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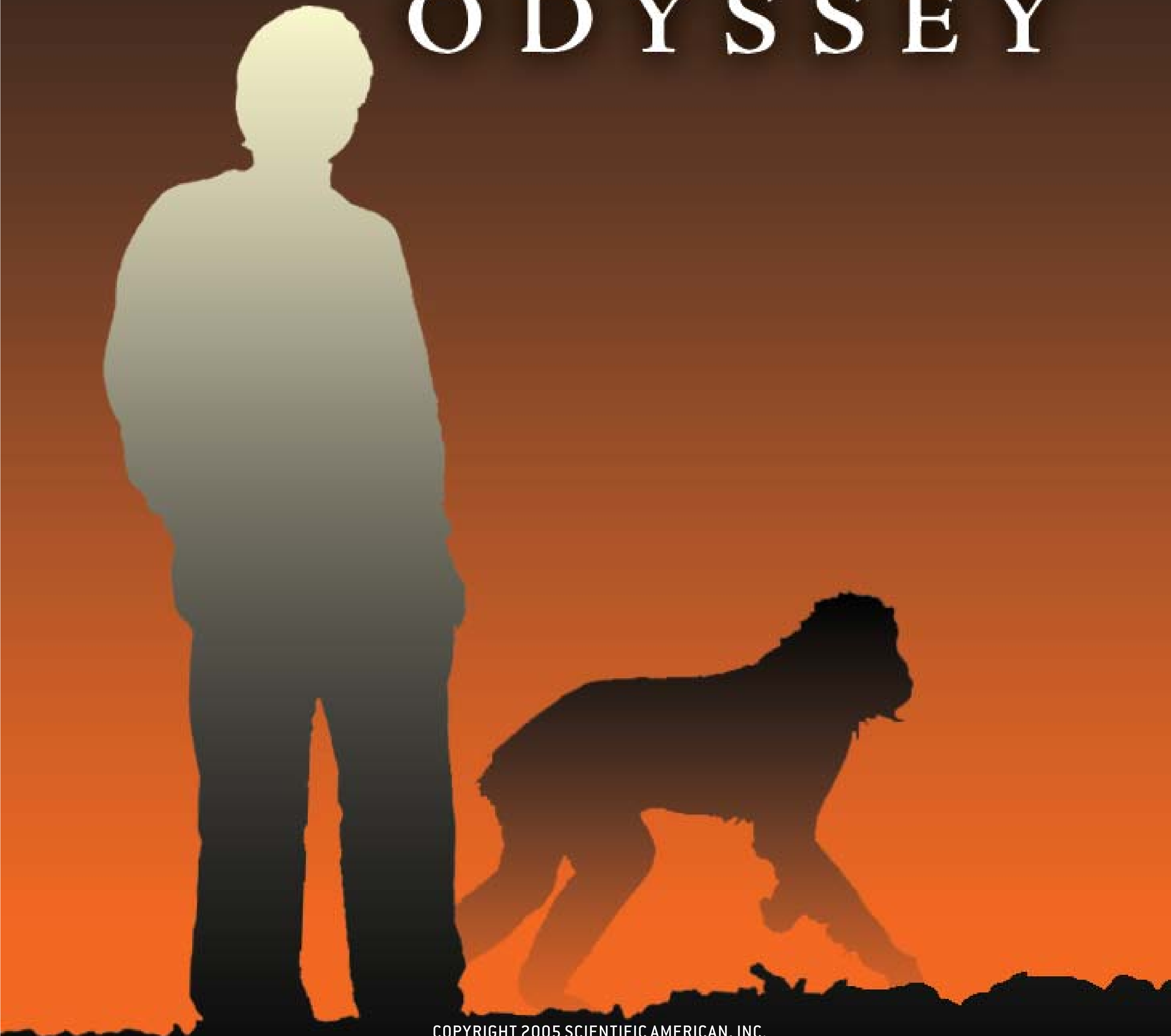
THE HUMAN ODYSSEY



THE HUMAN ODYSSEY

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If you want to know where you come from, those genealogy Web sites will get you only so far. To really plumb your origins, you'll need to look at the fossil record. And what a record it is, documenting millions of years of human and ape evolution.

This exclusive online issue highlights some of the most exciting paleoanthropological discoveries of the past decade. Travel back in time to the Miocene epoch, when Earth was truly a planet of the apes. Explore the intense debate surrounding the emergence of the first hominids in Africa. Discover when our kind started walking upright. Learn how spectacular fossils from the Republic of Georgia have toppled old ideas about when, how and why humans finally left the African motherland to colonize the rest of the world. And get inside the minds of our ancestors as they started thinking like us—much earlier than expected, it turns out.

