined with stones to deter the snakes and scorpions. Within the hour they pile into Land Cruisers and set off on a bone-rattling ride to the excavation.

The team is down one vehicle and short on seats in the remaining two, so archaeologist Hélène Roche has decided to stay at camp. Roche is an emeritus director of research at the French National Center for Scientific Research and an expert in early stone-tool technologies. She has short, sand-colored hair, and she dresses in desert hues. Her voice is low and crisp. Roche led the archae-

Map by Amanda Montañez

ological research in western Turkana for 17 years before handing the reins to Harmand and Lewis in 2011. She has returned for the second half of this expedition to see how they are faring. I remain at camp for the day to ask her about the history of work in this region.

"When I started in archaeology, we were just getting used to having stone tools at 1.8 [million years ago] at Olduvai," Roche recalls. In 1964 Kenyan paleoanthropologist Louis Leakey announced that he had found *Homo*-like fossils in association with what were then the oldest known artifacts in the world, stone tools from Tanzania's Olduvai Gorge (referred to as Oldowan tools). He assigned the fossils to a new species, *Homo habilis,* the "handy man," cementing the idea that stone toolmaking was linked to the emergence of *Homo*.

1

Hints that stone tools might have originated before *Homo* soon arrived, however. In the 1970s Roche, then a graduate student, discovered older Oldowan stone tools at a site in Ethiopia called Gona. When archaeologist Sileshi Semaw, now at the National Center for Research on Human Evolution in Burgos, Spain, and his colleagues eventually analyzed the tools, they reported them to be 2.6 million years old. Because no hominin remains turned up with the tools, researchers could not be sure which species made them. Semaw and his team proposed that a small-brained australopithecine species found at a different site nearby—*Australopithecus garhi*—was the toolmaker. Few were swayed by that argument, however. *Homo* was still the favorite candidate, even though, at the time, the oldest known *Homo* fossil was only 2.4 million years old. (A recent find has extended the fossil record of *Homo* back to 2.8 million years ago.)

Yet as old as they were, the Gona artifacts looked too skillfully wrought to represent humanity's first foray into stone-tool manufacturing. So did other ancient tools that began to emerge, including some from western Turkana. In the 1990s Roche found 2.3-million-year-old Oldowan stone tools at a site five miles from here known as Lokalalei 2c. She realized that in many instances, the site preserved entire knapping sequences that she could piece together like a 3-D puzzle. By refitting the Lokalalei flakes to the cores from which they were detached, Roche and her colleagues could show that toolmakers struck as many as 70 flakes from a single core. This impressive feat required an understanding of the rock shape best suited to flaking (flat on one side and convex on the other) and careful planning to maintain that shape while knapping. "You cannot imagine what it is like to hold the pieces together and reconstruct what [the toolmaker] has done and how he has done it, to go inside the prehistoric mind," she says.

It was becoming clear that the sophistication evident in the tools from Gona, Lokalalei and elsewhere could not have sprung fully formed from the minds of these knappers. Some kind of technological tradition must have preceded the Oldowan.

In 2010 far older signs of stone-tool technology came to light. Zeresenay Alemseged, now at the University of Chicago, and his colleagues reported that they had found two animal bones bearing what appeared to be cut marks from stone tools at the site of Dikika in Ethiopia. The bones dated to 3.4 million years ago, hundreds of thousands of years before the earliest known traces of *Homo*. The researchers credited the marks to *Australopithecus afarensis,* a species that was still apelike in many respects, with about as much gray matter as a chimpanzee has and a body that retained some adaptations to life in the trees—hardly the brainy, fully terrestrial hominin that researchers had traditionally expected the first butcher to be. The claims did not go unchallenged, however. Some experts countered that animals could have trampled the bones. Without the stone tools themselves, the critics argued, the Dikika scars could not qualify as tool-inflicted marks—and the question of just how far back in time technology originated remained unresolved.

AROUND THE TIME THE BATTLE OVER THE DIKIKA bones erupted, Harmand and Lewis began to hatch a plan to look for the older stone tools that the Dikika marks, along with the too-good-to-be-first tools from Gona and Lokalalei, implied should exist. In the summer of 2011 they set out in search of new archaeological sites on the western side of Lake Turkana.

The Turkana basin, as well as much of the Great Rift Valley in which it sits, is a paleoanthropologist's dream. Not only does it harbor an abundance of fossils and artifacts, but it preserves them in rocks that, with some sleuthing, can be dated with a relatively high degree of certainty. The region's history of volcanic eruptions and fluctuating water levels is recorded in the layers of sediment that have accumulated over eons to form a sort of layer cake. Water and wind erosion have exposed cross sections of the cake in locations throughout the basin. Tectonic activity has pushed some sections higher and other sections lower than they once were, but as long as any given exposure preserves at least a few layers of the cake, researchers can figure out where in the geologic sequence it comes from and thus how old it is.

EXCAVATORS CHIPPED away at the sediments for weeks before finding any artifacts (*1*). The first finds were flakes produced incidentally during knapping (*2*). A volcanic ash layer called the Toroto Tuff helped to establish the age of the site (*3*).

To navigate the rough, roadless landscape, the team drives in the dry riverbeds, called *lagas,* that snake through the region, running from the lake to points west. On July 9 of that year the researchers were headed to a site where, 12 years earlier, a different team had found a 3.5-million-year-old skull of another hominin species, *Kenyanthropus platyops,* when they took the wrong branch of the Lomekwi *laga* and got lost. Climbing a nearby hillside to get a better view of the terrain, they realized that they had ended up in just the kind of place that is promising for finding ancient remains. Outcrops of soft lake sediments, which tend to preserve fossils and artifacts well, surrounded them. And the researchers knew from previous geologic mapping of the region that all the sediments along this *laga* were more than 2.7 million years old. They decided to look around.

Within a couple of hours Sammy Lokorodi, one of the Turkana members of the team, found several rocks bearing hallmarks of knapping—adjacent, scoop-shaped scars where sharp flakes had been chipped off. Could these be the older, more primitive tools that the team was looking for? Maybe. But the tools were found on the surface. A modern-day human—perhaps a passing Turkana nomad—could have made them and left them there. The researchers knew that to make a convincing case that the tools were ancient, they would have to find more of them, sealed in sediments that had lain undisturbed since their deposition, and conduct detailed geologic analyses of the site to establish the age of the artifacts more precisely. Their work had just begun.

By the time the researchers went public with their discovery, describing it in 2015 in *Nature,* they had excavated 19 stone tools from a 140-square-foot area. And they had correlated the position of the sediment layer that held the tools to layers of rock with known ages, including a 3.31-million-year-old layer of compacted volcanic ash called the Toroto Tuff and a magnetically reversed layer from a time, 3.33 million years ago, when the earth's magnetic poles switched places. They had also located the source of the raw material for the tools—a 3.33-million-year-old layer of beach containing cobbles of volcanic basalt and phonolite, along with fish and crocodile fossils that show just how much higher lake levels were back then as compared with today. Together these clues indicated that the tools dated to a stunning 3.3 million years ago—700,000 years older than the Gona tools and half a million years older than the earliest fossil of *Homo*.

The artifacts have little in common with Oldowan tools. They are far larger, with some flakes the size of a human hand. And experiments indicate that they were knapped using different techniques. Oldowan knappers favored a freehand style, striking a hammerstone held in one hand against a core held in the other, Harmand explains. The Lomekwi knappers, in contrast, would either bang a core they held in both hands against an anvil lying on the ground or place a core on the anvil and hit it with a hammerstone. The methods and finished products demonstrate an understanding of the fracture mechanics of stone but show considerably less dexterity and planning than are evident in tools from Gona and Lokalalei. The researchers had found their pre-Oldowan stone-tool tradition. They call it the Lomekwian.

NOT EVERYONE IS CONVINCED THAT THE LOMEKWI tools are as old as the discovery team claims. Some skeptics contend that the team has not proved that the artifacts originated from the sediments dated to 3.3 million years ago. Discoveries made this field season, including the knapping debris, as well as a handful of new tools recovered during excavation, may help allay those concerns. But even researchers who accept the age and the argument that the rocks were shaped by hominins are grappling with what the find means.

First, who made the tools? To date, the team has not recovered any hominin remains from the site, apart from a single, enigmatic tooth. The age and geographical location of the tools suggest three possibilities: *K. platyops,* the only hominin species known to have inhabited western Turkana at the time; *A. afarensis,* the species found in association with the cut-marked animal bones from Dikika; and *Australopithecus deyiremeda,* a species that was recently named, based on a partial jawbone found in Ethiopia. Either *K. platyops* or *A. afarensis* would be surprising because both those species had a brain about the size of a chimp's—not the enlarged brain researchers thought the first toolmaker would have. (*A. deyiremeda*'s brain size is unknown.)

Small brain size is not the only anatomical trait that experts did not expect to see in an ancient knapper. Paleoanthropologists thought that tool use arose after our ancestors had abandoned life in the trees to become committed terrestrial bipeds. In this scenario, only after their hands had been freed from the demands of climbing could hominins evolve the hand shape needed to make stone tools. Yet studies of *A. afarensis,* the only one of these three species for which bones below the head have been found, indicate that although it was a capable biped on the ground, it retained some traits that would have allowed it to climb trees for food or safety. Just how important was the shift away from life in the trees to life on the ground in the emergence of stone-tool technology?

The Lomekwi 3 tools are also forcing scientists to reconsider why hominins invented stone tools to begin with. Reconstruction of the paleoenvironment of the greater Lomekwi area 3.3 million years ago indicates that it was wooded, not the savanna experts thought had forged *Homo*'s stone-working skills.

Perhaps the biggest question: Why are the Lomekwi 3 tools so isolated in time? If stone-tool manufacture was the game-changing development that experts have always thought it to be, why did it not catch on as soon as it first appeared and initiate the feedback loop that expanded the brain?

RECENT STUDIES MAY HELP EXPLAIN HOW A HOMININ MORE primitive than *Homo* could have come to make stone tools. It turns out that some of the differences in cognitive ability between hominins and other primates may not be as great as previously thought.

Observations of our closest primate cousins, for example, hint that even though they do not manufacture stone tools in the wild, they possess many of the cognitive abilities needed to do so. David Braun of George Washington University and Susana Carvalho of Oxford have found that in Bossou, Guinea, wild chimps that use stones to crack open nuts understand the physical properties of different rocks. The researchers shipped assorted stones from Kenya to Bossou and made them available to the chimps for their nut-cracking activities. Despite not having prior experience with these kinds of rock, the chimps consistently selected the ones with the best qualities for the job. And experiments with captive bonobos carried out by Nicholas Toth of the Stone Age Institute in Bloomington, Ind., and his colleagues have shown that they can be trained to make sharp flakes and use them to cut rope. "I have no doubt that our apes could replicate what [Harmand and her team] have at Lomekwi, given the right raw material," Toth asserts.

Even inventing stone tools in the first place may not have required special genius. Last fall Tomos Proffitt of Oxford and his colleagues reported that they had observed wild capuchin monkeys in Brazil's Serra da Capivara National Park unintentionally making sharp stone flakes that look for all the world like Oldowan tools. Quartzite cobbles abound in the monkeys' environment, and they will often pick up one cobble and bash it against another embedded in the ground that serves as an anvil. All the bashing dislodges sharp flakes that have the hallmarks of intentionally produced stone tools, including the scooplike shape that arises from what is known as conchoidal fracturing. The monkeys ignore the flakes, however. Instead they seem to be pulverizing the quartz to eat it—they pause between strikes to lick the resulting dust from the anvil. Perhaps early hominins invented their stone flakes by accident, too, or found naturally sharp stones in their environment, and only later, once they found a good use for them, began fashioning them on purpose.

The possibility that the Lomekwi toolmakers had hands that were at once capable of knapping and climbing in trees does not seem so improbable either, once one considers what our primate cousins can manage. The modern human hand, with its short, straight fingers and long, opposable thumb, is purpose-built for power, precision and dexterity—traits we exploit every time we swing a hammer, turn a key or send a text. Yet as the observations of chimps, bonobos and capuchins show, other primates with hands built for grasping tree branches can be surprisingly dexterous. The hands of partially arboreal hominins could have been similarly clever.

In fact, recent studies of the fossilized hand bones of three small-brained hominin species from South Africa—*Australopithecus africanus, Australopithecus sediba* and *Homo naledi*—show evidence for exactly this combination of activities. All three species have curved fingers—a trait associated with climbing. Yet in other respects, their hands look like those of toolmakers. Tracy Kivell and Matt Skinner, both at the University of Kent in England, examined the internal structure of the hand bones, which reflects the loading forces sustained in life, and found a pattern consistent with that seen in hominins known to have made and used stone tools and different from the internal structure of the hand bones of chimps. "Being a good climber and a dexterous toolmaker are not mutually exclusive," Kivell says. A variety of hand shapes can make and use stone tools, she explains. The changes the human hand eventually underwent just optimized it for the job.

FRIDAY IS *CHOMA* NIGHT FOR THE LOMEKWI TEAM—ROASTED goat will be served for dinner. Nick Taylor of Stony Brook, a droll Brit, is taking advantage of the menu to try to figure out what purpose the Lomekwi stone tools served. This morning one of the local Turkana shepherds brought the purchased animal for slaughter. This afternoon, as the sun begins its descent and meal preparations begin, Taylor asks camp kitchen manager Alfred "Kole" Koki to try to process the carcass with replicas of the Lomekwi tools. Koki, an experienced butcher, doubts they will work. But he gamely takes a two-inch-long flake and starts slicing. He manages to skin most of the animal and carves some of the meat with the sharp-edged rocks, discarding them as they become dull, before reclaiming his steel knife to finish the job.

Taylor observes how Koki instinctively holds each flake and how long it retains its edge before Koki requests a new one. Taylor keeps the used replica flakes so that later he and his colleagues can compare their damaged edges with those of the real

SONIA HARMAND and husband, Jason Lewis, co-direct the West Turkana Archaeological Project that discovered Lomekwi 3.

flakes. He will also collect some of the bones to study what kind of cut marks the carving might have left on them. And he will try using the tools to cut plant materials, including wood and tubers. In addition, Taylor is looking for any residues on the Lomekwi tools that might provide clues to what they were processing.

For whatever reason the Lomekwi hominins made stone tools, their tradition does not appear to have stuck. Nearly 700,000 years separates their implements from the next oldest tools at Gona. Perhaps hominins did indeed have a stone-tool culture spanning that time, and archaeologists have just not found it yet. But maybe the Lomekwi stone-working was just a flash in the pan, unrelated to the Oldowan technology that followed. Even the Oldowan record is patchy and variable, showing different tool styles at different times and places, without much continuity among them. As Roche puts it, "There is not one Oldowan but Oldowans."

This pattern suggests to many archaeologists that populations in multiple lineages of hominins and possibly other primates may have experimented with stone-tool production independently, only to have their inventions fizzle out, unbequeathed to the next generation. "We used to think that once you have toolmaking, we're off to the races," observes Dietrich Stout of Emory University. But maybe with these early populations, he says, technology was not important to their adaptation, so it simply faded away.

Around two million years ago, however, something changed. The tools from this period start to look as though they were manufactured according to the same rules. By around 1.7 million years ago a more sophisticated technology arises: the Acheulean. Known for its hand ax, the Swiss Army knife of the Paleolithic, the Acheulean tradition spread across Africa and into other parts of the Old World.

Braun thinks the shift has to do with improved information transmission. Chimps appear to have what he calls low-fidelity transmission of behavior based on observational learning. It works pretty well for simple tasks: by the end of his team's six-week-long experiment with the Bossou chimps, the entire community was using the rocks the same way. The activity seemed to spread by means of a recycling behavior in which one individual, typically a juvenile, would watch another, usually an adult, use a certain type of rock to crack nuts, after which the youngster would try to use the adult's tool set to achieve the same ends.

Modern humans, in contrast, actively teach others how to do complex things—from baking a cake to flying a plane—which is a high-fidelity form of transmission. Perhaps, Braun suggests, the variability seen in the Lomekwi tools and in those of the early Oldowan is the result of lower-fidelity transmission, and the standardization of the later Oldowan and the more sophisticated Acheulean signals the development of a more effective means of sharing knowledge, one that allowed humans to ratchet up their technological complexity.

AS ANCIENT AS THE TOOLS FROM LOMEKWI 3 ARE, THE team suspects that even older ones are out there, awaiting discovery. One day, while the rest of the team is excavating, Lewis, Lokorodi and Xavier Boës, a geologist at the French National Institute for Preventive Archaeological Research, set out to look for them. They head for an area known to have sediments older than those at Lomekwi 3, speeding up the *laga* in a cloud of dust. They are taking the same branch they meant to take on that day five years ago when they lost their way and discovered Lomekwi 3.

When they reach their destination, they fan out, eyes trained on the ground, scanning for signs of human handiwork in a sea of rocks baked red by the sun. Before long, Lokorodi spies cobbles bearing scoop-shaped scars. In theory, they could be more than 3.5 million years old. But the team will have to follow the same painstaking procedures it carried out at Lomekwi 3. The researchers will have to determine whether the rocks have been shaped by humans and, if so, figure out which stratigraphic level they eroded from, pinpoint the age of that level and then find more of them undisturbed in the ground. Lewis photographs the rocks and notes their location for possible survey in the future. The team will also explore a promising area about three miles from Lomekwi 3 that has sediments dating to more than four million years ago.

Figuring out what technology came before and after Lomekwi 3 and getting a clearer picture of how the environment was shifting will be critical to elucidating the correlations among dietary change, tools and the origins of *Homo*. "Maybe the links are all the same, but everything happened earlier," Lewis offers. "The pieces have exploded, but that doesn't mean they won't reassemble."

"We know quite a lot now but not enough," Roche says of the discoveries in western Turkana. "This is only the beginning." SA

MORE TO EXPLORE

3.3-Million-Year-Old Stone Tools from Lomekwi 3, West Turkana, Kenya. Sonia Harmand et al. in *Nature*, Vol. 521, pages 310–315; May 21, 2015.

Wild Monkeys Flake Stone Tools. Tomos Proffitt et al. in *Nature*, Vol. 539, pages 85–88; November 3, 2016.

FROM OUR ARCHIVES

Tales of a Stone Age Neuroscientist. Dietrich Stout; April 2016.

scientificamerican.com/magazine/sa

Humans Tamed Fire by 1 Million Years Ago

Kate Wong April 2, 2012

Image: matthewvenn via Flickr

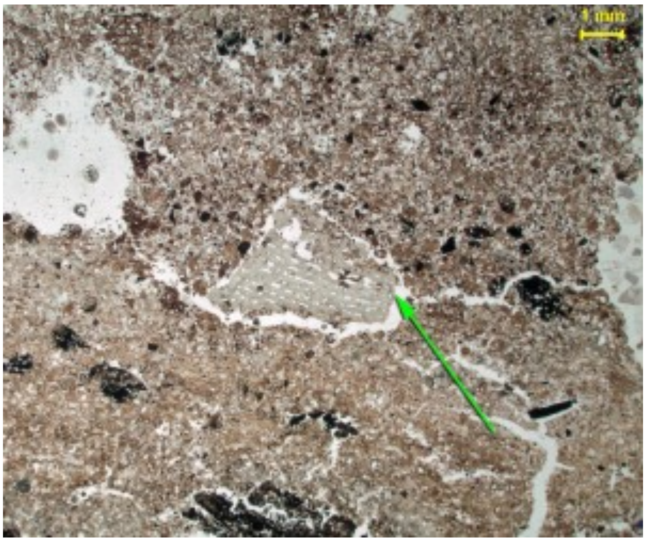
The ability to control fire marked a major milestone in human evolution, helping our ancestors stay warm in the cold, enhance the nutritional value of their food and keep predators at bay, among other uses. But exactly when humans mastered flame has proved difficult to establish. The oldest signs of fire in association with human activity date to around 1.5 million years ago, but because they come from open-air settings (as opposed to caves), the possibility exists that they represent wild fires instead of anthropogenic ones. Pretty much all of the unequivocal evidence of habitual fire use seemed to be less than 400,000 years old, the handiwork of Neandertals and anatomically modern humans. Until now.

Wonderwerk Cave, located in South Africa's

Researchers excavating the Wonderwerk Cave site in South Africa's Northern Cape province have uncovered burned remains that, at a million years old, precede those Neandertal and modern human hearths by a long shot. In a report detailing the finds, published online today in the *Proceeding of*

Northern Cape province, has yielded evidence of human-controlled fire dating to one million years ago. Image: Courtesy of M. Chazan

the National Academy of Sciences USA, Francesco Berna of Boston University and his colleagues say that the discovery is, to the best of their knowledge, "the earliest secure evidence for burning in an archaeological context."



Micrograph shows burned bone from Wonderwerk Cave. Image: Courtesy of P. Goldberg

Berna's team obtained blocks of sediment from a layer in the cave that contains stone tools made in the so-called Acheulean tradition, which is believed to have originated with the early human ancestor *Homo erectus*. Studying thin sections of the sediment blocks under a microscope, the scientists observed lots of ashed plant remains and tiny fragments of burned bone. Further analysis of the thin sections using Fourier transform infrared microspectroscopy, which reveals molecular structure, showed that some of the bones had been heated to temperatures of around 500 degrees Celsius. Preliminary data suggest that leaves and grasses, rather than wood, fueled these ancient fires. All told, the burned remains appear to have been the products of repeated, local combustion episodes that occurred in the vicinity of where the remains were discovered, 30 meters in from mouth of the cave.

The authors observe that their findings stand as “the most compelling evidence to date offering some support for the cooking hypothesis,” an idea put forth by Richard Wrangham of Harvard University. Wrangham has argued that the advent of cooking enabled the ballooning of human brain size that began around two million years ago in *H. erectus,* because it liberated more calories for energetically demanding brain tissue to use. A lack of indisputable evidence for human control of fire more than 400,000 years old has posed a major problem for this scenario. The findings from Wonderwerk Cave help to bridge that gap, yet the discovery still leaves another million years of cooking undocumented. But Berna and his collaborators suggest that microstratigraphic analyses of the sorts they conducted—studies that were previously restricted to much younger sediments--could reveal more evidence of fire use among our ancient forebears.

The views expressed are those of the author(s) and are not necessarily those of Scientific American.

ANTHROPOLOGY

the first cookout

Nearly two million years ago our ancestors began to barbecue. And those hot meals, Richard Wrangham argues, are what made us human

Interview by Kate Wong

With our supersized brains and shrunken teeth and guts, we humans are bizarre primates. Richard Wrangham of Harvard University has long argued that these and other peculiar traits of our kind arose as humans turned to cooking to improve food quality—making it softer and easier to digest and thus a richer source of energy. Humans, unlike any other animal, cannot survive on raw food in the wild, he observes. "We need to have our food cooked."

Based on the anatomy of our fossil forebears, Wrangham thinks that Homo erectus *had mastered cooking with fire by 1.8 million years ago. Critics have countered that he lacks evidence to support the claim that cooking enhances digestibility and that the oldest known traces of fire are nowhere near as old as his hypothesis predicts. New findings, Wrangham says, lend support to his ideas.*

IN BRIEF

WHO
RICHARD WRANGHAM

VOCATION | AVOCATION
Anthropologist

WHERE
Harvard University

RESEARCH FOCUS
Chimpanzee behavior, ecology and physiology, which contribute to understanding human evolution

BIG PICTURE
Cooking made us human.

Photograph by Guido Vitti

COOKED FOOD provides more energy and requires less chewing than raw food does—benefits that may have fueled the evolution of key human traits, such as large brain size.

Scientific American: How did you come up with the cooking hypothesis?

WRANGHAM: I think of two strands. One is that I was trying to figure out what was responsible for the evolution of the human body form, and I was sensitive to the fact that humans everywhere use fire. I started thinking about how long ago you would have to go back before humans did not use fire. And that suggested to me the hypothesis that they always used it because they would not have survived without it. Humans as a genus [*Homo*] are committed to sleeping on the ground. I do not want to sleep on the ground in Africa without fire to keep the wild animals at bay.

The other strand is that I've studied chimpanzees and their feeding behavior for many years. I've eaten everything that I can get ahold of that chimpanzees eat. And I have been very much aware of the deeply unsatisfying nature of those foods because they are often quite fibrous, relatively dry, and contain little sugar, and they are often strong-tasting—in other words, really nasty. So here we are, two very closely related species with completely different dietary habits. It was an obvious hypothesis that cooking does something special for the food we find in nature. But I was astonished to discover that there was no systematic evidence showing what cooking does to the net energetic gain that we get from our foods.

For the past 14 years I've been focused on that question because to make a satisfactory claim about humans being adapted to cooked food, we have to produce some real evidence about what cooking does to food. Experiments conducted by Rachel N. Carmody of Harvard University have now given us the evidence: if we cook, we get more energy from our food.

Other researchers hold that increased access to meat allowed the teeth and gut to shrink. Why do you think cooking better explains these changes?

It's quite clear that humans began eating meat from large animals by 2.5 million years ago and have left a steady record of cut marks on bones since then. The cooking hypothesis does not deny the importance of meat eating. But there is a core difficulty with attributing changes in digestive anatomy to this shift.

Selection pressure on digestive anatomy is strongest when food is scarce. Under such conditions, animals have very little fat on them, and fat-poor meat is a very poor food because if you have more than about 30 percent protein in your diet, then your ability to get rid of ammonia fast enough is overwhelmed. Nowadays in surveys of hunters and gatherers, what you find is that during periods of food scarcity, there is always a substantial inclusion of plants. Very often it's tubers. To eat those raw, you would have to have the digestive apparatus to handle tough, fibrous, low-carbohydrate plant foods—that is, large teeth and a big gut.

So your idea is that by cooking those plant foods, our ancestors could evolve a smaller gut and teeth—and avoid overdosing on lean meat. Let's turn now to what happened when food was not so scarce and animals were good to eat. You have argued that cooking may have helped early humans eat more meat by freeing them up to hunt. What is your logic?

A primate the size of an early human would be expected to spend about half of its day chewing, as chimpanzees do. Modern humans spend less than an hour a day, whether you're American or living in various subsistence societies around the world. So you've got four or five hours a day freed by the fact that you're eating relatively soft food. In hunter-gatherer life, men tend to spend this time hunting.

That observation raises the question of how much hunting was possible until our ancestors were able to reduce the amount of time they chewed. Chimpanzees like to eat meat, but their average hunt is just 20 minutes, after which they go back to eating fruit. Hunting is risky. If you fail, then you need to be able to eat your ordinary food. If you hunt too long without success, you won't have enough time to process your usual, lower-quality fare. It seems to me that it was only after cooking enabled individuals to save time on chewing that they could increase the amount of time spent on an activity that, for all its potential benefits, might not yield any food.

You have also suggested that cooking allowed the brain to expand. How would cooking do that?

With regard to the brain, fossils indicate a fairly steady increase in cranial capacity, starting shortly before two million years ago. There are lots of ideas about why selection favored larger brains, but the question of how our ancestors could afford them has been a puzzle. The problem is that brains use a disproportionate amount of energy and can never be turned off.

I have extended the idea put forward by Leslie C. Aiello, now at the Wenner-Gren Foundation in New York City, and Peter Wheeler of Liverpool John Moores University in England that after cooking became obligatory, the increase in food quality contributed to reduced gut size. Their newly small guts were energetically cheaper, allowing calories to be diverted to the brain.

In 2012 Karina Fonseca-Azevedo and Suzana Herculano-Houzel of the Federal University of Rio de Janeiro added a new wrinkle. Their calculations showed that on a raw diet, the number of calories needed to support a human-sized brain would require too many hours eating every day. They argued that cooking allowed our ancestors the extra energy needed to support more neurons, allowing the increase in brain size.

Cooking is not the only way to make food easier to digest. How does it compare with other methods?

Simply reducing the size of food particles and the structural integrity of food—through pounding, for example—makes it easier to digest. Carmody did a study that looked at tubers and meat as representative types of food that hunter-gatherers eat and asked how well mice fared when eating each of these foods, either raw versus cooked or whole versus pounded. She very carefully controlled the amount of food that the mice received, along with the amount of energy they expended moving around, and assessed their net energetic gain through looking at body-mass changes. She found that pounding had relatively little effect, whereas cooking led to significant increases in body weight whether the food was tubers or meat.

This is incredibly exciting because, amazingly, this is the first study that has ever been done to show that animals get more net energy out of their food when it is cooked than when it's raw. Second, it showed that even if pounding has some positive effects on energy gain, cooking has much bigger effects. [*Editors' note:*

Wrangham was a co-author on the study, published in 2011.]

Is there any genetic evidence to support the cooking hypothesis?
There is essentially nothing published yet. But we're very aware that a really interesting question is going to be whether or not we can detect, in the human genome, evidence of selection for genes related to utilizing cooked food. They might be concerned with metabolism. They might be concerned with the immune system. They might be concerned somehow with responses to Maillard compounds, which are somewhat dangerous compounds produced by cooking. This is going to be a very exciting area in the future.

A really interesting question is going to be whether or not we can detect, in the human genome, evidence of selection for genes related to utilizing cooked food.

A central objection to the cooking hypothesis has been that there is no archaeological evidence of controlled fire as far back as the hypothesis predicts. Currently the oldest traces come from one-million-year-old deposits in Wonderwerk Cave in South Africa. But you have recently identified an independent line of evidence that humans tamed fire earlier than the archaeological record suggests. How does that work support your thinking?
Chimpanzees love honey, yet they eat very little of it because they get chased away by bees. African hunters and gatherers, in contrast, eat somewhere between 100 and 1,000 times as much honey as chimpanzees do because they use fire. Smoke interferes with the olfactory system of the bees, and under those conditions, the bees do not attack. The question is: How long have humans been using smoke to get honey? That's where the honeyguide comes in. The greater honeyguide is an African species of bird that is adapted to guiding humans to honey. The bird is attracted to human activity—sounds of chopping, whistling, shouting, banging and, nowadays, motor vehicles. On finding people, the bird starts fluttering in front of them and then leads them off with a special call and waits for them to follow. Honeyguides can lead humans a kilometer or more to a tree that has honey in it. The human then uses smoke to disarm the bees and opens the hive up with an ax to extract the honey inside. The bird gains access to the hive's wax, which it eats.

It used to be thought that the bird's guiding behavior [which is innate, not learned] originated in partnership with the honey badger and that humans moved in on this arrangement later. But in the past 30 years it has become very clear that honey badgers are rarely, if ever, led to honey by honeyguides. If there's no living species other than humans that has this symbiotic relationship with the bird, could there have been some extinct species of something that favored the honeyguide showing this behavior? Well, obviously, the most reasonable candidates are the extinct ancestors of humans. The argument points very strongly to our ancestors having used fire long enough for natural selection to enable this relationship to develop.

Claire Spottiswoode of the University of Cambridge discovered that there are two kinds of greater honeyguide females: those that lay their eggs in ground nests and those that lay in tree nests. Then she found that the two types of behavior are associated with different lineages of mitochondrial DNA [DNA that is found in the energy-producing components of cells and passed down from mother to offspring]. Based on a fairly conservative assessment of the rate of mutation, Spottiswoode and her colleagues determined that the two lineages had been separated for about three million years, [providing a minimum estimate for the age of the greater honeyguide species]. That doesn't necessarily mean that the guiding habit, which depends on humans using fire, is that old—it could be more recent—but at least it tells you that the species is old enough to allow for much evolutionary change.

If cooking was a driving force in human evolution, does this conclusion have implications for how people should eat today?
It does remind us that eating raw food is a very different proposition from eating cooked food. Because we don't think about the consequences of processing our food, we are getting a misunderstanding of the net energy gain from eating. One of the ways in which this can be quite serious is if people who are dedicated to a raw-food diet don't understand the consequences for their children. If you just say, "Well, animals eat their food raw, and humans are animals, then it should be fine for us to eat our food raw," and you bring your children up this way, you're putting them at very severe risk. We are a different species from every other. It's fine to eat raw food if you want to lose weight. But if you want to gain weight, as with a child or an adult who's too thin, then you don't want to eat a raw diet. SA

***Kate Wong** is a senior editor at* Scientific American.

MORE TO EXPLORE

Energetic Consequences of Thermal and Nonthermal Food Processing. Rachel N. Carmody et al. in *Proceedings of the National Academy of Sciences USA,* Vol. 108, No. 48, pages 19199–19203; November 29, 2011.
Honey and Fire in Human Evolution. Richard Wrangham in *Casting the Net Wide: Papers in Honor of Glynn Isaac and His Approach to Human Origins Research.* Edited by Jeanne Sept and David Pilbeam. Oxbow Books, 2012.
Metabolic Constraint Imposes Tradeoff between Body Size and Number of Brain Neurons in Human Evolution. Karina Fonseca-Azevedo and Suzana Herculano-Houzel in *Proceedings of the National Academy of Sciences USA,* Vol. 109, No. 45, pages 18,571–18,576; November 6, 2012.

SCIENTIFIC AMERICAN ONLINE
Watch a video on why cooking makes food taste good at **ScientificAmerican.com/sep2013/cooking**

28/06 | Aula 6: O aparecimento dos primeiros traços que caracterizam os Neandertais, em Sima de los Huesos, Atapuerca, Espanha. Expressões de comportamentos simbólicos atribuídos a Neandertais. O desaparecimento dos Neandertais. O cruzamento *sapiens* e neandertais. A presença de genes neandertais nas populações humanas atuais.

Textos para leitura:
Neandertal Lineage Began in a "Game of Thrones" World | Kate Wong
Twilight of the Neandertals | Kate Wong
Neandertal Minds | Kate Wong
Did Neandertals Think Like Us? | Kate Wong
Oldest Cave Paintings May Be Creations of Neandertals, Not Modern Humans | Kate Wong

Neandertal Lineage Began in a "Game of Thrones" World

In a small chamber deep in the Atapuerca mountains in northern Spain lies one of the most extraordinary paleontological discoveries of all time: a massive assemblage of fossils belonging to an extinct member of the human family.

Kate Wong June 19, 2014

Skull from the Sima de los Huesos site in Spain shows early Neandertal features. Image: © Javier Trueba / Madrid Scientific Films

In a small chamber deep in the Atapuerca mountains in northern Spain lies one of the most extraordinary paleontological discoveries of all time: a massive assemblage of fossils belonging to an extinct member of the human family. The site is known as the Sima de los Huesos, the "pit of bones." And in it scientists have found clues to the origin of Neandertals.

Researchers have been excavating the site for years, recovering more than 6,500 bones from at least 28 individuals to date. The find offers a rare chance to study a prehistoric population, as opposed to an individual. Now a new analysis of 17 skulls from the site is yielding fresh insights. In a paper published today in *Science,* Juan Luis Arsuaga of the Centro Mixto UCM-ISII de Evolución y Comportamiento Humanos in

Madrid and his colleagues report that the fossils show that Neandertals have deep evolutionary roots, and that their distinctive traits evolved piecemeal rather than as a package deal.

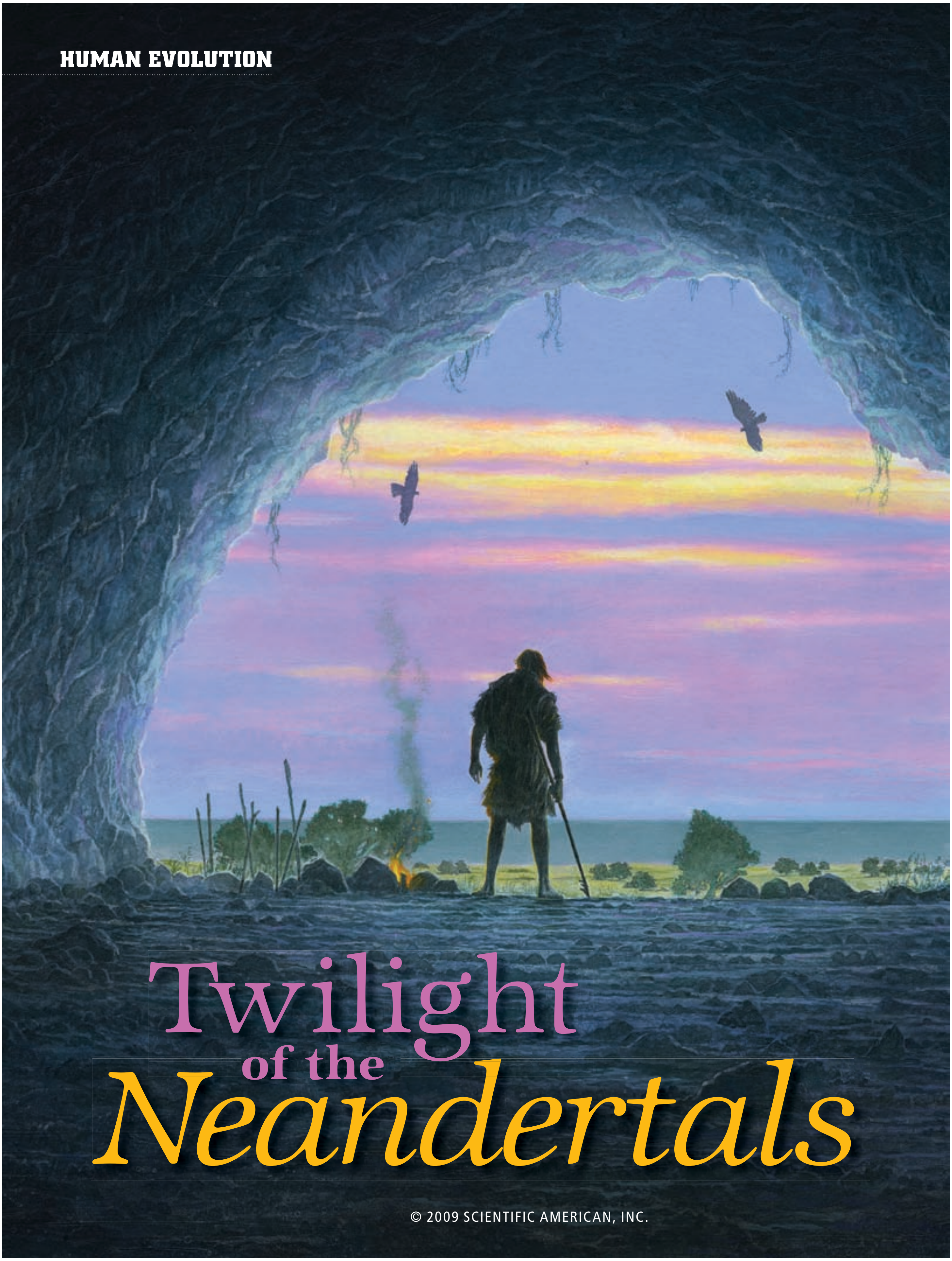
The Sima skulls date to around 430,000 years ago, during the Middle Pleistocene—a poorly understood period of human evolution. And they exhibit some key Neandertal characteristics, including a projecting midface, as well as a number of features in the teeth and jaws. They are the oldest fossils to show such affinities to our Neandertal cousins. But they lack the classic Neandertal "chignon" (a mound of bone at the rear of the skull) and other aspects of the Neandertal braincase. All told this mix of Neandertal and non-Neandertal traits indicates to the team that the Sima fossils represent an early member of the Neandertal clade—not *Homo neanderthalensis*, but a closely related species or subspecies.

Arsuaga and his colleagues observe that the Neandertal traits evident in the Sima skulls all relate to chewing, suggesting that "the origin of the Neandertal clade coincides with a masticatory specialization." But exactly what the specialization was is not yet clear, though researchers have previously argued that the Neandertals used their teeth as a grasping tool while preparing animal hides or processing food. For example, they might have gripped one end of a hide with one hand and the other end with their teeth, leaving one hand free to scrape the fur from the skin.

Only later in the evolution of the Neandertal lineage did brain size expand, attaining a volume close to that of anatomically modern *H. sapiens.* Yet though these increases in size occurred in parallel in the Neandertal and *H. sapiens* lineages, they did not produce identical brains in the two groups. In a commentary accompanying the *Science* report, paleoanthropologist Jean-Jacques Hublin of the Max Planck Institute for Evolutionary Anthropology in Leipzig notes that "there is clear evidence that the growth pattern of modern human brains deviates from that of Neandertals. In modern humans, parietal areas and cerebellum expand in early infancy, at a crucial stage for the establishment of cognitive skills."

At a press teleconference, Arsuaga likened Middle Pleistocene Europe to a Game of Thrones world in which different populations across the continent variously competed and co-mingled as they struggled to survive ice age climate swings. "Winter was coming," he said. "Winter came many times."

The views expressed are those of the author(s) and are not necessarily those of Scientific American.



Twilight of the Neandertals

KAZUHIKO SANO

Paleoanthropologists know more about Neandertals than any other extinct human. But their demise remains a mystery, one that gets curiouser and curiouser

By Kate Wong

Some 28,000 years ago in what is now the British territory of Gibraltar, a group of Neandertals eked out a living along the rocky Mediterranean coast. They were quite possibly the last of their kind. Elsewhere in Europe and western Asia, Neandertals had disappeared thousands of years earlier, after having ruled for more than 200,000 years. The Iberian Peninsula, with its comparatively mild climate and rich array of animals and plants, seems to have been the final stronghold. Soon, however, the Gibraltar population, too, would die out, leaving behind only a smattering of their stone tools and the charred remnants of their campfires.

Ever since the discovery of the first Neandertal fossil in 1856, scientists have debated the place of these bygone humans on the family tree and what became of them. For decades two competing theories have dominated the discourse. One holds that Neandertals were an archaic variant of our own species, *Homo sapiens,* that evolved into or was assimilated by the anatomically modern European population. The other posits that the Neandertals were a separate species, *H. neanderthalensis,* that modern humans swiftly extirpated on entering the archaic hominid's territory.

Over the past decade, however, two key findings have shifted the fulcrum of the debate away from the question of whether Neandertals and moderns made love or war. One is that analyses of Neandertal DNA have yet to yield the signs of interbreeding with modern humans that many researchers expected to see if the two groups mingled significantly. The other is that improvements in dating methods show that rather than disappearing immediately after the moderns invaded Europe, starting a little more than 40,000 years ago, the Neandertals survived for nearly 15,000 years after moderns moved in—hardly the rapid replacement adherents to the blitzkrieg theory envisioned.

These revelations have prompted a number of researchers to look more carefully at other factors that might have led to Neandertal extinction. What they are

KEY CONCEPTS

- Neandertals, our closest relatives, ruled Europe and western Asia for more than 200,000 years. But sometime after 28,000 years ago, they vanished.
- Scientists have long debated what led to their disappearance. The latest extinction theories focus on climate change and subtle differences in behavior and biology that might have given modern humans an advantage over the Neandertals.

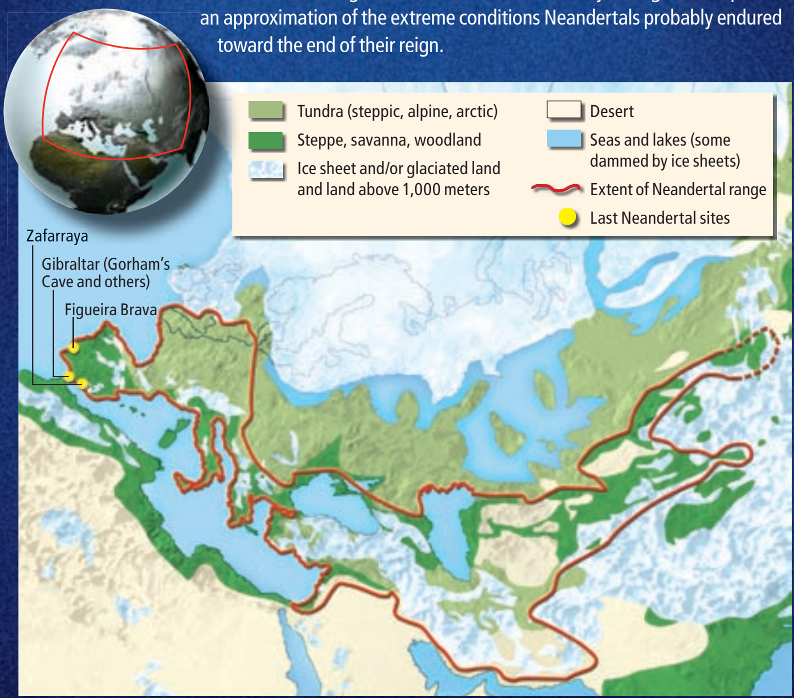
—The Editors

[HYPOTHESIS 1]

Did Climate Change Doom the Neandertals?

Starting perhaps around 55,000 years ago, climate in Eurasia began to swing wildly from frigid to mild and back again in the span of decades. During the cold snaps, ice sheets advanced and treeless tundra replaced wooded environments across much of the Neandertals' range. Shifts in the available prey animals accompanied these changes. Wide spacing between past climate fluctuations allowed diminished Neandertal populations sufficient time to bounce back and adapt to the new conditions.

This time, however, the rapidity of the changes may have made recovery impossible. By 30,000 years ago only a few pockets of Neandertals survived, hanging on in the Iberian Peninsula, with its comparatively mild climate and rich resources. These groups were too small and fragmented to sustain themselves, however, and eventually they disappeared. The map below shows conditions associated with the last glacial maximum, some 20,000 years ago, which provide an approximation of the extreme conditions Neandertals probably endured toward the end of their reign.



LAURIE GRACE; SOURCE FOR MAP: "RAPID ECOLOGICAL TURNOVER AND ITS IMPACT ON NEANDERTAL AND OTHER HUMAN POPULATIONS," BY CLIVE FINLAYSON AND JOSE S. CARRION, IN *TRENDS IN ECOLOGY AND EVOLUTION*, VOL. 22, NO. 4; 2007

finding suggests that the answer involves a complicated interplay of stresses.