After millions of years of sharing the landscape with multiple hominid forms, *Homo sapiens* eventually found itself alone, as one article in this compendium recounts. But the roots of our solitude may be shallower than previously thought: the recent and controversial discovery on Flores of miniature human remains suggests that our species coexisted alongside another human type as recently as 13,000 years ago.—*The Editors*

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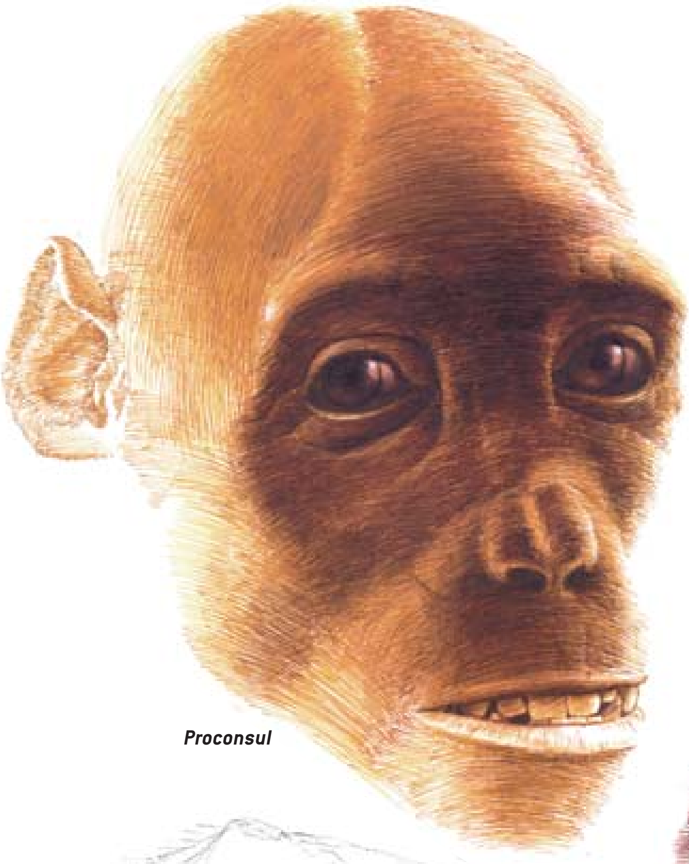
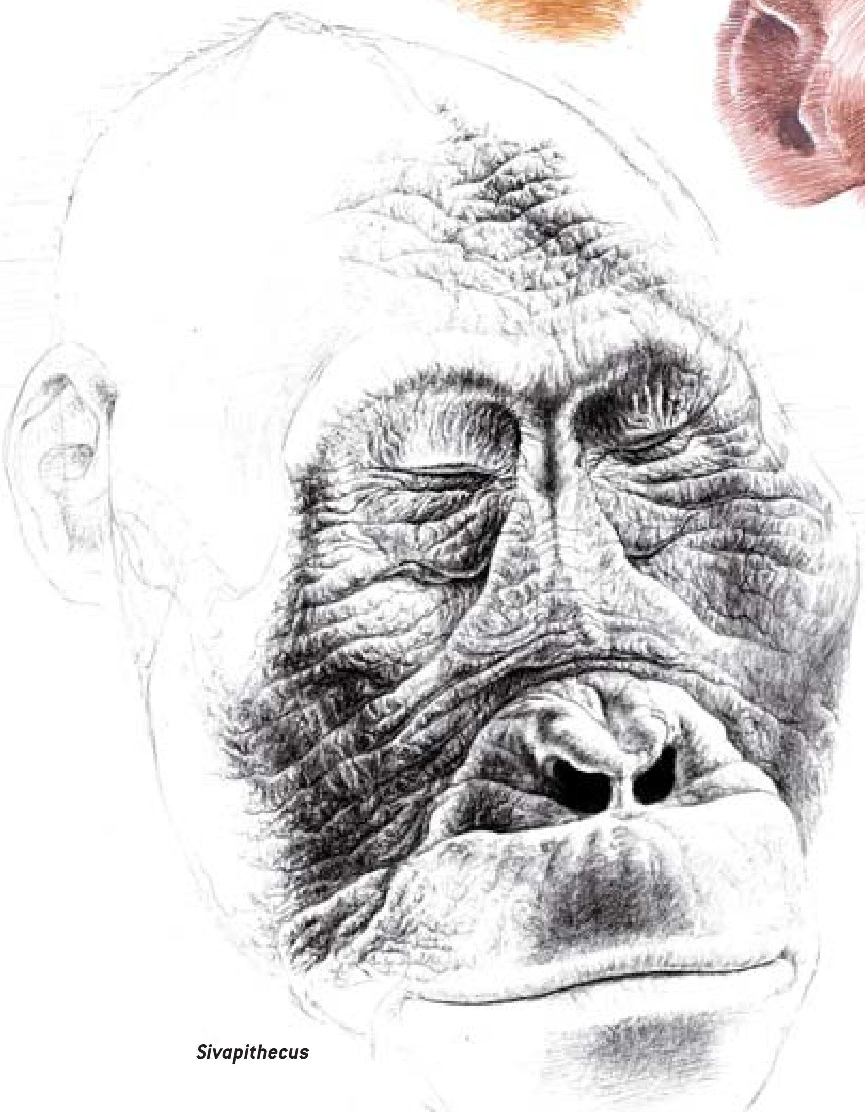


Proconsul

Dryopithecus



Sivapithecus

A DIVERSITY OF APES ranged across the Old World during the Miocene epoch, between 22 million and 5.5 million years ago. *Proconsul* lived in East Africa, *Oreopithecus* in Italy, *Sivapithecus* in South Asia, and *Ouranopithecus* and *Dryopithecus*—members of the lineage thought to have given rise to African apes and humans—in Greece and western and central Europe, respectively. These renderings were created through a process akin to that practiced by forensic illustrators. To learn more about how artist John Gurche drew flesh from stone, check out www.sciam.com/ontheweb

APES

By David R. Begun

Fossil ape reconstructions by John Gurche

originally published in August 2003

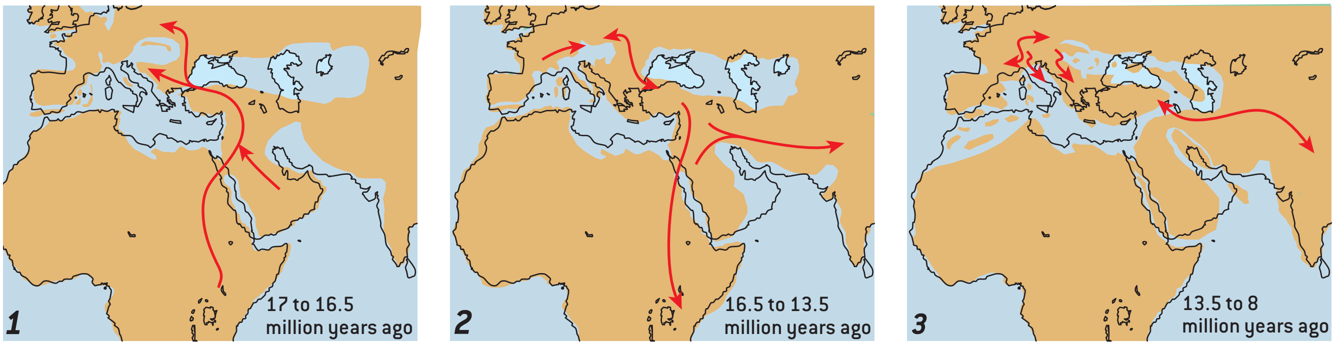
During the Miocene epoch, as many as 100 species of apes roamed throughout the Old World. New fossils suggest that the ones that gave rise to living great apes and humans evolved not in Africa but Eurasia

Ouranopithecus

Oreopithecus

"It is therefore probable that Africa was formerly inhabited by extinct apes closely allied to the gorilla and chimpanzee; as these two species are now man's closest allies, it is somewhat more probable that our early progenitors lived on the African continent than elsewhere."

So mused Charles Darwin in his 1871 work, *The Descent of Man.* Although no African fossil apes or humans were known at the time, remains recovered since then have largely confirmed his sage prediction about human origins. There is, however, considerably more complexity to the story than even Darwin could have imagined. Current fossil and genetic analyses indicate that the last common ancestor of humans and our closest living relative, the chimpanzee, surely arose in Africa, around six million to eight million years ago. But from where did this creature's own forebears come? Paleoanthropologists have long presumed that they, too,



LAURIE GRACE; MAP SOURCE: F. RÖGL IN *THE MIOCENE LAND MAMMALS OF EUROPE*, EDITED BY G. RÖSSNER AND K. HEISSIG. VERLAG DR. FRIEDRICH PFEIL, 1999

had African roots. Mounting fossil evidence suggests that this received wisdom is flawed.