A World in Flux

One of the most informative new lines of evidence bearing on why the Neandertals died out is paleoclimate data. Scholars have known for some time that Neandertals experienced both glacial conditions and milder interglacial conditions during their long reign. In recent years, however, analyses of isotopes trapped in primeval ice, ocean sediments and pollen retrieved from such locales as Greenland, Venezuela and Italy have enabled investigators to reconstruct a far finer-grained picture of the climate shifts that occurred during a period known as oxygen isotope stage 3 (OIS-3). Spanning the time between roughly 65,000 and 25,000 years ago, OIS-3 began with moderate conditions and culminated with the ice sheets blanketing northern Europe.

Considering that Neandertals were the only hominids in Europe at the beginning of OIS-3 and moderns were the only ones there by the end of it, experts have wondered whether the plummeting temperatures might have caused the Neandertals to perish, perhaps because they could not find enough food or keep sufficiently warm. Yet arguing for that scenario has proved tricky for one essential reason: Neandertals had faced glacial conditions before and persevered.

In fact, numerous aspects of Neandertal biology and behavior indicate that they were well suited to the cold. Their barrel chests and stocky limbs would have conserved body heat, although they would have additionally needed clothing fashioned from animal pelts to stave off the chill. And their brawny build seems to have been adapted to their ambush-style hunting of large, relatively solitary mammals—such as woolly rhinoceroses—that roamed northern and central Europe during the cold snaps. (Other distinctive Neandertal features, such as the form of the prominent brow, may have been adaptively neutral traits that became established through genetic drift, rather than selection.)

But the isotope data reveal that far from progressing steadily from mild to frigid, the climate became increasingly unstable heading into the last glacial maximum, swinging severely and abruptly. With that flux came profound ecological change: forests gave way to treeless grassland; reindeer replaced certain kinds of rhinoceroses. So rapid were these oscillations that over the course of an individual's lifetime, all the plants and animals that a person had grown up with could vanish and be replaced with unfamiliar flora and fauna. And then, just as quickly, the environment could change back again.

It is this seesawing of environmental conditions—not necessarily the cold, per se—that gradually pushed Neandertal populations to the point of no return, according to scenarios posited by such experts as evolutionary ecologist Clive Finlayson of the Gibraltar Museum, who directs the excavations at several cave sites in Gibraltar. These shifts would have demanded that Neandertals adopt a new way of life in very short order. For example, the replacement of wooded areas with open grassland would have left ambush hunters without any trees to hide behind, he says. To survive, the Neandertals would have had to alter the way they hunted.

Some Neandertals did adapt to their changing world, as evidenced by shifts in their tool types and prey. But many probably died out during these fluctuations, leaving behind ever more fragmented populations. Under normal circumstances, these archaic humans might have been able to bounce back, as they had previously, when the fluctuations were fewer and farther between. This time, however, the rapidity of the environmental change left insufficient time for recovery. Eventually, Finlayson argues, the repeated climatic insults left the Neandertal populations so diminished that they could no longer sustain themselves.

The results of a genetic study published this past April in *PLoS One* by Virginie Fabre and her colleagues at the University of the Mediterranean in Marseille support the notion that Neandertal populations were fragmented, Finlayson says. That analysis of Neandertal mitochondrial DNA found that the Neandertals could be divided into three subgroups—one in western Europe, another in southern Europe and a third in western Asia—and that population size ebbed and flowed.

Invasive Species

For other researchers, however, the fact that the Neandertals entirely disappeared only after moderns entered Europe clearly indicates that the invaders had a hand in the extinction, even if the newcomers did not kill the earlier settlers outright. Probably, say those who hold this view, the Neandertals ended up competing with the incoming moderns for food and gradually lost ground. Exactly what ultimately gave moderns their winning edge remains a matter of considerable disagreement, though.

One possibility is that modern humans were less picky about what they ate. Analyses of Neandertal bone chemistry conducted by Hervé Bocherens of the University of Tübingen in Germany suggest that at least some of these hominids specialized in large mammals, such as woolly rhinoceroses, which were relatively rare. Early modern humans, on the other hand, ate all manner of animals and plants. Thus, when moderns moved into Neandertal territory and started taking some of these large animals for themselves, so the argument goes, the Neandertals would have been in trouble. Moderns, meanwhile, could supplement the big kills with smaller animals and plant foods.

VIKTOR DEAK

RESURRECTING THE NEANDERTAL

Later this year researchers led by Svante Pääbo of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, are expected to publish a rough draft of the Neandertal genome. The work has prompted speculation that scientists might one day be able to bring back this extinct human. Such a feat, if it were technically possible, would raise all sorts of ethical quandaries: What rights would a Neandertal have? Would this individual live in a lab, or a zoo, or a household?

Moral concerns aside, what could researchers actually learn from a resurrected Neandertal? The answer is: less than you might think. A Neandertal born and raised in a modern setting would not have built-in Ice Age wisdom to impart to us, such as how to make a Mousterian stone tool or bring down a woolly rhinoceros. Indeed, he would not be able to tell scholars anything about the culture of his people. It is possible, however, that studying Neandertal biology and cognition could reveal as yet unknown differences between these archaic hominids and modern ones that might have given moderns a survival advantage.

"Neandertals had a Neandertal way of doing things, and it was great as long as they weren't competing with moderns," observes archaeologist Curtis W. Marean of Arizona State University. In contrast, Marean says, the moderns, who evolved under tropical conditions in Africa, were able to enter entirely different environments and very quickly come up with creative ways to deal with the novel circumstances they encountered. "The key difference is that Neandertals were just not as advanced cognitively as modern humans," he asserts.

Marean is not alone in thinking that Neandertals were one-trick ponies. A long-standing view holds that moderns outsmarted the Neandertals with not only their superior tool technology and survival tactics but also their gift of gab, which might have helped them form stronger social networks. The Neandertal dullards, in this view, did not stand a chance against the newcomers.

But a growing body of evidence indicates that Neandertals were savvier than they have been given credit for. In fact, they apparently engaged in many of the behaviors once believed to be strictly the purview of modern humans. As paleoanthropologist Christopher B. Stringer of London's Natural History Museum puts it, "the boundary between Neandertals and moderns has gotten fuzzier."

Sites in Gibraltar have yielded some of the most recent findings blurring the line between the two human groups. In September 2008 Stringer and his colleagues reported on evidence that Neandertals at Gorham's Cave and next-door Vanguard Cave hunted dolphins and seals as well as gathered shellfish. And as yet unpublished work shows that they were eating birds and rabbits, too. The discoveries in Gilbraltar, along with finds from a handful of other sites, upend the received wisdom that moderns alone exploited marine resources and small game.

More evidence blurring the line between Neandertal and modern human behavior has come from the site of Hohle Fels in southwestern Germany. There paleoanthropologist Bruce Hardy of Kenyon College was able to compare artifacts made by Neandertals who inhabited the cave between 36,000 and 40,000 years ago with artifacts from modern humans who resided there between 33,000 and 36,000 years ago under similar climate and environmental conditions. In a presentation given this past April to the

Paleoanthropology Society in Chicago, Hardy reported that his analysis of the wear patterns on the tools and the residues from substances with which the tools came into contact revealed that although the modern humans created a larger variety of tools than did the Neandertals, the groups engaged in mostly the same activities at Hohle Fels.

These activities include such sophisticated practices as using tree resin to bind stone points to wooden handles, employing stone points as thrusting or projectile weapons, and crafting implements from bone and wood. As to why the Hohle Fels Neandertals made fewer types of tools than did the moderns who lived there afterward, Hardy surmises that they were able to get the job done without them. "You don't need a grapefruit spoon to eat a grapefruit," he says.

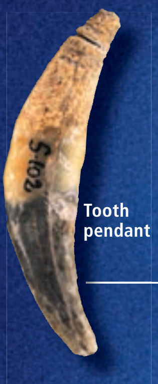
The claim that Neandertals lacked language, too, seems unlikely in light of recent discoveries. Researchers now know that at least some of them decorated their bodies with jewelry and probably pigment. Such physical manifestations of symbolic behavior are often used as a proxy for language when reconstructing behavior from the archaeological record. And in 2007 researchers led by Johannes Krause of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, reported that analyses of Neandertal DNA have shown that these hominids had the same version of the speech-enabling gene *FOXP2* that modern humans carry.


Knife

[HYPOTHESIS 2]

Were the Neandertals Outsmarted by Modern Humans?

A long-standing theory of Neandertal extinction holds that modern humans outcompeted Neandertals with their superior smarts. But mounting evidence indicates that Neandertals engaged in many of the same sophisticated behaviors once attributed to moderns alone (*table*). The findings reveal that at least some Neandertals were capable of symbolic thought—and therefore probably language—and that they had the tools and the know-how to pursue a wide range of foods. Still, these practices seem to have been more entrenched in modern human culture than in that of Neandertals, which may have given moderns the upper hand.


Tooth pendant


Bone awl


Seal jaw

EVIDENCE OF MODERN BEHAVIOR AMONG NEANDERTALS

TRAIT	COMMON	OCCASIONAL	ABSENT	UNCERTAIN
Art				✓
Pigment use	✓			
Jewelry		✓		
Symbolic burial of dead				✓
Long-distance exchange				✓
Microliths		✓		
Barbed points			✓	
Bone tools		✓		
Blades		✓		
Needles			✓	
Exploitation of marine resources		✓		
Bird hunting		✓		
Division of labor			✓	

Tiebreakers

With the gap between Neandertal and modern human behavior narrowing, many researchers are now looking to subtle differences in culture and biology to explain why the Neandertals lost out. "Worsening and highly unstable climatic conditions would have made competition among human groups all the more fierce," reflects paleoanthropologist Katerina Harvati, also at Max Planck. "In this context, even small advantages would become extremely important and might spell the difference between survival and death."

Stringer, for his part, theorizes that the moderns' somewhat wider range of cultural adaptations provided a slightly superior buffer against hard times. For example, needles left behind by modern humans hint that they had tailored clothing and tents, all the better for keeping the cold at bay. Neandertals, meanwhile, left behind no such signs of sewing and are believed by some to have had more crudely assembled apparel and shelters as a result.

Neandertals and moderns may have also differed in the way they divvied up the chores among group members. In a paper published in *Current Anthropology* in 2006, archaeologists Steven L. Kuhn and Mary C. Stiner, both at the University of Arizona, hypothesized that the varied diet of early modern Europeans would have favored a division of labor in which men hunted the larger game and women collected and prepared nuts, seeds and berries. In contrast, the Neandertal focus on large game probably meant that their women and children joined in the hunt, possibly helping to drive animals toward the waiting men. By creating both

COURTESY OF CLIVE FINLAYSON *Gibraltar Museum* (*jaw*); LABORATORY OF PREHISTORIC ETHNOLOGY, LA VARENDE COLLECTION (*artifacts*)

LAST BASTION of the Neandertals may have been a group of coastal caves in the British territory of Gibraltar, where the archaic hominids lived as recently as 28,000 years ago. Gibraltar and the rest of the Iberian Peninsula would have had a relatively mild climate and abundant food resources compared with much of Ice Age Europe.

a more reliable food supply and a safer environment for rearing children, division of labor could have enabled modern human populations to expand at the expense of the Neandertals.

However the Neandertals obtained their food, they needed lots of it. "Neandertals were the SUVs of the hominid world," says paleoanthropologist Leslie Aiello of the Wenner-Gren Foundation in New York City. A number of studies aimed at estimating Neandertal metabolic rates have concluded that these archaic hominids required significantly more calories to survive than the rival moderns did.

Hominid energetics expert Karen Steudel-Numbers of the University of Wisconsin–Madison has determined, for example, that the energetic cost of locomotion was 32 percent higher in Neandertals than in anatomically modern humans, thanks to the archaic hominids' burly build and short shinbones, which would have shortened their stride. In terms of daily energy needs, the Neandertals would have required somewhere between 100 and 350 calories more than moderns living in the same climates, according to a model developed by Andrew W. Froehle of the University of California, San Diego, and Steven E. Churchill of Duke University. Modern humans, then, might have outcompeted Neandertals simply by virtue of being more fuel-efficient: using less energy for baseline functions meant that moderns could devote more energy to reproducing and ensuring the survival of their young.

One more distinction between Neandertals and moderns deserves mention, one that could have enhanced modern survival in important ways. Research led by Rachel Caspari of Central Michigan University has shown that around 30,000 years ago, the number of modern humans who lived to be old enough to be grandparents began to skyrocket. Exactly what spurred this increase in longevity is uncertain, but the change had two key consequences. First, people had more reproductive years, thus increasing their fertility potential. Second, they had more time over which to acquire specialized knowledge and pass it on to the next generation—where to find drinking water in times of drought, for instance. "Long-term survivorship gives the potential for bigger social networks and greater knowledge stores," Stringer comments. Among the shorter-lived Neandertals, in contrast, knowledge was more likely to disappear, he surmises.

More clues to why the Neandertals faded away may come from analysis of the Neandertal genome, the full sequence of which is due out this year. But answers are likely to be slow to surface, because scientists know so little about the functional significance of most regions of the modern genome, never mind the Neandertal one. "We're a long way from being able to read what the [Neandertal] genome is telling us," Stringer says. Still, future analyses could conceivably pinpoint cognitive or metabolic differences between the two groups, for example, and provide a more definitive answer to the question of whether Neandertals and moderns interbred.

The Stone Age whodunit is far from solved. But researchers are converging on one conclusion: regardless of whether climate or competition with moderns, or some combination thereof, was the prime mover in the decline of the Neandertals, the precise factors governing the extinction of individual populations of these archaic hominids almost certainly varied from group to group. Some may have perished from disease, others from inbreeding. "Each valley may tell its own story," Finlayson remarks.

As for the last known Neandertals, the ones who lived in Gibraltar's seaside caves some 28,000 years ago, Finlayson is certain that they did not spend their days competing with moderns, because moderns seem not to have settled there until thousands of years after the Neandertals were gone. The rest of their story, however, remains to be discovered. ■

➥ MORE TO EXPLORE

Older Age Becomes Common Late in Human Evolution. Rachel Caspari and Sang-Hee Lee in *Proceedings of the National Academy of Sciences USA,* Vol. 101, No. 30, pages 10895–10900; July 27, 2004.

Rapid Ecological Turnover and Its Impact on Neanderthal and Other Human Populations. Clive Finlayson and José S. Carrión in *Trends in Ecology and Evolution,* Vol. 22, No. 4, pages 213–222; 2007.

Heading North: An Africanist Perspective on the Replacement of Neanderthals by Modern Humans. Curtis W. Marean in *Rethinking the Human Revolution.* Edited by Paul Mellars et al. McDonald Institute for Archaeological Research, Cambridge, 2007.

Neanderthal Exploitation of Marine Mammals in Gibraltar. C. B. Stringer et al. in *Proceedings of the National Academy of Sciences USA,* Vol. 105, No. 38, pages 14319–14324; September 23, 2008.

NATURAL HISTORY MUSEUM, LONDON (*caves*); LAURIE GRACE (*map*)

HUMAN EVOLUTION

NEANDERTAL MINDS

Analyses of anatomy, DNA and cultural remains have yielded tantalizing insights into the inner lives of our mysterious extinct cousins

By Kate Wong

IN BRIEF

Long-standing view of Neandertals, our closest relatives, holds that they lagged far behind anatomically modern *Homo sapiens* in terms of cognitive ability.

Studies show that they did differ from *H. sapiens* in their brain anatomy and DNA, but the functional significance of these differences is unclear.

Cultural remains provide clearer insights into the Neandertal mind—and narrow the supposed mental gap between them and us.

The findings suggest that factors unrelated to intelligence drove Neandertals to extinction and allowed *H. sapiens* to flourish.

Illustration by Giordano Polini

Kate Wong is a senior editor at *Scientific American.*

ON A CLEAR DAY IN GIBRALTAR, LOOKING OUT OF GORHAM'S CAVE, YOU can see the rugged northern coast of Morocco looming purple above the turquoise sea. Inside the cave, quiet prevails, save for the lapping of waves against its rocky beach. But offshore, the strait separating this southernmost tip of the Iberian Peninsula from the African continent bustles with activity. Fishing vessels troll the waters for tuna and marlin, cruise ships carry tourists gawking at Gibraltar's hulking limestone massif, and tankers ferry crude oil from the Mediterranean to points west. With its swift, nutrient-rich currents, mild climate and gateway location, the area has attracted humans for millennia.

One impressive group dwelled in the region for tens of thousands of years, weathering several ice ages here. During such times lower sea levels exposed a vast coastal plain in front of the cave, land that supported a variety of animals and plants. These individuals cleverly exploited the local bounty. They hunted large animals such as ibex and seals and small ones such as rabbits and pigeons; they fished for bream and gathered mussels and limpets from the distant shore; they harvested pine nuts from the surrounding evergreens. Sometimes they took ravens and eagles for their plumage to bedeck themselves with the beautiful black flight feathers. And they engraved their cave floor with symbols whose meaning has since been lost to time.

In all these ways, these people behaved just like our own *Homo sapiens* ancestors, who arose in Africa with the same anatomy we have today and later colonized every corner of the globe. But they were not these anatomically modern humans. They were Neandertals, our stocky, heavy-browed cousins, known to have lived in Eurasia between 350,000 and 39,000 years ago—those same Neandertals whose name has come to be synonymous in pop culture with idiocy and brutishness.

The scientific basis for that popular pejorative view has deep roots. Back in the early 1900s the discovery of the first largely complete Neandertal skeleton, from the site of La Chapelle-aux-Saints in France, gave rise to the group's image problem: deformities now known to reflect the old age of the individual were seen as signs of degeneracy and subhumanness.

Since then, the pendulum of paleoanthropological opinion has swung repeatedly between researchers who see Neandertals as cognitively inferior to *H. sapiens* and those who see them as our mental equals. Now a rash of new discoveries is fanning the debate. Some fossil and ancient DNA analyses seem to suggest that Neandertal brains were indeed different—and less capable—than those of *H. sapiens.* Yet mounting archaeological evidence indicates that Neandertals behaved in many of the same ways that their anatomically modern contemporaries did.

As scientists advance into the Neandertal mind, the mystery of why our closest relatives went extinct after reigning for hundreds of thousands of years is deepening. The race is on to solve this extinction riddle: such insight will help reveal what it was that distinguished our kind from the rest of the human family—and set anatomically modern humans on the path to becoming the enormously successful species we are today.

BONY INKLINGS

PALEOANTHROPOLOGISTS have long sought clues to Neandertal cognition in the fossilized skulls they left behind. By studying casts of the interior of the braincase, researchers can reconstruct the external form of an extinct human's brain, which reveals the overall size as well as the shape of certain of its regions. But those analyses have failed to turn up much in the way of clear-cut differences between Neandertal brains and those of *H. sapiens.* (Some experts think Neandertals were just another population of *H. sapiens.* This article treats the two groups as different human species, albeit very closely related ones.) Neandertal brains were a little flatter than ours, but they were just as big—indeed, in many cases they were larger, explains paleoneurologist Ralph Holloway of Columbia University. And their frontal lobes—which govern problem solving, among other tasks—were almost identical to those of *H. sapiens,* judging from the impression they left on the inside of the braincase. That impression does not reveal the internal extent or structure of those key brain regions, however. "Endocasts are the most direct evidence of brain evolution, but they are extremely limited in terms of giving you solid information about behavior," Holloway admits.

In a widely publicized study published in 2013, Eiluned Pearce of the University of Oxford and her colleagues purportedly got around some of the limitations of endocasts and provided a way of estimating the size of internal brain areas. The team used eye-socket size as a proxy for the size of the visual cortex, which is the brain region that processes visual signals. They found that the Neandertal skulls they measured had significantly larger eye sockets than modern humans have—the better for coping with the lower light levels available in their high-latitude homes, according to one theory—and thus larger visual cortices. With more real estate dedicated to processing visual information, Neandertals would have had less neural tissue left over for other brain regions, including the ones that help us maintain extensive social networks, which can buffer against hard times, the researchers argued.

Holloway is not convinced. His own endocast work indicates that there is no way to delineate and measure the visual cortex. And Neandertal faces are larger than those of anatomically modern humans, which might explain their larger eye sockets. Moreover, people today are hugely variable in the proportion of visual cortex they have relative to other brain regions, he observes, and this anatomical variability does not appear to correspond to differences in behavior.

Other fossil analyses have yielded similarly equivocal signals about the Neandertal mind. Studies of limb asymmetry and wear marks on tools as well as on the teeth (from using them to grasp items such as animal hides during processing) indicate that Neandertals were as right-handed as we moderns are. A strong tendency toward favoring the right hand is one of the traits that distinguishes *H. sapiens* from chimpanzees and corresponds to asymmetries in the brain that are believed to be related to language—a key component of modern human behavior. Yet studies of skull shape in Neandertal specimens representing a range of developmental stages indicate that the Neandertals attained their large brain size through a different developmental pathway than that of *H. sapiens*. Although Neandertal brains started off growing like modern brains in the womb, they diverged from the modern growth pattern after birth, during a critical window for cognitive development.

Those developmental differences may have deep evolutionary roots. An analysis of some 17 skulls dated to 430,000 years ago from the fossil site of Sima de los Huesos, in the Atapuerca Mountains in northern Spain, has shown that members of the population there, believed to have been Neandertal precursors, had smaller brains than later members of the lineage. The finding suggests that Neandertals did not inherit their large brain size from the last common ancestor of Neandertals and modern humans; instead the two species underwent a parallel brain expansion later in their evolution. Although Neandertal brains ended up approximately as large as ours, their independent evolution would have left plenty of opportunities for the emergence of brain differences apart from size, such as those affecting connectivity.

GENETIC HINTS

GLIMPSES OF SOME OF THOSE differences have come from DNA analyses. Since the publication of a draft of the Neandertal genome in 2010, geneticists have been mining ancient DNA to see how Neandertals and *H. sapiens* compare. Intriguingly, the Neandertals turn out to have carried a very similar variant we have of a gene called *FOXP2* that is thought to play a role in speech and language in humans. But other parts of the Neandertal genome appear to contrast with ours in significant ways. For one thing, Neandertals seem to have carried different versions of other genes involved in language, including *CNTNAP2*. Further, of the 87 genes in modern humans that differ significantly from their counterparts in Neandertals and another archaic hominin group, the Denisovans, several are involved in brain development and function.

Differences in the genetic codes of Neandertals and modern humans are not the whole story, however. The switching on and off of genes could have distinguished moderns from Neandertals, too, so that the groups differed in how robustly and under what circumstances they produced the substances encoded by their genes. Indeed, *FOXP2* itself appears to have been expressed differently in Neandertals than in *H. sapiens,* even though the protein it made was the same. Scientists have begun studying gene regulation in Neandertals and other extinct humans by examining the patterns of chemical tags known as methyl groups in ancient genomes. These tags are known to influence gene activity.

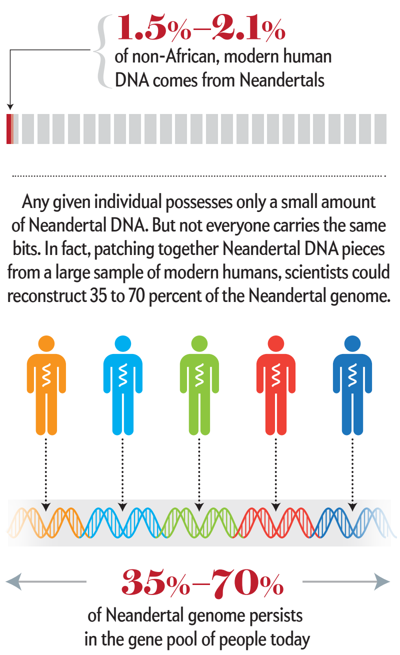
But whether or not differences in DNA sequences and gene activity translate to differences in cognition is the big question. To that end, intriguing clues have emerged from studies of people today who carry a small percentage of Neandertal DNA as a result of long-ago interbreeding between Neandertals and *H. sapiens*.

Geneticist John Blangero of the Texas Biomedical Research Institute runs a long-term study of extended families in San Antonio aimed at finding genes involved in complex diseases such as diabetes. In recent years he and his colleagues had begun looking at brain structure and function in the study participants. A biological anthropologist by training, Blangero started at one point to wonder how he could use living humans to answer such questions as what cognitive abilities Neandertals had.

A plan began to take shape. Over the course of their disease research, Blangero and his team had obtained whole-genome sequences and MRI scans of the brains of hundreds of patients. And they had developed a statistical method to gauge the effects of certain disease-linked gene variants on observable traits. Blangero realized that with the aid of their statistical tool, they could use the Neandertal genomes and his group's genetic and MRI data from living people to estimate the effects of the full complement of Nean-

Neandertal Legacy

Analysis of DNA recovered from several Neandertal fossils has revealed that Neandertals interbred with *Homo sapiens* after our species left Africa. Neandertal DNA lives on in many people today as a result of this long-ago mixing.

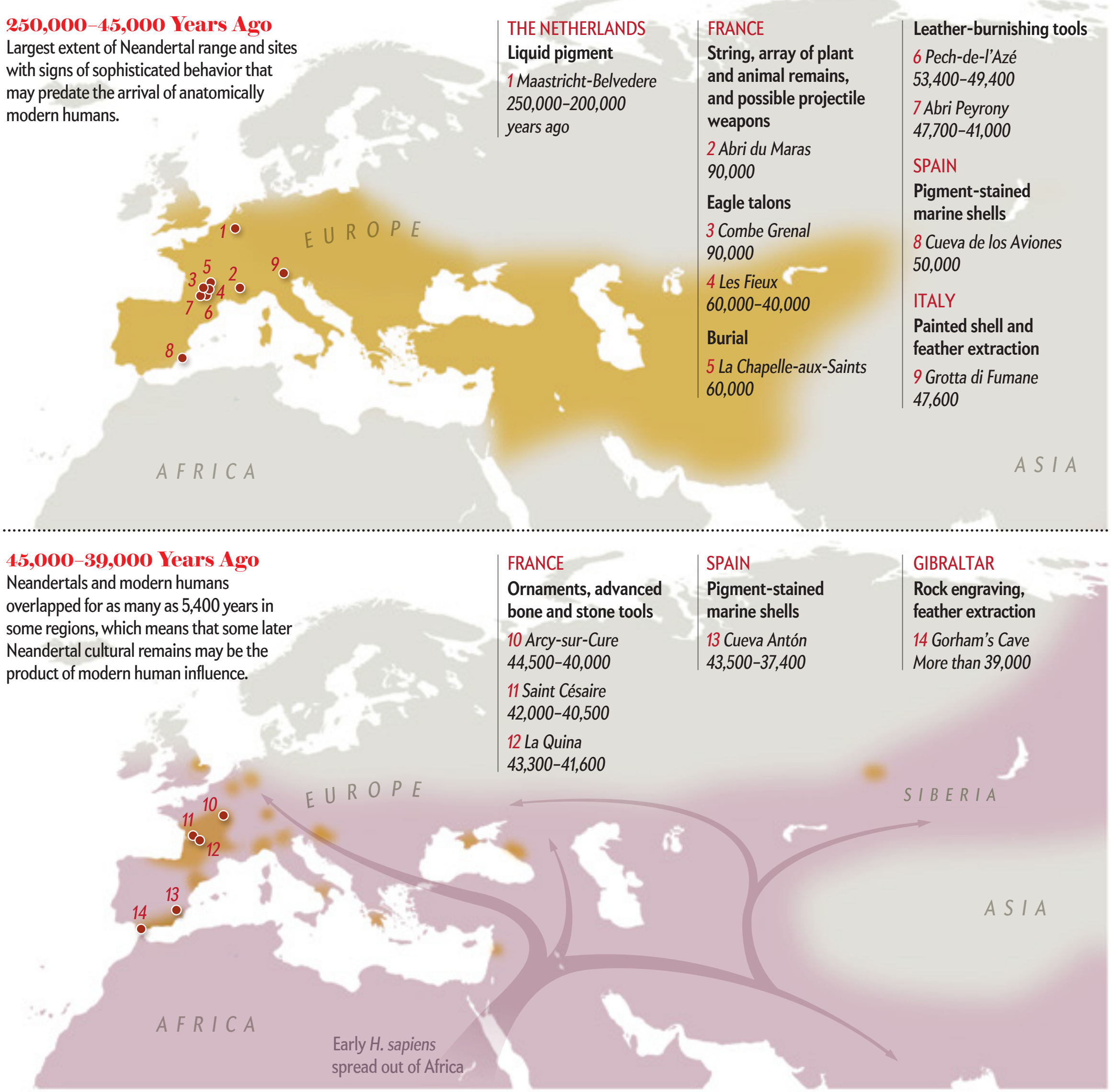


Graphic by 5W Infographics

The *Homo sapiens* Effect

Neandertals ruled Eurasia for hundreds of thousands of years until anatomically modern *H. sapiens* from Africa invaded their turf. Then the Neandertals faded away. Some experts have proposed that Neandertals lost out to the moderns because they lacked the language and social skills, technological ingenuity and foraging savvy that the newcomers had. Any hints of Neandertal sophistication from late Neandertal archaeological sites were chalked up to the influence of *H. sapiens.* Recent efforts to pinpoint the timing of Neandertal extinction, by redating a number of sites in Europe, indicate that Neandertals overlapped with *H. sapiens* for thousands of years in some places—ample time for Neandertals to have learned the ways of the interlopers. Yet over the past few years a flurry of discoveries attesting to Neandertal sophistication—from symbolic items and advanced tools to a wide variety of food remnants—have emerged from sites that clearly predate the arrival of *H. sapiens.* The question that scientists now face is whether the new arrivals were just better at these things or whether some other factor drove the Neandertals' demise.

Neandertal range · Early *Homo sapiens* range · ● Representative sites of Neandertal finds indicative of advanced behavior

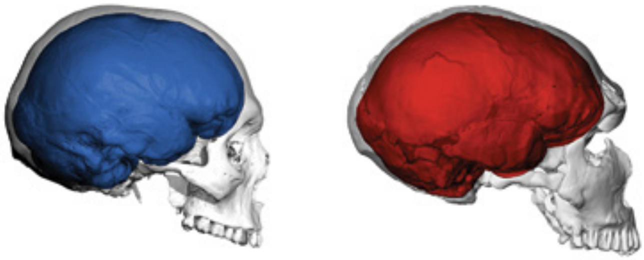


SOURCE: "THE TIMING AND SPATIOTEMPORAL PATTERNING OF NEANDERTHAL DISAPPEARANCE," BY TOM HIGHAM ET AL., IN *NATURE,* VOL. 512; AUGUST 21, 2014 (*Neandertal range*)

Maps by 5W Infographics

dertal genetic variants—the so-called polygenotype—on traits related to cognition.

Their results suggest that several key brain regions were smaller in Neandertals than in modern humans, including the gray matter surface area (which helps to process information in the brain), Broca's area (which seems to be involved in language) and the amygdala (which controls emotions and motivation). The findings also indicate that Neandertals would have had less white matter, translating to reduced brain connectivity. And other traits would have compromised their ability to learn and remember words. "Neandertals were almost certainly less cognitively adept," asserts Blangero, who presented his preliminary findings at the annual meeting of the American Association of Physical Anthropologists in Calgary last April. "I'm willing to bet on that one."



BRAIN SHAPE differs between a Neandertal (*right*) and a modern human (*left*), but how this difference might have affected thought is unknown.

FROM "A UNIQUELY MODERN HUMAN PATTERN OF ENDOCRANIAL DEVELOPMENT: INSIGHTS FROM A NEW CRANIAL RECONSTRUCTION OF THE NEANDERTAL NEWBORN FROM MEZMAISKAYA," BY PHILIPP GUNZ, SIMON NEUBAUER, LUBOV GOLOVANOVA, VLADIMIR DORONICHEV, BRUNO MAUREILLE AND JEAN-JACQUES HUBLIN, IN *JOURNAL OF HUMAN EVOLUTION*, VOL. 62, NO. 2; FEBRUARY 2012

Of course, without living Neandertals around today, Blangero cannot conduct cognitive assessments that would confirm or refute his inference. But there is, in theory, another way to put his hunch to the test. It would be possible, using existing technology, to study Neandertal brain cell function by genetically modifying modern human cells to have Neandertal DNA sequences, programming them to become neurons and observing the Neandertalized cells in petri dishes. Scientists could then examine the abilities of the neurons to conduct electrical impulses, to migrate to different brain regions and to produce projections (neurites) that aid in cell communication, for instance. Blangero notes that although there are ethical issues to consider where the creation of Neandertal cells is concerned, such work might actually help researchers identify genes involved in modern human brain disorders if the genetic changes compromise neuron function. Such findings could, in turn, lead to the discovery of new drug targets.

Not everyone is ready to draw conclusions about the Neandertal mind from DNA. John Hawks of the University of Wisconsin–Madison observes that Neandertals may have carried gene variants that affected their brain function but that have no counterparts in people today for comparison. He notes that if one were to predict Neandertal skin color based on the genes they share with modern humans, one would surmise that they had dark skin. Yet scientists now know Neandertals had some genes no longer in circulation that probably lightened their skin. But a bigger problem with attempting to suss out how Neandertal brains worked from their genes, Hawks says, is that for the most part researchers do not know how genes affect thought in our own kind. "We know next to nothing about Neandertal cognition from genetics because we know next to nothing about [modern] human cognition from genetics," he asserts.

ARCHAEOLOGICAL INSIGHTS

GIVEN THE LIMITATIONS of the fossil anatomy and the fact that ancient DNA research is still in its infancy, many researchers say the clearest window on the Neandertal mind is the cultural record these extinct humans left behind. For a long time, that record did not paint a particularly flattering picture of our vanished cousins. Early modern Europeans left behind elegant art, complex tools and remainders of meals attesting to an ability to exploit a wide variety of animals and plants that enabled them to adapt to new environments and shifting climate. Neandertals, in contrast, seemed to lack art and other symbolic remains; their tools were comparatively simple; and they appeared to have had a foraging strategy narrowly focused on large game. Stuck in their ways, the thinking went, the Neandertals simply could not adapt to deteriorating climate conditions and competition from the invading moderns.

In the 1990s, however, archaeologists began to find evidence contradicting that scenario—namely, a handful of decorative items and advanced tools attributed to Neandertals. Ever since, researchers have been at loggerheads over whether these items are Neandertal inventions as claimed; doubt has arisen because the items date to the end of the Neandertal dynasty, by which time *H. sapiens* was in the area, too. (Anatomically modern humans appear to have reached Europe by around 44,000 to 41,500 years ago, hundreds of thousands of years after Neandertals settled there.) Some skeptics think that *H. sapiens* made the sophisticated artifacts, which later got mixed in with the Neandertal remains. Alternatively, they offer, Neandertals may have copied the ingenious moderns or stolen their goods.

But that position is becoming harder to uphold in the face of a raft of discoveries over the past few years that evince Neandertal savvy prior to the spread of anatomically modern humans throughout Europe. "There's been a real sea change. Every month brings something new and surprising that Neandertals did," observes David Frayer of the University of Kansas. "And the new evidence is always that they were more sophisticated, not hicks."

Some of the most surprising discoveries reveal aesthetics and abstract thought in Neandertal cultures that predated the arrival of *H. sapiens*. These finds include the engraving and signs of feather use from Gorham's Cave. In fact, artifacts of this nature have turned up at archaeological sites across Europe. At the Grotta di Fumane in Italy's Veneto region, archaeologists found signs of feather use and a fossil snail shell collected from at least 100 kilometers away that had been stained red, suspended on a string and worn as a pendant at least 47,600 years ago. Cueva de los Aviones and Cueva Antón in southeastern Spain have also yielded seashells bearing traces of pigment. Some seem to have served as cups for mixing and holding red, yellow and sparkly black pigments that may have been cosmetics; others bear holes indicating that they were worn as jewelry. The modified shells date to as many as 50,000 years ago.

Other Neandertal leavings indicate that their yen for decorating reaches back further still. Sites in France and Italy document a tradition of harvesting eagle talons that spans from 90,000 to 40,000 years ago. Cut marks on the bones show that the Nean-

GIBRALTAR CAVES (*above*) **housed sophisticated Neandertals. An engraving (*right*) found in one of the caves adds to evidence that Neandertals thought symbolically.**

DAVID LIITTSCHWAGER *National Geographic* (cave); COURTESY OF STEWART FINLAYSON *The Gibraltar Museum* (cave marking)

dertals focused their efforts on obtaining the claws, not the flesh. This finding led investigators to conclude that the Neandertals exploited the eagles for symbolic reasons—probably to adorn themselves with the impressive talons—rather than dietary ones.

Even older hints of Neandertal aesthetics come from the site of Maastricht-Belvedere in the Netherlands, where archaeologists have found small splatters of red ochre, or iron oxide, in deposits dating to between 250,000 and 200,000 years ago at minimum. The scarlet pigment had been finely ground and mixed into a liquid that then dripped onto the ground. Researchers cannot know for sure what those Neandertals were doing with the red liquid, but painting is one obvious possibility. Indeed, when red ochre turns up at early modern human sites, investigators assume that it was used for decorative purposes.

In addition to rendering a far more resplendent portrait of our much maligned cousins, these new discoveries provide crucial insights into the Neandertal mind. Archaeologists have long considered art, including body decoration, to be a key indicator of modern cognitive abilities because it means that the makers had the capacity to conceive of something in the abstract and to convey that information in symbols. Symbolic thinking underpins our ability to communicate via language—one of the defining traits of modern humans and one that is seen as critical to our success as a species. If Neandertals thought symbolically, as they appear to have done, then they probably had language, too. In fact, abstract thought may have dawned in the human lineage even before the last common ancestor of Neandertals and *H. sapiens:* in December researchers unveiled a mussel shell from Indonesia that they contend was engraved with a geometric pattern by a more primitive ancestor, *Homo erectus,* around 500,000 years ago.

Symbolic thought is not the only component of behavior believed to have helped *H. sapiens* get ahead, however. The manufacture of tools with specialized uses is another element, one that Neandertals appear to have mastered as well. In 2013 Marie Soressi of Leiden University in the Netherlands and her collaborators announced their discovery of bone tools known as *lissoirs*—implements that leather workers today use to render animal hides more pliable, lustrous and impermeable to the elements—at two Neandertal sites in the Dordogne region of France dating to between 53,000 and 41,000 years ago. Judging from the wear marks on the artifacts, Neandertals used them for the same purpose. The Neandertals made the *lissoirs* from deer ribs, shaping the end of the bone that attaches to the sternum to form a rounded tip. To wield the tool, they pressed the tip into a dry hide at an angle and pushed it across the surface repeatedly, smoothing and softening the skin.

Fresh evidence of Neandertal ingenuity has also come from the site of Abri du Maras in southern France, which sheltered Neandertals around 90,000 years ago. Microscopic analyses of stone tools from the site, conducted by Bruce Hardy of Kenyon College and his colleagues, revealed traces of all manner of activities once thought to be beyond the ken of the species. For instance, the team found remnants of twisted plant fibers that would have been used for making string or cords, which then could have been fashioned into nets, traps and bags. Traces of wood turned up as well, suggesting that the Neandertals crafted tools from that material.

Residue analysis additionally gives the lie to the notion that Neandertals were perilously picky eaters. Studies of the chemical makeup of their teeth, along with analyses of animal remains from Neandertal sites, have suggested that Neandertals relied heavily on large, dangerous prey such as mammoth and

SCIENTIFIC AMERICAN ONLINE Read more about Neandertals at ScientificAmerican.com/feb2015/neandertals

BONE TOOL for leatherwork, shown here in four views, is among the advanced implements that Neandertals made.

bison rather than an array of animals depending on availability, as anatomically modern humans did. The Abri du Maras Neandertals apparently exploited a veritable menagerie of creatures, including small, fast animals such as rabbits and fish—all species previously thought to be out of reach for Neandertals, with their low-tech gear.

Some scholars have argued that an ability to live partly on plant foods gave *H. sapiens* an edge over Neandertals, allowing them to reap more sustenance from the same area of land. (Subsisting on plants is trickier for humans than for other primates because our big brains demand a lot of calories, and yet our small guts are poorly suited to digesting large quantities of raw roughage—a combination that requires intimate knowledge of plant foods and how to prepare them.) But the Abri du Maras Neandertals gathered edible plants, including parsnip and burdock, as well as edible mushrooms. And they were not alone.

According to studies led by Amanda Henry of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, Neandertals across a broad swath of Eurasia—from Iraq to Belgium—ate a variety of plants. Examining the tartar in Neandertal teeth and residues on stone tools, she determined that Neandertals consumed species closely related to modern wheat and barley, cooking them to make them palatable. She also found bits of starch from tubers and telltale components of date palms. The similarities to findings from early modern human sites were striking. "Any way we broke up the data, there were no significant differences between the groups," Henry remarks. "The evidence we have now does not suggest that the earliest modern humans in Eurasia were better at accessing plant foods."

A LONG FAREWELL

IF NEANDERTALS actually behaved in ways once thought to distinguish anatomically modern humans and fuel their rise to world domination, that likeness makes their decline and eventual extinction all the more puzzling. Why did they die out while *H. sapiens* survived? One theory is that moderns had a bigger tool kit that may have boosted their foraging returns. Modern humans evolved in Africa, where their population size was larger than that of Neandertals, Henry explains. With more mouths to feed, preferred resources such as easy game would have declined, and the moderns would have had to develop new tools to obtain other kinds of food. When they brought this cutting-edge technology with them out of Africa and into Eurasia, they were able to exploit that environment more effectively than the resident Neandertals could. In other words, moderns honed their survival skills under more competitive circumstances than Neandertals had faced and thus entered Neandertal territory with an advantage over the incumbents.

Not only did the large population size of *H. sapiens* spur innovation, but it helped to keep new traditions alive rather than letting them fizzle out with the last member of a small, isolated group. The bigger, more connected membership of *H. sapiens* "increasingly provided a more efficient ratchet effect to maintain and build on knowledge compared with earlier humans, including the Neandertals," offers Chris Stringer of the Natural History Museum in London. Still, the arrival of moderns did not spell instant doom for Neandertals. The latest attempt to track their decline, carried out by Thomas Higham of Oxford and his colleagues, applied improved dating methods to pinpoint the ages of dozens of Neandertal and early modern European sites from Spain to Russia. The results indicate that the two groups shared the continent for some 2,600 to 5,400 years before the Neandertals finally disappeared, around 39,000 years ago.

That lengthy overlap would have left plenty of time for mating between the two factions. DNA analyses have found that people today who live outside Africa carry an average of least 1.5 to 2.1 percent Neandertal DNA—a legacy from dalliances between Neandertals and anatomically modern humans tens of thousands of years ago, after the latter group began spreading out of Africa.

Maybe, some experts offer, mixing between the smaller Neandertal population and the larger modern one led to the Neandertal's eventual demise by swamping their gene pool. "There were never very many of them, there were people coming in from other areas and mixing with them, and they faded out," Frayer surmises. "The history of all living forms is that they go extinct," he adds. "That's not necessarily a sign that they were stupid, or culturally incapable, or adaptively incapable. It's just what happens." SA

MORE TO EXPLORE

Brain Development after Birth Differs between Neanderthals and Modern Humans. Phillip Gunz et al. in *Current Biology,* Vol. 20, No. 21, pages R921–R922; November 9, 2010.

Impossible Neanderthals? Making String, Throwing Projectiles and Catching Small Game during Marine Isotope Stage 4 (Abri du Maras, France). Bruce L. Hardy et al. in *Quaternary Science Reviews,* Vol. 82, pages 23–40; December 15, 2013.

A Rock Engraving Made by Neanderthals in Gibraltar. Joaquín Rodríguez-Vidal et al. in *Proceedings of the National Academy of Sciences USA,* Vol. 111, No. 37, pages 13,301–13,306; September 16, 2014.

FROM OUR ARCHIVES

Twilight of the Neandertals. Kate Wong; August 2009.

scientificamerican.com/magazine/sa

Did Neandertals Think Like Us?

João Zilhão defends his controversial view that our oft-maligned relatives shared our cognitive abilities

KEY CONCEPTS

- Scientists have traditionally considered *Homo sapiens* the only species to invent and use symbols.
- But over the past few decades archaeologists have discovered a handful of enigmatic artifacts hinting that our cousins the Neandertals—long dismissed as intellectually inferior—might have engaged in symbolic activities, too. Experts dismissed the finds, however, attributing them to modern humans instead.
- The recent discovery of Neandertal jewelry and body paint from two sites in Spain provides unequivocal evidence of Neandertal symbolism and suggests that modern human behavior has ancient roots.

—The Editors

For the past two decades archaeologist João Zilhão of the University of Bristol in England has been studying our closest cousins, the Neandertals, who occupied Eurasia for more than 200,000 years before mysteriously disappearing some 28,000 years ago. Experts in this field have long debated just how similar Neandertal cognition was to our own. Occupying center stage in this controversy are a handful of Neandertal sites that contain cultural remains indicative of symbol use—including jewelry—a defining element of modern human behavior. Zilhão and others argue that Neandertals invented these symbolic traditions on their own, before anatomically modern humans arrived in Europe around 40,000 years ago. Critics, however, believe the items originated with moderns.

But this past January, in a paper published in the *Proceedings of the National Academy of Sciences USA*, Zilhão and his colleagues reported on finds that could settle the dispute: pigment-stained seashells from two sites in Spain dated to nearly 50,000 years ago—10,000 years before anatomically modern humans made their way to Europe. Zilhão recently discussed the implications of his team's new discoveries with *Scientific American* staff editor Kate Wong. An edited version of their conversation follows.

SCIENTIFIC AMERICAN: Paleoanthropologists have been arguing about Neandertal behavior for decades. Why all the fuss?

JOÃO ZILHÃO: The debate of the past 25 years stems from the theory that anatomically modern humans originated in Africa as a new species and then spread out from there, replacing archaic humans such as the Neandertals. Added to this notion was the tenet that species are defined as much by anatomy as by behavior. Thus, Neandertals, not being modern in anatomy, could not by definition be modern in behavior.