Today's apes are few in number and in kind. But between 22 million and 5.5 million years ago, a time known as the Miocene epoch, apes ruled the primate world. Up to 100 ape species ranged throughout the Old World, from France to China in Eurasia and from Kenya to Namibia in Africa. Out of this dazzling diversity, the comparatively limited number of apes and humans arose. Yet fossils of great apes—the large-bodied group represented today by chimpanzees, gorillas and orangutans (gibbons and siamangs make up the so-called lesser apes)—have turned up only in western and central Europe, Greece, Turkey, South Asia and China. It is thus becoming clear that, by Darwin's logic, Eurasia is more likely than Africa to have been the birthplace of the family that encompasses great apes and humans, the hominids. (The term "hominid" has traditionally been reserved for humans and protohumans, but scientists are increasingly placing our great ape kin in the definition as well and using another word, "hominin," to refer to the human subset. The word "hominoid" encompasses all apes—including gibbons and siamangs—and humans.)

Perhaps it should not come as a surprise that the apes that gave rise to hominids may have evolved in Eurasia instead of Africa: the combined effects of migration, climate change, tectonic activity and ecological shifts on a scale unsurpassed since the Miocene made this region a hotbed of hominoid evolutionary experimentation. The result was a panoply of apes, two lineages of which would eventually find themselves well positioned to colonize Southeast Asia and Africa and ultimately to spawn modern great apes and humans.

Paleoanthropology has come a long way since Georges Cuvier, the French natural historian and founder of vertebrate paleontology, wrote in 1812 that "*l'homme fossile n'existe pas*" ("fossil man does not exist"). He included all fossil primates in his declaration. Although that statement seems unreasonable today, evidence that primates lived alongside animals then known to be extinct—mastodons, giant ground sloths and primitive ungulates, or hoofed mammals, for example—was quite poor. Ironically, Cuvier himself described what scholars would later identify as the first fossil primate ever named, *Adapis parisiensis* Cuvier 1822, a lemur from the chalk mines of Paris that he mistook for an ungulate. It wasn't until 1837, shortly after Cuvier's death, that his disciple Édouard Lartet described the first fossil higher primate recognized as such. Now known as *Pliopithecus,* this jaw from southeastern France, and other specimens like it, finally convinced scholars that such creatures had once inhabited the primeval forests of Europe. Nearly 20 years later Lartet unveiled the first fossil great ape, *Dryopithecus,* from the French Pyrénées.

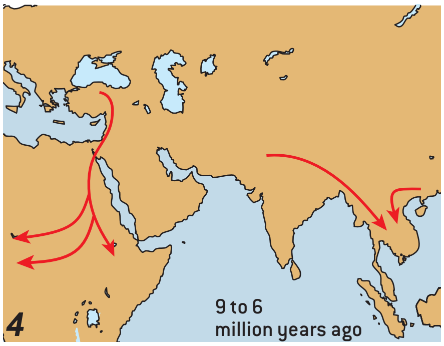
In the remaining years of the 19th century and well into the 20th, paleontologists recovered many more fragments of ape jaws and teeth, along with a few limb bones, in Spain, France, Germany, Austria, Slovakia, Hungary, Georgia and Turkey. By the 1920s, however, attention had shifted from Europe to South Asia (India and Pakistan) and Africa (mainly Kenya), as a result of spectacular finds in those regions, and the apes of Eurasia were all but forgotten. But fossil discoveries of the past two decades have rekindled intense interest in Eurasian fossil apes, in large part because paleontologists have at last recovered specimens complete enough to address what these animals looked like and how they are related to living apes and humans.