But there were problems with this model. In 1979 archaeologists working at the site of St. Césaire in France found a Neandertal skeleton in a layer containing cultural remains made in the so-called Châtelperronian tradition. At the time, experts believed that the Châtelperronian artifacts—body ornaments and sophisticated bone tools, among other elements—were manufactured by modern humans. But the St. Césaire find established its association with the Neandertals instead. Then, in 1995, researchers determined that the human remains found in the Châtelperronian levels of another French site, the Grotte du Renne at Arcy-sur-Cure, were also those of Neandertals.

To reconcile these discoveries with the idea

VIKTOR DEAK

▲ **NEANDERTAL ADORNMENTS appear to have included face paint and pendants, according to recent discoveries made at two sites in Spain. Such items indicate that Neandertals were capable of symbolic thought—a crucial element of modern human behavior.**

that modern humans alone were capable of such advanced practices, some researchers proposed that the artifacts somehow got mixed into the Neandertal deposits from overlying early-modern human deposits. Others argued that the Neandertals simply copied their modern human contemporaries or obtained the items from them through scavenging or trade but did not really understand them and never integrated them into their culture in the same way moderns did. This controversy has never really been settled to the satisfaction of all those involved, which is where our new finds from Spain come in.

SA: What exactly did you find and how did you find it?

JZ: The material comes from two sites. One is a cave in southeast Spain called Cueva de los Aviones, which was excavated in 1985 by Ricardo Montes-Bernárdez of the Fundación de Estudios Murcianos Marqués de Corvera. In his reports Montes-Bernárdez mentioned having found three perforated cockle shells in the deposits, but no one paid attention at the time. After reading about the shells in his papers a few years ago, I went to the museum housing the materials he collected and asked to see them. They immediately struck me as being of major importance because such shells are typically considered pendants when discovered in archaeological deposits. But we didn't know the age of the material, so the first thing was to select samples for radiocarbon dating. The dates came out at 48,000 to 50,000 years ago.

Because most of the shells in the collection had never been washed, I checked to see if there were other specimens of note. One of the shells turned out to be a Mediterranean oyster shell, the cleaning of which revealed a stain that I thought could be pigment residue. Analysis of the substance identified it as a mix of red pigment, called lepidocrocite, and finely ground up bits of dark red and black hematite and pyrite, which would have added sparkle. My colleagues and I also came across a naturally pointed horse bone bearing some reddish pigment on the tip. And we found lumps of yellow and red pigment, including a very large deposit of a mineral called natrojarosite, the quantity and purity of which indicated that it had been stored in a purse that eventually perished, leaving only the mineral behind.

SA: What did you unearth at the second site?

JZ: At around the same time that I was inspecting the Aviones collection, I was also going through the finds of the September 2008 field season at a large rock shelter some 60 kilometers inland from Aviones called Cueva Antón, where I have been excavating Neandertal deposits since 2006. One of the items was a perforated scallop shell that one of my undergraduate students had collected on the second day of excavation. I had originally thought it was a fossil shell unrelated to human activities. But when I started to clean it, I found it was very fresh and full of color. On closer inspection, it seemed that the whitish exterior of the shell had been painted with an orange pigment, which turned out to be a mix of hematite and another mineral called goethite.

SA: What do you think the Neandertals were doing with these items?

JZ: The interesting thing about natrojarosite is that it has only one known use, and that's as a cosmetic. So we infer that that's how it was used at Aviones as well. The horse bone with the reddish tip may have been used to mix or apply pigment or to pierce through hide that had been colored with pigment. And the unperforated Mediterranean oyster shell bearing the traces of a glittery red mixture was probably a paint cup. The simplest explanation for the natrojarosite and sparkly red pigment and the context in which they were found is some kind of body painting, specifically facial painting. But whether the Neandertals applied them on a daily basis after waking up or whether it was something that they did for ritual reasons on special occasions—for celebrations or perhaps for mourning—we don't know.

In addition, one of the perforated cockle shells from Aviones had bits of red ochre adhering to its inner side near the hole. In this case, the most likely scenario is that the shell had been painted, because you cannot use a shell with holes in it as a container. Thus, in addition to painting their bodies, the Neandertals at both sites painted perforated shells, which they presumably used as pendants.

▼ SCALLOP SHELL PENDANT **was painted with an orange pigment, perhaps so that the exterior of the shell (*right half*) matched the naturally colorful interior (*left half*). Pigment found on the tip of a naturally pointed horse foot bone (*above shell*) suggests that the Neandertals used the bone to mix or apply their paints.**

COURTESY OF FRANCESCO D'ERRICO *University of Bordeaux (foot bone)*; COURTESY OF JOÃO ZILHÃO *University of Bristol (shell fragments)*

SA: Your analyses did not yield evidence that the holes in the cockle and scallop shells at these sites were man-made, nor were you able to find traces of use on the edges of the holes themselves, so how do you know they were used decoratively?

JZ: These species are found only in deep water, so by the time they wash ashore they no longer contain any flesh, which means they were not collected for food. And they have pigments associated with them. What is the alternative? If you open any book of ethnographic shell ornaments from Africa or Oceania, you'll see examples of shells of these or related species with natural perforations used as ornaments.

SA: What are the implications of these discoveries in terms of understanding the origin of behavioral modernity in humans?

JZ: The one thing these finds make clear is that Neandertals were behaviorally modern. They were not like early modern humans anatomically, but they were cognitively as advanced or more so. There are several possible conclusions one could draw from this observation. Either modern cognition and modern behavior emerged independently in two different lineages, or they existed in the common ancestor of Neandertals and anatomically modern humans; or the groups we call Neandertals and modern humans were not different species and therefore we should not be surprised that despite the anatomical differences there are no cognitive differences, which is the conclusion I favor.

In my view, the emergence of modern human behavior is the slow, perhaps intermittent accumulation of knowledge that, as population densities increase, gives rise to social identification systems, which appear in the archaeological record in the form of personal ornaments, body painting, etcetera. That such early examples of behavioral modernity are rare is what we should expect. That's what the beginning of an exponential process like this one should look like.

SA: So modern behavior—as represented by body decoration, artwork, and so on—is the product of needing to communicate with or identify members of a growing population?

JZ: Yes, in a world where the frequency of encounters with strangers would be such that you need to have ways to know whether a stranger is friend or foe, whether it's someone to whom your kin owes favors or is owed favors.

SA: But do you think something had to change in the hardware, the brain, at some point in the human lineage before modern human behavior could arise?

JZ: Yes, I think that happened 1.5 million to two million years ago—or somewhere between 500,000 and a million years ago at the latest—when average brain size reached the modern range. If we could clone a human who lived 500,000 years ago, put him in a surrogate womb, and then after birth nurture him as a human of today, would he be able to fly an airplane? Maybe some of my colleagues would say no, but my answer is he would.

SA: If Neandertals in Spain were making ornaments 10,000 years before moderns arrived in Europe, do you think that, rather than Neandertals copying moderns, the reverse might have occurred?

JZ: Prior to entering Europe, modern humans did not have pierced or grooved mammal teeth like the ones found in the Châtelperronian, nor did they have perforated bivalve shells like the ones we found in Spain. But once they enter Europe, they have them. Where did the moderns get these ornaments? If we were talking about people in the Copper Age, we would conclude that the incomers got them from the locals. Why should we have a different logic for Neandertal things? ■

▲ **JOÃO ZILHÃO has long argued that Neandertals invented symbolic practices independently of anatomically modern humans. Here he sifts through sediments at a site located in the same region as the sites that yielded the Neandertal finds.**

COURTESY OF JOSEFINA ZAPATA

➥ MORE TO EXPLORE

The Morning of the Modern Mind. Kate Wong in *Scientific American,* Vol. 292, No. 6, pages 86–95; June 2005.

Twilight of the Neandertals. Kate Wong in *Scientific American,* Vol. 301, No. 2; pages 32–37; August 2009.

Symbolic Use of Marine Shells and Mineral Pigments by Iberian Neandertals. João Zilhão et al. in *Proceedings of the National Academy of Sciences USA,* Vol. 107, No. 3, pages 1023–1028; January 19, 2010.

Oldest Cave Paintings May Be Creations of Neandertals, Not Modern Humans

Kate Wong June 14, 2012

Hand stencils in El Castillo cave are older than previously thought. Image: courtesy of Pedro Saura

In a cave in northwestern Spain called El Castillo, ancient artists decorated a stretch of limestone wall with dozens of depictions of human hands. They seem to have made the images by pressing a hand to the wall and then blowing red pigment on it, creating a sort of stencil. Hand stencils are a common motif in the cave paintings of Spain and France, and like all cave art, they have long been considered to be the work of anatomically modern humans like us. But a new analysis of the age of the paintings in El Castillo and other Spanish caves shows that some of these paintings are much older than previously thought—old enough, in some cases, to be the handiwork of our cousins the Neandertals.

Determining the ages of cave paintings—from the hands in the Panel de las Manos in El Castillo to the mammoths and other Ice Age beasts that adorn the walls of Chauvet in France—has proved a difficult thing to do. Scientists can reliably assess the antiquity of human and animal bones as well as charcoal from hearths using proven techniques such as radiocarbon dating. But the thin layers of pigment found on cave walls usually do not contain the carbon needed for that approach, leaving archaeologists to estimate the age of the art based on its style or its apparent association with datable remains.

Now researchers writing in the June 15 issue of *Science* report that recent advances in another radiometric technique called uranium-thorium dating have allowed them to circumvent the problems of radiocarbon dating and determine minimum ages for the paintings. This dating method, which is based on the radioactive decay of uranium over time, has been around for decades. But only recently have scientists refined the technique such that they can apply it to samples small enough to get sufficiently precise results.

Archaeologists Alistair Pike of Bristol University in England and João Zilhão of the University of Barcelona in Spain and their colleagues used the uranium-thorium technique to date 50 paintings and engravings from 11 cave sites in Asturias and Cantabria. They did this by collecting samples of the thin crusts of calcium carbonate that formed atop the images through the same process that forms stalactites and stalagmites. The crusts incorporate small amounts of uranium, which decays into thorium over time. By analyzing the amount of thorium in a sample using a mass spectrometer, the researchers could determine how much time had passed since the crusts formed, thereby providing a minimum age for the images underneath.

Intriguingly, some of the paintings were significantly older than suspected. Experts thought that Spanish cave art was younger than French cave art. But the new results reveal one of the images at El Castillo—a large red disk on the Panel de las Manos—is at minimum 40,800 years old, making it some 4,000 years older than the Chauvet paintings, which were previously thought to be the oldest in the world. (Claims for comparably ancient cave art from Australia and India are not widely accepted on present evidence.) Other surprisingly old Spanish paintings identified in the study included a hand stencil from the Panel de las Manos that dates to at least 37,300 years ago and a club-shaped symbol from the famous Altamira cave that dates to 35,600 years ago at minimum.

Pike, Zilhão and their collaborators observe that the new results are consistent with the idea that the complexity of art increased gradually over time. The earliest dates they obtained were for non-figurative art—disks, hand stencils, and such--rendered in a single color. Only later did people paint animals and use pigments of multiple hues.

But the team's findings raise important questions about the artists behind the oldest paintings. The researchers note that anatomically modern humans arrived in western Europe around 41,500 years ago and thus may well have made the ancient Spanish paintings. But 42,000 years ago the only humans in Europe were Neandertals. In a press teleconference, Zilhão asserted that any art there that turns out to be older than 42,000 years must necessarily be attributed to Neandertals. He and Pike suspect that the red disk and hand stencil at El Castillo might well be Neandertal paintings, considering that the uranium-thorium dating results are minimum estimates, though Zilhão cautions that they haven't proved it. The researchers are currently looking at additional sites in western Europe to see if they can get dates older than 42,000 years ago. (Some scientists think modern humans arrived in Europe as early as 45,000 years ago—a claim that Zilhão says is unwarranted based on the available evidence.)

Cave painting wouldn't be the first sign of Neandertal sophistication. In recent years scientists have unearthed quite a few signs that our oft-maligned cousins were aesthetes. Archaeological evidence indicates that they made jewelry from teeth and shells, festooned themselves with feathers, and painted their skin. If they were decorating their bodies with symbols, many experts say, they almost certainly had language. In fact, anatomically modern humans and Neandertals might have inherited their capacity for symbolic thinking from their common ancestor. If so, the roots of our symbolic culture go back half a million years. As to why Neandertals, who lived in Europe for upwards of 250,000 years, appear not to have made art until the end of their reign, a number of experts argue that it was their encounters with incoming modern humans that stimulated innovation and self-expression—encounters that also spurred modern humans to greater creative heights.

The views expressed are those of the author(s) and are not necessarily those of Scientific American.

05/07 | Aula 7: Novas datações de arte rupestre na Europa: Panel de las Manos, Caverna El Castilho, Espanha. O comportamento dos Neandertais rediscutido. O possível uso de penas como adorno por Neandertais. Caverna Gorham. A mais antiga gravura rupestre em Gibraltar.

Textos para leitura:

Caveman Couture: Neandertals Rocked Dark Feathers | Kate Wong

World's Oldest Engraving Upends Theory of Homo sapiens Uniqueness | Kate Wong

Ancient Engraving Strengthens Case for Sophisticated Neandertals | Kate Wong

Neandertals Turned Eagle Talons into Jewerly 130,000 Years Ago | Kate Wong

Early Dates for 'Neanderthal Cave Art' May Be Wrong | Aubert/Brumm

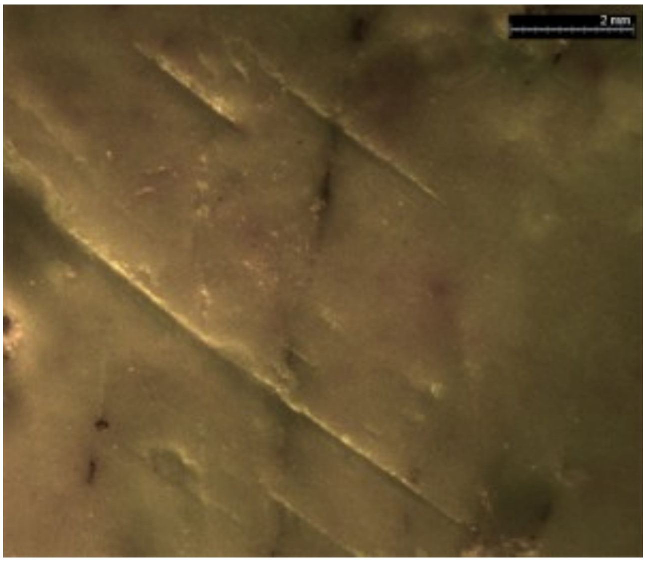
Caveman Couture: Neandertals Rocked Dark Feathers

Kate Wong September 18, 2012

Artist's conception of a Neandertal's feather decorations. Image: Antonio Monclova

GIBRALTAR—Jordi Rosell removes a thumbnail-size piece of reddish-tan bone from a sealed plastic bag, carefully places it under the stereomicroscope and invites me to have a look. Peering through the eyepieces I see two parallel lines etched in the specimen's weathered surface. Tens of thousands of years ago, in one of the seaside caves located here on the southernmost tip of the Iberian Peninsula, a Neandertal nicked the bone—a bit of shoulder blade from a bird known as the red kite--with a sharp stone tool in those two spots. Though it would hardly merit a second glance from the casual observer, this cutmarked fragment is helping to deliver what could be the coup de grâce to some enduring ideas about the cognitive abilities of our closest relatives.

Experts agree that Neandertals hunted large game, controlled fire, wore animal furs and made stone tools. But whether they also engaged in activities deemed to be more advanced has been a matter of heated debate. Some researchers have argued that Neandertals lacked the know-how to effectively exploit small prey, such as birds, and that they did not routinely express themselves through language and other symbolic behaviors. Such shortcomings put the Neandertals at a distinct disadvantage when anatomically modern humans availed of these skills invaded Europe—which was a Neandertal stronghold for hundreds of thousands of years—and presumably began competing with them, so the story goes.



Cutmarks made by a Neandertal on a wing bone from a griffon vulture. Image: Clive Finlayson

Over the past couple decades hints that Neandertals were savvier than previously thought have surfaced, however. Pigment stains on shells from Spain suggest they painted, pierced animal teeth from France are by all appearances Neandertal pendants. The list goes on. Yet in all of these cases skeptics have cautioned that the evidence is scant and does not establish that such sophistication was an integral part of the Neandertal gestalt.

The cutmarked bones from Gibraltar as well as bird remains from other sites could force them to rethink that view. In a paper published September 17 in *PLOS ONE,* paleontologist Clive Finlayson of the Gibraltar Museum, Rosell, a zooarchaeologist at Rovira I Virgili University in Tarragona, Spain, and their colleagues report on their analyses of animal remains from 1699 fossil sites in Eurasia and north Africa spanning the Pleistocene epoch. Their results show that Neandertals across western Eurasia were strongly associated with corvids (ravens and the like) and raptors (vultures and their relatives)—more so than were the anatomically modern humans who succeeded them.

The Neandertals seem unlikely to have hunted these birds for food. People today do not eat corvids or raptors. Moreover, if the Neandertals did hunt the birds for food, one would expect to see signs of butchery on those bones linked to fleshy parts of the bird, such as the breastbone. Yet the team's study of the bird bones from the Gibraltar sites found the cutmarks on wing bones, which have little meat—a sign that the Neandertals targeted the birds for their feathers rather than their meat.

Bonelli's eagle is one of the raptor species Neandertals hunted, presumably for its dark feathers. Image: Clive Finlayson

Exactly what the Neandertals were doing with the feathers is unknown, but because they specifically sought out birds with dark plumage, the researchers suspect that our kissing cousins were festooning themselves with the resplendent flight feathers. Not only are feathers beautiful, they are also lightweight, which makes them ideal for decoration, Finlayson points out. "We don't think it's a coincidence that so many modern human cultures across the world have used them."

The Neandertals may have separated the plumage from the wing bones while keeping it intact and used the skin as a sort of cape or headpiece, depending on the size of the bird. Finlayson says preliminary experimental evidence

Neandertals captured ravens and other corvids, too. Image: Clive Finlayson

shows that removal of the plumage in this way using flint tools creates cut marks similar to those observed on the ancient bird bones recovered from the Gibraltar caves.

This is not the first time scientists have found evidence that Neandertals used feathers. In 2011 a team of Italian researchers reported on cutmarked bird bones from Neandertal levels in Fumane Cave in northern Italy that revealed this practice. But some researchers dismissed the find as an isolated phenomenon. The new findings suggest that feathers were de rigueur for thousands of years not only among Gibraltar's Neandertals but quite possibly for Neandertals across Eurasia.

Clive Finlayson models griffon plumage. The ulna was removed from the carcass with a flint tool and the feathers left intact. Most of the birds Neandertals used were smaller and thus perhaps better suited to headdresses. Image: Kate Wong

Although archaeologists have often argued that Neandertals did not have the necessary technology to hunt birds, Rosell points out that many of these species are easily caught with bare hands. Vultures, for example, will hang out on tree branches in the morning, waiting for a wind to carry them away. During this time they are quite vulnerable to being captured. Neandertals could have also caught their favorite birds of prey while the birds were busy feeding on carcasses, he says. In addition, Gibraltar is on a key migratory route for many species, and the birds often arrive tired from the shifting winds. Perhaps Neandertals took advantage of this weakness.

Speakers at a conference on human evolution held in Gibraltar last week extolled the study, and agreed with the team's interpretation of the remains as evidence that Neandertals adorned themselves with the feathers as opposed to using them for some strictly utilitarian purpose. If the cutmarked bones from Gibraltar had been found in association with early modern humans, researchers would assume that the feathers were symbolic, says paleoanthropologist John Hawks of the University of Wisconsin notes. The same standards should apply to Neandertals. "We've got to now say that Neandertals were using birds. Period. They were using them a lot. They were wearing around their feathers," he comments. "They clearly cared. A purely utilitarian kind of person does not put on a feathered headdress."

Archaeologist John Shea of Stony Brook University observed that the preference for dark feathers mirrors the Neandertals' apparent preference for black manganese pigment, which is known from a few sites. Early *Homo sapiens,* in contrast, appears to have liked red pigment. "What our ancestors liked about red these Neandertals evidently liked about black. And both are very compelling kinds of colors," Shea says. "It means they had color symbolism. They were able to imbue colors in their natural world with some kind of arbitrary meaning."

"[This] is something many of us thought was unique to *Homo sapiens,"* Shea adds. “But [it] turns out to be either convergently evolved with Neandertals or more likely something phylogenetically ancient we simply haven’t picked up in the more ancient archaeological record. It’s probably something [our common ancestor] *Homo heidelbergensis* did, we just haven’t found archaeological evidence for it yet.”

The views expressed are those of the author(s) and are not necessarily those of Scientific American.

World's Oldest Engraving Upends Theory of Homo sapiens Uniqueness

It is getting harder and harder to figure out what distinguished Homo sapiens from other members of the human family and fueled our extraordinary success as a species.

Kate Wong December 3, 2014

MUSSEL SHELL was engraved by Homo erectus between 540,000 and 430,000 years ago. Image: Wim Lustenhouwer, VU University Amsterdam

It is getting harder and harder to figure out what distinguished *Homo sapiens* from other members of the human family and fueled our extraordinary success as a species. One popular notion holds that our propensity for symbolic thought, which underlies language, was key. For a long time, experts thought this capacity first emerged around 40,000 years ago in early Europeans, based on the seemingly sudden appearance of things like cave art and jewelry in the archaeological record there. But over the past two decades older evidence of art and body decoration, as well as other sophisticated practices, such as complex tool manufacture, have turned up at *H. sapiens* sites in the Near East and in Africa, where our species got its start. Furthermore, scientists have found evidence that our cousins the Neandertals were similarly capable in many respects.

Now comes news that an even older, more primitive human ancestor —*Homo erectus* from Asia—showed signs of symbolic thought, too. Researchers have discovered a shell engraved with a geometric pattern at a *H. erectus* site known as Trinil, on the Indonesian island of Java, that dates to between 540,000 and 430,000 years ago. The find is at least 300,000 years older than the oldest previously known engravings, which come from South Africa.

Analysis of the engraving, made on a freshwater mussel shell, suggests that its maker used a shark tooth or other hard, pointed object to create the zigzag design. "The engraving was probably made on a fresh shell specimen still retaining its brown [skin], which would have produced a striking pattern of white lines on a dark 'canvas,'" Josephine C. A. Joordens of Leiden University in the Netherlands and her colleagues surmise in their report, published online December 3 by *Nature*.

(*Scientific American* is part of Nature Publishing Group.)

Other shells from the site reveal that *H. erectus* opened them to eat their contents. And one specimen exhibits clear signs of having been modified to create a tool for cutting or scraping. It is the earliest known example of shell used as a raw material for tool manufacture, the authors say, and it may explain the lack of stone artifacts from this time period in Java: perhaps in the absence of good sources of stone suitable for making implements, *H. erectus* turned to shell instead.

GEOMETRIC DESIGN engraved on this mussel shell is 300,000 years older than engravings from South Africa that were previously thought to be the oldest. Image: Wim Lustenhouwer, VU University Amsterdam

It's wild to think of *H. erectus* foraging for mollusks along an ancient riverbank, making shell knives and painstakingly decorating shells with designs half a million years ago. But perhaps the most thrilling aspects of this find are that it suggests that many more such items—300,000 years' worth, in fact--are out there awaiting discovery, and it raises the question of just how much farther back in the human lineage such behaviors might have originated.

MORE TO EXPLORE:

[*Scientific American*'s human evolution issue (September 2014)]

Ancient Engraving Strengthens Case for Sophisticated Neandertals

One of the longest-running, most fervent debates in the history of human evolution research concerns the cognitive abilities of the Neandertals.

Kate Wong September 3, 2014

Engraving found in Gorham's Cave in Gibraltar dates to more than 39,000 years ago and is thought to have been made by a Neandertal. Image: Courtesy of Stewart Finlayson

One of the longest-running, most fervent debates in the history of human evolution research concerns the cognitive abilities of the Neandertals. Were they the slow-witted creatures of popular imagination or did an intellect like that of modern humans lurk behind that heavy brow? I think it's safe to say that these days most paleoanthropologists have abandoned the idea that the Neandertals were complete dolts, and the debate has shifted to the question of whether they were just fairly smart or whether they shared our special brand of genius. A new discovery lends support to the latter notion.

Researchers working in Gibraltar have found what they say is the first known example of an abstract pattern engraved by a Neandertal. The cross-hatched design was carved into the bedrock of a seaside shelter known as Gorham's Cave. Analysis of the engraving, which covers an area of around 300 square centimeters, indicates that the artist made each of the 13 lines in the image by running a pointed stone tool over the weathered surface of the rock repeatedly in the same direction. An estimated total of 188 to 317 strokes were required to complete the design—too many for it to be unintentional scratching. Neither did the marks resemble those produced experimentally when the researchers cut fresh pig skin with a stone blade on the same kind of rock surface.

Archaeologists consider art and other types of symbolic expression to be key elements of modern behavior, and good indicators that whoever made the symbols had language. Over the years, hints of Neandertal symbolism in the form of jewelry and other decorative items have emerged at a number of sites across Europe. But some skeptics have credited them to early modern humans, arguing either that their belongings got mixed in with the Neandertal remains or that Neandertals copied or acquired symbolic stuff from moderns. The age of the Gibraltar engraving is therefore critical. Because the bedrock at Gorham's Cave lies under a layer of Neandertal-made stone tools dated to 39,000 years ago, the engraving is believed to be older than those artifacts. Modern humans had not yet made it to Gibraltar by 39,000 years ago, so Neanderthals appear to have made the design in the absence of modern influence.

The engraving, which calls to mind a hashtag or tic-tac-toe board, may lack the aesthetic appeal of the spectacular cave paintings and engravings created by early modern humans at sites such as Chauvet and Lascaux in France, but it nevertheless attests to a cognitive ability that many scholars have ascribed to moderns alone. And, in fact, some of the oldest evidence for abstract thinking in modern humans—including 77,000-year-old engraved ochre plaques and 60,000-year-old engraved ostrich eggshell fragments from South Africa—bears simple geometric designs, too. What makes such designs so important, modest though they may appear, is that they are thought to encode information. In the case of the Neandertal hashtag, the researchers who described it observe that it marks a spot within a habitation area in a cave. "This engraving represents a deliberate design conceived to be seen by its Neandertal maker and, considering its size and location, by others in the cave as well," they conclude.

I'm quite sure that this finding will not end the debate over Neandertal smarts. Critics will question the age, the identity of the artist, the intent behind the pattern. Some will argue that even if it is a Neandertal artwork, it is a one-off event—the work of a single, freakishly brilliant individual--not representative of the broader Neandertal population. Archaeologists will need to find many more examples to persuade the skeptics. If it does turn out that Neandertals were our intellectual equals, however, that revelation will only deepen the mystery of why they went extinct: many scientists have surmised that modern humans were able to beat out the Neandertals and other human species as a result of their superior cognitive abilities.

Clive Finlayson of the Gibraltar Museum and his colleagues describe the Gorham's Cave engraving in a paper published online September 1 by the *Proceedings of the National Academy of Sciences USA*. For more on symbolic thought in Neandertals and early modern humans, check out the links below.

Neandertals Made Some of Europe's Oldest Art [Video]

The Mysterious Downfall of the Neandertals

Caveman Couture: Neandertals Rocked Dark Feathers

Did Neandertals Think Like Us?

Oldest Cave Paintings May Be Creations of Neandertals, Not Modern Humans

Ode to the Last Neandertal

The Morning of the Modern Mind

Engraved Ostrich Eggshell Fragments Reveal 60,000-Year-Old Graphic Design Tradition

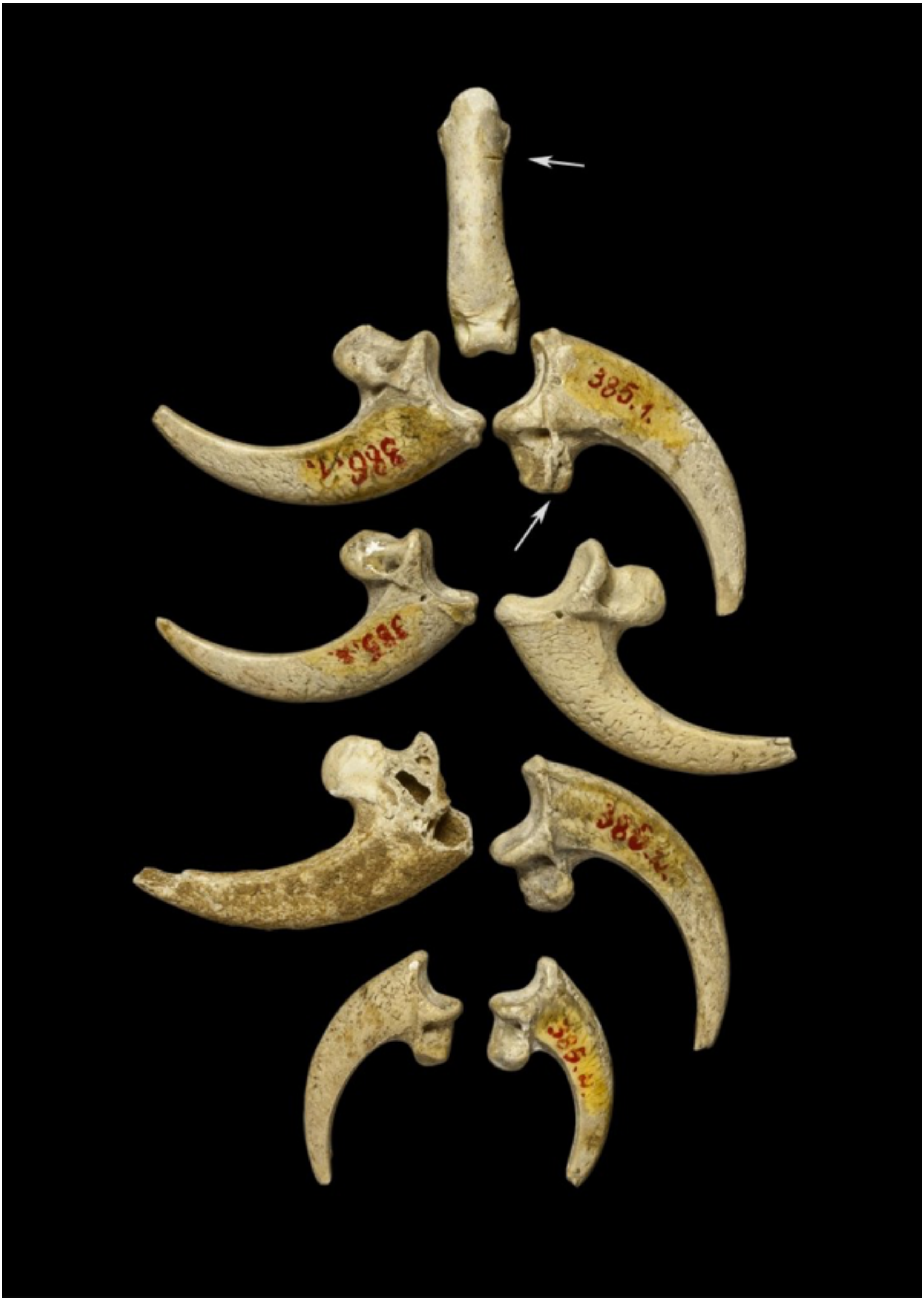
Ancient Engravings Push Back Origin of Abstract Thought

The views expressed are those of the author(s) and are not necessarily those of Scientific American.

Neandertals Turned Eagle Talons into Jewelry 130,000 Years Ago

As longtime readers may have noticed, I have an abiding interest in Neandertals. To help me keep up with the latest scientific insights into these mysterious relatives of ours, I have a Google alert set for "Neandertal" (and the alternate spelling, "Neanderthal").

Kate Wong March 12, 2015



Eagle talons from the site of Krapina in Croatia were harvested by Neandertals and worn as jewelry 130,000 years ago. Image: Luka Mjeda, Zagreb

As longtime readers may have noticed, I have an abiding interest in Neandertals. To help me keep up with the latest scientific insights into these mysterious relatives of ours, I have a Google alert set for "Neandertal" (and the alternate spelling, "Neanderthal"). I'm always excited to see the email notification that a new story about our closest relative is available for my reading pleasure. There's just one problem: nearly half the time, the story isn't about Neandertals at all. Rather the word appears as an invective hurled at whichever politician or other despised figure has attracted the writer's ire.

Neandertals are the Rodney Dangerfields of the human family—they don't get no respect. Despite mounting evidence that our prehistoric cousins hunted with great skill, made beautiful stone tools, showed compassion toward one another and buried their dead, among other advanced behaviors, the word Neandertal remains a widely used pejorative. Disdain toward Neandertals lingers even after the revelation several years ago that most people today carry their DNA, thanks to long-ago hook-ups between Neandertals and anatomically modern *Homo sapiens*.

Now a stunning new discovery underscores that it is time to welcome Neandertals in from the cold. Researchers have found markings on eagle talons from a well-known Neandertal site in Croatia that indicate Neandertals harvested the claws and wore them as jewelry. Such evidence attests to a capacity for symbolic thought, long considered a hallmark of modern humans. Davorka Radovčić of the Croatian Natural History Museum in Zagreb, David Frayer of the University of Kansas and their colleagues describe the find in a paper published March 11 in *PLOS ONE*.

This find is not the first to show Neandertals used raptor claws. Researchers have previously described isolated talons from several

Neandertal sites in Europe. But the new discovery, from the site of Krapina in northern Croatia, includes eight talons from at least three white-tailed eagles. The cut marks and polished facets on the talons suggest human modification rather than, say, trampling by animals. The researchers suggest that the talons were part of a single piece of jewelry, possibly a necklace, tied together with string or sinew.

What makes this discovery additionally important is that it predates by a long shot the arrival of anatomically modern *Homo sapiens* in Europe some 45,000 years ago. Many previous finds suggestive of Neandertal symbolism date to the interval during which Neandertals and moderns overlapped in Europe, leaving open the possibility that Neandertals simply copied the newcomers or that modern items got mixed in with Neandertal remains. But the Krapina assemblage dates to around 130,000 years ago—tens of thousands of years before moderns reached Europe. If the Neandertals there were making jewelry, their endeavor cannot be chalked up to modern influence. They must have conceived of this form of symbolic expression on their own.

Ultimately, such adornments feed into the million-dollar question of whether Neandertals had language, because both art and language stem from the ability to think symbolically. Archaeologists used to hold that symbolic thinking and other elements of so-called behavioral modernity emerged only within the past 50,000 years or so and in anatomically modern humans alone. But traces of symbolic behavior far older than that have emerged at early modern human sites in Africa. The fact that Neandertals decorated their bodies (and their cave homes) suggests that both Neandertals and moderns inherited this capacity for symbolic thinking—and, by extension, language—from an even older common ancestor.

For more on Neandertal cognition, check out my feature article in the

Journal of Human Evolution 125 (2018) 215–217

Contents lists available at ScienceDirect

Journal of Human Evolution

journal homepage: www.elsevier.com/locate/jhevol

News and Views

Early dates for ‘Neanderthal cave art’ may be wrong

Maxime Aubert [a, b, *], Adam Brumm [b], Jillian Huntley [a]

[a] Griffith Centre for Social and Cultural Research, Griffith University, Gold Coast, Queensland, Australia
[b] Australian Research Centre for Human Evolution, Environmental Futures Research Institute, Griffith University, Brisbane, Queensland, Australia

ARTICLE INFO

Article history:
Received 15 March 2018
Accepted 13 August 2018
Available online 30 August 2018

Keywords:
Cave art
Neanderthal
Uranium-series dating

Current evidence suggests that some Neanderthal populations engaged in modern human-like forms of symbolic behavior, including: the extensive and systematic use of ochers and other prepared mineral pigments (i.e., paint; Dayet et al., 2014; Heyes et al., 2016); use of perforated shells and various other modified and unmodified objects and substances as ornaments (e.g., ‘jewelry’), including bird feathers (Finlayson et al., 2012) and claws (Radovčić et al., 2015); manufacture of elaborate structures of unknown purpose inside deep cave passages (Jaubert et al., 2016); and engraving of non-figurative markings on bones (Majkic et al., 2017) and cortical areas of flaked stone artifacts (Majkic et al., 2018), and also on immobile rock surfaces (i.e., at Gorham's Cave; Rodríguez-Vidal et al., 2014). Scientific opinion is deeply divided over the meaning of these behaviors—the empirical evidence for which, in some instances, is not yet unanimously accepted. Indeed, the notion that even late-surviving Neanderthals had acquired aspects of cognitive ‘modernity’, either independently or through direct cultural contact (including interbreeding) with the first modern humans to enter Europe, remains a subject of lively debate.

In a recent paper, Hoffmann et al. (2018a) contended that parietal artworks from Spain date back to at least 64.8 ka, and were hence created by Neanderthals. These rock art dates, if verified, would be the world's oldest dated examples of cave art by far and consequently dramatically alter current thinking about the cognitive abilities of Neanderthals (Appenzeller, 2018). For some authorities, these sensational and widely publicized rock art dates provide the long-awaited ‘smoking gun’ evidence that incontestably demonstrates that Neanderthals and modern humans were, in terms of cognitive ability, strikingly similar. Hoffmann et al. (2018a) asserted that prior claims for Neanderthal art and symbolic behavior lack firm empirical support. However, we believe that similar ambiguities and problems exist in their current study, leading us to question the reliability of their rock art dating results.

Following the publication of the study by Hoffmann et al. (2018a), Pearce and Bonneau (2018) have also expressed caution about these datings. However, the main critique by the latter authors relates to what they regard as a disconcertingly wide range of dates obtained from multiple speleothems over the same motif. Such critique is naïve, because the dates being questioned purportedly provide minimum age estimates for the underlying artwork. Speleothem growth can be affected by several highly localized factors such as changes in the drip positions and/or water flows feeding the speleothems, which can start and stop forming at different times as a result. A similar view is also expressed in a response to Pearce and Bonneau (2018) by Hoffmann et al. (2018b).

Our own critique focuses on two key points: (1) whether dated red markings on flowstone curtains are evidence for rock art production; and (2) potential problems with the sampling methodology used to infer extremely old minimum ages for clearly discernible rock art motifs. Our paper is not intended to represent a full review of rock art dating using speleothems (for a comprehensive review, see Aubert et al., 2017), nor do we evaluate other contentious claims for Neanderthal art and symbolism. We refer only to what we regard as shortcomings in the identification of parietal art motifs and the stratigraphic relationship between the dated samples and pigment layers reported by Hoffmann et al. (2018a).

These researchers used uranium-series analysis to date Neanderthal ‘artworks’ in the form of red marks on flowstone curtains at Ardales. Spanish rock art specialists have produced many detailed analyses of Paleolithic cave art in the study region. However, data available in Hoffmann et al.'s (2018a) paper do not adequately explain the origin or materiality of the red markings in question. Consequently, it is not clear to us that these red marks are from paint or relate to rock art production. Red marks can occur naturally on limestone caves, particularly flowstone and other drapery, from numerous causes such as through organic compounds

* Corresponding author.
E-mail address: m.aubert@griffith.edu.au (M. Aubert).

https://doi.org/10.1016/j.jhevol.2018.08.004

(microorganisms), but also oxides transported in groundwater from clays and soils (Kusky and Cullen, 2010; White and Culver, 2011). Indeed, the sediments above Ardales contain abundant red iron oxide sources within Triassic redbeds (Martín-Algarra et al., 2009).

The physicochemical analysis of pigments has been increasingly practiced in rock art and human evolutionary research for decades (Chalmin and Huntley, 2017). Characterizing the chemical composition, structure and micromorphology of pigments, especially in cross-section, can provide information about their source(s), the manner in which they were applied to a panel ('chaîne opératoire') and postdepositional alteration. Such investigations are especially worthwhile where the cultural origin of images is uncertain (such as the aforementioned red marks on flowstone curtains at Ardales). For instance, detailed forensic investigations have been a critical part of arguing that the earliest examples for symbolic/artistic expressions made by Neanderthals and earlier hominins were deliberate (Dayet et al., 2014; Rodríguez-Vidal et al., 2014; Joordens et al., 2015; Majkić et al., 2018). To our knowledge, the red marks on flowstone curtains at Ardales have never been the subject of similar investigations.

Even if Hoffmann et al. (2018a) were to demonstrate that some or all of the dated red marks constitute paint (and are thus definitely cultural), it remains possible that the pigment on the curtains is unrelated to rock art production. For instance, it has long been presumed on the basis of excavated archaeological findings that Neanderthals painted themselves with red (and black) pigments—although how, and why, is unresolved. Given this, it is possible that the presence of red paint on some cave decorations may be explained by one or more secondary transfer events, such as painted skin or clothing fortuitously coming into contact with cave walls (Medina-Alcaide et al., 2018). There may be a number of explanations for how paint used by Neanderthals was unintentionally transferred to flowstone curtains, without the need to evoke rock art as the causative mechanism. It is germane to note, for instance, that pigment residues are commonly identified on stone tools, but one would have to make a very strong case that pigment-stained tools were deliberately painted (i.e., that they are 'portable art'), when the most parsimonious scenario is obviously that they were ocher-processing implements or were used to work painted material culture objects.

Our main criticism of Hoffmann et al. (2018a) study relates to the authors' dating of identifiable parietal art of a type long assumed to be have been created by modern humans (Bahn and Vertut, 1997). Specifically, they argue that Neanderthals produced a linear symbol (La Pasiega) and a hand stencil (Maltravieso) based on uranium-series dating of supposedly overlying carbonate deposits (Hoffmann et al., 2018a). As the authors point out, "The key condition is demonstrating an unambiguous stratigraphic relationship between the [dated carbonate] sample and the art whose age we wish to constrain" (Hoffmann et al., 2018a:912). However, establishing this relationship is not necessarily straightforward. In our opinion, it is possible that Hoffmann et al. (2018a) unintentionally dated carbonate deposits that were a part of the rock face, or 'canvas', upon which the images were created, and which may be far older than the artworks.

At La Pasiega and Maltravieso, Hoffmann et al. (2018a) did not cut a section through the carbonate deposits into the 'canvas', nor did they completely expose the underlying paint. Doing so would have allowed them to clearly observe the stratigraphic relationship between the layers of dated carbonate materials, the paints of the adjoining visible artworks, and the 'canvas'. Instead, in each case the team scraped the carbonate deposit until they considered that it was changing color (Hoffmann et al., 2018a). This was seen as indicating that they were coming close to the underlying paint of the artwork, and hence they stopped sampling at this point. The team then dated the sampled carbonate under the belief that it had formed on top of the paint layer corresponding to the nearby artwork, and thus could provide a minimum age for the art. But without directly exposing any part of the putative paint layer it is not possible to be certain that an apparent color change demonstrates that it is paint underneath the carbonate (Aubert et al., 2017). The color change noted during sampling might only be an indication of the proximity of 'canvas', not paint. Indeed, it is possible that, owing to differential weathering, the part of the 'canvas' covered over by carbonate deposits could be different in color to exposed areas of 'canvas', to the point where it could be mistaken for paint if not directly observed. Moreover, in our view, a color change is not evident from most images in the paper (Hoffmann et al., 2018a).

Our research in limestone karst areas of Sulawesi (Aubert et al., 2014) has focused on dating small cauliflower-like calcitic growths found in association with rock art (Fig. 1A–C). Known as coralloid speleothems, or 'cave popcorn', these are similar to features dated by Hoffmann et al. (2018a) such as Maltravieso. We have identified coralloids that appear to overlie rock art and which initially seem ideal for providing minimum ages for associated motifs. However, closer inspection sometimes reveals remnants of paint on the exterior surface of the coralloid (Fig. 1D). In other cases, we have cut a section through the coralloid, revealing that there is no paint inside it or on the surface of the 'canvas' below. In both scenarios, it is clear that the coralloid was present on the 'canvas' prior to the creation of the artwork. So some coralloids associated with rock art are outwardly deceptive: either artists painted around these small raised areas on the 'canvas' (practically impossible for stencil art) or they were painted over and weathering has since removed the paint (Fig. 1D). The surest way to assess their suitability for dating is to cut a section from coralloid to 'canvas', or to expose the underlying paint, which, in our experience, tends to have a more vibrant hue than exposed areas of paint from the same artwork, presumably owing to its preservation for many millennia under calcite (i.e., the paints laminated in calcite have not undergone major oxidation or other alternations).

Cave art provides an invaluable and irreplaceable record of ancient human visual culture, and it is never a simple matter or an easy choice from an ethical perspective to justify its partial destruction for scientific research. However, archeology, by nature, often involves the destruction of the primary evidence, including the exhumation of stratified archaeological deposits and the sampling of sediments and/or human fossils for scientific investigation such as ancient DNA analysis and dating—the archaeological study of rock art is no different. The removal of speleothem near parietal art is destructive. It is therefore crucial to find the right balance between impacts to a site/artifact and the archaeological questions to be answered by such destruction. If a sample is to be submitted for scientific dating, its relationship to the artwork should be unquestionable. Depending on the archaeological question to be answered, such as studying art development through time, it is sometimes justifiable to sample through the pigment layer in order to obtain maximum ages. In our view, it is more important to avoid sampling sites that could further damage the artwork, such as areas located above parietal art on the cave walls where water flows could leach freshly exposed calcium carbonate from sampling sites and redeposit it on the artwork below.

Neanderthals could have made rock art of some kind but owing to sampling problems, in particular, we do not believe that this has been sufficiently demonstrated by Hoffmann et al.'s (2018a) study.

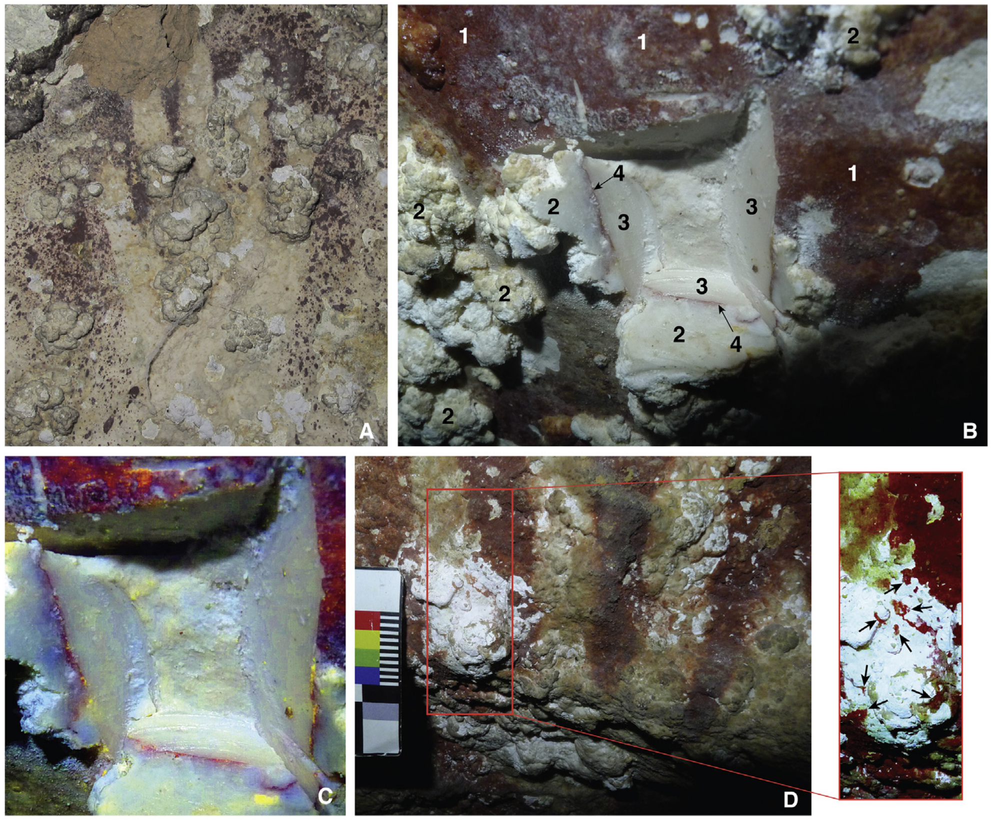


Figure 1. Coralloid speleothems associated with rock art on Sulawesi. A) Hand stencil partly covered with coralloids. B) Section of a sampled coralloid overlying a hand stencil, revealing the stratigraphic relationship between the carbonate deposit and associated artwork; 1 = red paint from the stencil; 2 = coralloid; 3 = interior of the rock face (i.e., the 'canvas') on which the stencil was made; 4 = layer of red pigment that is continuous with the paint of the adjacent stencil and is overlaid by the sampled coralloid. C) Close-up of sample area in B, with the image enhanced using DStretch software (Clogg et al., 2000). D) Traces of red paint on the external surface of a highly weathered coralloid that was clearly present on the 'canvas' prior to the creation of this stencil art. The inset panel shows this image enhanced using DStretch software; arrows highlight remnants of paint still visible on the heavily exfoliated surface of the coralloid.

Acknowledgments

We thank the editor, associate editor, and the two anonymous referees for their thoughtful comments. M.A and A.B. are supported by grants from the Australian Research Council (FT170100025 & FT160100119).

References

Appenzeller, T., 2018. Europe's first artists were Neandertals. Science 359, 852–853.

Aubert, M., Brumm, A., Ramli, M., Sutikna, T., Saptomo, E.W., Hakim, B., Morwood, M.J., van den Bergh, G.D., Kinsley, L., Dosseto, A., 2014. Pleistocene cave art from Sulawesi, Indonesia. Nature 514, 223–227.

Aubert, M., Brumm, A., Taçon, P.S.C., 2017. The timing and nature of human colonization of Southeast Asia in the Late Pleistocene: a rock art perspective. Current Anthropology 58, S553–S566.

Bahn, P.G., Vertut, J., 1997. Journey Through the Ice Age. University of California Press, Berkeley.

Chalmin, E., Huntley, J., 2017. Characterizing rock art pigments. In: David, B., McNiven, I.J. (Eds.), The Oxford Handbook of the Archaeology and Anthropology of Rock Art. https://doi.org/10.1093/oxfordhb/9780190607357.013.48.

Clogg, P., Díaz-Andreu, M., Larkman, B., 2000. Digital image processing and the recording of rock art. Journal of Archaeological Science 27, 837–843.

Dayet, L., d'Errico, F., Garcia-Moreno, R., 2014. Searching for consistencies in Châtelperronian pigment use. Journal of Archaeological Science 44, 180–193.

Finlayson, C., Brown, K., Blasco, R., Rosell, J., Negro, J.J., Bortolotti, G.R., Finlayson, G., Sánchez Marco, A., Pacheco, F.G., Vidal, J.R., Carrión, J.S., 2012. Birds of a feather: Neanderthal exploitation of raptors and corvids. PLoS One 7, e45927.

Heyes, P.J., Anastasakis, K., De Jong, W., Van Hoesel, A., Roebroeks, W., Soressi, M., 2016. Selection and use of manganese dioxide by Neanderthals. Scientific Reports 6, 22159.

Hoffmann, D.L., Standish, C.D., García-Diez, M., Pettitt, P.B., Milton, J.A., Zilhão, J., Alcolea-González, J.J., Cantalejo-Duarte, P., Collado, H., de Balbín, R., Lorblanchet, M., Ramos-Muñoz, J., Weniger, G.-Ch., Pike, A.W.G., 2018a. U-Th dating of carbonate crusts reveals Neandertal origin of Iberian cave art. Science 359, 912–915.

Hoffmann, D.L., Standish, C.D., Pike, A.W.G., García-Diez, M., Pettitt, P.B., Angelucci, D.E., Villaverde, V., Zapata, J., Milton, J.A., Alcolea-González, J.J., Cantalejo-Duarte, P., Collado, H., de Balbín, R., Lorblanchet, M., 2018b. Dates for Neanderthal art and symbolic behaviour are reliable. Nature Ecology & Evolution 2, 1044–1045.

Jaubert, J., Verheyden, S., Genty, D., Soulier, M., Cheng, H., Blamart, D., Burlet, C., Camus, H., Delaby, S., Deldicque, D., Edwards, R.L., 2016. Early Neanderthal constructions deep in Bruniquel Cave in southwestern France. Nature 534, 111–114.

Joordens, J.C., d'Errico, F., Wesselingh, F.P., Munro, S., De Vos, J., Wallinga, J., Ankjærgaard, C., Reimann, T., Wijbrans, J.R., Kuiper, K.F., Mücher, H.J., 2015. *Homo erectus* at Trinil on Java used shells for tool production and engraving. Nature 518, 228–232.

Kusky, T.M., Cullen, K.E. (Eds.), 2010. Encyclopaedia of Earth and Space Science. Infobase Publishing, New York.

Majkić, A., Evans, S., Stepanchuk, V., Tsvelykh, A., d'Errico, F., 2017. A decorated raven bone from the Zaskalnaya VI (Kolosovskaya) Neanderthal site, Crimea. PLoS One 12, e0173435.

Majkić, A., d'Errico, F., Stepanchuk, V., 2018. Assessing the significance of Palaeolithic engraved cortexes. A case study from the Mousterian site of Kiik-Koba, Crimea. PLoS One 13, e0195049.

Martín-Algarra, A., Mazzoli, S., Perrone, V., Rodríguez-Cañero, R., Navas-Parejo, P., 2009. Variscan tectonics in the Malaguide Complex (Betic Cordillera, southern Spain): stratigraphic and structural Alpine versus pre-Alpine constraints from the Ardales area (Province of Malaga). I. Stratigraphy. Journal of Geology 117, 241–262.

Medina-Alcaide, M.Á., Garate-Maidagan, D., Ruiz-Redondo, A., Sanchidrián-Torti, J.L., 2018. Beyond art: The internal archaeological context in Paleolithic decorated caves. Journal of Anthropological Archaeology 49, 114–128.

Pearce, D.G., Bonneau, A., 2018. Trouble on the dating scene. Nature Ecology & Evolution 2, 925–926.

Radovčić, D., Sršen, A.O., Radovčić, J., Frayer, D.W., 2015. Evidence for Neandertal jewelry: Modified white-tailed eagle claws at Krapina. PLoS One 10, e0119802.

Rodríguez-Vidal, J., d'Errico, F., Giles Pacheco, F., Blasco, R., Rosell, J., Jennings, R.P., Queffelec, A., 2014. A rock engraving made by Neanderthals in Gibraltar. Proceedings of the National Academy of Sciences USA 111, 13301–13306.

White, W.B., Culver, D.C. (Eds.), 2011. Encyclopaedia of Caves. Academic Press, Oxford.

12/07 | Aula 8: A herança genética neandertal no homem moderno. 1% a 4% dos genes das pessoas de fora da África são de neandertais. Os genes relacionados a doenças e a características positivas que deles herdamos. O surgimento do pensamento simbólico. A revolução criativa do Paleolítico Superior. O fóssil mais antigo com alguns traços típicos do *Homo sapiens*.

Textos para leitura:
Oldest Homo sapiens Bones Found in Europe | Ann Gibbons
Did Neanderthals Make Art? | Bruce Hardy
Neandertal Genome Study Reveals That We Have a Little Caveman in Us | Kate Wong
Sex with Neandertals Introduced Helpful and Harmful DNA into Modern Human Genome | Kate Wong
World's Oldest Homo sapiens Fossils Found in Marocco | Ann Gibbons

HUMAN EVOLUTION

Oldest *Homo sapiens* bones found in Europe

Pendants of cave bear teeth spark debate about cultural links to Neanderthals

By **Ann Gibbons**

During a warm spell about 47,000 years ago, a small band of people took shelter in a cave on the northern slope of the Balkan Mountains in what is now Bulgaria. There, they butchered bison, wild horses, and cave bears, leaving the cave floor littered with bones and a wealth of artifacts—ivory beads, pendants made with cave bear teeth, and stone blades stained with red ochre.

This region had long been home to Neanderthals, who left stone tools in the same cave more than 50,000 years ago. But these cave dwellers were new to Europe, as an international team reports in *Nature* this week. Researchers re-excavated the cave and used a cutting-edge toolkit of their own to identify a molar and a handful of bone fragments as belonging to *Homo sapiens*, our own species. Precise new dates show these cave dwellers lived as early as 47,000 years ago, which makes them the earliest known members of our species in Europe.

The last Neanderthals didn't vanish from Western Europe until about 40,000 years ago, so the two kinds of humans must have overlapped on the continent for at least 5000 years; previous DNA studies have shown that they mated. The new work is reigniting a long-standing debate about how Neanderthals and moderns may have influenced each other's cultures, because it links moderns to a package of artifacts that resemble those made later by Neanderthals. "It's a wonderful example of pulling all these lines of evidence together to make a solid argument that *H. sapiens* were the authors" of some of those artifacts, says paleoanthropologist Katerina Harvati of the University of Tübingen.

Bones of early *H. sapiens* in Europe are scarce, so researchers try to identify them from tools and artifacts thought to be unique to modern humans. Those include sophisticated artifacts known as the Aurignacian, including bladelets, carved figurines, and musical instruments dating from 43,000 to 33,000 years ago. The reign of the Neanderthals, from about 400,000 to 40,000 years ago, is marked by less refined Mousterian tools. But researchers have puzzled over who crafted "transitional" artifacts—a grab bag of bone tools, beads, and jewelry immediately preceding the Aurignacian. One of these toolkits, called the Initial Upper Paleolithic (IUP), shows up in the Middle East about 47,000 years ago and later appears across Eurasia.

Partial fossils found with artifacts at one site in the United Kingdom and one in Italy suggested *H. sapiens* made some transitional assemblages, but questions persist about those dates at those sites. The Bulgarian cave, called Bacho Kiro, yielded human fossils in the 1970s, but those were lost.

In 2015, a team of researchers re-excavated Bacho Kiro cave in Bulgaria and found modern human bones and a tooth.

Paleoanthropologist Jean-Jacques Hublin and colleagues at the Max Planck Institute for Evolutionary Anthropology joined forces with Bulgarian researchers to re-excavate Bacho Kiro in 2015. They uncovered thousands of bones, stone and bone tools, beads and pendants, and a human molar.

The shape of the molar marked it as a member of *H. sapiens*, but many of the bones were too fragmentary to tell whether they were animal or human. So, the Max Planck team scrutinized proteins in the bone. They extracted collagen from 1271 fragments and applied a new method called ZooMs to analyze them. Four fragments from the older layers were human. Researchers then extracted DNA from these bones and the tooth and found that the mitochondrial sequences—the most abundant DNA in many fossils—were those of *H. sapiens*. The team is now analyzing the fossils' nuclear DNA.

Meanwhile, Max Planck radiocarbon dating specialist Helen Fewlass and her colleagues directly dated collagen from 95 bones. They report in *Nature Ecology & Evolution* that the human bones and artifacts date from 43,650 to 45,820 years ago. The ages of animal bones modified by people suggest they were in the cave "probably beginning from 46,940" years ago, Fewlass says. At about this time, the climate of Europe had begun to warm, which may have enticed *H. sapiens* with IUP toolkits to venture north from the Middle East, into the Balkans and beyond, Hublin says. (The DNA of these early arrivals shows, however, that they left no descendants in Europe today.)

Hublin notes that pendants made from the teeth of cave bears at Bacho Kiro are similar to pendants thought to be the handiwork of later Neanderthals and crafted about 42,000 to 44,000 years ago—the so-called Châtelperronian industry, first found at the Grotte du Renne site in France. He argues that this supports his longheld contention that Neanderthals picked up this type of pendant from moderns.

Others say that extrapolation goes too far. "Transitional" technologies such as the IUP are so diverse and widespread that it's not clear that only one kind of human invented them, says archaeologist Nick Conard, also at the University of Tübingen. And archaeologist Francesco d'Errico of the University of Bordeaux, who has long debated Hublin over Neanderthals' abilities, points to earlier notched bone scrapers and beadlike objects as evidence that Neanderthals could create sophisticated art and technology well before they met modern humans.

Debate is sure to continue, but archaeologists welcome the "very significant" dates at Bacho Kiro, says Tom Higham, a radiocarbon specialist at the University of Oxford. "For the first time, we're able to pin the IUP as being made by anatomically modern humans in Europe." ■

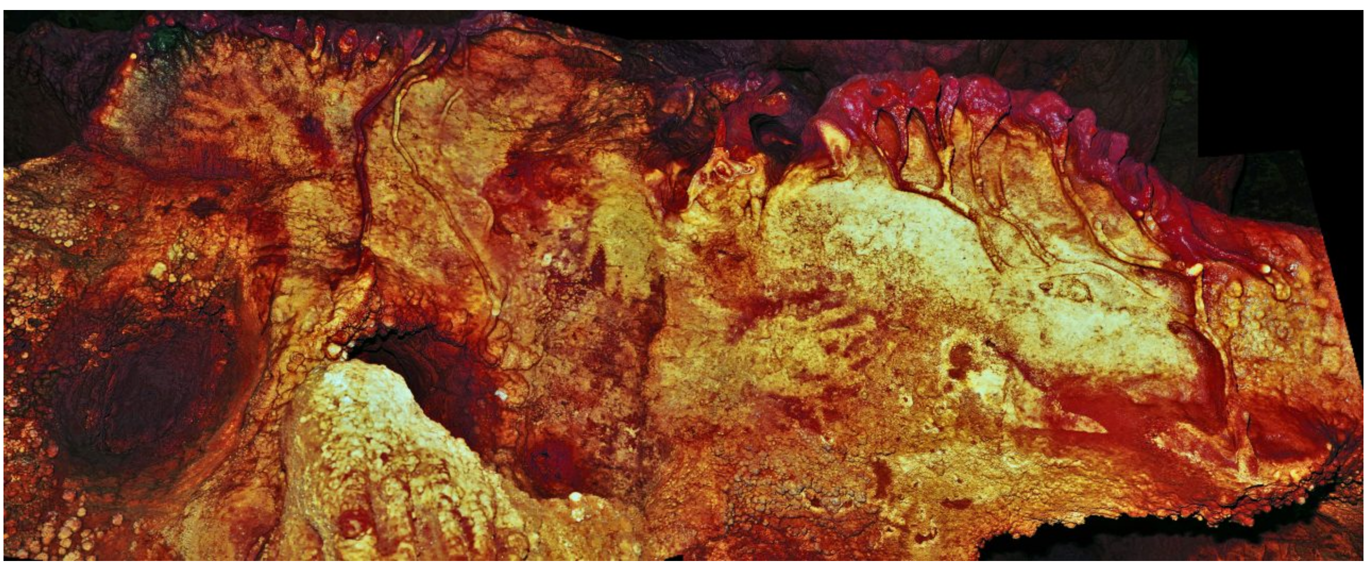
ESSAY / EXPRESSIONS

Did Neanderthals Make Art?

Experts continue to debate whether Neanderthals were painters and jewelry-makers. A paleoanthropologist explores the evidence for Neanderthal art and the sources of people's skepticism.

By BRUCE HARDY

11 AUG 2022



Maltravieso Cave in Spain is decorated with hand stencils, one of which was dated to at least 66,000 years ago, when Neanderthals lived in Europe.

Hipólito Collado Giraldo

*

AS A NEANDERTHAL RESEARCHER, I'm familiar with the stereotypes of *Homo neanderthalensis*: dull, unintelligent, lacking the imagination to do more than bash each other on the head. They just sat around, gnawing on mammoth, awaiting their inevitable extinction. So, in 2018, I was excited when I saw a headline announcing "It's Official: Neanderthals Created Art." I quickly found the scientific article and read that new evidence from Spain had dated art in three caves at more than 65,000 years old. The only people in Europe at that time were Neanderthals!

Wait, I thought. It won't be long before someone will question the date or suggest it was really modern humans who got there earlier and painted the caves. Sure enough, as soon as researchers said "Neanderthal art," an NPR science news correspondent responded doubtfully, "If new evidence shows that humans actually arrived earlier than scientists now think, well, that's the pattern of science."

I wasn't surprised. A year later, 44 researchers co-authored a paper critiquing the study from Spain, writing, "there is still no convincing archaeological evidence that Neanderthals created Iberian cave art."

So, what is the evidence for Neanderthal art? And why are so many people skeptical that Neanderthals had the cognitive capability to make paintings, ornamentation, and other symbolic creations?

DID NEANDERTHALS MAKE CAVE PAINTINGS?

When most people think about Paleolithic art, they picture the 20,000-year-old paintings in Lascaux Cave or the 36,000-year-old paintings in Chauvet Cave, both located in France. These are generally associated with modern humans during the Upper Paleolithic—not Neanderthals, who lived around 400,000 to 40,000 years ago in Europe and parts of Asia. [1]

But, actually, dating cave paintings is notoriously difficult. They are generally made with mineral-based pigments that can't be directly dated because they don't contain organic matter. A few may contain organic material such as charcoal, which can be radiocarbon dated, but that only works for paintings younger than 50,000 years. For many cave paintings, researchers assume they are younger than 40,000 years or so, but they can't establish a definite age.

That's one of the exciting aspects of the aforementioned study in Spain. Archaeologists used uranium-thorium dating on tiny stalactites and stalagmites that formed over the top of the pigment.

Neanderthal Origin of Iberian Cave Art (Science)

These carbonate deposits, left behind when water and carbon dioxide move through rock, can provide a minimum age for the cave paintings beneath them.

The researchers used this method on three cave paintings: a red, ladder-like image at La Pasiega in northern Spain; hand stencils at Maltravieso in western Spain; and a curtain of stalagmites painted red at Ardales in southern Spain. All of them dated to approximately 65,000 years ago.

But the results have been challenged on methodological grounds (a dispute over the movement of uranium in groundwater in the caves) and by the conviction that only modern humans made art. Repeated claims and counter-claims mean it is unlikely that this controversy will be resolved any time soon. Still, there is evidence in other places that Neanderthals had the capacity for creativity.

DID NEANDERTHALS ENGRAVE BONES?

A promising recent find comes from the Neanderthal site of Einhornhöhle (Unicorn Cave) in northern Germany. In 2021, archaeologists announced the recovery of an engraved toe bone of *Megaloceros giganteus*, an extinct deer that could grow to about 7 feet tall, with an antler span of 12 feet! This toe bone is etched with six engravings that form five offset stacked chevrons. The angles formed by the intersecting lines are quite regular, ranging from 92.3 to 100.3 degrees. A second set of four short lines are incised on the proximal end.

These are not cut-marks related to butchery (deer toes are not terribly meaty) and were clearly made intentionally to form a pattern. In this case, the dates aren't disputed. Radiocarbon dating at the site, and of the bone itself, suggest it is at least 51,000 years old.

Why would someone select the toe bone of a giant deer that is very rare in this area and engrave a series of chevrons onto it?

Clearly the pattern has no practical value. The authors suggest that the engraving, and possibly the choice of animal, must have symbolic meaning. And art is all about symbolism—representing an idea or object in some other form. For me, that speaks strongly to symbolic thought in Neanderthals.

00:00 00:30

But as you might expect, when something that looks symbolic is associated with Neanderthals, it doesn't take long for people to give at least partial credit to modern humans. In this case, DNA was recently recovered from modern human fossils dating to more than 45,000 years ago at Zlatý Kůň, Czech Republic. The fossils contain long stretches of Neanderthal DNA, suggesting interbreeding occurred before 50,000 years. Some posit that the Neanderthals who exchanged genes with the ancestors of Zlatý Kůň also exchanged knowledge.

Here we go again. Neanderthals did something symbolic? Nah, they just copied modern humans. I think I've heard this story before.

DID NEANDERTHALS BUILD STONE CIRCLES?

How about Bruniquel Cave in southwestern France? This one is odd. More than 300 meters inside the cave lie multiple structures constructed from almost 400 stalagmite fragments (also called speleofacts). Two large circular structures, composed of up to four layers of stacked stalagmite fragments, stretch around 2 to 7 meters across and about 40 centimeters high. These are accompanied by several other accumulations of stalagmites. Based on reddening and blackening of some of the fragments, it appears that all of the structures are associated with fire.

Archaeologists dated the structures by looking at the age of broken stalagmites and when they began to regrow. The results consistently pointed to the structures being about 176,500 years old. At that time, the only ancestral human species in France were Neanderthals.

No light penetrates this part of the cave's dark zone, so Neanderthals would have had to bring their own. Then, it seems, they collected and deliberately placed hundreds of speleofacts in circles and made fires that reddened and blackened many of them. According to the researchers, this demonstrates that Neanderthals were capable of complex spatial and social organization.

In Bruniquel Cave in France, Neanderthals appear to have created artful circles from hundreds of stalagmite fragments.
Luc-Henri Fage/SSAC/Wikimedia Commons

Why did the Neanderthals do this? Was it some sort of ritual? To be honest, we'll never know. Is it art? That depends on what you consider art. One definition of art is that it is creative behavior with no practical purpose. By that definition, I'd say it fits.

For the most part, this find was fairly well-received. Some pointed out, however, that while Neanderthals made the structures, they did so while "leaving no trace of graphic activity."

So, nice try, Neanderthals. But if you don't paint the cave walls, does it really count as art?

DID NEANDERTHALS MAKE JEWELRY?

When it comes to jewelry—or personal adornment in archaeological terminology—there isn't just a single example. At least 23 raptor talons, mostly from the formidable white-tailed eagle, have been found at 10 Neanderthal sites ranging in age from 130,000 to 42,000 years ago.

The talons are scratched with cut marks, indicating they were intentionally removed. Given the lack of meat on an eagle's toe, these weren't food items. Researchers found animal tissue—possibly a remnant of a leather cord—on the surface of one talon found at Krapina, Croatia. This suggests the talon was hung on a bracelet or necklace.

Further evidence of Neanderthal use of birds comes from Fumane, Italy. Raptor wing bones show signs of cutting and scraping for the purpose of removing feathers. We're not sure what they did with the feathers, but one possibility is personal decoration.

Also, in Cueva de los Aviones in Spain, scientists have found perforated, pigmented shells possibly between 115,000 and 120,000 years old. Were these objects of personal adornment? Other shells at the site have multiple pigments inside them, suggesting they functioned as containers to mix colors.

These objects, structures, and paintings are not an exhaustive catalog of Neanderthal symbolism, but you have to admit the evidence is adding up.

HOW MUCH NEANDERTHAL ART DISAPPEARED?

All this evidence has one thing in common: preservation. It survived for archaeologists to find today, albeit in fragmentary and degraded form. Bone, mineral pigment, and stalagmites are durable. But look around you: Your clothing, the table, and that picture on the wall are perishable. They will likely decay well before 50,000 to 100,000 years have passed. Only a minuscule percentage of the material culture from the Paleolithic has survived. Yet we're still finding evidence for symbolism and art. So, how much art was created and then vanished?

The earliest-carved figurines come from what is today southern Germany and date to between 36,000 and 40,000 years ago. They are made of ivory. Do you really think the first time someone carved something, they chose ivory? Wood is a lot easier to carve. And what about cave paintings? Were the first drawings done in ochre on cave walls? It's doubtful. How about drawing in the sand or painting on skin?

The stereotype of the artless Neanderthal and the artful modern human was rooted in 19th-century prejudices.

Of course, anthropologists can't see this missing majority of creations today, but they had to be there. After all, absence of evidence is not evidence of absence.

Art must be older than we think. It did not arise de novo with modern humans in the form of durable materials. And yet, that seems to be the narrative in paleoanthropology. Every time a new discovery is put forward that could be Neanderthal art or symbolism, it is questioned. But why?

WHY DO PEOPLE DOUBT NEANDERTHALS MADE ART?

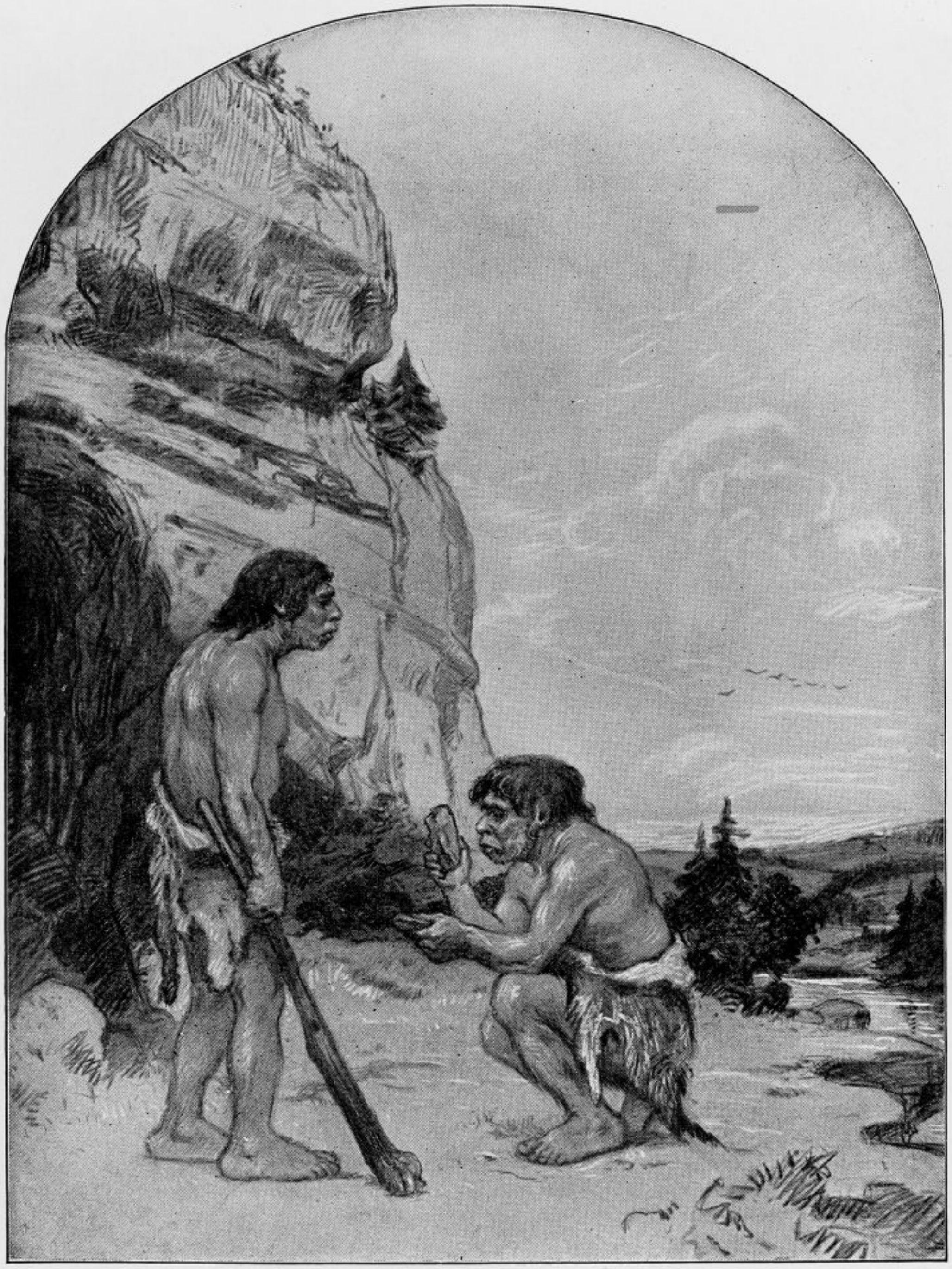
In the 2013 animated film *The Croods*, Grug—a Neanderthal who fears newfangled human inventions like shoes and a shell horn—finds glimmers of humanity when he first paints on a cave wall. This portrayal of Neanderthal deficiencies and modern human superiorities is deeply engrained in popular culture and science. And it began in the mid-1800s.

At the time, one of the great intellectual debates concerned the antiquity of humans. Much of the world was still operating under a biblical framework. So the idea that humans had been around for a long time, or that they had evolved, was controversial.

The first ancestral human fossil to be recognized as possibly ancient was a Neanderthal, found in Germany's Neander Valley in 1856. It had a long, low skull with large brow ridges. It might be human, scholars thought, but just barely. Then in 1868, modern human fossils were uncovered at the Cro-Magnon rock shelter in France. These fossils, with their high foreheads, looked anatomically modern.

In 1879, the first recognized cave art was found by amateur archaeologist Marcelino Sanz de Sautuola at Altamira Cave in northern Spain. Despite the lack of any associated fossil remains, these cave paintings were attributed to Cro-Magnons. Without sufficient evidence, art became seen as one of the hallmarks of true humanity.

Neanderthals, with their low foreheads and allegedly brutish nature, provided the perfect contrast. They were extinct. They had lost out to the "true men" with their painted caves and creative nature. This idea was enshrined for decades in books and museums around the world.



Pl. I. Neanderthal man at the station of Le Moustier, overlooking the valley of the Vézère, Dordogne. Drawing by Charles R. Knight, under the direction of the author.

Charles Knight's illustration portrays slouching Neanderthals puzzling over a rock.

Charles R. Knight/Wellcome Collection

In a stark contrast, Knight depicts Cro-Magnons as ingenious, fire-wielding muralists.
Charles R. Knight/Wikimedia Commons

Henry Fairfield Osborn, a long-time curator at the American Museum of Natural History, worked with artist Charles Knight to illustrate the different stages of the Paleolithic in books and murals. In these images, Neanderthals are depicted as hunched-over creatures who don't seem to have the imagination to do anything besides stare uncomprehendingly at a rock. The Cro-Magnons are shown holding a scapula bone for a painter's palette while deftly drawing the curve of a bison's hump on a cave wall.

In the eyes of Osborn and others of the time, the western European Cro-Magnon was seen as the original artist and the original human. Is it surprising, then, that Osborn was a leader in eugenics and anti-immigration who cited ancient history as justification for his views? For Osborn, Neanderthals and Cro-Magnons never mixed, so why should different "races" today? (Of course, Neanderthals and modern humans *did* mix, and the today?" (Of course, Neanderthals and modern humans *did* mix, and the genomes of all humans today typically contain anywhere from 0.3 to 4 percent Neanderthal DNA.)

Looking back at history, it's clear that the stereotype of the artless Neanderthal and the artful modern human was rooted in prejudices of the time. People projected Western ideals and aesthetics onto Paleolithic "art," which, in turn, were deployed to define "primitive art" made by non-Western "savage" peoples. Art made us human, but not all humans had the same art. Even today, some art produced by non-Western peoples is described as "folk art" or "primitive art" rather than just art.

So, did Neanderthals make art?

Yes, they did. It's important to recognize that—not only to give credit where it's due, but also because past prejudices have power in the present, and only by recognizing these biases can people hope to overcome them.

Bruce Hardy

Bruce Hardy is a paleoanthropologist and archaeologist specializing in Neanderthals. His research focuses on understanding stone tool use through microscopic residue analysis. He is a professor of anthropology at Kenyon College in Gambier, Ohio, where he teaches his students Neanderthal skills such as making fire and wooden spears. In 2020, he and his colleagues published evidence of the oldest-known surviving string, circa 50,000 years old, from the Neanderthal site of Abri du Maras in France. He also teaches a course on science and pseudoscience.

Neandertal Genome Study Reveals That We Have a Little Caveman in Us

The sequence shows that Neandertals and modern humans interbred, and that their DNA persists in us

Kate Wong May 6, 2010

Credit: Frank Vinken

Researchers sequencing Neandertal DNA have concluded that between 1 and 4 percent of the DNA of people today who live outside Africa came from Neandertals, the result of interbreeding between Neandertals and early modern humans.

A team of scientists led by Svante Pääbo of the Max Planck Institute for Evolutionary Anthropology in Leipzig pieced together the first draft of the sequence—which represents about 60 percent of the entire genome—using DNA obtained from three Neandertal bones that come from Vindija cave in Croatia and are more than 38,000 years old. The researchers detail their analysis of the sequence in the May 7 *Science*.

The evidence that Neandertals contributed DNA to modern humans came as a shock to the investigators. "First I thought it was some kind of statistical fluke," Pääbo remarked during a press teleconference on May 5. "We as a consortium came into this with a very, very strong bias against gene flow," added team member David Reich of Harvard University. But when the researchers conducted additional analyses, the results all pointed to the same conclusion.

Rethinking the Gene Pool

The finding contrasts sharply with Pääbo's previous work. In 1997 he and his colleagues sequenced the first Neandertal mitochondrial DNA . Mitochondria are the cell's energy-generating organelles, and they have their own DNA, which is distinct from the much longer DNA sequence that resides in the cell's nucleus. Their analysis revealed that Neandertals had not made any contributions to modern mitochondrial DNA. Yet because mitochondrial DNA represents only a tiny fraction of an individual's genetic makeup, the possibility remained that Neandertal nuclear DNA might tell a different story. Still, additional genetic analyses have typically led researchers to conclude that *Homo sapiens* arose in Africa and replaced the archaic humans it encountered as it spread out from its birthplace without mingling with them.

But mingle they apparently did, according to the new study. When Pääbo's team looked at patterns of nuclear genome variation in present-day humans, it identified 12 genome regions where non-Africans exhibited variants that were not seen in Africans and that were thus candidates for being derived from the Neandertals, who lived not in Africa but Eurasia. Comparing those regions with the same regions in the newly assembled Neandertal sequence, the researchers found 10 matches, meaning 10 of these 12 variants in non-Africans came from Neandertals. (Where the other two segments came from remains unknown.)

Intriguingly, the researchers failed to detect a special affinity to Europeans—a link that might have been expected given that Neandertals seem to have persisted in Europe longer than anywhere else before disappearing around 28,000 years ago. Rather, the Neandertal sequence was equally close to sequences from present-day people from France, Papua New Guinea and China, even though no Neandertal specimens have turned up in the latter two parts of the world. By way of explanation, the investigators suggest that the interbreeding occurred in the Middle East between 45,000 and 80,000 years ago, before moderns fanned out to other parts of the Old World and split into different groups.

Bolstering Multiregional Theory?

Intermixing does not surprise paleoanthropologists who have long argued on the basis of fossils that archaic humans, such as the Neandertals in Eurasia and *Homo erectus* in East Asia, mated with early moderns and can be counted among our ancestors—the so-called multiregional evolution theory of modern human origins. The detection of Neandertal DNA in present-day people thus comes as welcome news to these scientists. "It is important evidence for multiregional evolution," comments Milford H. Wolpoff of the University of Michigan, the leading proponent of the theory.

The new finding shows that "gene flow across taxonomic boundaries happens," observes geneticist Michael F. Hammer of the University of

Arizona. Hammer is among the minority of geneticists who have espoused the idea of gene flow between archaic and modern populations. His own studies of the DNA of people living today have uncovered, for example, a stretch of DNA that seems to have come from encounters between moderns and *H. erectus*.

Some experts suspect that the estimate for the amount of Neandertal DNA people carry today could rise with further studies—if a Neandertal from the Middle East were sequenced, for instance. In addition, says paleoanthropologist John Hawks of the University of Wisconsin, the current study might be obscuring a contribution of Neandertal genes to the African gene pool, because the team specifically looked to explain genetic diversity in non-Africans compared with Africans. He and his colleagues are currently working on a way to assess that possibility.

Many researchers concur that the results disprove the strict Out of Africa replacement model of modern human origins. In a prepared statement Out of Africa theorist Christopher B. Stringer of the Natural History Museum in London said "although I have never ruled out the possibility of interbreeding, I have considered this to have been small and insignificant in the bigger picture of our evolution— for example, the results of isolated interbreeding events could easily have been lost in the intervening millennia. Now, the Neanderthal genome strongly suggests those genes were not lost, and that many of us outside of Africa have some Neanderthal inheritance." But Stringer maintains that the origin of our species is mostly an Out of Africa story.

Population geneticist Laurent Excoffier of the University of Bern in Switzerland agrees that Out of Africa is still the most plausible model of modern human origins, noting that the alleged admixture did not continue as moderns moved into Europe. “In all scenarios of speciation, there is a time during which two diverging species remain interfertile,” he explains.

Other Forebears as Well?

Pääbo, for his part, says that now that his team has shown that early modern humans interbred with one archaic group, he thinks other archaic humans might have passed along genes to us through interbreeding. Whether such contributions might have been beneficial remains unknown, however, although the Neandertal DNA in non-Africans does not seem to encode anything particularly important from a functional standpoint.

In addition to illuminating how Neandertals and moderns interacted, the Neandertal genome is helping researchers to figure out which parts of the modern human genome separate us from all other creatures. “Many traits that distinguish humans from chimps are believed to have evolved more recently than the human–Neanderthal split,” observes biostatistician Katherine S. Pollard of the Gladstone Institutes at the University of California, San Francisco. “A Neanderthal genome is a very important step towards determining the genetic basis for these characteristics that define the modern human species.”

Thus far, Pääbo’s group has identified a number of modern human genome regions containing sequence variation that is not seen in Neandertals and that may have helped modern humans adapt. Some of these regions play a role in cognitive development, sperm movement and the physiology of the skin.

But exactly how these slight changes to the modern human sequence affected the functioning of these genome regions remains to be determined. “A complete understanding of this is really a stepwise process,” team member Richard E. Green of the University of California, Santa Cruz, remarked at the press teleconference. “What we have done here is take a really important step forward. We can say exactly what changes happened recently with very high resolution.” Says Pääbo: “This is just the beginning of the exploration of human uniqueness that is now possible.”

Sex with Neandertals Introduced Helpful and Harmful DNA into Modern Human Genome

Over the past few years a number of studies of ancient and contemporary genomes have reached the same stunning conclusion: early human species interbred, and people today carry DNA from archaic humans, including the Neandertals, as a result of those interspecies trysts.

Kate Wong January 30, 2014

Neandertal DNA survives in Asian and European people today. Image: 120, via Wikimedia Commons

Over the past few years a number of studies of ancient and contemporary genomes have reached the same stunning conclusion: early human species interbred, and people today carry DNA from archaic humans, including the Neandertals, as a result of those interspecies trysts. Now two new analyses of modern human genomes are providing insights into how the acquisition of Neandertal DNA affected anatomically modern *Homo sapiens* tens of thousands of years ago and how it continues to affect people today.

In the first study, Sriram Sankararaman and David Reich of Harvard

University and their colleagues compared a complete Neandertal genome sequence with 1,004 modern human sequences to see which regions of the modern genome contain Neandertal DNA. Like other researchers before them, they observed that Asians and Europeans have DNA from Neandertals, whereas Africans have little or no Neandertal DNA. The pattern is consistent with a scenario in which early modern humans mated with Neandertals they encountered when they migrated out of Africa and into Eurasia, where Neandertals had lived for hundreds of thousands of years.

Moreover, the team determined that Neandertal DNA is not distributed evenly across the genome. Some genes have a high proportion of Neandertal ancestry (which is to say, many people today carry the Neandertal versions of these genes). Those genes with the highest Neandertal ancestry are associated with keratin, a protein found in skin and hair. The Neandertal variants of these genes may well have helped early modern humans adapt to the new environments they found themselves in as they spread into Eurasia. But the researchers also found that people today carry Neandertal genes that are associated with diseases including Crohn's, type 2 diabetes and lupus.

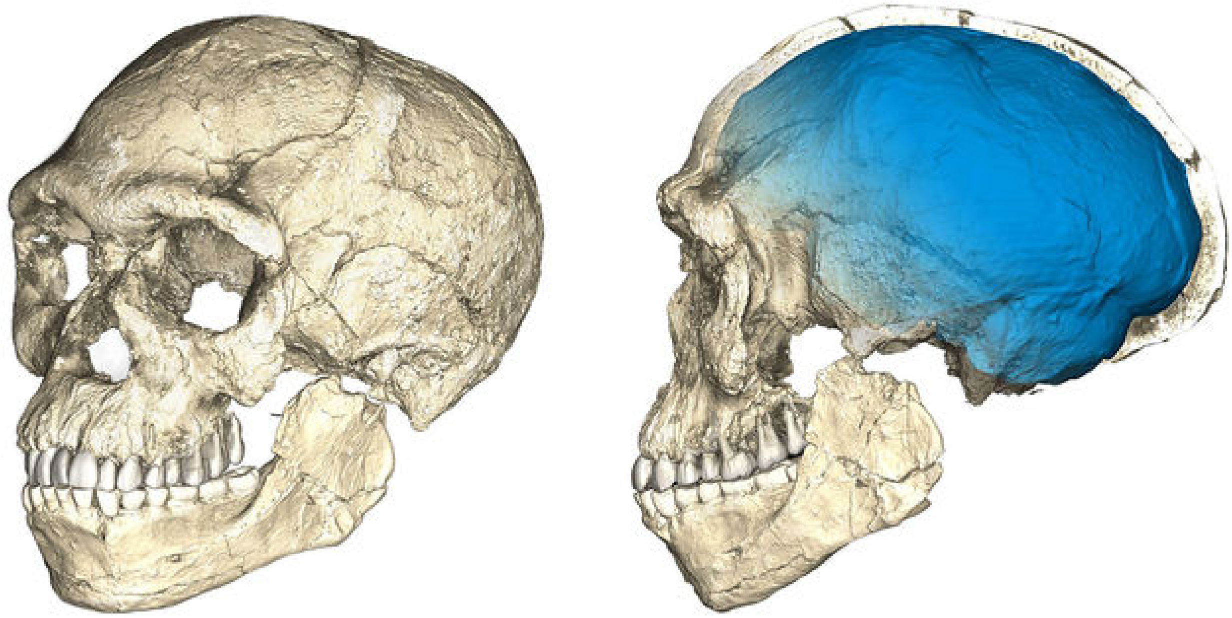
Intriguingly, other regions of the modern human genome have no or very low Neandertal contribution, notably the X chromosome and genes related to the functioning of the testes. According to Sankararaman, Reich and their collaborators, the absence of Neandertal genetic material in these regions suggests that male hybrids who inherited a Neandertal X chromosome were infertile, and thus unable to pass their genes along to the next generation. The researchers detail their findings in a paper published in the December 30 *Nature.* (*Scientific American* is part of Nature Publishing Group.)

In the second study, published by *Science,* Benjamin Vernot and Joshua M. Akey of the University of Washington screened whole genome sequences from 665 living Europeans and Asians for telltale signs of Neandertal contributions. Their results show that although non-Africans individually inherited between 1 and 3 percent of their genomes from Neandertals, different people carry different bits of Neandertal genetic material. Together these sequences represent around 20 percent of the Neandertal genome.

Like the other team, Vernot and Akey found evidence that Neandertals passed along beneficial skin genes to modern humans, including some linked to pigmentation. And they, too, observed genome regions devoid of Neandertal contributions. One such region contains the gene FOXP2, which plays an important role in speech.

Vernot and Akey's work is additionally interesting in that they were able to use statistical and computational methods to identify the Neandertal contributions in the genomes of modern-day people without using a Neandertal genome to guide their search. This work raises the possibility that simply by analyzing the genomes of people alive today, scientists will be able to discover and describe extinct human species that mated with early *H. sapiens* but that, unlike Neandertals, are unknown from the fossil record. Previous studies of genomes of living people have hinted at dalliances between early *H. sapiens* and unknown archaic humans in Africa. Perhaps this approach will shine a light on these mysterious skeletons in our closet.

The views expressed are those of the author(s) and are not necessarily those of Scientific American.



A composite computer reconstruction of fossils from Jebel Irhoud shows a modern, flattened face paired with an archaic, elongated braincase © PHILIPP GUNZ, MPI EVA LEIPZIG

World's oldest *Homo sapiens* fossils found in Morocco

By **Ann Gibbons** | Jun. 7, 2017 , 1:00 PM

For decades, researchers seeking the origin of our species have scoured the Great Rift Valley of East Africa. Now, their quest has taken an unexpected detour west to Morocco: Researchers have redated a long-overlooked skull from a cave called Jebel Irhoud to a startling 300,000 years ago, and unearthed new fossils and stone tools. The result is the oldest well-dated evidence of *Homo sapiens*, pushing back the appearance of our kind by 100,000 years.