Overview/*Ape Revolution*

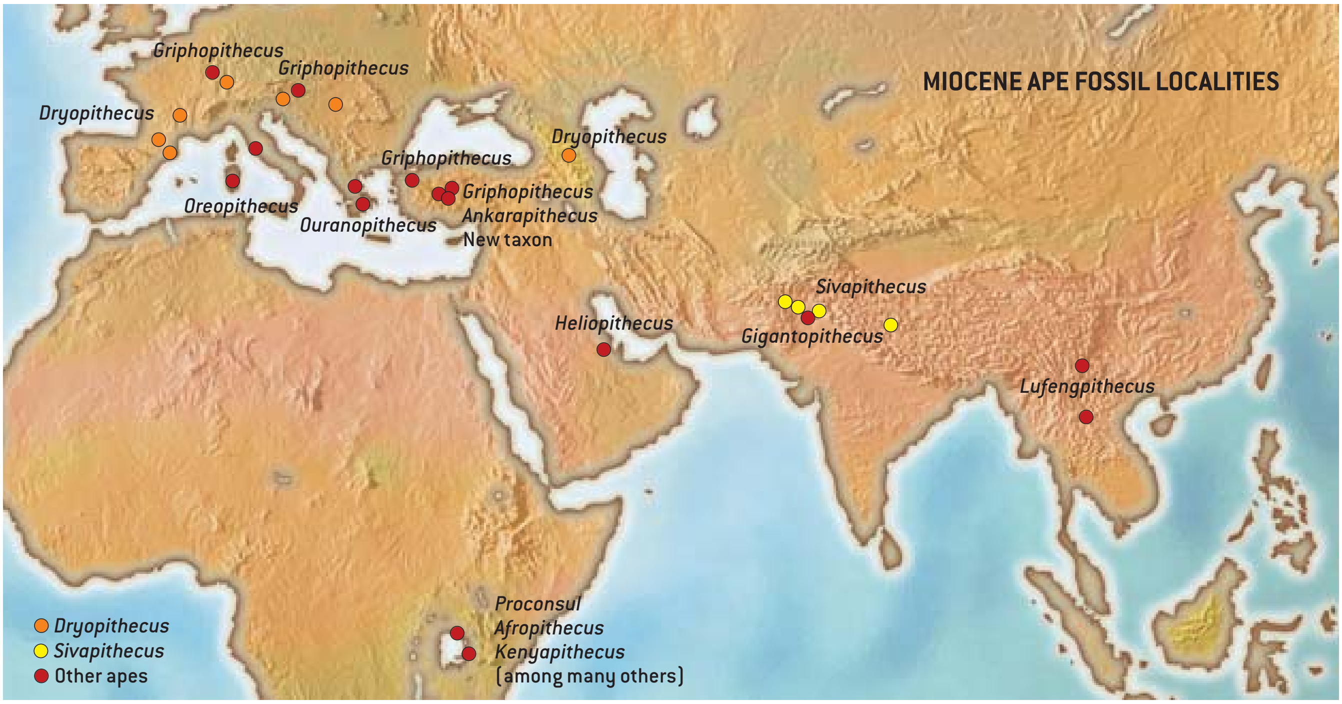
- Only five ape genera exist today, and they are restricted to a few pockets of Africa and Southeast Asia. Between 22 million and 5.5 million years ago, in contrast, dozens of ape genera lived throughout the Old World.
- Scientists have long assumed that the ancestors of modern African apes and humans evolved solely in Africa. But a growing body of evidence indicates that although Africa spawned the first apes, Eurasia was the birthplace of the great ape and human clade.
- The fossil record suggests that living great apes and humans are descended from two ancient Eurasian ape lineages: one represented by *Sivapithecus* from Asia (the probable forebear of the orangutan) and the other by *Dryopithecus* from Europe (the likely ancestor of African apes and humans).

The First Apes

TO DATE, RESEARCHERS have identified as many as 40 genera of Miocene fossil apes from localities across the Old World—eight times the number that survive today. Such diversity seems to have characterized the ape family from the outset: almost as soon as apes appear in the fossil record, there are lots of them. So far 14 genera are known to have inhabited Africa during the early Miocene alone, between 22 million and 17 million years ago. And considering the extremely im-



APES ON THE MOVE: Africa was the cradle of apekind, having spawned the first apes more than 20 million years ago. But it was not long before these animals colonized the rest of the Old World. Changes in sea level alternately connected Africa to and isolated it from Eurasia and thus played a critical role in ape evolution. A land bridge joining East Africa to Eurasia between 17 million and 16.5 million years ago enabled early Miocene apes to invade Eurasia (*1*). Over the next few million years, they spread to western Europe and the Far East, and great apes evolved; some primitive apes returned to Africa (*2*). Isolated from Africa by elevated sea levels, the early Eurasian great apes radiated into a number of forms (*3*). Drastic climate changes at the end of the Late Miocene wiped out most of the Eurasian great apes. The two lineages that survived—those represented by *Sivapithecus* and *Dryopithecus*—did so by moving into Southeast Asia and the African tropics (*4*).



perfect nature of the fossil record, chances are that this figure significantly underrepresents the number of apes that actually existed at that time.