"This stuff is a time and a half older than anything else put forward as *H. sapiens*," says paleoanthropologist John Fleagle of the State University of New York in Stony Brook.

The discoveries, reported in *Nature*, suggest that **our species came into the world face-first**, evolving modern facial traits while the back of the skull remained elongated like those of archaic humans. The findings also suggest that the earliest chapters of our species's story may have played out across the African continent. "These hominins are on the fringes of the world at that time," says archaeologist Michael Petraglia of the Max Planck Institute for the Science of Human History in Jena, Germany.

Back in 1961, miners searching for the mineral barite stumbled on a stunningly complete fossil skull at Jebel Irhoud, 75 kilometers from Morocco's west coast. With its big brain but primitive skull shape, the skull was initially assumed to be an African Neandertal. In 2007, researchers published a date of 160,000 years based on radiometric dating of a human tooth. That suggested that the fossil represented a lingering remnant of an archaic species, perhaps *H. heidelbergensis*, which may be the ancestor of both Neandertals and *H. sapiens*. In any case, the skull still appeared to be younger than the oldest accepted *H. sapiens* fossils.

Those fossils were found in East Africa, long the presumed cradle of human evolution. At Herto, in Ethiopia's Great Rift Valley, researchers dated *H. sapiens* skulls to about 160,000 years ago; farther south at Omo Kibish, two skullcaps are dated to about 195,000 years ago, making them the oldest widely accepted members of our species, until now. "The mantra has been that the speciation of *H. sapiens* was somewhere around 200,000 years ago," Petraglia says.

Some researchers thought the trail of our species might have begun earlier. After all, geneticists date the split of humans and our closest cousins, the Neandertals, to at least 500,000 years ago, notes paleoanthropologist John Hawks of the University of Wisconsin in Madison. So you might expect to find hints of our species somewhere in Africa well before 200,000 years ago, he says.

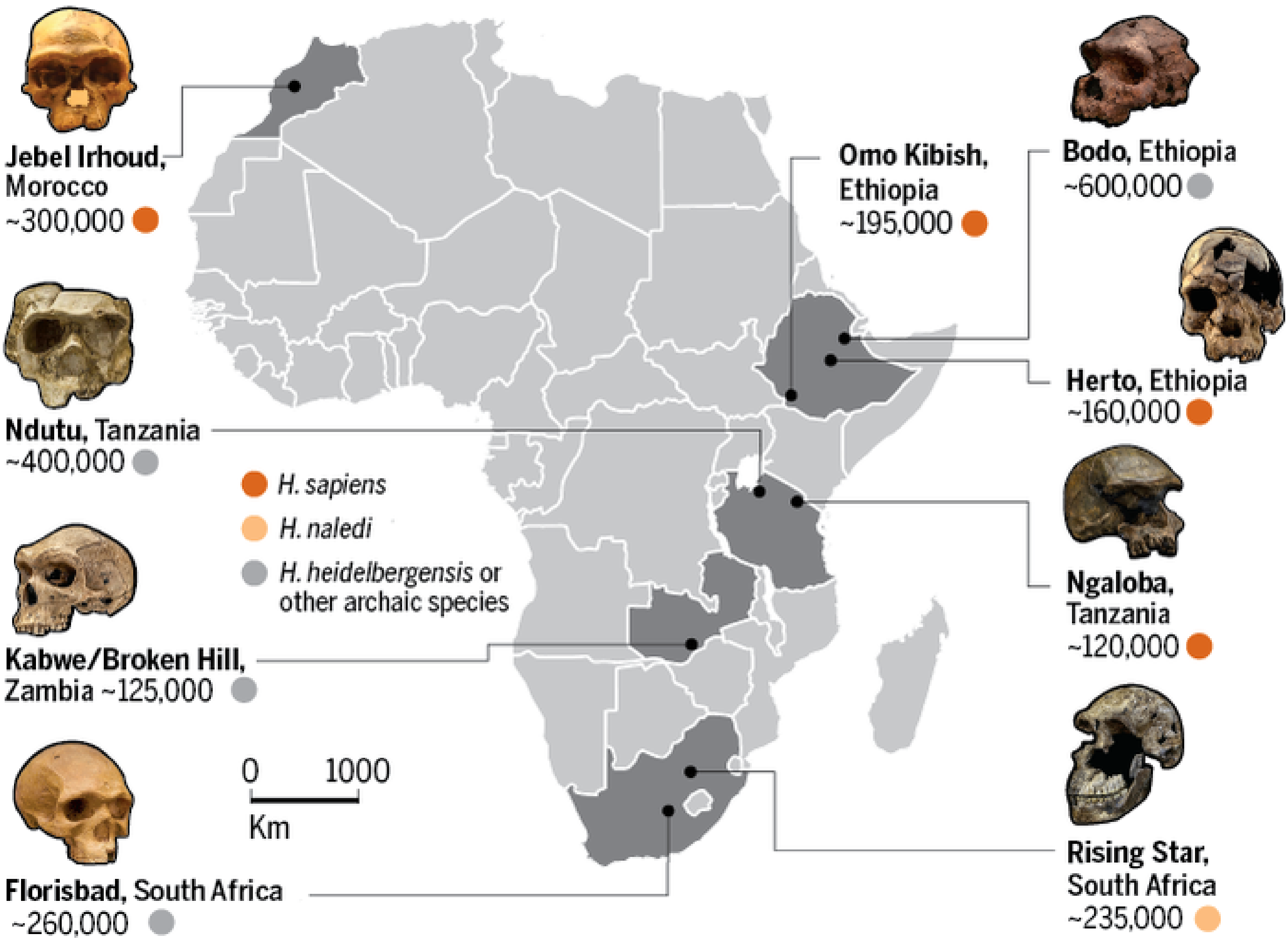
One of the few people who continued to ponder the Jebel Irhoud skull was French paleoanthropologist Jean-Jacques Hublin, who had begun his career in 1981 studying a jaw found at Jebel Irhoud. When he moved to the Max Planck Institute of Evolutionary Anthropology in Leipzig, Germany, he got funding to reopen the now-collapsed cave, which is 100 kilometers west of Marrakesh, Morocco. Hublin's team began new excavations in 2004, hoping to date the small chunk of intact sediment layers and tie them to the original discovery layer. "We were very lucky," Hublin says. "We didn't just get dates, we got more hominids."

The team now has new partial skulls, jaws, teeth, and leg and arm bones from at least five individuals, including a child and an adolescent, mostly from a single layer that also contained stone tools. In their detailed statistical analysis of the fossils, Hublin and paleoanthropologist Philipp Gunz, also of the Max Planck in Leipzig, find that a new partial skull has thin brow ridges.

And its face tucks under the skull rather than projecting forward, similar to the complete Irhoud skull as well as to people today. But the Jebel Irhoud fossils also had an elongated brain case and "very large" teeth, like more archaic species of *Homo*, the authors write.

The pan-African dawn of *Homo sapiens*

New dates and fossils from Jebel Irhoud in Morocco suggest that our species emerged across Africa. The new findings may help researchers sort out how these selected fossils from the past 600,000 years are related to modern humans and to one another.



(GRAPHIC) G. Grullón/*Science*; (DATA) Smithsonian Human Origins Program; (PHOTOS, COUNTERCLOCKWISE FROM TOP LEFT) Ryan Somma/Wikimedia Commons; James Di Loreto & Donald H. Hurlbert/Smithsonian Institution/Wikimedia Commons; SHOP; SHOP; University of the Witwatersrand; SHOP; Housed in National Museum of Ethiopia, Addis Ababa, Photo Donation: ©2001 David L. Brill, humanoriginsphotos.com; SHOP

The fossils suggest that faces evolved modern features before the skull and brain took on the globular shape seen in the Herto fossils and in living people. "It's a long story—it wasn't that one day, suddenly these people were modern," Hublin says.

Neandertals show the same pattern: Putative Neandertal ancestors such as 400,000-year-old fossils in Spain have elongated, archaic skulls with specialized Neandertal traits in their faces. "It's a plausible argument that the face evolves first," says paleoanthropologist Richard Klein of

Stanford University in Palo Alto, California, although researchers don't know what selection pressures might drive this.

This scenario hinges on the revised date for the skull, which was obtained from burnt flint tools. (The tools also confirm that the Jebel Irhoud people controlled fire.) Archaeologist Daniel Richter of the Max Planck in Leipzig used a thermoluminescence technique to measure how much time had elapsed since crystalline minerals in the flint were heated by fire. He got 14 dates that yielded an average age of 314,000 years, with a margin of error from 280,000 to 350,000 years. This fits with another new date of 286,000 years (with a range of 254,000 to 318,000 years), from improved radiometric dating of a tooth. These findings suggest that the previous date was wrong, and fit with the known age of certain species of zebra, leopard, and antelope in the same layer of sediment. "From a dating standpoint, I think they've done a really good job," says geochronologist Bert Roberts of the University of Wollongong in Australia.

Once Hublin saw the date, "we realized we had grabbed the very root of the whole species lineage," he says. The skulls are so transitional that naming them becomes a problem: The team calls them early *H. sapiens* rather than the "early anatomically modern humans" described at Omo and Herto.

Some people might still consider these robust humans "highly evolved *H. heidelbergensis*," says paleoanthropologist Alison Brooks of The George Washington University in Washington, D.C. She and others, though, think they do look like our kind. "The main skull looks like something that could be near the root of the *H. sapiens* lineage," says Klein, who says he would call them "protomodern, not modern."

The team doesn't propose that the Jebel Irhoud people were directly ancestral to all the rest of us. Rather, they suggest that these ancient humans were part of a large, interbreeding population that spread across Africa when the Sahara was green about 300,000 to 330,000 years ago; they later evolved as a group toward modern humans. "*H. sapiens* evolution happened on a continental scale," Gunz says.

Support for that picture comes from the tools that Hublin's team discovered. They include hundreds of stone flakes that had been hammered repeatedly to sharpen them and two cores—the lumps of stone from which the blades were flaked off—characteristic of the Middle Stone Age (MSA). Some researchers thought that archaic humans such as *H. heidelbergensis* invented these tools. But the new dates suggest that this kind of toolkit, found at sites across Africa, may be a hallmark of *H. sapiens*.

The finds will help scientists make sense of a handful of tantalizing and poorly dated skulls from across Africa, each with its own combination of modern and primitive traits. For example, the new date may strengthen a claim that a somewhat archaic partial skull at Florisbad in South Africa, roughly dated to 260,000 years ago, may be early *H. sapiens*. But the date may also widen the distance between *H. sapiens* and another species, *H. naledi*, **that lived at this time in South Africa**.

The connections among these skulls and the appearance of MSA tools across Africa at this time and possibly earlier shows "a lot of communication across the continent," Brooks says. "This shows a pan-African phenomenon, with people expanding and contracting across the continent for a long time."

Posted in: **Archaeology**, **Human Evolution**
doi:10.1126/science.aan6934

Ann Gibbons

Ann is a contributing correspondent for *Science*.
Twitter

More from News

Airport construction threatens unexplored archaeological sites in Peru

Mysterious human relatives moved into 'penthouse' Siberian cave 100,000 years earlier than thought

New remains discovered at site of famous Neanderthal 'flower burial'

Got a tip?

How to contact the news team

19/07 | Aula 9: A descoberta de um pequeno hominínio na Ilha de Flores com características muito primitivas, mas datação recente. O “efeito ilha” de encolhimento de mamíferos grandes. O anão *Homo floresiensis* seria a redução de qual hominínio? Novas descobertas na Jordânia ajudam a explicar o floresiensis. As descobertas em Denisova, Rússia.

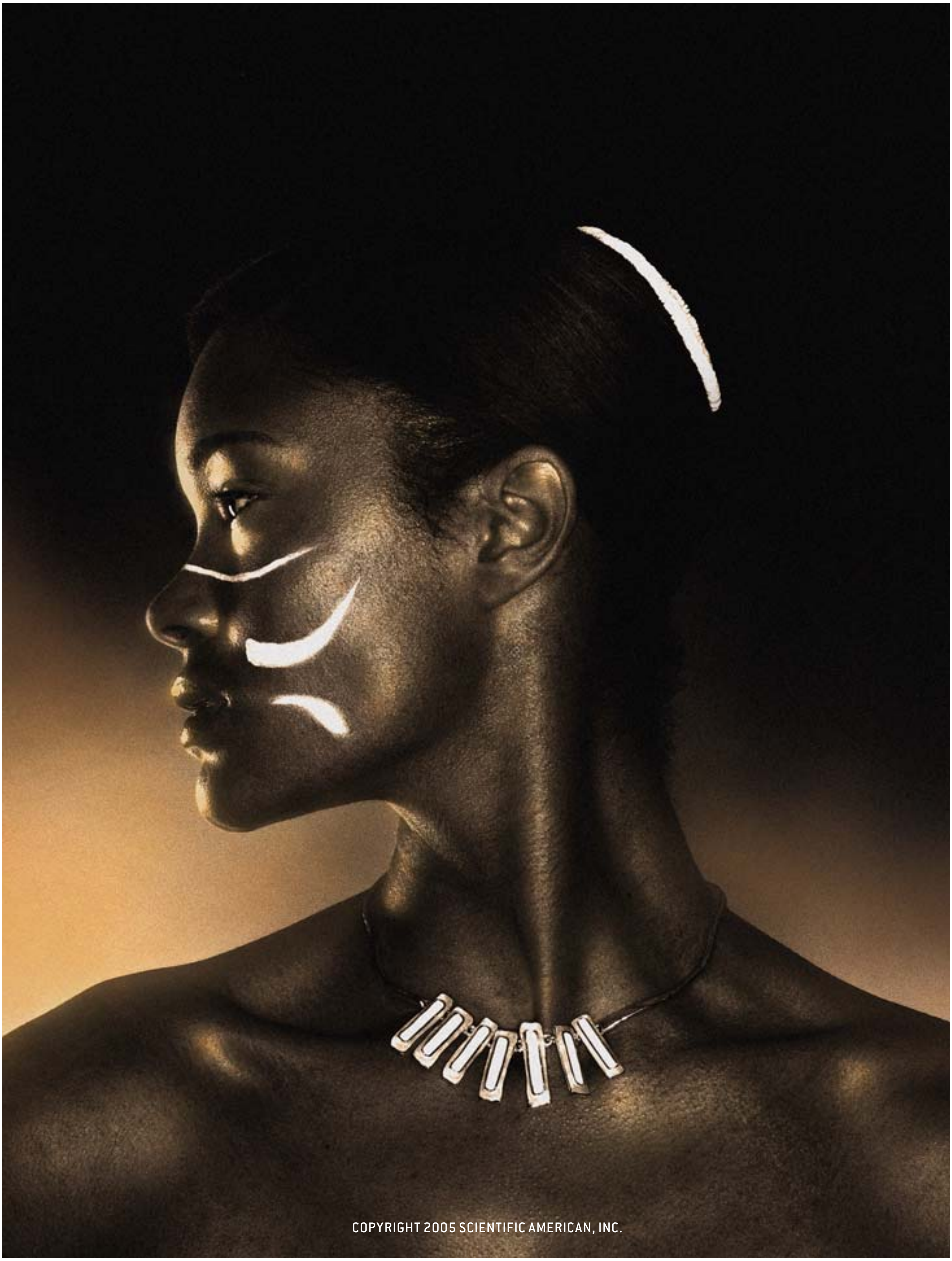
Textos para leitura:
The Morning of The Modern Mind | Kate Wong
Is This Indonesian Cave Painting the Earliest Portrayal of a Mythical Story? | Kate Wong
Fossils Hint at Long-Sougth Ancestor of Weirdest Human Species | Kate Wong
Rethinking the Hobbits of Indonesia | Kate Wong
How Islands Shrink People | Ann Gibbons

PERSONAL ADORNMENT with jewelry and body paint may have started far earlier than previously thought. Early indications of such symbol use—believed by many archaeologists to be a key component of modern human behavior—include 75,000-year-old shell beads (*left*) from Blombos Cave in South Africa.

The Morning of the Modern Mind

Controversial discoveries suggest that the roots of our vaunted intellect run far deeper than is commonly believed

BY KATE WONG



CAPE TOWN, SOUTH AFRICA—Christopher Henshilwood empties a tiny plastic bag and hands me a square of worn blue cardstock to which 19 snail shells no larger than kernels of corn have been affixed in three horizontal rows. To the casual onlooker, they might well appear unremarkable, a handful of discarded mollusk armor, dull and gray with age. In fact, they may be more precious than the glittering contents of any velvet-lined Cartier case.

The shells, discovered in a cave called Blombos located 200 miles east of here, are perfectly matched in size, and each bears a hole in the same spot opposite the mouth, notes Henshilwood, an archaeologist at the University of Bergen in Norway. He believes they were collected and perforated by humans nearly 75,000 years ago to create a strand of lustrous, pearllike beads. If he is correct, these modest shells are humanity's crown jewels—the oldest unequivocal evidence of personal adornment to date and proof that our ancestors were thinking like us far earlier than is widely accepted.

Snail shells were collected from an estuary 12 miles away from Blombos Cave and then pierced with a bone awl. Wear marks around the holes indicate that they were strung together to create perhaps a necklace or bracelet.

FRANCESCO D'ERRICO *University of Bordeaux*; AFRICAN HERITAGE RESEARCH INSTITUTE AND UNIVERSITY OF BERGEN (*snail shell beads, page 86 and above*); RANDY HARRIS (*preceding page*)

A Behavioral Big Bang

BY MOST ACCOUNTS, the origin of anatomically modern *Homo sapiens* was a singularly African affair. In 2003 the unveiling of fossils found in Herto, Ethiopia, revealed that this emergence had occurred by 160,000 years ago. And this past February researchers announced that they had redated *H. sapiens* remains from another Ethiopian site, Omo Kibish, potentially pushing the origin of our species back to 195,000 years ago.

Far less clear is when our kind became modern of mind. For the past two decades, the prevailing view has been that humanity underwent a behavioral revolution around 40,000 years ago. Scholars based this assessment primarily on the well-known cultural remains of Ice Age Europeans. In Europe, the relevant archaeological record is divided into the Middle Paleolithic (prior to around 40,000 years ago) and the Upper Paleolithic (from roughly 40,000 years ago onward), and the difference between the two could not be more striking. Middle Paleolithic people seem to have made mostly the same relatively simple stone tools humans had been producing for tens of thousands of years and not much else. The Upper Paleolithic, in contrast, ushered in a suite of sophisticated practices. Within a geologic blink of an eye, humans from the Rhône Valley to the Russian plain were producing advanced weaponry, forming long-distance trade networks, expressing themselves through art and music, and generally engaging in all manner of activities that archaeologists typically associate with modernity. It was, by all appearances, the ultimate Great Leap Forward.

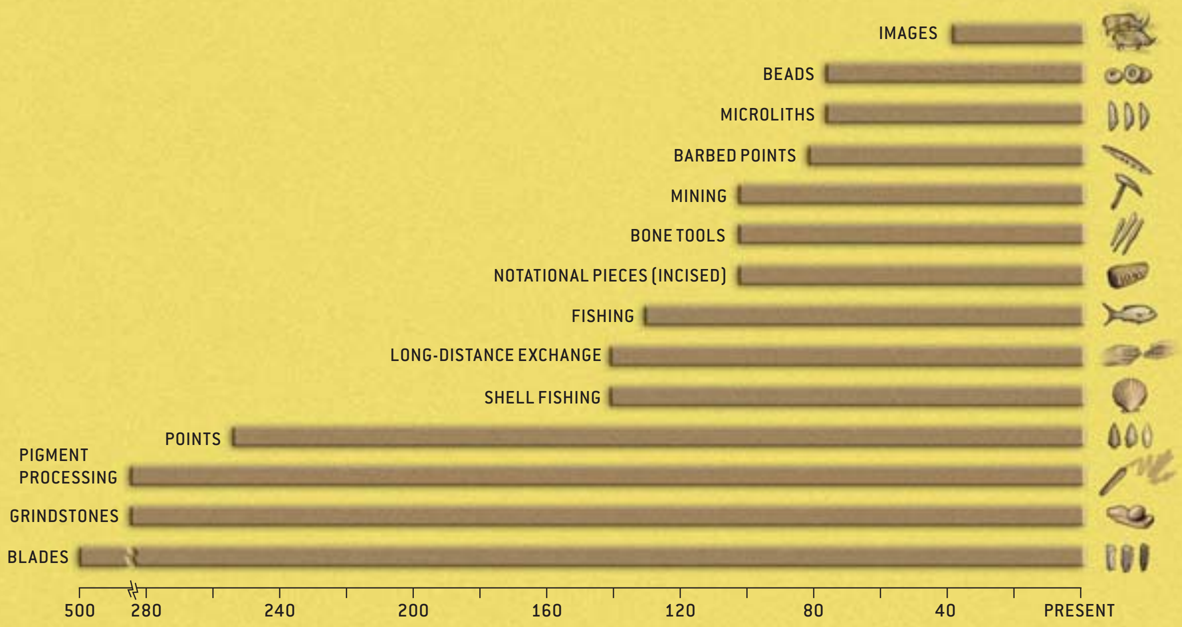
Perhaps not coincidentally, it is during this Middle to Upper Paleolithic transition that humans of modern appearance had begun staking their claim on Europe, which until this point was strictly Neandertal territory. Although the identity of the makers of the earliest Upper Paleolithic artifacts is not known with certainty, because of a lack of human remains at the sites, they are traditionally assumed to have been anatomically modern *H. sapiens* rather than Neandertals. Some researchers have thus surmised that confrontation between the two populations awakened in the invaders a creative ability that had heretofore lain dormant.

Other specialists argue that the cultural explosion evident in Europe grew out of a shift that occurred somewhat earlier in Africa. Richard G. Klein of Stanford University, for one, contends that the abrupt change from the Middle to the Upper Paleolithic mirrors a transition that took place 5,000 to 10,000 years beforehand in Africa, where the comparative culture periods are termed the Middle and Later Stone Age. The impetus for this change, he theorizes, was not an encounter with another hominid type (for by this time in Africa, *H. sapiens* was free of competition with other human species) but rather a genetic mutation some 50,000 years ago that altered neural processes and thereby unleashed our forebears' powers of innovation.

Overview/*Evolved Thinking*

- Archaeologists have traditionally envisioned *Homo sapiens* becoming modern of mind quickly and recently—sometime in the past 50,000 years, more than 100,000 years after attaining anatomical modernity.
- New discoveries in Africa indicate that many of the elements of modern human behavior can be traced much farther back in time.
- The finds suggest that our species had a keen intellect at its inception and exploited that creativity in archaeologically visible ways only when it was advantageous to do so—when population size increased, for instance.
- *H. sapiens* may not have been the only hominid to possess such advanced cognition: some artifacts hint that Neandertals were comparably gifted.

STONE AGE SOPHISTICATION



Archaeological discoveries in Africa have revealed that elements of modern human behavior can be traced back far beyond the 40,000-year mark (*above*), contrary to earlier claims based on the European record. But experts agree that many more people routinely engaged in these practices after that date than before it. A number of hypotheses for what set the stage for this tipping point—not all of which are mutually exclusive—have been put forth (*below*).

Symbolism. The invention of external storage of information—whether in jewelry, art, language or tools—was the watershed event in modern human behavioral evolution, according to Christopher Henshilwood of the University of Bergen in Norway. *Homo sapiens* probably had the hardware required for symbolic thought by the time the species arose, at least 195,000 years ago, hence the occasional early glimpses of it in the archaeological record. But only once symbolism became the basis for human behavioral organization—resulting in the formation of trade and alliance networks, for example—was its full potential realized.

Ecological disaster. Genetic data suggest that *H. sapiens* experienced a bottleneck some 70,000 years ago. Stanley H. Ambrose of the University of Illinois posits that it was the fallout from an eruption of Sumatra's Mount Toba at around that time that may have brought on a devastating six-year-long volcanic winter and subsequent 1,000-year ice age. Those individuals who cooperated and shared resources with one another—beyond their local group boundaries—were the best equipped to survive in the harsh environs and pass their genes along to the next generation. The extreme conditions favored a transition from the troop level of social organization to that of the tribe.

Projectile technology. The innovation of projectile weapons between 45,000 and 35,000 years ago allowed humans to kill large game—and other humans—from a safe distance. This, says John Shea of Stony Brook University, provided people with a strong incentive to cooperate, which would in turn have fostered the development of social networks through which information could be readily shared.

Population growth. Modern ways bubbled up and disappeared at different times and in different places until the population size reached critical mass. At that point, confrontation between groups and competition for resources sparked symbolic behavior and spurred technological innovation, contend researchers, including Alison Brooks of George Washington University and Sally McBrearty of the University of Connecticut. And with more people to pass on these traditions, they began to stick, rather than dying out with the last member of a group.

Brain mutation. A genetic mutation roughly 50,000 years ago had the lucky effect of rewiring the human brain such that it was capable of symbolic thought—including language—argues Richard G. Klein of Stanford University. Humans carrying this mutation had a considerable advantage over those who did not and quickly outcompeted and replaced them.

ALISON KENDALL; SOURCE: UPDATED FROM S. MCBREARTY AND A. S. BROOKS IN *JOURNAL OF HUMAN EVOLUTION*, VOL. 39, NO. 5, PAGES 453–563; NOVEMBER 2000

Mapping Modernity

Humans who looked like us had evolved by 195,000 years ago, as evidenced by *Homo sapiens* fossils from the site of Omo Kibish in Ethiopia. But received archaeological wisdom holds that humans did not begin behaving like us until nearly 150,000 years later. That notion stems largely from cultural remains uncovered in Europe, where art, ritual, technological advances and other indications of modern thinking flowered spectacularly and suddenly after about 40,000 years ago, around the time that anatomically modern humans started colonizing Europe.

Recent finds, including those from Blombos Cave in South Africa, are revealing that many sophisticated practices emerged long before 40,000 years ago at sites outside of Europe, suggesting that humans were our cognitive equals by the time they attained anatomical modernity, if not earlier. Indeed, the fact that at least some Neandertals appear to have thought symbolically raises the possibility that such capacities were present in the last common ancestor of Neandertals and *H. sapiens*. The map below shows the locations of the sites mentioned in the article.

Neandertal-made pierced tooth from Arcy-sur-Cure, France: 33,000 years old

Oldest evidence of painting in Africa from Apollo 11 Rock Shelter in Namibia: 28,000 years old

Ivory water bird, among the earliest pieces of figurative art known, from Hohle Fels Cave, Germany: 30,000–35,000 years old

Scraped, heat-treated red ochre, possibly used in ritual burial act, from Qafzeh Cave in Israel: 92,000 years old

Bone harpoon from Katanda, Democratic Republic of the Congo: 80,000 years old

Ostrich eggshell bead from Loiyangalani, Tanzania: 40,000–200,000 years old

LUCY READING-IKKANDA (*map*); RANDALL WHITE *New York University* (*pierced tooth*); GERALD NEWLANDS (*Apollo 11 painting*); HILDE JENSEN *University of Tübingen* (*ivory water bird*); GAVRIEL LARON AND ERELLA HOVERS *Institute of Archaeology, Hebrew University of Jerusalem* (*red ochre*); CHIP CLARK *National Museum of Natural History* (*bone harpoon*); ARIZONA STATE UNIVERSITY (*ostrich eggshell bead*)

Key evidence for this model, Klein says, comes from a site in central Kenya called Enkapune Ya Muto, the "twilight cave," that places the origin of the Later Stone Age at 45,000 to 50,000 years ago. There Stanley H. Ambrose of the University of Illinois and his team have uncovered obsidian knives, thumbnail-size scrapers and—most notably—tiny disk-shaped beads fashioned from ostrich eggshell in Later Stone Age levels dating back some 43,000 years. Strands of similar beads are still exchanged as gifts today among the !Kung San hunter-gatherers of Botswana. Ambrose posits that the ancient bead makers at Enkapune Ya Muto created them for the same reason: to foster good relationships with other groups as a hedge against hard times. If so, according to Klein, a genetically conferred ability to communicate through symbols—in concert with the cognitive prowess to conceive of better hunting technology and resource use—may have been what enabled our species finally, nearly 150,000 years after it originated, to set forth from its mother continent and conquer the world.

Seeds of Change

IN RECENT YEARS, however, a small but growing number of archaeologists have eschewed the big bang theories of the origin of culture in favor of a fundamentally different model. Proponents believe that there was no lag between body and brain. Rather, they contend, modern human behavior emerged over a long period in a process more aptly described as evolution than revolution. And some workers believe that cognitive modernity may have evolved in other species, such as the Neandertals, as well.

The notion that our species' peerless creativity might have primeval roots is not new. For years, scientists have known of a handful of objects that, taken at face vaue, suggest that humans were engaging in modern practices long before *H. sapiens* first painted a cave wall in France. They include three 400,000-year-old wooden throwing spears from Schöningen, Germany; a 233,000-year-old putative figurine from the site of Berekhat Ram in Israel; a 60,000-year-old piece of flint incised with concentric arcs from Quneitra, Israel; two 100,000-year-old fragments of notched bone from South Africa's Klasies River Mouth Cave; and a polished plate of mammoth tooth from Tata in Hungary, dated to between 50,000 and 100,000 years ago. Many archaeologists looked askance at these remains, however, noting that their age was uncertain or that their significance was unclear. Any sign of advanced intellect that did seem legitimately ancient was explained away as a one-off accomplishment, the work of a genius among average Joes.

That position has become harder to defend in the face of the growing body of evidence in Africa that our forebears' mental metamorphosis began well before the start of the Later Stone Age. In a paper entitled "The Revolution That Wasn't: A New Interpretation of the Origin of Modern Human Behavior," published in the *Journal of Human Evolution* in 2000, Sally McBrearty of the University of Connecticut and Alison S. Brooks of George Washington University laid out their case.

Many of the components of modern human behavior said to emerge in lockstep between 40,000 and 50,000 years ago, they argued, are visible tens of thousands of years earlier at Middle Stone Age locales. Moreover, they appear not as a package but piecemeal, at sites far-flung in time and space.

At three sites in Katanda, Democratic Republic of the Congo, Brooks and John Yellen of the Smithsonian Institution have found elaborate barbed harpoons carved from bone that they say date to at least 80,000 years ago, which would place them firmly within the Middle Stone Age. These artifacts exhibit a level of sophistication comparable to that seen in 25,000-year-old harpoons from Europe, not only in terms of the complexity of the weapon design but the choice of raw material: the use of bone and ivory in tool manufacture was not thought to have occurred until the Later Stone Age and Upper Paleolithic. In addition, remains of giant Nile catfish have turned up with some of the Katanda harpoons, suggesting to the excavators that people were going there when the fish were spawning—the kind of seasonal mapping of resources previously thought to characterize only later humans.

Blombos ochre, engraved with a stone point, may reflect record keeping or a design aesthetic. The effort required to prepare the substrate and produce the markings suggests a premeditated act, rather than doodling.

Other Middle Stone Age sites, such as ≠Gi (the "≠" denotes a click sound) in Botswana's Kalahari Desert, which is dated to 77,000 years ago, have yielded butchered animal remains that have put paid to another oft-made claim, namely, that these ancient people were not as competent at hunting as Later Stone Age folks. The residents at ≠Gi appear to have regularly pursued such large and dangerous prey as zebra and Cape warthog. And Hilary J. Deacon of Stellenbosch University has suggested that at sites such as South Africa's Klasies River Mouth Cave humans more than 60,000 years ago were deliberately burning grassland to encourage the growth of nutritious tubers, which are known to germinate after exposure to fire.

Some discoveries hint that certain alleged aspects of behavioral modernity arose even before the genesis of *H. sapiens*. Last summer excavations by McBrearty's team at a site near Lake Baringo in Kenya turned up stone blades—once a hallmark of the Upper Paleolithic material cultures—more than 510,000 years old. At a nearby locality, in levels dated to at least 285,000 years ago, her team has uncovered vast quantities of red ochre (a form of iron ore) and grindstones for processing it, signaling to McBrearty that the Middle Stone Age people at Baringo were using the pigment for symbolic purposes—to decorate their bodies, for instance—just as many humans do today. (Baringo is not the only site to furnish startlingly ancient evidence of ochre processing—Twin Rivers Cave in Zambia has yielded similar material dating back to more than 200,000 years ago.) And 130,000-year-old tool assemblages from Mumba Rock Shelter in Tanzania include flakes crafted from obsidian that came from a volcanic flow about 200 miles away—compelling evidence that the hominids who made the implements traded with other groups for the exotic raw material.

Critics, however, have dismissed these finds on the basis of uncertainties surrounding, in some cases, the dating and, in others, the intent of the makers. Ochre, for one, may have been used as mastic for attaching blades to wooden handles or as an antimicrobial agent for treating animal hides, skeptics note.

Smart for Their Age

IT IS AGAINST this backdrop of long-standing controversy that the discoveries at Blombos have come to light. Henshilwood discovered the archaeological deposits at Blombos Cave in 1991 while looking for much younger coastal hunter-gatherer sites to excavate for his Ph.D. Located near the town of Still Bay in South Africa's southern Cape, on a bluff overlooking the Indian Ocean, the cave contained few of the Holocene artifacts he was looking for but appeared rich in Middle Stone Age material. As such, it was beyond the scope of his research at the time. In 1997, however, he raised the money to return to Blombos to begin excavating in earnest. Since then, Henshilwood and his team have unearthed an astonishing assemblage of sophisticated tools and symbolic objects and in so doing have sketched a portrait of a long-ago people who thought like us.

From levels dated by several methods to 75,000 years ago have come an array of advanced implements, including 40 bone tools, several of which are finely worked awls, and hundreds of bifacial points made of silcrete and other difficult-to-shape stones, which the Blombos people could have used to hunt the antelopes and other game that roamed the area. Some of the points are just an inch long, suggesting that they may have been employed as projectiles. And the bones of various species of deep-sea fish—the oldest of which may be more than 130,000 years old—reveal that the Blombos people had the equipment required to harvest creatures in excess of 80 pounds from the ocean.

Hearths for cooking indicate that the cave was a living site, and teeth representing both adults and children reveal that a family group dwelled there. But there are so many of the stone points, and such a range in their quality, that Henshilwood wonders whether the occupants may have also had a workshop in the tiny cave, wherein masters taught youngsters how to make the tools.

CHAD HENNING; AFRICAN HERITAGE RESEARCH INSTITUTE AND UNIVERSITY OF BERGEN

They may have passed along other traditions as well. The most spectacular material to emerge from Blombos is that which demonstrates that its occupants thought symbolically. To date, the team has recovered one piece of incised bone, nine slabs of potentially engraved red ochre and dozens of the tiny beads—all from the same 75,000-year-old layers that yielded the tools. In addition, sediments that may date back to more than 130,000 years ago contain vast quantities of processed ochre, some in crayon form.

Scientists may never know exactly what meaning the enigmatic etchings held for their makers. But it is clear that they were important to them. Painstaking analyses of two of the engraved ochres, led by Francesco d'Errico of the University of Bordeaux in France, reveal that the rust-colored rocks were hand-ground on one side to produce a facet that was then etched repeatedly with a stone point. On the largest ochre, bold lines frame and divide the crosshatched design.

Bead manufacture was likewise labor-intensive. Henshilwood believes the marine tick shells, which belong to the *Nassarius kraussianus* snail, were collected from either of two estuaries, located 12 miles from the cave, that still exist today. Writing in the January issue of the *Journal of Human Evolution,* Henshilwood, d'Errico and their colleagues report that experimental reconstruction of the process by which the shells were perforated indicates that the precocious jewelers used bone points to punch through the lip of the shell from the inside out—a technique that commonly broke the shells when attempted by team members. Once pierced, the beads appear to have been strung, as evidenced by the wear facets ringing the perforations, and traces of red ochre on the shells hint that they may have lain against skin painted with the pigment.

In the case for cognitive sophistication in the Middle Stone Age, "Blombos is the smoking gun," McBrearty declares. But Henshilwood has not convinced everyone of his interpretation. Doubts have come from Randall White of New York University, an expert on Upper Paleolithic body ornaments. He suspects that the perforations and apparent wear facets on the *Nassarius* shells are the result of natural processes, not human handiwork.

BLOMBOS CAVE was a veritable garden of Eden when humans lived there 75,000 years ago, observes discoverer Christopher Henshilwood. Freshwater springs burbled at the base of the cliff, and the bounty of the sea lay in the backyard. Tasty eland and other antelope roamed the area, and the climate was about as mild as it is today. Henshilwood and his team have been digging in the cave's Middle Stone Age deposits since 1997, carefully recording the location of each artifact unearthed. This year marks their ninth excavation season.

CHRISTOPHER S. HENSHILWOOD *African Heritage Research Institute and University of Bergen*

Here Today, Gone Tomorrow

IF READ CORRECTLY, however, the remarkable discoveries at Blombos offer weighty evidence that at least one group of humans possessed a modern mind-set long before 50,000 years ago, which may in some ways make previous claims for early behavioral modernity easier to swallow. So, too, may recent finds from sites such as Diepkloof in South Africa's Western Cape, which has produced pieces of incised ostrich eggshell dated to around 60,000 years ago, and Loiyangalani in Tanzania, where workers have found ostrich eggshell beads estimated to be on the order of 70,000 years old.

Yet it remains the case that most Middle Stone Age sites show few or none of the traits researchers use to identify fully developed cognition in the archaeological record. Several other locales in South Africa, for example, have yielded the sophisticated bifacial points but no evidence of symbolic behavior. Of course, absence of evidence is not evidence of absence, as prehistorians are fond of saying. It is possible the people who lived at these sites did make art and decorate their bodies, but only their stone implements have survived.

Perhaps the pattern evident thus far in the African record—that of ephemeral glimpses of cognitive modernity before the start of the Later Stone Age and ubiquitous indications of it after that—is just an artifact of preservational bias or the relatively small number of African sites excavated so far. Then again, maybe these fits and starts are exactly what archaeologists should expect to see if anatomically modern *H. sapiens* possessed the capacity for modern human behavior from the get-go but tapped that potential only when it provided an advantage, as many gradualists believe.

The circumstances most likely to elicit advanced cultural behaviors, McBrearty and others hypothesize, were those related to increased population size. The presence of more people put more pressure on resources, forcing our ancestors to devise cleverer ways to obtain food and materials for toolmaking, she submits. More people also raised the chances of encounters among groups. Beads, body paint and even stylized tool manufacture may have functioned as indicators of an individual's membership and status in a clan, which would have been especially important when laying claim to resources in short supply. Symbolic objects may have also served as a social lubricant during stressful times, as has been argued for the beads from Enkapune Ya Muto.

"You have to make good with groups around you because that's how you're going to get partners," Henshilwood observes. "If a gift exchange system is going on, that's how you're maintaining good relations." Indeed, gift giving may explain why some of the tools at Blombos are so aesthetically refined. A beautiful tool is not going to be a better weapon, he remarks, it is going to function as a symbolic artifact, a keeper of the peace.

Conversely, when the population dwindled, these advanced practices subsided—perhaps because the people who engaged in them died out or because in the absence of competition they simply did not pay off and were therefore forgotten. The Tasmanians provide a recent example of this relationship: when Europeans arrived in the region in the 17th century, they encountered a people whose material culture was simpler than even those of the Middle Paleolithic, consisting of little more than basic stone flake tools. Indeed, from an archaeological standpoint, these remains would have failed nearly all tests of modernity that are commonly applied to prehistoric sites. Yet the record shows that several thousand years ago, the Tasmanians possessed a much more complex tool kit, one that included bone tools, fishing nets, and bows and arrows. It seems that early Tasmanians had all the latest gadgetry before rising sea levels cut the island off from the mainland 10,000 years ago but lost the technology over the course of their small group's separation from the much larger Aboriginal Australian population.

This might be why South African sites between 60,000 and 30,000 years old so rarely seem to bear the modern signature: demographic reconstructions suggest that the human population in Africa crashed around 60,000 years ago because of a precipitous drop in temperature. Inferring capacity from what people produced is inherently problematic, White observes. Medieval folks doubtless had the brainpower to go to the moon, he notes. Just because they did not does not mean they were not our cognitive equals. "At any given moment," White reflects, "people don't fulfill their entire potential."

Tools from Blombos are more sophisticated than those typically found at Middle Stone Age sites. The bone implements include awls worked to a fine point and polished with ochre to achieve a smooth patina.

HARRY TYLER; AFRICAN HERITAGE RESEARCH INSTITUTE AND UNIVERSITY OF BERGEN

Symbol-Minded

THE DEBATE OVER when, where and how our ancestors became cognitively modern is complicated by the fact that experts disagree over what constitutes modern human behavior in the first place. In the strictest sense, the term encompasses every facet of culture evident today—from agriculture to the iPod. To winnow the definition into something more useful to archaeologists, many workers employ the list of behavioral traits that distinguish the Middle and Upper Paleolithic in Europe. Others use the material cultures of modern and recent hunter-gatherers as a guide. Ultimately, whether or not a set of remains is deemed evidence of modernity can hinge on the preferred definition of the evaluator.

Taking that into consideration, some experts instead advocate focusing on the origin and evolution of arguably the most important characteristic of modern human societies: symbolically organized behavior, including language. "The ability to store symbols externally, outside of the human brain, is the key to everything we do today," Henshilwood asserts. A symbol-based system of communication might not be a perfect proxy for behavioral modernity in the archaeological record, as the Tasmanian example illustrates, but at least researchers seem to accept it as a defining aspect of the human mind as we know it, if not *the* defining aspect.

It remains to be seen just how far back in time symbolic culture arose. And discoveries outside of Africa and Europe are helping to flesh out the story. Controversial evidence from the rock shelters of Malakunanja II and Nauwalabila I in Australia's Northern Territory, for instance, suggests that people had arrived there by 60,000 years ago. To reach the island continent, emigrants traveling from southeastern Asia would have to have built sturdy watercraft and navigated a minimum of 50 miles of open water, depending on the sea level. Scholars mostly agree that any human capable of managing this feat must have been fully modern. And in Israel's Qafzeh Cave, Erella Hovers of the Hebrew University of Jerusalem and her team have recovered dozens of pieces of red ochre near 92,000-year-old graves of *H. sapiens*. They believe the lumps of pig-

SYMBOLIC BEHAVIOR may not have originated in Europe, but its early record there is rich. Chauvet Cave, in the Ardèche region of France, contains the oldest cave paintings in the world. Its galleries showcase a menagerie of Ice Age creatures, including lions (*top left*), rendered in ochre 35,000 years ago. Ancient Europeans also had a love of music, as evidenced by this 32,000-year-old bone flute from Isturitz, France (*bottom left*). And they buried their dead with sometimes breathtaking ceremony, as seen above in this replica of a 28,000-year-old burial of two children and thousands of beads and other grave goods from Sungir, Russia.

JEAN CLOTTES; FRENCH MINISTRY OF CULTURE (*Chauvet Cave*); RÉUNION DES MUSÉES NATIONAUX/ART RESOURCE, NY (*bone flute*); KENNETH GARRETT *National Geographic Image Collection* (*Sungir burial*)

ment were heated in hearths to achieve a specific hue of scarlet and then used in funerary rituals.

Other finds raise the question of whether symbolism is unique to anatomically modern humans. Neandertal sites commonly contain evidence of systematic ochre processing, and toward the end of their reign in Europe, in the early Upper Paleolithic, Neandertals apparently developed their own cultural tradition of manufacturing body ornaments, as evidenced by the discovery of pierced teeth and other objects at sites such as Quinçay and the Grotte du Renne at Arcy-sur-Cure in France [see "Who Were the Neandertals?" by Kate Wong; Scientific American, April 2000]. They also interred their dead. The symbolic nature of this behavior in their case is debated because the burials lack grave goods. But this past April at the annual meeting of the Paleoanthropology Society, Jill Cook of the British Museum reported that digital microscopy of remains from Krapina Rock Shelter in Croatia bolsters the hypothesis that Neandertals were cleaning the bones of the deceased, possibly in a kind of mortuary ritual, as opposed to defleshing them for food.

Perhaps the ability to think symbolically evolved independently in Neandertals and anatomically modern *H. sapiens*. Or maybe it arose before the two groups set off on separate evolutionary trajectories, in a primeval common ancestor. "I can't prove it, but I bet [*Homo*] *heidelbergensis* [a hominid that lived as much as 400,000 years ago] was capable of this," White speculates.

For his part, Henshilwood is betting that the dawn of symbol-driven thinking lies in the Middle Stone Age. As this article was going to press, he and his team were undertaking their ninth field season at Blombos. By the end of that period they will have sifted through a third of the cave's 75,000-year-old deposits, leaving the rest to future archaeologists with as yet unforeseen advances in excavation and dating techniques. "We don't really need to go further in these levels at Blombos," Henshilwood says. "We need to find other sites now that date to this time period." He is confident that they will succeed in that endeavor, having already identified a number of very promising locales in the coastal De Hoop Nature Reserve, about 30 miles west of Blombos.

Sitting in the courtyard of the African Heritage Research Institute pondering the dainty snail shells in my hand, I consider what they might have represented to the Blombos people. In some ways, it is difficult to imagine our ancient ancestors setting aside basic concerns of food, water, predators and shelter to make such baubles. But later, perusing a Cape Town jeweler's offerings—from cross pendants cast in gold to diamond engagement rings—it is harder still to conceive of *Homo sapiens* behaving any other way. The trinkets may have changed somewhat since 75,000 years ago, but the all-important messages they encode are probably still the same. SA

Kate Wong is editorial director of ScientificAmerican.com

MORE TO EXPLORE

The Revolution That Wasn't: A New Interpretation of the Origin of Modern Human Behavior. Sally McBrearty and Alison S. Brooks in *Journal of Human Evolution,* Vol. 39, No. 5, pages 453–563; November 2000.

Emergence of Modern Human Behavior: Middle Stone Age Engravings from South Africa. Christopher S. Henshilwood et al. in *Science,* Vol. 295, pages 1278–1280; February 15, 2002.

The Dawn of Human Culture. Richard G. Klein, with Blake Edgar. John Wiley & Sons, 2002.

The Invisible Frontier: A Multiple Species Model for the Origin of Behavioral Modernity. Francesco d'Errico in *Evolutionary Anthropology,* Vol. 12, No. 4, pages 188–202; August 5, 2003.

The Origin of Modern Human Behavior: Critique of the Models and Their Test Implications. Christopher S. Henshilwood and Curtis W. Marean in *Current Anthropology,* Vol. 44, No. 5, pages 627–651; December 2003.

Prehistoric Art: The Symbolic Journey of Humankind. Randall White. Harry N. Abrams, 2003.

***Nassarius kraussianus* Shell Beads from Blombos Cave: Evidence for Symbolic Behavior in the Middle Stone Age.** Francesco d'Errico, Christopher Henshilwood, Marian Vanhaeren and Karen van Niekerk in *Journal of Human Evolution,* Vol. 48, No. 1, pages 3–24; January 2005.

Is This Indonesian Cave Painting the Earliest Portrayal of a Mythical Story?

Archaeologists have dated figurative rock art from Sulawesi to at least 43,900 years ago

Kate Wong

In Room 67 of the Prado Museum in Madrid, Francisco Goya's Saturn enthralls viewers with a scene of abomination.The painting depicts the Greek myth of Cronus (Saturn in the Roman version), who ate his children for fear of being overthrown by them. Critics have interpreted Goya's rendition—the cannibal god shown wide-eyed with apparent horror, shame and madness as he devours his son—as an allegory of the ravages of war, the decay of Spanish society, the artist's declining psychological state. It is one of the great narrative artworks of all time. Vanishingly few people attain such mastery of visual storytelling, of course, but even in its lesser forms, such creative expression is special: only our species, *Homo sapiens*, is known to invent fictional tales and convey them through representational imagery.

Archaeologists have eagerly sought the origins of our distinctive artistic behavior. For a long time the oldest examples of figurative art (as opposed to abstract mark making) and depictions of fictitious creatures all came from sites in Europe dated to less than 40,000 years ago. But in recent years researchers have uncovered older instances of figurative art in Southeast Asia. Now archaeologists working on the island of Sulawesi in Indonesia have found the oldest figurative art to date. In a paper published in December in *Nature,* Maxime Aubert, Adhi Agus Oktaviana and Adam Brumm, all at Griffith University in Australia, and their colleagues report that the art—a cave painting—appears to show several fantastical human figures hunting real-life animals. If they are right, the find could also constitute the oldest pictorial record of storytelling and supernatural thinking in the world.

An Ancient Scene

The team discovered the ancient painting in 2017 in a cave known as Leang Bulu' Sipong 4 in southern Sulawesi's karst region of Maros-Pangkep, a dramatic landscape of jutting limestone towers and cliffs. On the cave's craggy wall, six tiny hunters confront a large buffalo, brandishing ropes or spears. Nearby, other hunters set on more buffaloes, as well as pigs. The hunters appear humanlike but exhibit mysterious animal traits—one possesses a tail, for instance, and another has a beak. Such human-animal hybrids are called therianthropes (derived from the Greek words for "beast" and "human"), and they are considered to be indicators of spiritual thinking—the bull-headed minotaur of Greek mythology, for example, and the jackal-headed Egyptian god Anubis. The researchers suggest that the various figures—all rendered in a pigment with the color of old rust—are part of the same scene and that it may show a communal hunting strategy known as a game drive, in which prey are flushed from cover and driven toward hunters.

To date the images, the researchers measured the radioactive decay of uranium in mineral deposits that had formed atop them. Sampling deposits from various parts of the scene, the team obtained minimum dates ranging from 43,900 to 35,100 years ago. If the painting is at least 43,900 years old, as Aubert and his colleagues argue, it would best the previous record holder for oldest figurative artwork—a 40,000-year-old painting of a cowlike animal found in a cave in Borneo—by several thousand years. It would also beat the 39,000- to 40,000-year-old

Löwenmensch ("lion man") figurine from Germany, which has long held pride of place as the earliest therianthrope, as well as a 17,000-year-old hunting scene from France's famed Lascaux Cave.

Cave painting was discovered by archaeologists at a site called Leang Bulu' Sipong 4 on the Indonesian island of Sulawesi (*1*). The entrance to the cave, located high above the ground, is difficult to access (*2*). Credit: Kim Newman

The geographic location of the painting is significant. Although experts have long recognized that humans originated in Africa, "Europe was once thought of as a 'finishing school' for humanity," says archaeologist April Nowell of the University of Victoria in Canada, because all the oldest known examples of art and other sophisticated behaviors were found there. But in reality, the pattern of discoveries just reflected the disproportionate amount of archaeological research that was being carried out in Europe, especially in France. "This new discovery adds to an already rich record of early and varied rock art from [Indonesia and Australia] and underscores the importance of conducting research outside Europe," Nowell says.

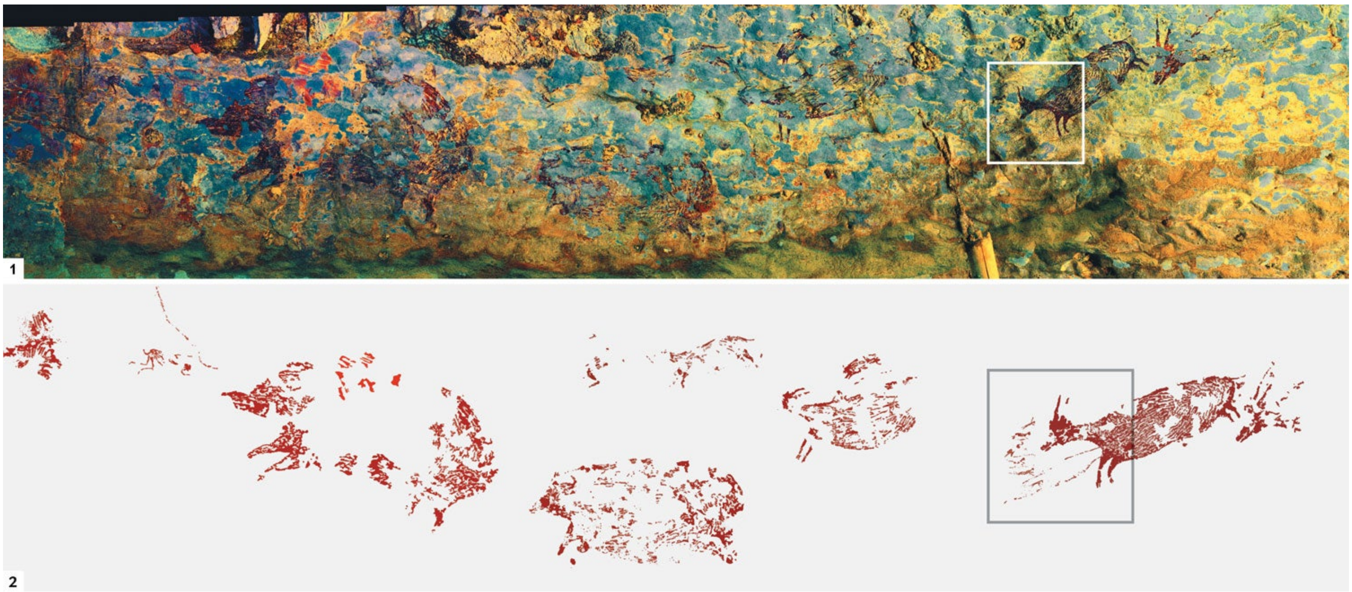
Credit: Mapping Specialists

The position of the newfound painting, in a cave whose entrance some 23 feet above the ground is hard for modern visitors to access without a ladder or climbing equipment, is also intriguing. In Europe, early cave paintings are often found in deep, pitch-dark passages that would have been difficult to get to and work in, which suggests that these places perhaps had special meaning to the artists. Brumm notes that in Sulawesi, ancient images are mostly found near the entrances to caves and rock-shelters, so they occur in the light zone, not the dark one. But as in the case of the Leang Bulu' Sipong 4 painting, they were created in high, hard-to-reach caves and niches in the region's limestone towers and cliff faces. “Apart from the art, these sites otherwise show no evidence for human habitation, and we assume ancient people used them just for image making,” Brumm says. “Why, we don’t know. But perhaps creating cave art in such inaccessible, liminal locations high above the ground surface had some sort of deeper cultural and symbolic significance.” He adds that to reach these spots, the artists presumably had to climb up vines or perhaps bamboo poles—or, in some cases, pick their way through the networks of interior cave passages inside the karst towers. But although the ancient artists in Sulawesi and their counterparts in Europe may both have made their creations in places imbued with meaning and used some similar stylistic conventions in portraying their subjects, “any direct historical or cultural connection between the ice age animal art in Indonesia and Europe is unlikely,” Brumm says.

Indeed, although the newly found painting may push back the date for the earliest figurative, therianthropic and narrative art, it reveals little about the driving force behind the emergence of such creative expression. For decades scholars have puzzled over what seems to have been a long lag between the origin of modern human anatomy and modern human behaviors such as creating art. Whereas modern anatomy evolved hundreds of thousands of years ago, the elements of modern behavior—as revealed through the material culture preserved in the archaeological record—coalesced rather later. Some have posited that a late-breaking cognitive shift might have supercharged our ancestors’ powers of ingenuity. Others suppose that cultural, social or environmental factors—or some combination thereof—stoked their creative fires. “This cave art we have dated doesn’t provide any direct insight into this interesting question—sadly!” Brumm says. But in light of the available evidence, he suspects that fictional storytelling arose long before this painting—“perhaps even before our species spread out of Africa.”

The image may also illuminate other aspects of the psyches of our predecessors. “One of the most interesting things about humans is our enhanced working memory,” Nowell explains. “It allows us to plan for the future, sequence events in our minds before enacting them and, of course, tell stories.” She notes that anthropologist Polly Wiessner of the University of Utah has shown that among many contemporary hunter-gatherers, people talk about different things depending on the time of day. During daylight hours they tend to gossip or discuss economic issues or politics. At night, in contrast, they tell stories and sing songs.

Figures interpreted as therianthropes—mythical beings that are part human, part animal—are said to hunt a small buffalo endemic to the region in one section of the cave painting. Credit: Ratno Sardi



Although some of the imagery has worn away, a photostitched panorama of the full rock art panel (*1*) and a tracing of the panel (*2*) show additional therianthropic figures, along with several buffaloes as well as some wild pigs. Samples of mineral deposits that formed atop the figures were dated using uranium-series analysis, which measures the radioactive decay of uranium. The samples yielded minimum dates ranging from 43,900 to 35,100 years ago. Credit: Adhi Agus Oktaviana, Ratno Sardi and Adam Brumm (*1*, *2*)

"Stories and songs are what bring people together," Nowell remarks. "This panel suggests that this tradition of storytelling goes back [tens of] thousands of years. These stories can be about real events or mythological ones—they can instruct and entertain at the same time." Although we will probably never know what the Sulawesi tableau was about specifically, she says, "as we collect these stories, these scenes, we begin to develop an understanding of what was meaningful to these particular people at this particular time and place."

Open Questions

Regarding who painted the figures in Leang Bulu' Sipong 4: No human skeletal remains have turned up in that cave or at any other site on Sulawesi from that time period. We know human species besides *H. sapiens*, including *Neandertals*, made art, although so far it appears to have been exclusively abstract. We also know other human species inhabited Southeast Asia in the not so distant past: *Homo floresiensis* resided on the Indonesian island of Flores 60,000 years ago, *Homo* *luzonensis* lived in the Philippines as recently as 50,000 years ago, and a genetic study has concluded that a late-surviving group of Denisovans may have interbred with *H. sapiens* in Indonesia or New Guinea just 15,000 years ago. Asked whether one of these other species might have painted the hunting scene, Brumm says, "Given the sophisticated nature of the imagery, our working hypothesis is that modern humans—people with essentially the same cognitive 'architecture' as us—made this cave art. It is presumed that these people became established in Sulawesi as part of the initial wave of migration of *Homo sapiens* into Indonesia at least 70,000 to 50,000 years ago."

But the sophistication of the imagery is a matter of some dispute. Archaeologist Paul Pettitt of Durham University in England, an expert on early art who was not involved in the new study, points out that although one animal in the group is at least 43,900 years old, most of the other figures are not dated. "'Scenes' are very rare in Pleistocene art," he observes. "If this were in Europe, Africa or North America, it would date to no more than [10,000] years ago." Pettitt notes that the so-called therianthropes are out of scale with the animals they are said to be hunting. "Could they be unrelated to the animals?" he wonders. Or might they even have been painted at a much later time? "We know that in Europe, 'painted caves' were actually decorated in several phases separated by thousands of years," he says. Geochemical analysis of the pigments involved could be used to establish confidence that the images in Leang Bulu' Sipong 4 are contemporary.

Pettitt is also not convinced the hunters are therianthropes—or even humanlike. "Some are vague and certainly open to question," he says. "Even the clearest examples could be quadrupeds," he adds, remarking on the horizontal depiction of these figures. And the alleged spears are merely "long lines that just pass close to some 'humans'—hardly weapons in hand," he says. "So it is an open issue as to whether these represent humans and, if it is a scene, one of hunting."

Future work may bring resolution. The discovery team's surveys in the region have turned up many more sites containing figurative paintings that remain to be dated. Perhaps they will furnish new clues to the origins of the image-making, storytelling, myth-inventing modern human mind.

Fossils Hint at Long-Sought Ancestor of Weirdest Human Species

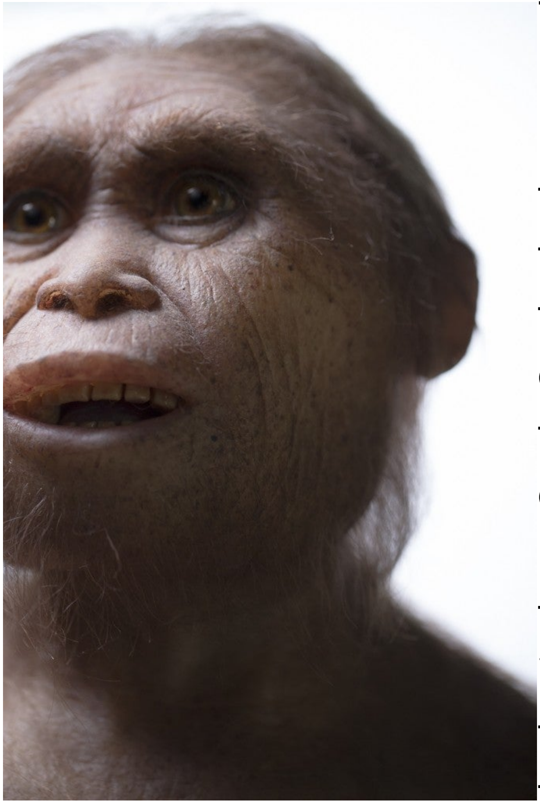
700,000-year-old remains from Indonesia could elucidate the murky origins of the "hobbits" in our family tree

Kate Wong June 9, 2016

Skull of an anatomically modern human (*right*) dwarfs the *H. floresiensis* skull from the site of Liang Bua on Flores (*left*). The area highlighted in blue shows the area of jaw anatomy preserved in the new jaw fossil from Mata Menge. Credit: Kinez Riza

It is often said that every family has that one weird relative. Among the species that make up the human family, that relative is surely *Homo floresiensis*. Nicknamed the hobbit, this creature stood just over a meter tall with short legs, big feet and a tiny brain the size of a grapefruit—all primitive traits associated with human ancestors from millions of years ago. Yet *H. floresiensis* lived on the island of Flores in Indonesia as recently as 60,000 years ago, by which point human species with modern body and brain proportions—including *Homo sapiens* and Neandertals—were well established elsewhere in the world.

How did the Flores hobbits come to have their out-of-time features? Scientists have been puzzling over this question ever since the bizarre remains, found in a cave called Liang Bua in western Flores, were unveiled in 2004. Now new finds have emerged from another site on the island. Their discoverers say these fossils, which date to 700,000 years ago, illuminate the hobbits' mysterious origin. But other researchers are not so sure.



Homo floresiensis is a mini human species that lived on the island of Flores in Indonesia as recently as 60,000 years ago. Reconstruction by Atelier Elisabeth Daynes. *Credit: Kinez Riza*

To date, paleoanthropologists have focused mainly on two competing hypotheses about how *H. floresiensis* evolved. The first holds that it descended from *Homo erectus,* a taller, larger-brained species that was the first member of the human family to spread out of Africa into other parts of the world. In this scenario the diminutive body and brain of *H. floresiensis* evolved after its ancestor reached Flores, as adaptations to the limited food available on the island. Such dwarfing is well known in other large mammal species that colonize islands, including members of the elephant family, but had never before been documented in humans.

The second explanation posits that *H.*

floresiensis descended from a more primitive ancestor that itself had a small body and brain, possibly *Homo habilis* or a member of the genus *Australopithecus*. In this scenario, *H. floresiensis* would have already been small when it arrived on Flores, retaining those primitive features—as well as others found in the arm, wrist, hand and foot—from its direct ancestor. But ancestors that primitive have never been discovered outside of Africa.

A third scenario, advanced by a small but vocal minority, is that the remains do not represent a distinct species at all but instead belong to *H. sapiens* individuals who had some kind of developmental disorder.

The absence of any human fossils from Flores that are older than the Liang Bua remains has hampered efforts to test these hypotheses—until now. In a pair of papers published in the June 9 *Nature,* Gerrit van den Bergh and Adam Brumm of the University of Wollongong in Australia and their colleagues announced their discovery of a collection of human fossils from a site in central Flores called Mata Menge that date to 700,000 years ago. The researchers have provisionally assigned the fossils—a piece of a small lower jaw and six small isolated teeth from at least three individuals—to *H. floresiensis* and suggest that they represent the direct ancestor of the Liang Bua hobbits.

Researchers have recovered a piece of lower jaw (above) and several teeth from the site of Mata Menge on Flores. The remains date to 700,000 years ago and are as small as those of the much younger *H. floresiensis* remains found at the site of Liang Bua. *Credit: Kinez Riza*

Analysis of the new jaw and teeth showed that they are similar in size and shape to their counterparts from Liang Bua, albeit less specialized in several respects, which is what one would expect to see in an ancestral hobbit. The authors note that other evidence from Mata Menge and Liang Bua support this close connection between the two groups: The simple stone tools at both sites are remarkably similar, too. The team also compared the Mata Menge jaw and teeth with those of other human species, including *Australopithecus* and *H. habilis,* and concluded that on the whole their find was more derived than those species, with features that call to mind *H. erectus.* Thus, they argue, their results support the hypothesis that *H. floresiensis* is a dwarfed descendant of *H. erectus* rather than a scion of a more primitive human ancestor.

The Mata Menge remains hint that this dwarfing occurred surprisingly quickly. The oldest known evidence of humans on Flores—a collection of stone tools from a site called Wolo Sege—date to around a million years ago. No human remains have turned up in association with those ancient tools, but if they were made by the big ancestor of the tiny Mata Menge people that lived 700,000 years ago, then the hobbits' small body size may have evolved within perhaps just 300,000 years. That rapid diminution stands in sharp contrast to an evolutionary trend seen in other human fossils from the Pleistocene epoch, which spanned the time from around 2.6 million to 11,600 years ago. "Human body and brain size increased in the Pleistocene, but Flores shows that it was not unidirectional," Van den Bergh said during a press teleconference on June 6.

Animal fossils found at the site show that the Mata Menge humans lived in a savannalike habitat with grasslands and fresh water nearby. Rodents, crocodiles, elephant relatives called stegodonts, Komodo dragons and an array of birds shared their world. Whether the pint-size people might have eaten any of these creatures is unknown; their stone tools would have enabled butchery, but the researchers did not find cut marks on any of the animal bones.

Paleoanthropologists not involved in the new discovery call the finds exciting and important. "They have made a very strong case" for a link between the Mata Menge fossils and the remains from Liang Bua, comments Fred Grine of Stony Brook University, S.U.N.Y., an expert on early human teeth. He notes that the small size of the new specimens would be enough to suggest such a relationship; the shape similarities strengthen the claim. Grine shares the team's view that the remains support the notion that *H. floresiensis* is a dwarfed descendant of *H. erectus*. He adds that the new fossils kill the notion that the hobbits were merely diseased *H. sapiens* individuals. It is "difficult to argue this with another substantially older site now preserving the same type of material," he explains.

Molar and incisor teeth are among the Mata Menge finds. *Credit: Kinez Riza*

But other experts have reservations about the team's claims. Shara Bailey of New York University, who also specializes in fossil human teeth, says that nothing about the Mata Menge specimens ties them to *H. floresiensis* from Liang Bua apart from possibly the small size of the lower jaw. The shape characteristics of the Mata Menge teeth do not demonstrate a link, she contends, although they do not preclude such a link either. Bailey adds that the discovery of a lower third premolar (P3 in the parlance of anatomists) at Mata Menge could help settle the matter, because that tooth has a very distinctive shape in *H. floresiensis* from Liang Bua. "If they found a lower P3 that closely resembled the P3 of [Liang Bua], then I would be convinced," she says.

Adam van Arsdale of Wellesley College, who specializes in fossil human jaws, expresses similar doubts about the argument that the Mata Menge remains represent the direct ancestor of the Liang Bua hobbits. “I am skeptical that the morphology of the specimens they have is sufficient to truly exclude specific relationships between the Mata Menge material and other Pleistocene [human] lineages,” he says. That is, the new finds are not diagnostic enough to rule out alternative possibilities for where they belong in the human family tree.

More definitive fossils may come. “The search is ongoing,” Brumm remarked in the press teleconference. He and his colleagues are now excavating sediments at Mata Menge dating to 900,000 years ago as well as other, earlier sites in the Soa Basin region of Flores. Topping his wish list: “legs and arms, wrists and feet, which are where the really curious features of *floresiensis* appear.”

Rethinking the Hobbits of Indonesia

New analyses reveal the mini human species to be even stranger than previously thought and hint that major tenets of human evolution need revision

BY KATE WONG

PHOTOGRAPHS BY DJUNA IVEREIGH

KEY CONCEPTS

- In 2004 researchers working on the island of Flores in Indonesia found bones of a miniature human species—formally named *Homo floresiensis* and nicknamed the hobbit—that lived as recently as 17,000 years ago.
- Scientists initially postulated that *H. floresiensis* descended from *H. erectus,* a human ancestor with body proportions similar to our own.
- New investigations show that the hobbits were more primitive than researchers thought, however—a finding that could overturn key assumptions about human evolution.

—The Editors

In 2004 a team of Australian and Indonesian scientists who had been excavating a cave called Liang Bua on the Indonesian island of Flores announced that they had unearthed something extraordinary: a partial skeleton of an adult human female who would have stood just over a meter tall and who had a brain a third as large as our own. The specimen, known to scientists as LB1, quickly received a fanciful nickname—the hobbit, after writer J.R.R. Tolkien's fictional creatures. The team proposed that LB1 and the other fragmentary remains they recovered represent a previously unknown human species, *Homo floresiensis*. Their best guess was that *H. floresiensis* was a descendant of *H. erectus*—the first species known to have colonized outside of Africa. The creature evolved its small size, they surmised, as a response to the limited resources available on its island home—a phenomenon that had previously been documented in other mammals, but never humans.

The finding jolted the paleoanthropological community. Not only was *H. floresiensis* being held up as the first example of a human following the so-called island rule, but it also seemed to reverse a trend toward ever larger brain size over the course of human evolution. Furthermore, the same deposits in which the small-bodied, small-brained individuals were found also yielded stone tools for hunting and butchering animals, as well as remainders of fires for cooking them—rather advanced behaviors for a creature with a brain the size of a chimpanzee's. And astonishingly, LB1 lived just 18,000 years ago—thousands of years after our other late-surviving relatives, the Neandertals and *H. erectus*, disappeared [see "The Littlest Human," by Kate Wong; SCIENTIFIC AMERICAN, February 2005].

Skeptics were quick to dismiss LB1 as nothing more than a modern human with a disease that

stunted her growth. And since the announcement of the discovery, they have proposed a number of possible conditions to explain the specimen's peculiar features, from cretinism to Laron syndrome, a genetic disease that causes insensitivity to growth hormone. Their arguments have failed to convince the hobbit proponents, however, who have countered each diagnosis with evidence to the contrary.

A Perplexing Pastiche

Nevertheless, new analyses are causing even the proponents to rethink important aspects of the original interpretation of the discovery. The recent findings are also forcing paleoanthropologists to reconsider established views of such watershed moments in human evolution as the initial migration out of Africa by hominins (the group that includes all the creatures in the human line since it branched away from chimps).

Perhaps the most startling realization to emerge from the latest studies is how very primitive LB1's body is in many respects. (To date, excavators have recovered the bones of an estimated 14 individuals from the site, but LB1 remains the most complete specimen by far.) From the outset, the specimen has invited comparisons to the 3.2-million-year-old Lucy—the best-known representative of a human ancestor called *Australopithecus afarensis*—because they were about the same height and had similarly small brains. But it turns out LB1 has much more than size in common with Lucy and other pre-*erectus* hominins. And a number of her features are downright apelike.

A particularly striking example of the bizarre morphology of the hobbits surfaced this past May, when researchers led by William L. Jungers of Stony Brook University published their analysis of LB1's foot. The foot has a few modern fea-

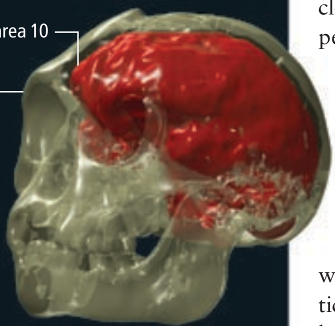
STRANGE SKELETON from Flores, Indonesia, calls into question which human ancestor was the first to leave Africa—and when. Archaeologist Thomas Sutikna (*left*) is one of the leaders of the excavation of the cave that yielded the skeleton.

[THE EVIDENCE]

A Mysterious Mosaic

To date, excavators have recovered the remains of about 14 individuals from Liang Bua, a cave site on Flores. The most complete specimen is a nearly complete skeleton called LB1 that dates to 18,000 years ago. Some of its characteristics call to mind those of apes and of australopithecines such as the 3.2-million-year-old Lucy. Other traits, however, are in keeping with those of our own genus, *Homo.* This mélange of primitive features (*yellow*) and modern ones (*blue*) has made it difficult to figure out where on the human family tree the hobbits belong.

Homo traits	Ape and australopithecine traits



BRAIN is the size of a chimpanzee's. But a virtual reconstruction—generated from CT scans of the interior of the braincase—indicates that despite its small size, the organ had a number of advanced features, including an enlarged Brodmann area 10, a part of the brain that has been theorized to play a role in complex cognitive activities. Such features may help explain how a creature with a brain the size of a chimp's was able to make stone tools.

WRIST resembles that of an African ape. Of particular interest is a bone called the trapezoid (*shown*), which has a pyramidal form. Modern humans, in contrast, have a trapezoid shaped like a boot, which facilitates tool manufacture and use by better distributing forces across the hand.

FOOT is exceptionally long compared with the short leg. This relative foot length is comparable to that seen in bonobos, and it suggests the hobbits were inefficient runners. Other apelike traits include long, curved toes and the absence of an arch. Yet the big toe aligns with the rest of the toes, among other modern characteristics.

tures—for instance, the big toe is aligned with the other toes, as opposed to splaying out to the side as it does in apes and australopithecines. But by and large, it is old-fashioned. Measuring around 20 centimeters in length, LB1's foot is 70 percent as long as her short thighbone, a ratio unheard of for a member of the human family. The foot of a modern human, in contrast, is on average 55 percent as long as the femur. The closest match to LB1 in this regard, aside from, perhaps, the large-footed hobbits of Tolkien's imagination, is a bonobo. Furthermore, LB1's big toe is short, her other toes are long and slightly curved, and her foot lacks a proper arch—all primitive traits.

"A foot like this one has never been seen before in the human fossil record," Jungers declared in a statement released to the press. It would not have made running easy. Characteristics of the pelvis, leg and foot make clear that the hobbits walked upright. But with their short legs and relatively long feet, they would have had to use a high-stepping gait to avoid dragging their toes on the ground. Thus, although they could probably sprint short distances—say, to avoid becoming dinner for one of the Komodo dragons that patrolled Flores—they would not have won any marathons.

If the foot were the only part of the hobbit to exhibit such primitive traits, scientists might have an easier time upholding the idea that *H. floresiensis* is a dwarfed descendant of *H. erectus* and just chalking the foot morphology up to an evolutionary reversal that occurred as a consequence of dwarfing. But the fact is that archaic features are found throughout the entire skeleton of LB1. A bone in the wrist called the trapezoid, which in our own species is shaped like a boot, is instead shaped like a pyramid, as it is in apes; the clavicle is short and quite curved, in contrast to the longer, straighter clavicle that occurs in hominins of modern body form; the pelvis is basin-shaped, as in australopithecines, rather than funnel-shaped, as in *H. erectus* and other later *Homo* species. The list goes on.

Indeed, from the neck down LB1 looks more like Lucy and the other australopithecines than *Homo*. But then there is the complicated matter of her skull. Although it encased a grapefruit-size brain measuring just 417 cubic centimeters—a volume within the range of chimpanzees and australopithecines—other cranial features, such as the narrow nose and prominent brow arches over each eye socket, mark LB1 as a member of our genus, *Homo*.

WILLIAM L. JUNGERS *Stony Brook University (skeleton)*; COURTESY OF KIRK E. SMITH *Mallinckrodt Institute of Radiology, Washington University School of Medicine (skull)*

Primitive Roots

Fossils that combine *Homo*-like skull characteristics with primitive traits in the trunk and limbs are not unprecedented. The earliest members of our genus, such as *H. habilis,* also exhibit a hodgepodge of old and new. Thus, as details of the hobbits' postcranial skeletons have emerged, researchers have increasingly wondered whether the little Floresians might belong to a primitive *Homo* species, rather than having descended from *H. erectus,* which scientists believe had modern body proportions.

A new analysis conducted by doctoral candidate Debbie Argue of the Australian National University in Canberra and her colleagues bolsters this view. To tackle the problem of how the hobbits are related to other members of the human family, the team employed cladistics—a method that looks at shared, novel traits to work out relationships among organisms—comparing anatomical characteristics of LB1 to those of other members of the human family, as well as apes.

In a paper in press at the *Journal of Human Evolution,* Argue and her collaborators report that their results suggest two possible positions for the *H. floresiensis* branch of the hominin family tree. The first is that *H. floresiensis* evolved after a hominin called *H. rudolfensis,* which arose some 2.3 million years ago but before *H. habilis,* which appeared roughly two million years ago. The second is that it emerged after *H. habilis* but still well before *H. erectus,* which arose around 1.8 million years ago. More important, Argue's team found no support for a close relationship between *H. floresiensis* and *H. erectus,* thereby dealing a blow to the theory that the hobbits were the product of island dwarfing of *H. erectus.* (The study also rejected the hypothesis that hobbits belong to our own species.)

If the hobbits are a very early species of *Homo* that predates *H. erectus,* that positioning on the family tree would go a long way toward accounting for LB1's tiny brain, because the earliest members of our genus had significantly less gray matter than the average *H. erectus* possessed. But Argue's findings do not solve the brain problem entirely. LB1 aside, the smallest known noggin in the genus *Homo* is a *H. habilis* specimen with an estimated cranial capacity of 509 cubic centimeters. LB1's brain was some 20 percent smaller than that.

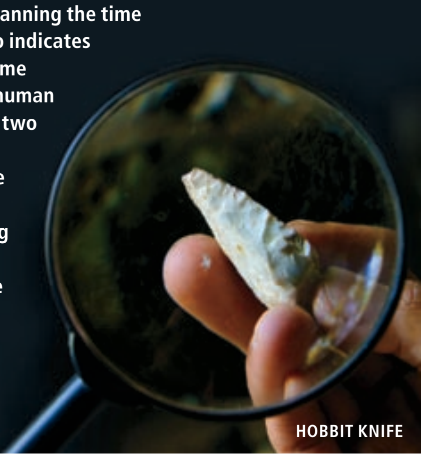
Could island dwarfing still have played a role in determining the size of the hobbit's brain? When the discovery team first attributed LB1's wee brain to this phenomenon, critics complained that her brain was far smaller than it should be for a hominin of her body size, based on known scaling relationships. Mammals that undergo dwarfing typically exhibit only moderate reduction in brain size. But study results released this past May suggest that dwarfing of mammals on islands may present a special case. Eleanor Weston and Adrian Lister of the Natural History Museum in London found that in several species of fossil hippopotamus that became dwarfed on the African island nation of Madagascar, brain size shrank significantly more than predicted by standard scaling models. Based on their hippo model, the study authors contend, even an ancestor the size of *H. erectus* could conceivably attain the brain and body proportions of LB1 through island dwarfing.

The work on hippos has impressed researchers such as Harvard University's Daniel Lieberman. In a commentary accompanying Weston and Lister's report in *Nature,* Lieberman wrote that their findings "come to the rescue" in terms of explaining how *H. floresiensis* got such a small brain.

Although some specialists favor the original interpretation of the hobbits, Mike Morwood of the University of Wollongong in Australia, who helps to coordinate the Liang Bua project, now thinks the ancestors of LB1 and the gang were early members of *Homo* who were already small—much smaller than even the tiniest known *H. erectus* individuals—when they arrived on Flores and then "maybe underwent a little insular dwarfing" once they got there.

Did *Homo sapiens* Copy Hobbits?

Analysis of hobbit implements spanning the time from 95,000 to 17,000 years ago indicates that the tiny toolmakers used the same so-called Oldowan techniques that human ancestors in Africa employed nearly two million years ago. The hobbits combined these techniques in distinctive ways, however—a tradition that the modern humans who inhabited Liang Bua starting 11,000 years ago followed, too. This finding raises the intriguing possibility that the two species made contact and that *H. sapiens* copied the hobbits' style of tool manufacture, rather than the other way around.



HOBBIT KNIFE

SICK HUMAN HYPOTHESES

Scientists who doubt that LB1 belongs to a new human species argue that she is simply a modern human with a disease resulting in a small body and small brain. Those who think LB1 does represent a new species, however, have presented anatomical evidence against each of the proposed diagnoses, several of which are listed below.

Laron syndrome, a genetic disease that causes insensitivity to growth hormone.

Myxoedematous endemic cretinism, a condition that arises from prenatal nutritional deficiencies that hinder the thyroid.

Microcephalic osteodysplastic primordial dwarfism type II, a genetic disorder whose victims have small bodies and small brains but nearly normal intelligence.

[FIELD NOTES]

Digging for Hobbits

Liang Bua (*right*) is a large limestone cave located in the lush highlands of western Flores. Beyond the remains of some 14 hobbits, excavations there have yielded thousands of stone tools, as well as the bones of Komodo dragons, elephantlike stegodonts, giant rats and a carnivorous bird that stood some three meters high. The hobbits seem to have occupied the cave from around 100,000 to 17,000 years ago, They may have been drawn to Liang Bua because of its proximity to the Wae Racang River, which would have attracted thirsty prey animals. Researchers are now looking for clues to why, after persisting for so long, the hobbits eventually vanished. They are also eager to recover a second small skull. Such a find would establish that LB1 and the other specimens do indeed represent a new species and are not just the remains of diseased modern humans. Bones and teeth containing DNA suitable for analysis would be likewise informative. —***K.W.***

▲ The hobbit occupation levels at Liang Bua extend deep into the moist ground. To keep the walls of the trenches from collapsing, which could kill workers, the team employs a sophisticated shoring system.

▶ Inside the pit team members carefully scrape away dirt layer by layer, exposing bones and artifacts as they go. They record the position of each item of interest before placing it into a plastic bag. Meanwhile the dirt itself is loaded into buckets that are sent up to the surface for closer inspection.

▼ An excavator examines a *Stegodon* rib. The concentration of stone tools in this spot indicates that the hobbits butchered the creature here.

▲ The sediment removed from the excavation pit is thoroughly examined for bone and artifact fragments that might have gone unnoticed in the pit. The local Manggarai villagers who work at the site sort through the sediment in three stages: first with their hands (*shown*), then by sieving the dry sediment through screens, and last by taking the sediment bucket by bucket out to a station set up in the rice paddy outside the cave and wetting the contents before sieving them again, in hopes of recovering even the tiniest teeth and shards of bone.

Artifacts left behind by the hobbits support the claim that *H. floresiensis* is a very primitive hominin. Early reports on the initial discovery focused on the few stone tools found in the hobbit levels at Liang Bua that were surprisingly sophisticated for a such a small-brained creature—an observation that skeptics highlighted to support their contention that the hobbits were modern humans, not a new species. But subsequent analyses led by Mark W. Moore of the University of New England in Australia and Adam R. Brumm of the University of Cambridge have revealed the hobbit toolkit to be overall quite basic and in line with the implements produced by other small-brained hominins. The advanced appearance of a handful of the hobbit tools at Liang Bua, Moore and Brumm concluded, was produced by chance, which is not unexpected considering that the hobbits manufactured thousands of implements.

To make their tools, the hobbits removed large flakes from rocks outside the cave and then struck smaller flakes off the large flakes inside the cave, employing the same simple stone-working techniques favored by humans at another site on Flores 50 kilometers east of Liang Bua called Mata Menge 880,000 years ago—long before modern humans showed up on the island. (The identity of the Mata Menge toolmakers is unknown, because no human remains have turned up there yet, but they conceivably could be the ancestors of the diminutive residents of Liang Bua.) Furthermore, the Liang Bua and Mata Menge tools bear a striking resemblance to artifacts from Olduvai Gorge in Tanzania that date to between 1.2 million and 1.9 million years ago and were probably manufactured by *H. habilis*.

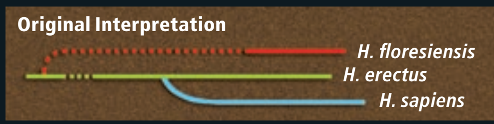
Tiny Trailblazer

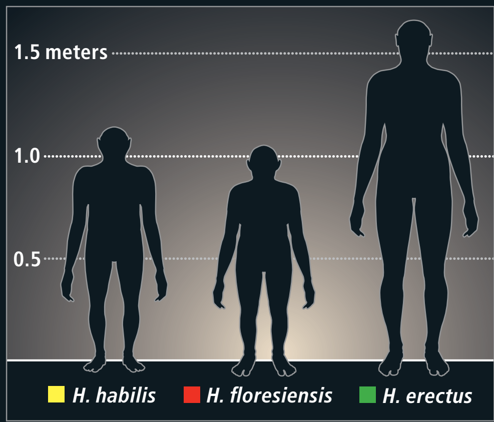
In some ways, the latest theory about the enigmatic Flores bones is even more revolutionary that the original claim. "The possibility that a very primitive member of the genus *Homo* left Africa, perhaps roughly two million years ago, and that a descendant population persisted until only several thousand years ago, is one of the more provocative hypotheses to have emerged in paleoanthropology during the past few years," reflects David S. Strait of the University at Albany. Scientists have long believed that *H. erectus* was the first member of the human family to march out of the natal continent and colonize new lands, because that is the hominin whose remains appear outside of Africa earliest in the fossil record. In explanation, it was pro-

[FINDINGS]

The Hobbits' Roots

Researchers originally believed that LB1 (*left*) and the other hobbits, formally known as *Homo floresiensis,* were descendants of a human ancestor with essentially modern body proportions known as *H. erectus* that shrank dramatically in response to the limited resources available on their island home. But a new analysis suggests *H. floresiensis* is significantly more primitive than *H. erectus* and evolved either right after one of the earliest known members of our genus, *H. habilis* (*right tree*) or right before it (*far right tree*). Either way, the study implies that *H. floresiensis* evolved in Africa, along with the other early *Homo* species, and was already fairly small when the species reached Flores, although it may have undergone some dwarfing when it got there.





posed that humans needed to evolve large brains and long striding limbs and to invent sophisticated technology before they could finally leave their homeland.

Today the oldest unequivocal evidence of humans outside of Africa comes from the Republic of Georgia, where researchers have recovered *H. erectus* remains dating to 1.78 million years ago [see "Stranger in a New Land," by Kate Wong; Scientific American, November 2003]. The discovery of the Georgian remains dispelled that notion of a brawny trailblazer with a tricked-out toolkit, because they were on the small side for *H. erectus,* and they made Oldowan tools, rather than the advanced, so-called Acheulean implements experts expected the first pioneers to make. Nevertheless, they were *H. erectus.*

But if proponents of the new view of hobbits are right, the first intercontinental migrations were undertaken hundreds of thousands of years earlier than that—and by a fundamentally different kind of human, one that arguably had more in common with primitive little Lucy than the colonizer paleoanthropologists had envisioned. This scenario implies that scientists could conceivably locate a long-lost chapter of human prehistory in the form of a two-million-year record of this primitive pioneer stretching between Africa and Southeast Asia if they look in the right places.

This suggestion does not sit well with some researchers. "The further back we try to push the divergence of the Flores [hominin], the more difficult it becomes to explain why a [hominin] lineage that must have originated in Africa has left only one trace on the tiny island of Flores," comments primate evolution expert Robert Martin of the Field Museum in Chicago. Martin remains unconvinced that *H. floresiensis* is a legitimate new species. In his view, the possibility that LB1—the only hobbit whose brain size is known—was a modern human with an as yet unidentified disorder that gave rise to a small brain has not been ruled out. The question, he

[IMPLICATIONS]

➥ MORE TO EXPLORE

The Primitive Wrist of *Homo floresiensis* and Its Implications for Hominin Evolution. Matthew W. Tocheri et al. in *Science,* Vol. 317, pages 1743–1745; September 21, 2007.

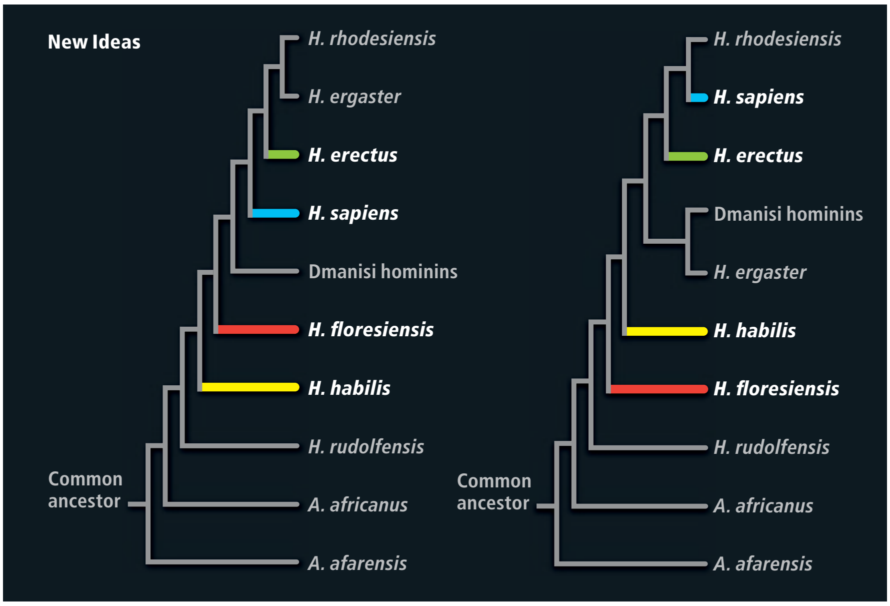
A New Human: The Startling Discovery and Strange Story of the "Hobbits" of Flores, Indonesia. Mike Morwood and Penny van Oosterzee. Smithsonian, 2007.

The Foot of *Homo floresiensis*. W. L. Jungers et al. in *Nature,* Vol. 459, pages 81–84; May 7, 2009.

***Homo floresiensis* and the African Oldowan.** Mark W. Moore and Adam R. Brumm in *Interdisciplinary Approaches to the Oldowan.* Edited by Erella Hovers and David R. Braun. Springer, 2009.

***Homo floresiensis:* A Cladistic Analysis.** Debbie Argue et al. in *Journal of Human Evolution* (in press).

LB1's Virtual Endocast, Microcephaly and Hominin Brain Evolution. Dean Falk et al. in *Journal of Human Evolution* (in press).



BASED ON "*HOMO FLORESIENSIS*: A CLADISTIC ANALYSIS," DEBBIE ARGUE ET AL. IN *JOURNAL OF HUMAN EVOLUTION* (IN PRESS) (*trees*)

says, is whether such a condition can also explain the australopithecinelike body of LB1.

In the meantime, many scientists are welcoming the shake-up. LB1 is "a hominin that no one would be saying anything about if we found it in Africa two million years ago," asserts Matthew W. Tocheri of the Smithsonian Institution, who has analyzed the wrist bones of the hobbits. "The problem is that we're finding it in Indonesia in essentially modern times." The good news, he adds, is that it suggests more such finds remain to be recovered.

"Given how little we know about the Asian hominin record, there is plenty of room for surprises," observes Robin W. Dennell of the University of Sheffield in England. Dennell has postulated that even the australopithecines might have left Africa, because the grasslands they had colonized in Africa by three million years ago extended into Asia. "What we need, of course, are more discoveries—from Flores, neighboring islands such as Sulawesi, mainland Southeast Asia or anywhere else in Asia," he says.

Morwood, for his part, is attempting to do just that. In addition to the work at Liang Bua and Mata Menge, he is helping to coordinate two projects on Sulawesi. And he is eyeing Borneo, too. Searching the mainland for the ancestors of the Liang Bua hobbits will be difficult, however, because rocks of the right age are rarely exposed in this part of the world. But with stakes this high, such challenges are unlikely to prevent intrepid fossil hunters from trying. "If we don't find something in the next 15 years or so in that part of the world, I might start wondering whether we got this wrong," Tocheri reflects. "The predictions are that we should find a whole bunch more." ■

Kate Wong is a staff editor and writer at Scientific American.

Blazing a Trail

The textbook account of human origins holds that *H. erectus* was the first human ancestor to wander out of Africa and colonize distant lands around 1.8 million years ago. But the evidence from Flores suggests that an older, more primitive forebear was the original pioneer, one who ventured away from the natal continent perhaps around two million years ago. If so, then paleoanthropologists may have missed a significant chunk of the human fossil record spanning nearly two million years and stretching from Africa to Southeast Asia.

Already hobbit hunter Mike Morwood (*right*) is looking for more remains of *H. floresiensis* and its ancestors at two sites on Sulawesi. And he thinks further excavation at Niah cave in north Borneo could produce evidence of hominins much older than the ones at Liang Bua. The mainland will be harder to comb, because rocks of the right age are rarely exposed there.

HUMAN EVOLUTION

How islands shrink people

Evolutionary dwarfing affected living people on the island of Flores, and may explain the stature of the extinct hobbit

By **Ann Gibbons**

Living on an island can have strange effects. On Cyprus, hippos dwindled to the size of sea lions. On Flores in Indonesia, extinct elephants weighed no more than a large hog, but rats grew as big as cats. All are examples of the so-called island effect, which holds that when food and predators are scarce, big animals shrink and little ones grow. But no one was sure whether the same rule explains the most famous example of dwarfing on Flores, the odd extinct hominin called the hobbit, which lived 60,000 to 100,000 years ago and stood about a meter tall.

Now, genetic evidence from modern pygmies on Flores—who are unrelated to the hobbit—confirms that humans, too, are subject to so-called island dwarfing. On p. 511, an international team reports that Flores pygmies differ from their closest relatives on New Guinea and in East Asia in carrying more gene variants that promote short stature. The genetic differences testify to recent evolution—the island rule at work. And they imply that the same force gave the hobbit its short stature, the authors say.

"Flores is a magical place where things go and get small," says population geneticist Joshua Akey at Princeton University, a co-author of the study. "This is the only example in the world where insular dwarfism has arisen twice in hominins."

Princeton postdoc Serena Tucci set out to study the Rampasasa pygmies of Flores, who average just 145 centimeters tall. Famed Indonesian paleoanthropologist Teuku Jacob, now deceased, had controversially proposed that the Rampasasa people inherited some traits from the hobbit, whom he thought was a modern human. To explore the pygmies' ancestry, Tucci and her then-adviser, Ed Green of the University of California (UC), Santa Cruz, traveled to Flores. With the pygmies' permission, they began a "model" collaboration with Indonesian researchers, says molecular biologist and co-author Herawati Sudoyo of the Eijkman Institute for Molecular Biology in Jakarta. Her colleagues gathered spit and blood from 32 people and extracted the DNA. Then, Eijkman researcher Gludhug Purnomo hand-carried samples to Green's lab, where he helped sequence 2.5 million single nucleotide polymorphisms, or alleles, in every individual, plus 10 complete genomes.

The team found no trace of archaic DNA that could be from the hobbit. Instead, the pygmies were most closely related to other East Asians. The DNA suggested that their ancestors came to Flores in several waves: in the past 50,000 years or so, when modern humans first reached Melanesia; and in the past 5000 years, when settlers came from both East Asia and New Guinea.

> ***"Humans are not as special as we think. This shows we evolve like all other animals."***
>
> **Serena Tucci**, Princeton University

The pygmies' genomes also reflect an environmental shift. They carry an ancient version of a gene that encodes enzymes to break down fatty acids in meat and seafood. It suggests their ancestors underwent a "big shift in diet" after reaching Flores, perhaps eating pygmy elephants or marine foods, says population geneticist Rasmus Nielsen of UC Berkeley, who was not part of the study.

The pygmies' genomes are also rich in alleles that data from the UK Biobank have linked to short stature. Other East Asians have the same height-reducing alleles, but at much lower frequencies. This suggests natural selection favored existing genes for shortness while the pygmies' ancestors were on Flores. "We can't say for sure that they got shorter on Flores, but what makes this convincing is they're comparing the Flores population to other East Asian populations of similar ancestry," says population geneticist Iain Mathieson of the University of Pennsylvania.

The discovery fits with a recent study suggesting evolution also favored short stature in people on the Andaman Islands, Green says. Such selection on islands boosts the theory that the hobbit, too, was once a taller species, who dwindled in height over millennia on Flores.

"If it can happen in hippos, it can happen in humans," Tucci says. "Humans are not as special as we think. This shows we evolve like all other animals." ■

Published by AAAS

26/07 | Aula 10: Últimas notícias sobre os denisovanos, uma nova espécie do gênero *Homo* definida inicialmente a partir de DNA. Achados que podem dar aos denisovanos uma aparência física.

Textos para leitura:

No Bones About It: Ancient DNA from Siberia Hints at Previously Unknown Human Relative | Kate Wong

Ancient Skulls May Belong to Elusive Humans Called Denisovans | Ann Gibbons

Moderns Said to Mate with Late-Surviving Denisovans | Ann Gibbons

Ancient Jaw Gives Elusive Denisovans a Face | Ann Gibbons

'Dragon Man' May Be an Efusive Denisovan | Ann Gibbons

No Bones about It: Ancient DNA from Siberia Hints at Previously Unknown Human Relative

For the first time, researchers describe a new type of human ancestor on the basis of DNA rather than anatomy

Kate Wong March 24, 2010

Credit: Johannes Krause

For much of the past five million to seven million years over which humans have been evolving, multiple species of our forebears co-existed. But eventually the other lineages went extinct, leaving only our own, *Homo sapiens*, to rule Earth. Scientists long thought that by 40,000 years ago *H. sapiens* shared the planet with only one other human species, or hominin: the Neandertals. In recent years, however, evidence of a more happening hominin scene at that time has emerged. Indications that *H. erectus* might have persisted on the Indonesian island of Java until 25,000 years ago have surfaced. And then there's *H. floresiensis*—the mini human species commonly referred to as the hobbits—which lived on Flores, another island in the Indonesian archipelago, as recently as 17,000 years ago.

Now researchers writing in the journal *Nature* report that they have found a fifth kind of hominin that may have overlapped with these species. (*Scientific American* is part of Nature Publishing Group.) But unlike all the other known members of the human family, which investigators have described on the basis of the morphological characteristics of their bones, the new hominin has been identified solely on the basis of its DNA.

Johannes Krause and Svante Pääbo of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, and their colleagues obtained the DNA from a fossilized pinky finger bone found at Denisova Cave in the Altai Mountains of southern Siberia. The species was impossible to determine from the shape and size of the bone—it simply did not contain any diagnostic morphological traits. But there were good reasons to believe it came from a Neandertal or an early modern human. For one, the bone was recovered from a stratigraphic layer of the cave dated to between 50,000 and 30,000 years ago that contained artifacts belonging to the so-called Middle Paleolithic and Upper Paleolithic industries associated with these two groups. For another, Neandertals and modern humans were the only hominins known to have lived in this region during that time period. But the DNA the team extracted from the Denisova pinky bone turned out to be markedly different from DNA sequences previously obtained from early modern humans and Neandertals.

The researchers focused on a type of DNA known as mitochondrial DNA (mtDNA). Mitochondria are the power plants of the cell, and they have their own DNA that is separate from that housed in the cell nucleus and is passed down from mother to offspring. Because each cell has thousands of mitochondria, but only a single nucleus, mitochondrial DNA is much more abundant than nuclear DNA and is therefore more likely than the latter to be preserved in fossilized bone. To date, scientists have sequenced the mitochondrial genomes of both Neandertal and early modern human individuals, and the sequences for the two groups are quite distinctive.

Comparing the order of the genetic "letters"—or base-pairs, as they are termed—making up the Denisova mtDNA with the sequences of modern day humans and an early modern human, Krause and his collaborators found that the Denisova mtDNA differed from humans today in nearly twice as many letter positions as Neandertal mtDNAs do. Further analysis indicated that the most recent common mtDNA ancestor of the Denisova individual, Neandertals and modern humans dates to around a million years ago (making it twice as old as the most recent common mtDNA ancestor of Neandertals and moderns). This divergence date, the team says, indicates that the Denisova mtDNA is distinct from that of the H. erectus population that left Africa 1.9 million years ago, and also from that of the Neandertal ancestor *H. heidelbergensis*, which branched off from the lineage leading to modern humans around 466,000 years ago. As such, the researchers contend the Denisova mtDNA reveals a previously unrecognized migration out of Africa by a hitherto unknown group of hominins. (The team is holding off on giving the creature a formal name for now, but informally they refer to it as X-woman.)

"The data that they provide is certainly of the nature to arrive at the conclusions that they do," comments Stephan Schuster of The

Pennsylvania State University, who worked on the recent sequencing of Archbishop Desmond Tutu's nuclear genome as well as the nuclear genome sequencing of a woolly mammoth. "All the detected sequence differences clearly indicate that this is a novel variant of a [hominin]."

Paleoanthropologist Ian Tattersall of the American Museum of Natural History in New York City noted that the finding should not necessarily come as a surprise. "We know the fossil record is far from complete, but what we have already shows that the [hominin] evolutionary bush is quite luxuriantly branching," he remarks. "One more branch is not something that ought to give us indigestion."

The association of the mystery hominin with those Middle and Upper Paleolithic artifacts is peculiar though, because elsewhere in Eurasia they have only turned up with Neandertal and modern human remains. Krause notes that it is possible that the pinky bone originated in an older, deeper layer of the cave sediments and over time got mixed in with the overlying artifacts. Thus far, however, there is no evidence for extensive perturbation. Another possibility, he says, is that the finger bone is that of an early modern human who carried an ancient mtDNA as a result of interbreeding between his or her ancestors and this previously unknown hominin group.

But other experts are not so sure about the team's interpretation of their data. "I don't know—and nobody else does—how many base-pair changes make a new species," says Erik Trinkaus of Washington University in Saint Louis, an authority on Neandertals and early modern humans. "I would like to have more than the number of mtDNA base pair differences to go on."

"The result doesn't mean that they've found a new species, and I don't believe it requires a separate pre-Neandertal migration out of Africa," argues John Hawks of the University of Wisconsin–Madison, whose research focuses on human genetic evolution. "Those explanations are both compatible with the result, but I don’t think the data require them yet." Hawks notes that the history of an mtDNA sequence—which is just a tiny fraction of a person's total DNA—does not necessarily reflect the history of a species.

A comparably distinctive nuclear genome sequence would significantly strengthen the claim that the Denisova mtDNA represents a previously unknown type of hominin. To that end, Krause and Pääbo are launching a Denisova genome project to obtain a full nuclear genome sequence from the bone that yielded the novel mtDNA. Comparisons of this genome with the full genome sequence they have obtained for the Neandertal as well as with the genomes of people living today could yield insights into the genetic changes that defined H. sapiens. "At the end we get more information about the big question [of] what makes humans humans," Krause reflects.

Meanwhile, paleoanthropologists are eager for more fossils to confirm the DNA-based claim. With luck, continued excavation at Denisova cave this summer will turn up additional remains—and put a face on this long-lost relative.

Ancient skulls may belong to elusive humans called Denisovans

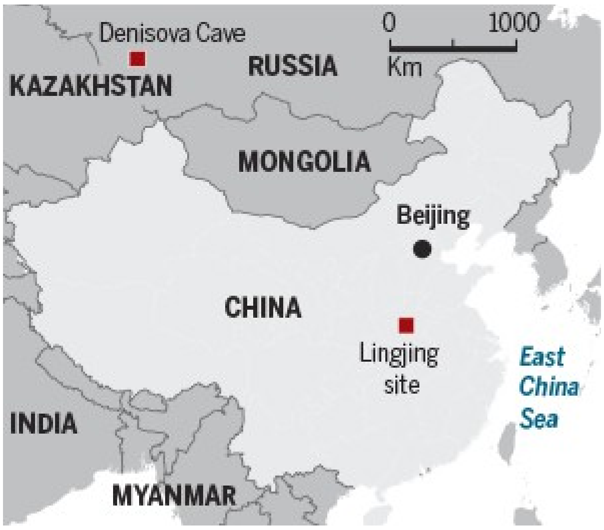
By Ann Gibbons Mar. 2, 2017.

Since their discovery in 2010, the extinct ice age humans called Denisovans have been known only from bits of DNA, taken from a sliver of bone in the Denisova Cave in Siberia, Russia. Now, two partial skulls from eastern China are emerging as prime candidates for showing what these shadowy people may have looked like.

In a paper published this week in *Science*, a Chinese-U.S. team presents 105,000- to 125,000-year-old fossils they call "archaic *Homo*." They note that the bones could be a new type of human or an eastern variant of Neandertals. But although the team avoids the word, "everyone else would wonder whether these might be Denisovans," which are close cousins to Neandertals, says paleoanthropologist Chris Stringer of the Natural History Museum in London.

The new skulls "definitely" fit what you'd expect from a Denisovan, adds paleoanthropologist María Martinón-Torres of the University College London —"something with an Asian flavor but closely related to Neandertals." But because the investigators have not extracted DNA from the skulls, "the possibility remains a speculation."

Back in December 2007, archaeologist Zhan-Yang Li of the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP) in Beijing was wrapping up his field season in the town of Lingjing, near the city of Xuchang in the Henan province in China (about 4000 kilometers from the Denisova Cave), when he spotted some beautiful quartz stone tools eroding out of the sediments. He extended the field season for two more days to extract them. On the very last morning, his team discovered a yellow piece of rounded skull cap protruding from the muddy floor of the pit, in the same layer where he had found the tools.



The team went back for another six seasons and managed to find 45 more fossils that fit together into two partial crania. The skulls lack faces and jaws. But they include enough undistorted pieces for the team to note a close resemblance to Neandertals. One cranium has a huge brain volume of 1800 cubic centimeters—on the upper end for both Neandertals and moderns—plus a Neandertal-like hollow in a bone on the back of its skull. Both crania have prominent brow ridges and inner ear bones that resemble those of Neandertals but are distinct from our own species, *Homo sapiens*.

However, the crania also differ from the western Neandertals of Europe and the Middle East. They have thinner brow ridges and less robust skull bones, similar to early modern humans and some other Asian fossils. "They are not Neandertals in the full sense," says co-author Erik Trinkaus, a paleoanthropologist at Washington University in St. Louis in Missouri.

Nor are the new fossils late-occurring representatives of other archaic humans such as *H. erectus* or *H. heidelbergensis*, two species that were ancestral to Neandertals and modern humans. The skulls are too lightly built and their brains are too big, according to the paper.

The skulls do share traits with some other fossils in east Asia dating from 600,000 to 100,000 years ago that also defy easy classification, says paleoanthropologist Rick Potts of the Smithsonian National Museum of Natural History in Washington, D.C. Those features include a broad cranial base where the skull sits atop the spinal column and a low, flat plateau along the top of the skull. The Lingjing crania also resemble another archaic early human skull that dates to 100,000 years ago from Xujiayao in China's Nihewan Basin 850 kilometers to the north, according to co-author Xiu-Jie Wu, a paleoanthropologist at IVPP.

Wu thinks those fossils and the new skulls "are a kind of unknown or new archaic human that survived on in East Asia to 100,000 years ago." Based on similarities to some other Asian fossils, she and her colleagues think the new crania represent regional members of a population in eastern Asia who passed local traits down through the generations in what the researchers call regional continuity. At the same time, resemblances to both Neandertals and modern humans suggest that these archaic Asians mixed at least at low levels with other archaic people.

To other experts, the Denisovans fit that description: They are roughly dated to approximately 100,000 to 50,000 years ago, and their DNA shows that after hundreds of thousands of years of isolation, they mixed both with Neandertals and early modern humans. "This is exactly what the DNA tells us when one tries to make sense of the Denisova discoveries," says paleoanthropologist Jean-Jacques Hublin of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. "These Chinese fossils are in the right place at the right time, with the right features."

But Wu and Trinkaus say they can't put fossils in a group defined only by DNA. "I have no idea what a Denisovan is," Trinkaus says. "Neither does anybody else. It's a DNA sequence."

The only way to truly identify a Denisovan is with DNA. IVPP paleogeneticist Qiaomei Fu says she tried to extract DNA from three pieces of the Xuchang fossils but without success.

Regardless of the new skulls' precise identity, "China is rewriting the story of human evolution," Martinón-Torres says. "I find this tremendously exciting!"

directs training efforts for the wellness center, acknowledges that OSU has a lot of ground to make up to become a preeminent medical research organization. “The [psychiatry] department has zero history of NIH [National Institutes of Health] grants,” he says. “But we’ve got four in review right now.” In addition, the center’s first two addiction medicine fellows start this summer, and he hopes to have six in the next cohort.

Beaman says he left the University of Arkansas in 2015 and returned to his alma mater because the medical school had made addressing the state’s mounting opioid crisis a priority. “Our mission is to train primary care physicians to work in rural and underserved areas,” says OSU’s Kayse Shrum, who became the youngest and first female president of an Oklahoma medical school when she was promoted into the job in 2013. “And that’s where the [addiction] crisis is most acute. So we began hiring psychiatrists with expertise in addiction medicine.”

Shrum and Beaman also benefited from serendipity. The medical school at their archrival, the University of Oklahoma (OU) in Norman, is known nationally for its efforts to combat cancer and cardiovascular disease, and last year its faculty members could boast of 105 NIH grants. (OSU has one, a capacity-building grant to study adverse childhood experiences.) But in 2016, OU officials decided addiction medicine was no longer a priority and ended the training program.

“We lost our funding, and I retired after 25 years there,” says emeritus professor William Yarborough, who ran the program. “Meanwhile, OSU was ramping up its program. So once [the state and Purdue] reached a deal, there really wasn’t anybody else at the table,” says Yarborough, who is president of the Oklahoma Society of Addiction Medicine.

State Attorney General Mike Hunter (left) joins Oklahoma State University medical school President Kayse Shrum (right) to announce a settlement.

Beaman’s department has swelled from three to 20 faculty members in the past 3 years, and he expects the settlement and the endowment to accelerate that growth. “There are three or four people who I anticipate being able to hire almost immediately,” he says. “And I’ll also go on the road. Maybe I’m being a Pollyanna, but who wouldn’t want to be part of what I hope will be the first sign of the end of the country’s opioid epidemic?”

The settlement creates an endowment that is likely to generate less than $10 million a year in new spending. That new pot is dwarfed by the $500 million that NIH will spend this year on its new Helping to End Addiction Long-term Initiative, launched in April 2018. And even that amount, public health advocates say, is minuscule compared with the magnitude of the opioid epidemic and the pressing need for treatment facilities, medical providers, and prevention.

Cheryl Healton, dean of public health at New York University in New York City, praises Oklahoma Attorney General Mike Hunter for negotiating a deal that funnels most of the money to those needs. “That’s a far cry from the tobacco settlement,” she says, referring to the $126 billion tobacco companies have paid out to date to 46 states under a 1998 agreement.

For many years Healton led a national public antismoking campaign financed by the massive settlement. State officials were given the power to allocate the money as they saw fit, however, and less than 1% of it has gone to tobacco prevention programs, even as tobacco companies continue to spend billions each year on marketing their products.

Healton says there’s an urgent need for a similar, sustained national public education campaign to combat the opioid epidemic. The best chance for that, she says, is a well-focused, master settlement of the pending opioid cases, something that a federal judge in Ohio has tried to pull off, so far unsuccessfully. Absent that, Healton worries that any deals struck by individual states and localities could wind up being too little, too late, to save many lives.

“Compared with tobacco, the use of opioids is likely to grow,” she warns. “And it’s up to all of us to be a countervailing force.” ■

HUMAN EVOLUTION

Moderns said to mate with late-surviving Denisovans

Genomes from New Guineans suggest mixing, perhaps as recently as 15,000 years ago

By **Ann Gibbons**, *in Cleveland, Ohio*

The elusive Denisovans, the extinct cousins of Neanderthals, are known only from the scraps of bone and teeth they left in Siberia’s Denisova Cave and the genetic legacy they bequeathed to living people across Asia. A new study of that legacy in people from New Guinea now suggests that, far from being a single group, these mysterious humans were so diverse that their populations were as distantly related to each other as they were to Neanderthals.

In another startling suggestion, the study implies that one of those groups may have survived and encountered modern humans as recently as 15,000 to 30,000 years ago—tens of thousands of years later than researchers had thought. “A late surviving lineage [of Denisovans] could have interbred with *Homo sapiens*” in Southeast Asia, paleoanthropologist Chris Stringer of the Natural History Museum in London, not a member of the team, said in a Skype interview at the annual meeting of the American Association of Physical Anthropologists here last week.

Researchers already knew living people from a vast area spanning the Philippines and New Guinea to China and Tibet have inherited 3% to 5% of their DNA from Denisovans. The leading scenario had suggested that as modern humans swept out of Africa, they first encountered Neanderthals and mated with them; hence, all people in Europe and Asia now have 1% to 3% of their DNA from Neanderthals. The ancestors of Asians then met Denisovans 50,000 years ago or so and acquired additional DNA from those archaic people.

For the new study, an international team analyzed the complete genomes of 161 people from 14 groups in Indonesia and Papua New Guinea. In the DNA of 60 people from New

Some of the last Denisovans may have intermingled with modern humans on mountainous New Guinea or nearby islands.

Guinea, population biologist Murray Cox of Massey University in Palmerston North, New Zealand, molecular biologist Herawati Sudoyo of the Eijkman Institute for Molecular Biology in Jakarta, and their colleagues found an unexpected twist. The first Denisovan DNA discovered, from the cave in Russia, comes from a single population (which geneticists have labeled D0). But "Papuans carry DNA from at least two [other] Denisovan populations, called D1 and D2," Cox said in his talk, which was filmed in advance and played at the meeting.

When the team members analyzed the DNA with three statistical methods, they found that the two additional sources of Denisovan DNA came from populations so distantly related that they had diverged more than 283,000 years ago. The D2 population is even more distant from the Siberian Denisovans, having split off roughly 363,000 years ago. That makes those two populations almost as distantly related to each other as they are to Neanderthals, Cox says. "We used to think of Denisovans as a single group," says Cox, who suggests as an aside that the D2 group might even need a new name.

The D1 DNA isn't seen in people outside New Guinea, and it's found on large chunks of chromosome that haven't been mixed over time, suggesting it entered the modern human genome recently—about 30,000 years ago, and perhaps just 15,000 years ago. Cox's team suggests a group of Denisovans survived in the remote mountains or islands of New Guinea and mated with modern humans.

The finding of two Denisovan lineages in New Guineans adds to results reported in *Cell* last year by a team including postdoc Serena Tucci of Princeton University, who co-organized the session. They found that East Asians had two sources of Denisovan DNA, suggesting at least two mixing events. But they did not find evidence that New Guineans got Denisovan DNA from two sources.

The multiple encounters with Denisovans gave living people in Indonesia and Papua New Guinea 400 new gene variants, including an immune gene variant (*TNFAIP3*) and a gene involved in diet (*WDFY2*). "People are turning up in hospitals in Australia carrying this gene [*TNFAIP3*]; it has clinical implications for how they respond to autoimmune diseases," Cox said in his talk.

Not everyone is convinced by the late dates. "There are definitely multiple Denisovan populations, but the claim that they interbred 15,000 to 30,000 years ago is extraordinary," says population geneticist Benjamin Vernot of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany.

"I'm skeptical," adds Cosimo Posth of the Max Planck Institute for the Science of Human History in Jena, Germany. He suggests that the hints of a recent mating could reflect an encounter of previously isolated modern populations rather than of moderns and Denisovans. In this scenario, modern humans mated with Denisovans, and then the modern populations diverged, with each branch retaining a different set of Denisovan genes. The moderns then reconnected, bringing the two sets of Denisovan DNA together again.

Whatever happened on New Guinea, it seems that Denisovans mixed with modern humans often. In a separate talk, Xinjun Zhang of the University of California, Los Angeles, reported that Tibetans also got their Denisovan DNA from two encounters. And population geneticist Alan Rogers of the University of Utah in Salt Lake City said that his analysis suggests Denisovans and Neanderthals themselves were the product of interbreeding. He used computational modeling to test different scenarios for how Denisovans, Neanderthals, and modern humans acquired each other's DNA. He concluded that the common ancestor of Denisovans and Neanderthals interbred with another extinct "superarchaic" member of the human family, possibly *H. erectus*, about 700,000 years ago or so. "There was an awful lot of mixing whenever hominins got together," he says.

The Denisovan findings add new urgency to the effort to find more than scraps of this mysterious hominin. At the meeting, paleoanthropologist Bence Viola of the University of Toronto in Canada described the first chunk of skull bone found of a Denisovan—a coaster-size piece of thick parietal bone from the back of the skull, found in Denisova Cave and containing Denisovan DNA. It suggests "a large individual, which fits with the [large] teeth" from the cave, Viola says. The bone offers guidance for paleoanthropologists sorting through specimens for Denisovans. "It raises many more questions than it answers, but I'm hopeful" that researchers will be able to link Denisovan DNA to more-complete bones, Viola says. ■

PHOTO: DOZIER MARC/HEMIS.FR/GETTY IMAGES

IN DEPTH

HUMAN EVOLUTION

Ancient jaw gives elusive Denisovans a face

New protein method identifies first Denisovan outside of Siberia, on Tibetan Plateau

By **Ann Gibbons**

Thirty-nine years ago, a Buddhist monk meditating in a cave on the edge of the Tibetan Plateau found something strange: a human jawbone with giant molars. The fossil eventually found its way to scientists. Now, almost 4 decades later, a groundbreaking new way to identify human fossils based on ancient proteins shows the jaw belonged to a Denisovan, a mysterious extinct cousin of Neanderthals.

The jawbone is the first known fossil of a Denisovan outside of Siberia's Denisova Cave in Russia, and gives paleoanthropologists their first real look at the face of this lost member of the human family. "We are finally 'cornering' the elusive Denisovans," paleoanthropologist María Martinón-Torres of the National Research Center on Human Evolution in Burgos, Spain, wrote in an email. "We are getting their smiles!"

Together, the jaw's anatomy and the new method of analyzing ancient proteins could help researchers learn whether other mysterious fossils in Asia are Denisovan. "We now can use this fossil and this wonderful new tool to classify other fossil remains that we can't agree on," says paleoanthropologist Aida Gomez-Robles of University College London, who reviewed the paper, which appears in *Nature* this week.

The international team of researchers also reports that the jawbone is at least 160,000 years old. Its discovery pushes back the earliest known presence of humans at high altitude by about 120,000 years.

A massive search for Denisovans has been underway ever since paleogeneticists extracted DNA from the pinkie of a girl who lived more than 50,000 years ago in Denisova Cave and found she was a new kind of human. Max Planck Society researchers have since sequenced DNA from several Denisovans from the cave (*Science*, 1 February, p. 438), but the fossils—isolated teeth and bits of bone—were too scanty to show what this enigmatic hominin looked like. Denisovans must have been widespread, because many living people in Melanesia and Southeast Asia carry traces of DNA from multiple encounters between modern humans and Denisovans (*Science*, 5 April, p. 12). But although intriguing fossils across Asia could be Denisovan, they have not yielded the DNA that could confirm their identity.

The proteins in this lower jawbone, which was found by a Chinese monk in a holy cave high on the Tibetan Plateau (top), identify it as Denisovan.

Enter the new jawbone, found by an unidentified monk in Baishiya Karst Cave in Xiahe county in China at an altitude of 3200 meters on the margins of the Tibetan Plateau, according to co-author Dongju Zhang, an archaeologist at Lanzhou University in northwestern China. She traced the jawbone's discovery by interviewing local people in Xiahe, who told her they remembered human bones from the large cave, which is next to a Buddhist shrine and is still a holy place as well as tourist attraction. Recognizing the jaw's unusual nature, the monk gave it to the sixth Gung-Thang living Buddha, one of China's officially designated "living Buddhas," who consulted scholars and then gave the jaw to Lanzhou University. The jawbone was so "weird" that researchers there didn't know how to classify it, and it sat on shelves for years, Zhang says.

She and geologist Fahu Chen, also from Lanzhou University and the Institute of Tibetan Plateau Research in Beijing, showed the jaw to paleoanthropologist Jean-Jacques Hublin of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. After seeing its large molars—as big as ones found in Denisova Cave—Hublin immediately suspected it was Denisovan.

PHOTOS: DONGJU ZHANG/LANZHOU UNIVERSITY

Max Planck paleogeneticists couldn't get DNA from the jaw, but Hublin's graduate student Frido Welker had found in his doctoral work that Neanderthals, modern humans, and Denisovans differ in the amino acid sequence of key proteins. Welker, now a postdoc at the University of Copenhagen, was able to extract collagen, a common structural protein, from a molar of the Xiahe jawbone. He found its amino acid sequence most closely matched that of Denisovans.

Other team members dated a carbonate crust that had formed on the skull by measuring the radioactive decay of uranium in the carbonate. They got a date of 160,000 years ago—a "firm minimum date" for the skull, says geochronologist Rainer Grün of Griffith University in Nathan, Australia, who is not a member of the team.

The date suggests Denisovans would have had tens of thousands of years to adapt to the altitude of Tibet by the time modern humans arrived in the region, some 30,000 to 40,000 years ago. Encounters between modern humans and Denisovans adapted to high altitude could explain how the Tibetans of today came by a Denisovan gene that helps them cope with thin air (*Science*, 30 November 2018, p. 1049). "It seems likely that ancestral Tibetans interacted with Denisovans, as they began to move upslope," archaeologist David Madsen of the University of Texas in Austin wrote in an email.

The jaw's features could be a template for spotting other Denisovans. "Its distinct large molars and premolar roots differ from those of Neanderthals," and the jawbone "is very primitive and robust," says Hublin, who sees a resemblance to a jawbone found off the coast of Taiwan known as the Penghu mandible.

What anatomy can't confirm, proteins might. "The protein analyses allow us to see landscapes where DNA cannot reach"—from warmer climates or much more ancient sites where fragile DNA doesn't persist, Martinón-Torres says. Other researchers have a half-dozen fossils they want to test for proteins or compare with the Xiahe jaw.

The implications are far-reaching. "Forget the textbooks," says archaeologist Robin Dennell of the University of Sheffield in the United Kingdom. "Human evolution in Asia is far more complex than we currently understand, and probably does involve multiple lineages, some of which probably engaged with our species."

Meanwhile, Chen and Zhang did their first excavation at the cave in December 2018, with permission from local villagers and Buddhists. They dug two small trenches where they have already found stone tools and cut-marked rhino and other animal bones. "We do have hope we'll find more Denisovans," Zhang says. ■

FUNDING

Austerity cuts threaten future of science in Argentina

Young scientists are left with few career options while labs scramble to pay for equipment, reagents, and cleaning

By **Lindzi Wessel**

Thousands of scientists from labs across Argentina stayed home on 30 April, joining a nationwide strike against the government's latest round of austerity measures, according to estimates from research leaders. One of their key rallying points: a call to restore lost opportunities for young researchers who began their education during a time of high investment in science but now have little hope of continuing their careers in Argentina.

In the latest blow, the National Scientific and Technical Research Council (CONICET), headquartered in Buenos Aires, announced on 5 April that it had a mere 450 new first-time investigator positions available for this year's roughly 2600 graduates of Ph.D. and postdoctoral programs—leaving a record number of trainees without jobs. The previous government had projected that about 1400 new jobs would be available. Without a position with CONICET, which employs more than 20,000 researchers in hundreds of centers around the country, young scientists have few opportunities.

> ***"You think 100 times before running an experiment and you pray it won't fail."***
> **Juan Pablo Jaworski**, National Institute of Agricultural Technology

CONICET institute directors themselves are fighting the cuts. On 13 April, 140 paid their own way to the city of Córdoba for an emergency meeting. "The number of directors attending was significant evidence of the crisis we are facing right now," says biological anthropologist Rolando González-José, an institute head at the National Patagonian Center in Puerto Madryn. (CONICET did not respond to emails from *Science*.)

The meeting resulted in a manifesto demanding "the immediate implementation of a plan to rescue CONICET," including a scholarship extension for the trainees who missed out on a job and are now scrambling for other opportunities. It also called for an emergency budget increase for CONICET. The group has yet to receive a response from the government.

The plight of science reflects a broad economic crisis in Argentina, where massive inflation and a slipping peso have forced many government agencies and private businesses to tighten their belts. The nation recently received a bailout package of more than $57 billion from the International Monetary Fund that comes with stiff requirements, including a commitment to cut the deficit to zero this year.

The impact on science has already been dramatic. Investment in R&D was just 0.26% of gross domestic product in 2018, down from 0.53% just 3 years earlier. Many CONICET institutes have cut back on such basic needs as cleaning and security services, as well as on research operations. The peso's drop has made imported equipment and reagents virtually unaffordable. "You think 100 times before running an experiment and you pray it won't fail," says Juan Pablo Jaworski, a CONICET virologist at the National Institute of Agricultural Technology.

The dismal job prospects for young researchers are bound to accelerate Argentina's brain drain, says Alberto Kornblihtt, head of CONICET's Institute for Physiology, Molecular Biology, and Neurosciences. Kornblihtt recently saw two junior principal investigators leave his institute to find labs abroad after struggling to make ends meet for a year. "We can't just say you don't have any place in this country, go abroad," he says.

The protests will continue. CONICET directors are planning their own push for public support at a 22 May national *cabildo abierto*, or open council, a form of protest structured around public debate. Yet González-José can't help but feel pessimistic, because the scientific community has been ignored before. The resistance is getting stronger, he concedes, but "the resistance is getting stronger because the problems are getting worse." ■

Lindzi Wessel is a freelance journalist in Santiago.

A massive, remarkably complete skull from China may reveal the long-sought face of a Denisovan, a kind of ancient human known chiefly from DNA.

PHOTOS: XIJUN NI

PALEOANTHROPOLOGY

'Dragon Man' may be an elusive Denisovan

Paleoanthropologists are both excited and puzzled by "wonderful skull" from China

By **Ann Gibbons**

Almost 90 years ago, Japanese soldiers occupying northern China forced a Chinese man to help build a bridge across the Songhua River in Harbin. While his supervisors weren't looking, he found a treasure buried in the riverbank: a remarkably complete human skull. He wrapped up the heavy cranium and lowered it into a well to hide it from the Japanese. Today, the skull is finally coming out of hiding as "Dragon Man," the newest member of the human family, who lived more than 146,000 years ago.

In three papers in the year-old journal *The Innovation*, paleontologist Qiang Ji of Hebei GEO University and his team describe the skull and argue it represents a new species that is a sister group to *Homo sapiens*, even closer kin to us than were the Neanderthals. Other researchers question that idea. But they suspect the large skull, which the team calls *H. longi* (*long* means dragon in Mandarin), has an equally exciting identity: It may be the long-sought skull of a Denisovan, an elusive human relative from Asia known chiefly from DNA. "It's a wonderful skull; I think it's the best skull of a Denisovan that we'll ever have," says paleoanthropologist Jean-Jacques Hublin of the Max Planck Institute for Evolutionary Anthropology.

The stunning fossil was brought to light by the bridge builder's grandchildren, who retrieved it from the well after their grandfather told them about it on his deathbed. They donated it to the Geoscience Museum at Hebei GEO University. (The family asked to remain anonymous.) But the man died without saying precisely where he had found the fossil, leaving the researchers uncertain of its geological context.

> **"I think it probably is a Denisovan."**
> **Chris Stringer**, Natural History Museum

So Ji enlisted several researchers to help date the skull. Geochronologist Rainer Grün of Griffith University, Nathan, in Australia and colleagues linked strontium isotopes in sediment crust from its nasal cavities to a 9-meter layer of sediments around the bridge, which they dated to between 138,000 and 309,000 years ago. Uranium series dating on the bone itself gives it a minimum age of 146,000 years.

Next, the researchers tried to identify the skull. Paleontologist Xijun Ni of the Chinese Academy of Sciences and Hebei GEO University, who led the effort, was initially puzzled: The massive skull held a brain comparable in size to that of modern humans. But it couldn't be a member of *H. sapiens* because it had larger, almost square eye sockets, thick brow ridges, and a wide mouth, and its one remaining molar was huge. So Ni compared 55 traits of the skull—including its length, brow size, and dental features—with those of 95 other fossilized skulls, jaws, or teeth from the genus *Homo* from around the world. A computer model then sorted the fossils into family trees, and the tree that fit best with the data had four main clusters. The new skull nestled in a cluster with several other skulls from China's Middle Pleistocene, 789,000 to 130,000 years ago. Within that cluster, the new skull was most closely related to a jawbone from Xiahe Cave on the Tibetan Plateau.

Ni says the entire cluster of Chinese fossils was closer to early *H. sapiens* than the Neanderthals in the sample were. "Our discovery suggests that the new lineage we identified that includes *Homo longi* is the actual sister group of *H. sapiens*," he told *Science*. If so, Dragon Man and his kin would displace Neanderthals as modern humans' closest known relative.

Ni says he chose to publish in the little-known journal *The Innovation*, part of the Cell family of journals, "because they promised that they can handle our submissions very fast and will respect our choice of novel research methods." Others are less respectful. "When I saw this analysis, I nearly fell off my chair," Hublin says. He and others question how the team concluded that the skull—which lacks a lower jaw—is closely related to the Xiahe lower jaw.

They also question Li's overall classification of the skull as a new lineage, close to modern humans. "It's premature to name a new species, especially a fossil with no context, with contradictions in the data set," says María Martinón-Torres, a paleoanthropologist at CENIEH, the national center for research on human evolution in Spain. Paleoanthropologist Marta Mirazón Lahr of the University of Cambridge calls the find fascinating, but says she's "skeptical of the statements about humans' long-lost sister lineage."

Instead, she and others say, Dragon Man is probably a Denisovan, an extinct cousin of the Neanderthals. To date, the only clearly identified Denisovan fossils are a pinkie bone, teeth, and a bit of skull bone from Denisova Cave in Siberia, where Denisovans lived off and on from 280,000 to 55,000 years ago. But the enormous, "weird" molar from the new skull fits with the molars from Denisova, says Bence Viola, a paleoanthropologist at the University of Toronto, who analyzed the Denisova fossils with Hublin. The link with the Xiahe Cave jawbone, if correct, would strengthen the case, as a protein from that fossil as well as ancient DNA in the sediments of the cave strongly suggest it was a Denisovan.

The authors concede that their critics have a point. "I think it probably is a Denisovan," says Chris Stringer, a paleoanthropologist at London's Natural History Museum and co-author on two of the papers. DNA analysis of the new skull could resolve the issue. But the team says it does not want to risk destroying the tooth or other bone to get DNA or protein.

If the new skull is indeed from a Denisovan, the team's claim to have found the closest human ancestor would crumble. DNA studies have established that Denisovans and Neanderthals formed sister groups, more closely related to each other than to *H. sapiens*. But Dragon Man would still be a landmark fossil. Viola hopes researchers can analyze its DNA, so that "I can finally look into the eyes of a Denisovan." ■

Researchers hope this black-footed albatross chick, settling in on Guadalupe Island, will return here to breed.

CONSERVATION BIOLOGY

Black-footed albatrosses find a new home across an ocean

International project offers a model for tricky translocation of seabirds threatened by rising sea level

By **Rodrigo Pérez Ortega**

On the morning of 16 June, Snowflake spread its wings and let the strong, cold wind of Guadalupe Island help it take a first flight away from its nest. But this was not the first time the young black-footed albatross had soared above the North Pacific Ocean: Five months before, as an egg, Snowflake had been flown more than 6000 kilometers on a commercial airline—in economy plus seating—from Midway Atoll northwest of Hawaii to the remote Guadalupe Island in Mexico.

Snowflake's own flight, just 3 days before World Albatross Day, marked a milestone in a binational project of the United States and Mexico, aimed at keeping the birds safe from the rising sea levels that threaten their survival. On Midway, they "were destined to drown," says Julio Hernández Montoya, a conservation biologist with the nonprofit Island Ecology and Conservation Group (GECI), who helped lead the effort.

Now, with nesting sites on higher ground, the albatross will be more resilient to environmental threats, says Axel Moehrenschlager of the Calgary Zoo. "One of the things that's really, crucially wonderful is that you're putting more eggs in more baskets," he says. Moehrenschlager, who chairs the translocation specialist group at the International Union for Conservation of Nature (IUCN), calls the project "potentially groundbreaking." Three projects have moved albatrosses within the United States and Japan. But this first transfer of a seabird species between nations "is exactly the type of approach that we need on a global level," he says.

He and other conservation scientists caution that translocations are not first-line interventions for saving species—but sometimes, they are the only option. In the past 30 years, he notes, there has been a 30-fold increase in translocations of species ranging from corals to elephants.

Albatrosses, top predators in the ocean's food chain, can spend years without touching land and fly thousands of kilometers in search of food. But they return every year to mate and nest in the islands where they were born. About 95% of the world's black-footed albatrosses (*Phoebastria nigripes*) nest in the Hawaiian islands; Midway Atoll, in a remote part of the state, is home to close to 21,600 breeding pairs, about one-third of the global breeding population.

PHOTO: © GECI/J.A. SORIANO

02/08 | Aula 11: As novas descobertas e polêmicas. O *Homo luzonensis*, quando os *sapiens* saíram da África. O *Homo naledi*.

Textos para leitura:
Philippine Fossils Add Surprising New Species to Human Family Tree | Kate Wong
Uma Outra Jornada para o sapiens | Rocha/Neves
This Small-Brained Human Species May Have Buried Its Dead, Controlled Fire and Made Art | Kate Wong
Possible New Human Species Found through 300,000-Year-Old Jawbone Fossil | Dyani Lewis

Philippine Fossils Add Surprising New Species to Human Family Tree

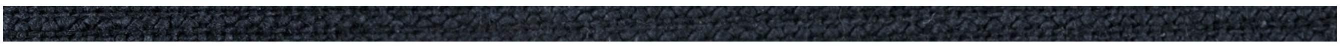
The second tiny ancestor found in the islands of southeast Asia, Homo luzonensis challenges prevailing views of early human dispersal and adaptability

Kate Wong April 11, 2019

Fossil teeth of *Homo luzonensis*, a newly identified species of human that lived on the island of Luzon in the Philippines, exhibit a combination of primitive and derived traits. Credit: Callao Cave Archaeology Project

The human family tree just got a little more luxuriant and a lot more interesting. Scientists say fossils discovered in a cave on the island of Luzon in the Philippines represent a previously unknown branch of humanity, a species they call *Homo luzonensis*. The remains reveal a tiny variety of human with a number of startlingly primitive traits that lived as recently as 50,000 to 67,000 years ago, overlapping in time with our own species, *Homo sapiens*, as well as other hominins (members of the human family) including the Neandertals, Denisovans and *Homo floresiensis.* The find raises important questions about early hominin evolution and biogeography, and highlights just how much of human prehistory remains to be discovered.

The discovery of *H. luzonensis* has been years in the making. The first hint of it surfaced in 2007 when archaeologists digging in Callao Cave, a popular tourist attraction on Luzon, recovered a single fossil foot bone. The bone was clearly petite, comparable in size to the foot bones of the small-bodied Negrito people who live on Luzon today. Yet its shape was "really weird," recalls paleoanthropologist Florent Détroit of the National Museum of Natural History in Paris. Détroit suspected that the fossil specimen came from "something more interesting than a small *Homo sapiens,*" he says. But with only a single bone to go on, he could not make a compelling case for that interpretation. So when he and his colleagues published their description of the foot bone in 2010, they concluded only that it belonged in the genus *Homo.* Which species it came from remained uncertain.



Toe bone of *Homo luzonensis* is curved, a trait associated with climbing. Credit: Callao Cave Archaeology Project

Over the next few years the researchers returned to the cave to look for more bones. They hit pay dirt, recovering 12 additional fossils—assorted teeth as well as hand and foot bones—for a total of 13 specimens representing at least three individuals. Detroit and his collaborators describe the new fossils in a paper published in the April 11 *Nature*.

One of a Kind

The fossils exhibit a mosaic of so-called primitive and derived characteristics. The primitive aspects call to mind our ancient ancestors such as *Australopithecus afarensis,* the species to which the famous 3.1-million-year-old Lucy skeleton belongs; the derived ones resemble *H. sapiens*. Looking at the teeth, for example, the premolars of *H. luzonensis* are large and one of them has an extra tooth root—primitive features. The molars, in contrast, are very small and strikingly modern. Together those dental traits are “a very special combination that doesn’t exist in any of the comparative samples we studied,” Détroit observes.

Still, the teeth alone would not be enough to justify naming a new species, explains María Martinón-Torres of the National Research Center on Human Evolution in Spain. The key thing, she says, is “the combination of these teeth with those hands and feet.” Intriguingly, the hands and feet of *H. luzonensis* are quite primitive, with curved finger and toe bones, which are typically seen in species that climb trees. Although people today can and do climb trees, humans lost most of their adaptations to arboreality after ditching life in the trees life for life on the ground millions of years ago. So a human ancestor from 67,000 years ago or later with climbing anatomy is unexpected, to say the least. Considering the teeth and hand and foot bones together, “I agree with the authors that the combination of features is like nothing we have seen before,” Martinón-Torres says.

How on earth did *H. luzonensis* end up with this unique mix of traits? This is the million-dollar question. Identifying the ancestor(s) of *H. luzonensis* is impossible at this stage. Stone tools and butchered animal bones from another site on the island hint that humans of some sort inhabited Luzon more than 700,000 years ago. But in the absence of any bones of the ancient butchers themselves, whether they might have been *H. luzonensis* or forerunners of *H. luzonensis* is unknown. The only other hominin fossils from the Philippines are 30,000-year-old bones of *H. sapiens* found on Palawan island,some ofwhich are small, but they lack the primitive features seen in *H. luzonensis.* Other human ancestors are known to have lived elsewhere in eastern Asia at around the same time as *H. luzonensis*, but the fossil evidence is insufficient to connect the Luzon hominins to any of these other groups. And attempts to extract DNA from the fossils—which could shed light on the origin of *H. luzonensis* and how it is related to other members of the human family—have failed.

Excavations in Callao Cave, a popular tourist attraction on Luzon, have yielded fossils of *H. luzonensis* and some butchered animal bones, but no stone tools. Credit: Callao Cave Archaeology Project

Unclear Origins

Experts are entertaining speculative ideas about the origin of *H. luzonensis,* each of which would revise the story of human origins in important ways if borne out by further evidence. To fully appreciate the the potential impact of these explanations, however, we have to first revisit a find from 15 years ago. In 2004 scientists working on the island of Flores in Indonesia unveiled an astonishing discovery: remains of a miniature human with a small brain and a host of other primitive traits that, like *H. luzonensis,* lived until relatively recently. The bones were said to represent a previously unknown member of the human family, *Homo floresiensis,* which was promptly nicknamed the hobbit species after J.R.R. Tolkien's diminutive characters.

Researchers put forth two evolutionary scenarios to explain the hobbit's

striking characteristics. In the first, *H. floresiensis* descended from large-bodied, large-brained *Homo erectus* and evolved its small size as an bodied, large-brained *Homo erectus* and evolved its small size as an adaptation to the limited food resources available on the island—a phenomenon known as island dwarfing. Alternatively, *H. floresiensis* inherited its small proportions and other out-of-time features from a more primitive ancestor—an australopithecine of some sort—that somehow managed to disperse from Africa into Asia.

Both possibilities flouted entrenched ideas about human evolution. Although other large mammals are known to follow the island dwarfing rule, humans were traditionally thought to be exempt, the idea being that the ability to invent cultural solutions to life's challenges has buffered humans from many of the environmental forces that have shaped other animals. And australopithecine fossils have never been found outside Africa—the oldest known members of the human family found beyond the mother continent all belong to *Homo.* (A handful of skeptics proposed that the Flores bones instead came from a modern human with a disease that affected its growth, but no disorder proposed thus far can account for the hobbit's suite of features.)

Similar evolutionary scenarios could explain the Luzon fossils. "Given the recent increase in the number of small-bodied, late-surviving [human species] that show many australopith-like features, I think we need to reevaluate whether all of this material should be classified as *Homo,*" says Tracy Kivell, a paleoanthropologist at the University of Kent in England. In addition to *H. luzonensis* and *H. floresiensis,* a small human ancestor from South Africa called *Homo naledi,* announced in 2015,falls into this category. (Like *H. luzonensis, H. naledi* also has curved fingers indicative of climbing.) "With all of the new, weird and wonderful discoveries lately, I wouldn't rule out that more primitive hominins made it out of Africa and that the small-bodied *Homo* species with australopith-like features have evolved from something more primitive," Kivell remarks.

Alternatively, a large-bodied ancestor like *Homo erectus* might have colonized multiple islands in southeast Asia and undergone dwarfing in each locale. Differences between dwarfed species could reflect adaptations to local conditions. For instance, *H. luzonensis* appears to have lived in a forested environment that might have favored climbing ability.

Another potential factor bears mention. DNA studies have shown that human groups including *H. sapiens,* Neandertals and Denisovans interbred from time to time. In theory, similar mixing could have contributed to the mosaic of traits found in the fossils from Callao Cave, according to biological anthropologist Rebecca Ackermann of the University of Cape Town. Certain aspects of the premolars in particular may be consistent with hybridization, though she cautions that it is not possible given the available evidence from known hybrids to establish definitively that hybridization occurred in this case.

Island Explorers

In part because of the evidence for gene flow between human groups during this time period, as well as the lack of comparative material from this region, Ackermann does not support the new species designation for the Luzon fossils. “I actually feel quite strongly that all this species naming is missing the point,” she contends. The real significance of the Luzon discovery, she says, is that it illustrates the extreme diversity of human ancestors during the last few hundred thousand years—“the result of their having populated a huge range of contexts under the influence of various evolutionary forces.”

Which brings us to another burning question about *H. luzonensis:* how did it end up on Luzon in the first place? Luzon is surrounded by deep water. Even during times of lower sea levels, getting to the island would still have required crossing a daunting expanse of open ocean. Researchers grappled with the same problem when *H. floresiensis* first came to light. Like Luzon, Flores is a deep-water island. Some experts proposed that the hobbits must have had boats to make the journey. Yet the hobbit's brain was only about the size of a chimpanzee's and its stone tools were relatively simple—not what one might expect of a species that could make boats. Others suggested that the hobbits or their ancestors were swept out to sea during a big storm or tsunami and washed up on Flores, perhaps hitching a ride on drifting mats of vegetation—a stroke of incredibly good luck.

With only *H. floresiensis* to go on, the issue remained unresolved. But with the discovery of *H. luzonensis* there are now two primitive hominin species on record that inhabited two different deep-water islands in Southeast Asia during the late Pleistocene (the period between 126,000 and 12,000 years ago), which changes the equation. "One strange event may be luck; two suggest something more interesting," asserts John Hawks, an anthropologist at the University of Wisconsin–Madison. What is more, he says, there is good archaeological evidence (though no fossils) of hominins on Sulawesi—another Indonesian island surrounded by deep water—well before modern humans were in the region. "These hominins were crossing water barriers. We don't know how regular it was, but I have to think that each successful population is a survivor of many possibly unsuccessful attempts." The big-picture lesson here is that these early ancestors "were much more adaptable than we used to give them credit for," Hawks says. "They were smart, they learned from each other, and they transmitted traditions that helped them quickly adapt to new ecologies."

CRÂNIO DE HERTO,
encontrado na Etiópia.

EVOLUÇÃO HUMANA

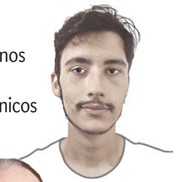
Uma outra jornada para o sapiens

Evidências sobre a antiguidade da primeira saída do *Homo sapiens* da África revelam a mudança de perspectiva que a paleoantropologia e a arqueologia atravessam. A ideia de uma única leva migratória deixando o continente por volta de 50 mil anos e colonizando todo o Velho Mundo não se sustenta mais

Gabriel Rocha e Walter Neves

agefotostock/Alamy/Fotoarena

Gabriel Rocha é estagiário do Laboratório de Estudos Evolutivos Humanos e do Instituto de Estudos Avançados da Universidade de São Paulo. Vem trabalhando com morfologia craniana de hominínios plio-pleistocênicos e com o desenvolvimento evolutivo da linguagem humana.



Walter Neves é professor sênior do Instituto de Estudos Avançados da Universidade de São Paulo. Sua pesquisa se concentra em macroevolução humana e na ocupação inicial das Américas. Desde o início da carreira se dedica à divulgação científica para o grande público.

O principal modelo para explicar a origem e a dispersão do *Homo sapiens*, ou humano moderno, pontuava que surgimos na África há 150 mil anos e deixamos o continente há 50 mil anos para explorar os mais remotos pontos do planeta. Esse limiar de 50 mil anos teria sido cruzado apenas após o surgimento do Paleolítico Superior, um período marcado por uma explosão tecnológica, tanto da pedra lascada e da indústria óssea, quanto do desenvolvimento artístico. No entanto, estudos recentes têm nos contado uma versão diferente dessa história.

Diversas linhas de evidências deixam claro que o *Homo sapiens* surgiu no continente africano. A genética nos mostra que todas as populações humanas atuais têm uma origem comum na África, em algum ponto do nosso passado. Paralelamente, os registros fósseis mais antigos da nossa espécie também estão em território africano, não restando dúvidas sobre o local de nascimento da humanidade.

Os fósseis de *Homo sapiens* mais antigos que conhecemos hoje vêm do leste africano. Omo Kibish 1 e 2 são dois crânios datados em 230 mil anos, e Herto, outro crânio sapiens datado em 165 mil anos, todos encontrados na Etiópia. A princípio, esses seriam os registros fósseis mais antigos da nossa espécie. Um quarto candidato é o crânio de Florisbad, na África do Sul, mas a mistura de características primitivas e avançadas que apresenta, e a datação pouquíssimo confiável de 260 mil anos, tornam difícil o entendimento do seu lugar na nossa linhagem.

Em 2017, pesquisadores revisitaram o sítio arqueológico de Jebel Irhoud, no Marrocos, escavado nos anos 1960, na tentativa de redatarem os fósseis ali encontrados e estabelecer uma data confiável para aquilo que seria um novo candidato a figurar na seleta lista dos primeiros sapiens. A tentativa deu certo e os fósseis foram datados em 315 mil anos! A grande questão então seria determinar se tais fósseis são mesmo de *Homo sapiens*, e nesse ponto a história se complica. Os materiais encontrados em Jebel Irhoud poderiam representar os mais antigos membros da nossa espécie. No entanto, apresentam uma mistura peculiar de características e carecem de traços únicos do nosso grupo. A face retraída parece bastante moderna e os dentes são muito semelhantes aos dos sapiens. Entretanto, a caixa craniana alongada se assemelha à de outras espécies arcaicas como o *Homo heidelbergensis* e em nada se parece com a nossa, que apresenta um formato globular. Além disso, a mandíbula não apresenta um traço muito típico da nossa espécie, o queixo. Esse conjunto de traços indica que os fósseis de Jebel Irhoud fazem parte de um grupo proximamente relacionado aos sapiens, mas muitos pesquisadores ainda estão insatisfeitos em incluí-los na nossa espécie.

Tendo em vista que os registros mais confiáveis dos primeiros sapiens ainda são os fósseis encontrados na Etiópia, leste africano, passamos a olhar então para quando iniciamos nossa odisseia.

SAÍDA(S) DA ÁFRICA

O MODELO MAIS FAMOSO sobre a dispersão do *Homo sapiens* é conhecido como *Out of Africa* (Para fora da África), e afirma que saímos do continente há 50 mil anos e substituímos todas as espécies arcaicas que fomos encontrando pelo caminho. Essa data foi determinada com base no registro arqueológico e no DNA de populações atuais. A princípio, os fósseis humanos mais antigos fora da África eram os materiais de Qafzeh e Skull, em Israel, datados em cerca de 100 mil anos. Claramente, os fósseis de Israel representavam uma exceção ao modelo vigente e a explicação era a de que esses seriam uma pequena população, insignificante do ponto de vista demográfico, muito pontual, já que naquela época o Oriente Médio era praticamente uma extensão da África. A grande migração há 50 mil anos se mantinha, portanto, de pé.

Grande parte dessa ideia se baseava também em um eurocentrismo muito presente no meio científico da época. Até então, os registros mais antigos de sapiens na Europa não ultrapassavam os 40 mil anos, o que não mudou muito até hoje. Com duas disputáveis exceções, os registros mais confiáveis de sapiens no continente alcançam hoje no máximo 47 mil anos. Um único dente de leite encontrado na gruta Mandrin, há cerca de um mês, na França, pode retroagir essa data para 54 mil anos, mas ainda é cedo para maiores

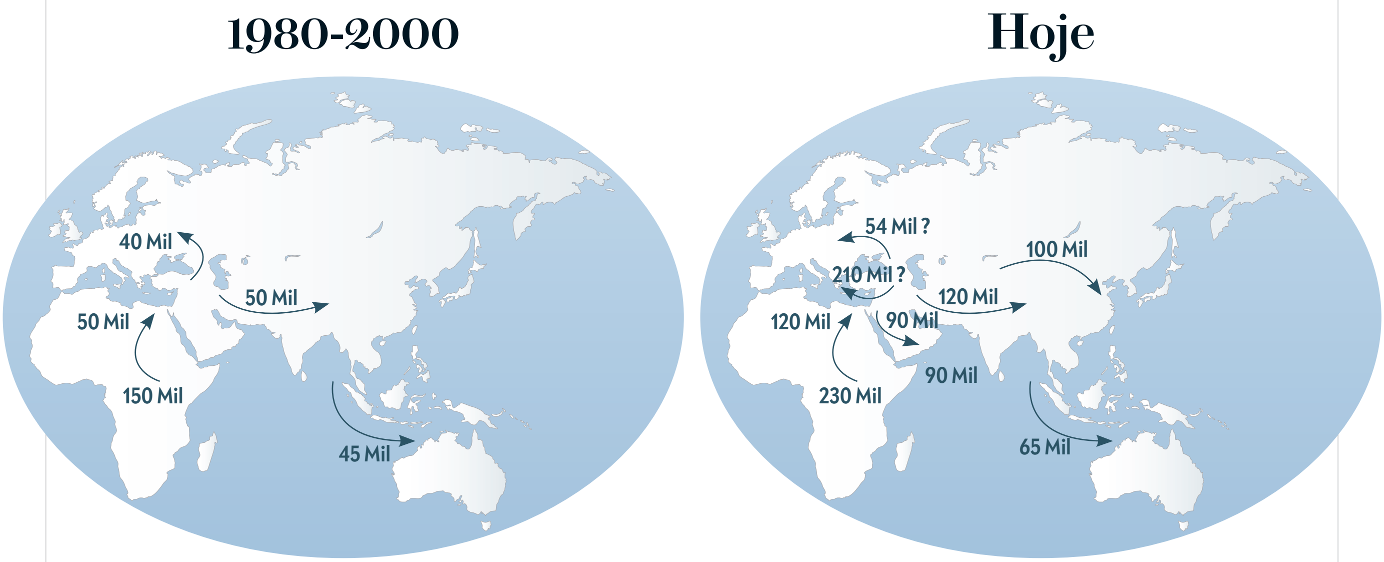
DIFERENÇA CRANIANA: comparação entre os crânios de Jebel Irhoud 1 (315 mil anos, *acima*), de caixa craniana alongada, e de Herto (165 mil anos, *abaixo*), de caixa craniana globular.

The Natural History Museum/Alamy/Fotoarena - agefotostock/Alamy/Fotoarena

conclusões. Nesse aspecto, os olhares voltados majoritariamente para a Europa ofuscaram o registro arqueológico de outras regiões. Como pisamos tão tardiamente em território europeu, a ideia de que saímos somente 50 mil anos atrás da África fazia sentido, mas, como foi visto, sítios arqueológicos no Oriente Médio já indicavam que estávamos, talvez, olhando para o lado errado.

Nos últimos anos tem ficado cada vez mais evidente o papel essencial do continente asiático na nossa compreensão da Evolução Humana. Sabemos, hoje, que ao menos sete espécies habitaram a região entre 2 milhões e 50 mil anos atrás, número que tende a aumentar. Não poderia ser diferente com a história do sapiens, e aqui começamos a examinar o atual registro fóssil da região, com o objetivo de o contrastarmos com o modelo anterior. As primeiras evidências de uma ocupação do continente asiático por humanos modernos mais antiga que 50 mil anos começaram a chamar a atenção no início dos anos 2000 e ganharam força a partir de 2010. Em 2002, pesquisadores interessados em conhecer melhor a antiguidade do sítio chinês Liujiang, que gerou fósseis de *Homo sapiens*, dataram o material em aproximadamente 120 mil anos. Essa datação é ainda questionada, o que obscurece a importância desse material. Desde então, a China passou a se destacar na medida em que produzia cada vez mais registros de uma presença humana antiga em seu território. Em 2010 um fragmento de mandíbula e dois dentes identificados como de sapiens foram encontrados na caverna de Zhiren e datados entre 130 e 100 mil anos. No mesmo ano, um conjunto de dentes de sapiens foi reportado na caverna de Huanglong e datado entre 100 e 80 mil anos. Em 2014, mais dois dentes humanos da caverna de Luna foram publicados, com idades em torno de 120 e 70 mil anos.

Outros trabalhos recentes vêm reportando novos



MODELOS SINTÉTICOS da origem e da dispersão do *Homo sapiens* (*à esquerda*, modelo que predominou até recentemente; *à direita*, modelo proposto nos últimos anos).

materiais do sudeste asiático. Em 2015, 47 dentes foram identificados na caverna de Fuyan, novamente na China, e datados entre 120 e 80 mil anos. Em 2017 alguns fósseis do sítio Tam Pà Ling, no Laos, foram datados em torno de 63 mil anos, ao passo que alguns dentes encontrados em Lida Ajer, Sumatra, têm entre 73 e 63 mil anos. É importante saber que há questionamentos sobre a segurança das datações de alguns desses sítios, mas é notável o crescente número de evidências da presença de humanos modernos no leste e no sudeste asiático anterior a 50 mil anos.

Voltando brevemente para o oeste, no sítio Al Wusta, na Arábia Saudita, uma falange humana publicada em 2018 e datada em 90 mil anos endossa as descobertas chinesas. No mesmo ano, um fragmento de maxila e alguns dentes foram reportados em Israel, no sítio Misliya, datando entre 177 e 194 mil anos. No entanto, essas datas foram fortemente questionadas posteriormente e restam incertas.

Um último caso a ser analisado vem, curiosamente, da Europa: um fragmento craniano potencialmente sapiens, encontrado na caverna de Apidima, na Grécia, e datado em 210 mil anos. Esse indivíduo não somente estaria entre os mais antigos humanos fora da África como também entre os mais antigos humanos conhecidos. E pior, na Europa! Além disso, outro ponto que chama a atenção é o contexto em que foi encontrado, a centímetros de um crânio neandertal, 40 mil anos mais recente. A discrepância nas datações pode ser explicada por diferentes momentos de deposição dos fósseis no local onde foram encontrados. O fragmento recuperado compreende a porção posterior do crânio, uma região muito útil no diagnóstico de espécies homininias e que indica a classificação do fóssil como *Homo sapiens*. Mas vale dizer que muitos pesquisadores ainda se mantêm céticos quanto a isso.

Além dos fósseis, informações importantes sobre a dispersão do *Homo sapiens* também podem ser extraídas das ferramentas líticas. Diversos autores têm publicado nos últimos anos trabalhos apontando semelhanças entre as ferramentas encontradas na África e outras produzidas no Oriente Médio e sudeste asiático há cerca de 100 mil anos. Um número crescente de sítios na Arábia Saudita, Omã, Emirados Árabes, Índia e outras localidades, com datações entre 130 e 80 mil anos, poderiam estar associados ao sapiens, mas a ausência de fósseis impede uma conclusão mais precisa. Artefatos encontrados na Austrália também indicam uma idade mínima de 65 mil anos para a ocupação humana daquela região.

Ainda há uma terceira fonte de evidências que pode ser útil, o DNA. A genética tem sido reportada como a principal apoiadora do modelo *Out of Africa*. Isso se deve ao fato de que estudos comparando o DNA de grupos humanos identificaram que os ancestrais das populações humanas não africanas atuais saíram da África por volta de 80-50 mil anos. No entanto, pesquisas mais recentes têm revelado traços genéticos de dispersões humanas mais antigas. Análises genéticas identificaram que ao menos 2% do DNA de alguns grupos atuais do sudeste asiático têm origem em uma dispersão mais antiga que 75 mil anos. Além disso, foram identificados traços de cruzamentos entre sapiens e neandertais há cerca de 100 mil anos. Nesse sentido, os dados mostram que as expansões mais antigas do sapiens não podem ser encaradas como irrelevantes. Isso porque, agora, temos evidências de que essas expansões contribuíram geneticamente na formação de populações humanas

ESCULTURA DE HOMEM-LEÃO, de cerca de 38 mil anos, encontrada na Alemanha. Até recentemente, acreditava-se ser o exemplar mais antigo de um artefato simbólico.

atuais e até de outras espécies como os neandertais.

Esse número crescente de evidências revelando a antiguidade da primeira saída do *Homo sapiens* da África revela a mudança de perspectiva que a paleoantropologia e a arqueologia atravessam. Em especial, é notável a necessidade de revisão do modelo *Out of Africa* dos anos 1980 para a origem e a dispersão do sapiens. A ideia de uma única leva migratória deixando o continente por volta de 50 mil anos e colonizando todo o Velho Mundo não se sustenta mais. Com as descobertas pontuadas até aqui, se torna proeminente a visão de não uma, mas diversas saídas da África, com diferentes densidades e em diferentes direções. As evidências mais antigas que 50 mil anos provenientes, principalmente, do sudeste asiático promovem novas leituras de materiais como os fósseis de Qafzeh e Skhul, que ganham outra perspectiva, não podendo mais ser interpretados como pontuais e evolutivamente irrelevantes. A partir de agora, os registros antigos de humanos modernos fora da África precisam ser encarados como levas migratórias pioneiras e absolutamente importantes para entendermos o processo de expansão da nossa espécie.

O QUE LEVAMOS CONOSCO

SABIDAMENTE, nossa espécie é dotada de uma criatividade impressionante. O *Homo sapiens* parece se distinguir de outros animais por sua cognição, em especial nossa capacidade de desenvolver pensamentos abstratos e criar símbolos. No registro arqueológico encontramos evidências de pensamento simbólico através de traços ritualísticos e artísticos. Pinturas e gravuras rupestres, esculturas, ornamentos corporais e sepultamentos são algumas das manifestações simbólicas que podemos verificar nos sítios arqueológicos. Na época da formulação do modelo *Out of Africa*, as evidências mais antigas de traços simbólicos estavam na Europa, como o famoso Homem-leão, uma escultura antropomórfica de 38 mil anos encontrada na Alemanha. Esses vestígios produziram a ideia de que tais comportamentos teriam emergido por lá, associados ao surgimento do Paleolítico Superior. Nesse aspecto, diversos pesquisadores propuseram que nossa capacidade de pensamento simbólico emergiu somente um pouco antes da saída da África, há cerca de 50 mil anos. No entanto, hoje sabemos que os mais antigos vestígios arqueológicos de simbolismo de que tínhamos conhecimento estavam na Europa simplesmente porque não conhecíamos mais profundamente o registro arqueológico dos últimos 150 mil anos de outras regiões. Isso pode ser explicado novamente pela excessiva atenção sobre a Europa, que vinha ofuscando a pesquisa em outras regiões. No entanto, demonstrado o viés que ocorria, e com a consolidação da origem do sapiens na África, ficou clara a necessidade de procurarmos por evidências de comportamento simbólico em outras regiões, principalmente no nosso continente de origem.

A situação começou a se modificar por volta dos anos 2000, com um crescente corpo de trabalhos apontando para o uso de ocre por populações humanas mais antigas que 60 mil anos na África. A produção do ocre pode estar relacionada com o uso desse material de cor vermelha ou laranja em pinturas corporais, um indicador de simbolismo. Contudo, esse item também pode estar relacionado com atividades funcionais do cotidiano, o que levanta dúvidas sobre sua associação ao uso simbólico.

À medida que o interesse por esse passado simbólico na África aumentou, não demorou para que novas evidências surgissem. Em 2002 pesquisadores encontraram na caverna de Blombos, na África do Sul, desenhos geométricos gravados em placas de ocre datados em 77 mil anos. Nos anos seguintes, a caverna continuou produzindo registros reveladores. Em 2005, 39 conchas de moluscos perfuradas foram recuperadas no sítio e datadas em torno de 80 mil anos. Com tamanho semelhante e apresentando desgaste ao redor das perfurações, as conchas indicam terem sido utilizadas como contas de colar ou de pulseiras.

Em 2013 pesquisadores publicaram outro registro sul-africano extraordinário, agora da caverna Diepkloof: um conjunto de mais de 400 fragmentos de ovos de avestruz gravados com padrões geométricos altamente padronizados, datados entre 110 e 80 mil anos. A crescente onda de evidências de simbolismo anteriores a 40 mil anos nos mostra que esses comportamentos simbólicos possuem raízes no continente africano e já estavam em ebulição muito antes de nossa espécie atingir a Europa. À medida que nos espalhamos pelo planeta, levamos um pouco dessa cultura conosco, deixando marcas pelo caminho. É o caso das pinturas rupestres de Sulawesi, na Indonésia, as representações figurativas mais antigas já encontradas, com cerca de 45 mil anos, no extremo leste do planeta. Sob essa óptica, o que o sapiens produziu na Europa não marca o surgimento da capacidade simbólica. Na verdade, são elementos de uma história muito mais profunda, enraizada na África, e que carregamos conosco nessa viagem para fora daquele continente.

VIZINHANÇA

PARA ALÉM DESSAS REVISÕES nas datas de quando saímos da África, há também que se pensar outro tópico do modelo anterior, a ideia de que substituímos todas as espécies que encontramos pelo caminho sem interação biológica. No final da década de 1990, cientistas foram capazes de, pela primeira vez, recuperar DNA de um dos nossos parentes extintos, os neandertais. Primeiramente, algumas sequências de DNA mitocondrial foram extraídas e nenhum sinal de hibridização foi encontrado, o que era compatível com a ideia de que nós os substituímos completamente quando chegamos à Europa.

A situação começou a mudar conforme os estudos com DNA antigo progrediram. Com a recuperação de mais partes do genoma dos nossos primos extintos e comparações com o DNA de humanos modernos, foi encontrado DNA neandertal no genoma de populações humanas atuais. Ficou claro que não somente sapiens e neandertais interagiram sexualmente, como também a frequência desses encontros foi muito maior do que previamente se supunha, o que faz com que hoje todos os humanos não africanos possuam entre 1% e 4% de DNA neandertal em seu código genético.

Em 2010, pesquisadores reportaram uma nova espécie homininia para o continente asiático, os denisovanos. Não conhecemos nada sobre a morfologia dessa espécie, porque a sua descoberta se deu com base no DNA extraído de um mísero osso da mão. Desde então, pouquíssimo material adicional desses primos misteriosos foi encontrado. Como só os conhecemos pelo genoma e pelas ferramentas que produziram, nada podemos dizer das suas características físicas, mas o conhecimento do seu material genético possibilitou descobertas importantes. Paralelamente ao caso dos neandertais, sabemos hoje que nossos ancestrais sapiens também se interessaram pelos denisovanos. Em vista disso, grande parte da população humana atual, em especial os povos do sudeste asiático, apresenta porcentagens semelhantes de DNA denisovano em seu código genético. No Tibete essa porcentagem chega a 7%. Assim, o quadro da expansão sapiens começou a mudar profundamente. Abandonamos a visão simplista de substituição total e passamos a entrever uma história complexa de miscigenação com esses grupos extintos.

Os avanços recentes com DNA antigo mostraram um retrato diferente daquele previsto pelo restrito modelo *Out of Africa*. À luz das evidências atuais, não simplesmente substituímos as espécies que cruzaram nosso caminho, mas nos relacionamos sexualmente com elas. Entretanto, algum grau de competição e uma influência nossa em seus processos de extinção não podem ser descartados.

UM NOVO OLHAR

O MONTANTE CRESCENTE de indícios da presença antiga do *Homo sapiens* na Eurásia e na Oceania apontam para a necessidade de revisitarmos o modelo que prevalecia na literatura sobre a origem e a dispersão do homem moderno. Evidentemente, a explicação de uma única leva migratória retumbante há 50 mil anos não se sustenta mais. Com as evidências de dispersões antigas, fica claro que nossa espécie saiu da África antes do surgimento do Paleolítico Superior, desmontando a ideia de que sua invenção foi necessária para nossa expansão pelo mundo. É imprescindível que encaremos nossa saída da África não como uma colonização rápida e tardia, mas sim como um complexo cenário envolvendo múltiplas ondas migratórias que carregaram consigo parte de suas culturas. Boas perguntas a serem feitas como as motivações para as múltiplas saídas da África, ou o porquê de termos demorado tanto tempo para adentrar o território europeu, ainda precisam de respostas adequadas. Mas, sem sombra de dúvidas, está na hora de escrevermos uma nova história para o sapiens. SA

Pierre-Jean Texier | Fine Art Images/Album/Fotoarena

GRAVURAS EM OVOS DE AVESTRUZ encontradas no sítio de Diepkloof, na África do Sul, datadas entre 110 e 80 mil anos (*acima*); *abaixo*, gravura em placa de ocre de 77 mil anos do sítio de Blombos, na África do Sul.

JUNE 5, 2023 | 8 MIN READ

This Small-Brained Human Species May Have Buried Its Dead, Controlled Fire and Made Art

Extraordinary claims about the small-brained human relative *Homo naledi* challenge prevailing view of cognitive evolution

BY KATE WONG

The fossil human species *Homo naledi,* which was discovered in the Rising Star cave system in South Africa by a team led by *National Geographic* explorer in residence Lee Berger, may have engaged in surprisingly sophisticated behaviors, considering its small brain size. Credit: Mark Thiessen/*National Geographic*

Anthropology

In the millions of years over which humans have been evolving, brain size has tripled, and behavior has become exponentially more elaborate. Early, small-brained hominins (members of the human family) made only simple stone tools. Later, brainier ancestors invented more sophisticated implements and developed more advanced subsistence strategies. As for behavioral complexity in our own eggheaded species, *Homo sapiens,* well, we went all out—developing technology that carried us to every corner of the planet, ceremonially burying our dead, forming extensive social networks and creating art, music and language rich in shared meaning. Scientists have long assumed that increasing brain size drove these technological and cognitive advances. Now startling new discoveries at a fossil site in South Africa are challenging this bedrock tenet of human evolution.

Researchers working in the Rising Star cave system near Johannesburg, South Africa, report that they have found evidence that the small-brained fossil human species *Homo naledi* engaged in several sophisticated behaviors that were previously associated exclusively with large-brained hominins. Describing their findings in three preprint papers that were posted on the server bioRxiv on June 5 and will be published in the journal *eLife,* they contend that *H. naledi,* whose brain was around a third of the size of our own, used fire as a light source, went to great lengths to bury its dead and engraved designs that were probably symbolic in the rock walls of the cave system. The findings are preliminary, but if future research bears them out, scientists may need to rethink how we became human.

H. naledi is a relatively recent addition to the pantheon of known hominin species. In 2013 and 2014 a team led by paleoanthropologist Lee Berger of the University of the Witwatersrand, Johannesburg, now a *National Geographic* explorer in residence, recovered more than 1,500 fossil specimens belonging to at least 15 individuals from deep within Rising Star. The fossils revealed a hominin with an unexpected combination of old and new traits. It walked fully upright like modern humans do, and its hands were dexterous like ours. But its shoulders were built for climbing, and its teeth were shaped like those of earlier hominins in the genus *Australopithecus,* explains team member John Hawks of the University of Wisconsin–Madison. Most striking of all, *H. naledi* had a brain size of just 450 to 600 cubic centimeters. For comparison, *H. sapiens* brain size averages around 1,400 cubic centimeters. Berger and his team announced the discovery as a species new to science in 2015. Two years later they were able to establish the age of the fossils, dating them to between 335,000 and 236,000 years ago—surprisingly recent for a species with such a small brain and other primitive traits.

Controversy has roiled around *H. naledi* from the outset. The remains were found in parts of the cave system that are incredibly challenging to access today and that, as far as the team knows, were just as difficult to reach back when *H. naledi* visited. Hardly any bones of medium or large animals are known from the site, as might be expected if creatures, including *H. naledi,* unwittingly fell into the cave. And according to the discovery team, the site lacks any evidence that the bones were transported by rushing water. The implication, Berger and his collaborators argued, was that *H. naledi* individuals entered this subterranean cave system deliberately to deposit their dead. If that were the case, they must have used a light source —namely fire—to navigate Rising Star's dark and treacherous tunnels, chutes and chambers. But mortuary behavior and control of fire have long been considered the exclusive purview of larger-brained hominins. Without any direct evidence of fire or deliberate interment of the bodies, the suggestion that *H. naledi* might have been surprisingly sophisticated, given its small brain size remained firmly in the realm of speculation.

A crosshatched design is one of many engravings that may have been made by *H. naledi* on the cave walls in Rising Star. Berger discovered the engravings in July 2022. Credit: Berger et al., 2023

Subsequent work in the cave has materially strengthened that case. Berger and his colleagues report evidence for burials in two locations in Rising Star, the Dinaledi Chamber and the Hill Antechamber. *H. naledi* corpses were intentionally placed in pits that had been dug in the ground, and the bodies were then covered with dirt. In one case, the corpse was arranged in the pit in a fetal position—a common feature of early *H. sapiens* burials. In another *H. naledi* burial, a rock that the team describes as stone-tool-like was found next to the hand of one of the deceased. If it is indeed a stone tool or other manufactured artifact, it's the only one that has been discovered in association with *H. naledi* to date.

After finding the burials, Berger and Hawks set their sights on searching Rising Star for more clues to the culture of *H. naledi.* And this time Berger wanted to explore the cave system himself. A large man, he had never been able to get into the parts of Rising Star where the *H. naledi* remains are found—he just couldn't fit through the tightest points on the route into the fossil chambers. Berger hired a team of skinny scientists to do all the exploration and excavation that led to the initial research publications. Then, last summer, after losing 55 pounds (25 kilograms), Berger finally ventured into the heart of Rising Star. And that's when he noticed soot on the ceiling and charcoal and bits of burned bone on the floor, which indicated that fire had been used in the cave. At the same time, team member Keneiloe Molopyane of the University of the Witwatersrand, who was excavating another part of the cave system known as the Dragon's Back, found a hearth. "Almost every space within these burial chambers, adjacent chambers and even the hallways ... has evidence of fire," Berger says.

Berger also made another, arguably more astonishing discovery that day in Rising Star: designs carved in the cave walls. The engravings consist of isolated lines and geometric motifs, including crosses, squares, triangles, X's, hash marks and scalariform, or ladderlike, shapes. The markings were deeply incised into dolomite rock in locations close to the burials in the Dinaledi Chamber and Hill Antechamber. Dolomite is a particularly hard rock that measures around 4.7 on the Mohs scale of mineral hardness—"about halfway to a diamond," Berger says. That means the engravers would have had to put considerable effort into making these marks. The engraved surfaces also appear to have been smoothed with hammerstones and polished with dirt or sand, according to the researchers. And some engraved areas gleam with a residue that may be the result of the rock being repeatedly touched.

If *H. naledi,* with its small brain, was burying its dead, using fire as a light source and creating engravings, then scientists may need to rethink the connection between brain size and behavior. We need to step back and try to understand "the social and community emotional dynamics that allow this kind of complex behavior without having this big, complex brain," says team member Agustín Fuentes of Princeton University. Taking this perspective makes us think about human evolution in a new way, he adds, and reminds us that "we know a lot less than we thought we did."

"It's challenging our perceptions of what it means to be human, what it means to be intelligent enough to make art, what it means to communicate graphically," says Genevieve von Petzinger, an authority on rock art, who was not involved in the new papers. Just 25 years earlier the conventional understanding was that *Homo sapiens* invented art in Europe 35,000 years ago. Over the past two decades researchers have uncovered evidence that our cousins the Neandertals and Denisovans made art, too. *H. naledi* had a much smaller brain than those hominins, though. Von Petzinger notes that the Rising Star findings are preliminary and that researchers have yet to carry out the detailed studies that will allow them to figure out "who was making what, where and when." But, she adds, "I think as long as we approach this as being the start of a new and exciting conversation, then we've got nothing to lose by being open-minded about it."

Some experts who were not involved in the new research think Berger and his colleagues are getting ahead of themselves. "I'm not convinced that the team have demonstrated that this was deliberate burial, i.e. the excavation of a shallow grave, deposit of a corpse in it and subsequent covering of that corpse with the sediment excavated," says archaeologist Paul Pettitt of Durham University in England. A complete excavation of the remains would probably resolve the matter, he says, but the researchers' "sensible" decision to leave some deposits intact for now means that "their data are partly investigated and, however impressive they are, sadly do not present a clear and unambiguous demonstration of deliberate burial." Pettitt suggests that seasonal, low-energy movement of water in the cave system might have washed *H. naledi*'s remains into natural depressions in the ground.

Archaeologist Michael Petraglia of Griffith University in Australia thinks the researchers have made a good case for the burials, but he questions the claims that *H. naledi* was responsible for the engravings. One big problem is that scientists have yet to directly date the marks. The discovery team argues that there are no indications that any hominins other than *H. naledi* and modern cavers have entered the dark zone of Rising Star, where the fossil and archaeological materials have been found, and that the designs are therefore best attributed to *H. naledi.* Petraglia isn't persuaded, however. "The evidence that *Homo naledi* made the rock engravings is weak. Though skeletal material and the engravings are in the same cave context, at present there is no way to directly associate them," he says. The fire evidence is similarly problematic: the researchers have yet to publish dates for the material. "I have no reason to believe, at this stage, that *Homo naledi* controlled fire, and I await convincing scientific evidence to prove this is the case," Petraglia says.

The team is working to obtain that evidence and more, including genetic material, which could reveal the relationships among the *H. naledi* individuals found at the site, for example. And the scientists are hoping to involve other researchers in their efforts as they think through how best to proceed with studying the wealth of material in the cave system. Some types of analysis depend on inherently destructive methods, such as excavation; others depend on less invasive ones, such as laser scanning. "You've now met a species that's more complex than contemporary large-brained hominins, and this was its space," Berger says of Rising Star. "What do we do with it? Destroy it? Respect it? I think we should discuss this as a community."

KATE WONG is an award-winning science writer and senior editor at *Scientific American* focused on evolution, ecology, anthropology, archaeology, paleontology and animal behavior. She is fascinated by human origins, which she has covered for more than 25 years. Recently she has become obsessed with birds. Her

reporting has taken her to caves in France and Croatia that Neandertals once called home, to the shores of Kenya's Lake Turkana in search of the oldest stone tools in the world, to Madagascar on an expedition to unearth ancient mammals and dinosaurs, to the icy waters of Antarctica where humpback whales feast on krill, and on a "Big Day" race around the state of Connecticut to find as many bird species as possible in 24 hours. Kate is co-author, with Donald Johanson, of *Lucy's Legacy: The Quest for Human Origins*. She holds a bachelor of science degree in biological anthropology and zoology from the University of Michigan.

More by Kate Wong

Popular Stories

DIET | DECEMBER 1, 2023

How Much Caffeine Is Too Much?

Caffeine can help you feel energized. But is there a limit to how much your body can handle?

JOANNA THOMPSON

MATHEMATICS | NOVEMBER 27, 2023

An Ancient Art Form Topples Assumptions about Mathematics

The sand drawings of Vanuatu follow principles from a branch of mathematics known as graph theory

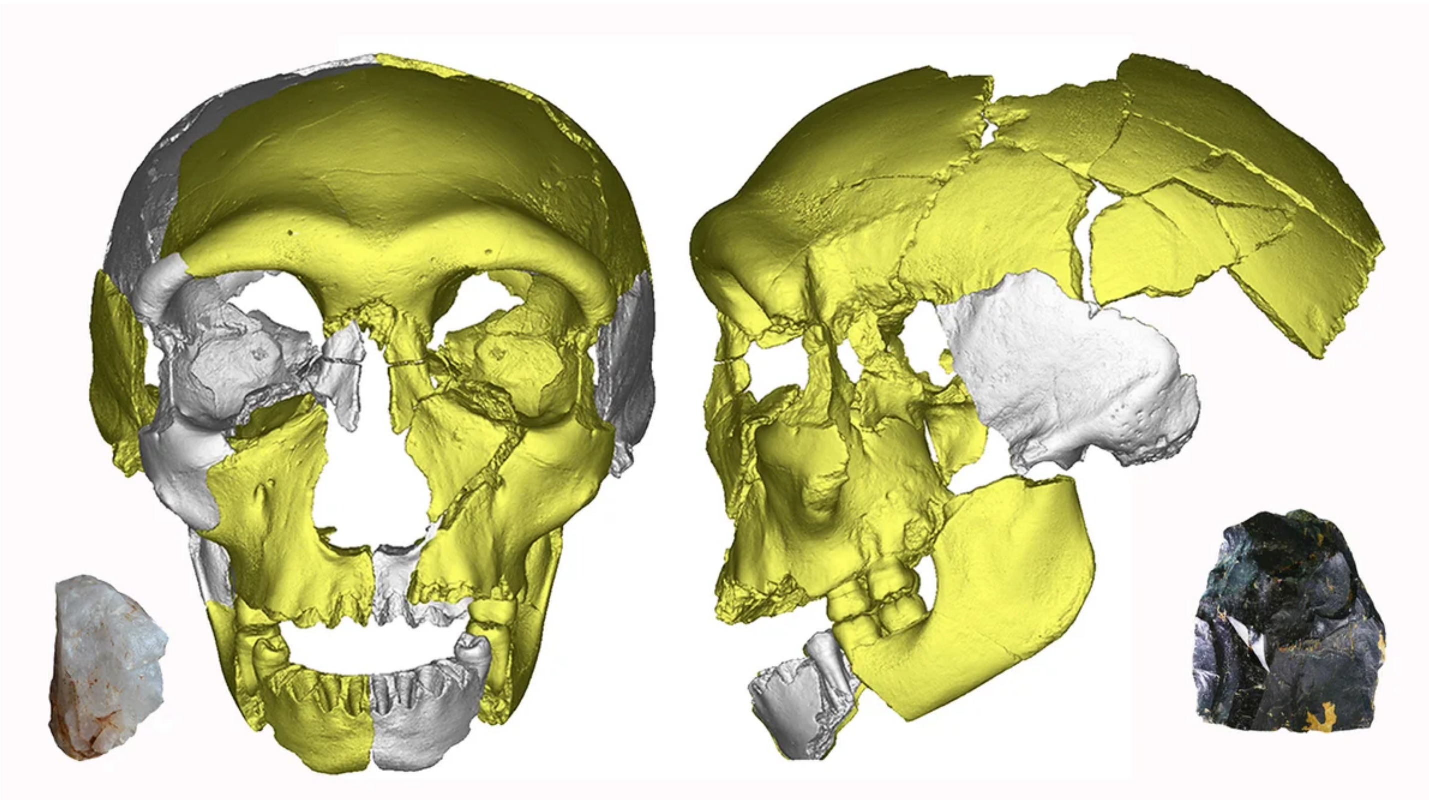
ALBAN DA SILVA

SEPTEMBER 19, 2023 | 3 MIN READ

Possible New Human Species Found through 300,000-Year-Old Jawbone Fossil

A jawbone from eastern China that displays both modern and archaic features could represent a new branch of the human family tree

BY NATURE MAGAZINE & DYANI LEWIS



A digital reconstruction of the juvenile skull found in Hualongdong, China. Credit: Xiu-Jie Wu and Erik Trinkhaus

Evolution

A fossilized jawbone discovered in a cave in eastern China bears a curious mix of ancient and modern features, according to a detailed analysis that compares it with dozens of other human specimens. The finding, published in the *Journal of Human Evolution*, indicates that the 300,000-year-old bone could have belonged to an as-yet undescribed species of archaic human.

Scientists excavating a cave called Hualongdong, located in Anhui province in eastern China, have unearthed remains of 16 individuals that date to around 300,000 years ago. Several fragments belong to the skull of a 12-to-13-year-old juvenile.

Xiujie Wu, a palaeoanthropologist at the Institute of Vertebrate Paleontology and Paleoanthropology in Beijing, and her colleagues first described the skull in 2019. But in 2020, while sifting through trays of animal bones found in the cave, they identified a fragment of a mandible — the lower part of the jaw — that could be another piece of the same skull.

The discovery has enabled a more detailed analysis of where the Hualongdong people fit on the human family tree. The mandible has a mixture of both modern and archaic features. For example, the bone along the jawline is thick, a feature shared with early human species, such as *Homo erectus*. It also lacks a true chin, the presence of which is a key feature of *Homo sapiens*. But the side of the mandible that attaches to the upper jaw is thinner than those of archaic hominins and more reminiscent of that of modern humans.

ANCIENT AND MODERN

The analysis deepens the mystery of which ancient human species inhabited the region during the Middle to Late Pleistocene epoch, a period spanning almost 800,000 years that preceded the end of the last Ice Age, around 12,000 years ago.

A digital comparison of the newly uncovered mandible with 83 other jawbones confirmed a strange mix of ancient and modern anatomical features. Wu and her colleagues used juvenile and adult bones from Neanderthals (*Homo neanderthalensis*), which lived in Eurasia until 40,000 years ago, *H. sapiens* from around the world, and *H. erectus*, a species whose range extended from eastern Africa to the southeast Asian islands of Indonesia between 1.9 million and 250,000 years ago.

Wu says that the *H. sapiens*-like features of the jawbone set it apart from those of other hominins from the Middle Pleistocene, including those of a 160,000-year-old Denisovan from Tibet and of the around 770,000-year-old remains known as Peking Man. She adds that the Hualongdong people could represent a previously unknown ancestor or close relative of early *H. sapiens.*

But the notion that modern humans arose from ancestors in Asia is not widely accepted. The oldest *H. sapiens* fossils, which date to 230,000 years ago, are from sites in Ethiopia.

CONFUSING PICTURE

The picture of human occupation in East Asia during the Pleistocene is a confusing one, says Yameng Zhang, a palaeoanthropologist at Shandong University in Jinan, China. He says that numerous species of archaic hominin inhabited East Asia during the Middle Pleistocene, a period from around 800,000 to 126,000 years ago. It is unclear whether any of these could be ancestors of modern humans — like Neanderthals and Denisovans, they might simply have died out.

The combination of ancient and modern features in the Hualongdong mandible is similar to those of remains found during the early 2000s at the

Jebel Irhoud archaeological site in Morocco, says María Martinón-Torres, a palaeoanthropologist at the National Research Center on Human Evolution in Burgos, Spain, who was part of the team that described the findings at Hualongdong. The Jebel Irhoud remains — which include several skull fragments and a nearly complete mandible — have an age similar to that of the Hualongdong ones and are thought to belong to one of the earliest members of the evolutionary lineage that includes *H. sapiens*. "More fossils and studies are necessary to understand [the Hualongdong people's] precise position in the human family tree," she says.

Martinón-Torres adds that ancient proteins extracted from the bones could shed further light on how the Hualongdong people are related to modern humans, as well as to more-archaic species.

This article is reproduced with permission and was first published on Septemer 18, 2023.

First published in 1869, *NATURE* is the world's leading multidisciplinary science journal. Nature publishes the finest peer-reviewed research that drives ground-breaking discovery, and is read by thought-leaders and decision-makers around the world.

More by Nature magazine

DYANI LEWIS is a senior reporter for *Nature*.

More by Dyani Lewis

Popular Stories