Like living apes, these creatures varied considerably in size. The smallest weighed in at a mere three kilograms, hardly more than a small housecat; the largest tipped the scales at a gorillalike heft of 80 kilograms. They were even more diverse than their modern counterparts in terms of what they ate, with some specializing in leaves and others in fruits and nuts, although the majority subsisted on ripe fruits, as most apes do today. The biggest difference between those first apes and extant ones lay in their posture and means of getting around. Whereas modern apes exhibit a rich repertoire of locomotory modes—from the highly acrobatic brachiation employed by the arboreal gibbon to the gorilla's terrestrial knuckle walking—early Miocene apes were obliged to travel along tree branches on all fours.

To understand why the first apes were restricted in this way, consider the body plan of the early Miocene ape. The best-known ape from this period is *Proconsul,* exceptionally complete fossils of which have come from sites on Kenya's Rusinga Island [see "The Hunt for Proconsul," by Alan Walker and Mark Teaford; Scientific American, January 1989]. Specialists currently recognize four species of *Proconsul,* which ranged in size from about 10 kilograms to possibly as much as 80 kilograms. *Proconsul* gives us a good idea of the anatomy and locomotion of an early ape. Like all extant apes, this one lacked a tail. And it had more mobile hips, shoulders, wrists, ankles, hands and feet than those of monkeys, presaging the fundamental adaptations that today's apes and humans have for flexibility in these joints. In modern apes, this augmented mobility enables their unique pattern of movement, swinging from branch to branch. In humans, these capabilities have been exapted, or borrowed, in an evolutionary sense, for enhanced manipulation in the upper limb—something that allowed our ancestors to start making tools, among other things.

At the same time, however, *Proconsul*

THE AUTHOR

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What Is an Ape, Anyway?

MONKEY *PROCONSUL* GREAT APE

LIVING APES—chimpanzees, gorillas, orangutans, gibbons and siamangs—and humans share a constellation of traits that set them apart from other primates. To start, they lack an external tail, which is more important than it may sound because it means that the torso and limbs must meet certain requirements of movement formerly executed by the tail. Apes and humans thus have highly flexible limbs, enabling them to lift their arms above their heads and to suspend themselves by their arms. (This is why all apes have long and massive arms compared to their legs; humans, for their part, modified their limb proportions as they became bipedal.) For the same reason, all apes have broad chests, short lower backs, mobile hips and ankles, powerfully grasping feet and a more vertical posture than most other primates have. In addition, apes are relatively big, especially the great apes (chimps, gorillas and orangutans), which grow and reproduce much more slowly than other simians do. Great apes and humans also possess the largest brains in the primate realm and are more intelligent by nearly all measures—tool use, mirror self-recognition, social complexity and foraging strategy, among them—than any other mammal.

Fossil apes, then, are those primates that more closely resemble living apes than anything else. Not surprisingly, early forms have fewer of the defining ape characteristics than do later models. The early Miocene ape *Proconsul,* for example, was tailless, as evidenced by the morphology of its sacrum, the base of the backbone, to which a tail would attach if present. But *Proconsul* had not yet evolved the limb mobility or brain size associated with modern apes. Researchers generally agree that the 19-million-year-old *Proconsul* is the earliest unambiguous ape in the fossil record. The classification of a number of other early Miocene "apes"—including *Limnopithecus, Rangwapithecus, Micropithecus, Kalepithecus* and *Nyanzapithecus*—has proved trickier, owing to a lack of diagnostic postcranial remains. These creatures might instead be more primitive primates that lived before Old World monkeys and apes went their separate evolutionary ways. I consider them apes mainly because of the apelike traits in their jaws and teeth. *—D.R.B.*

and its cohorts retained a number of primitive, monkeylike characteristics in the backbone, pelvis and forelimbs, leaving them, like their monkey forebears, better suited to traveling along the tops of tree branches than hanging and swinging from limb to limb. (Intriguingly, one enigmatic early Miocene genus from Uganda, *Morotopithecus,* may have been more suspensory, but the evidence is inconclusive.) Only when early apes shed more of this evolutionary baggage could they begin to adopt the forms of locomotion favored by contemporary apes.

Passage to Eurasia

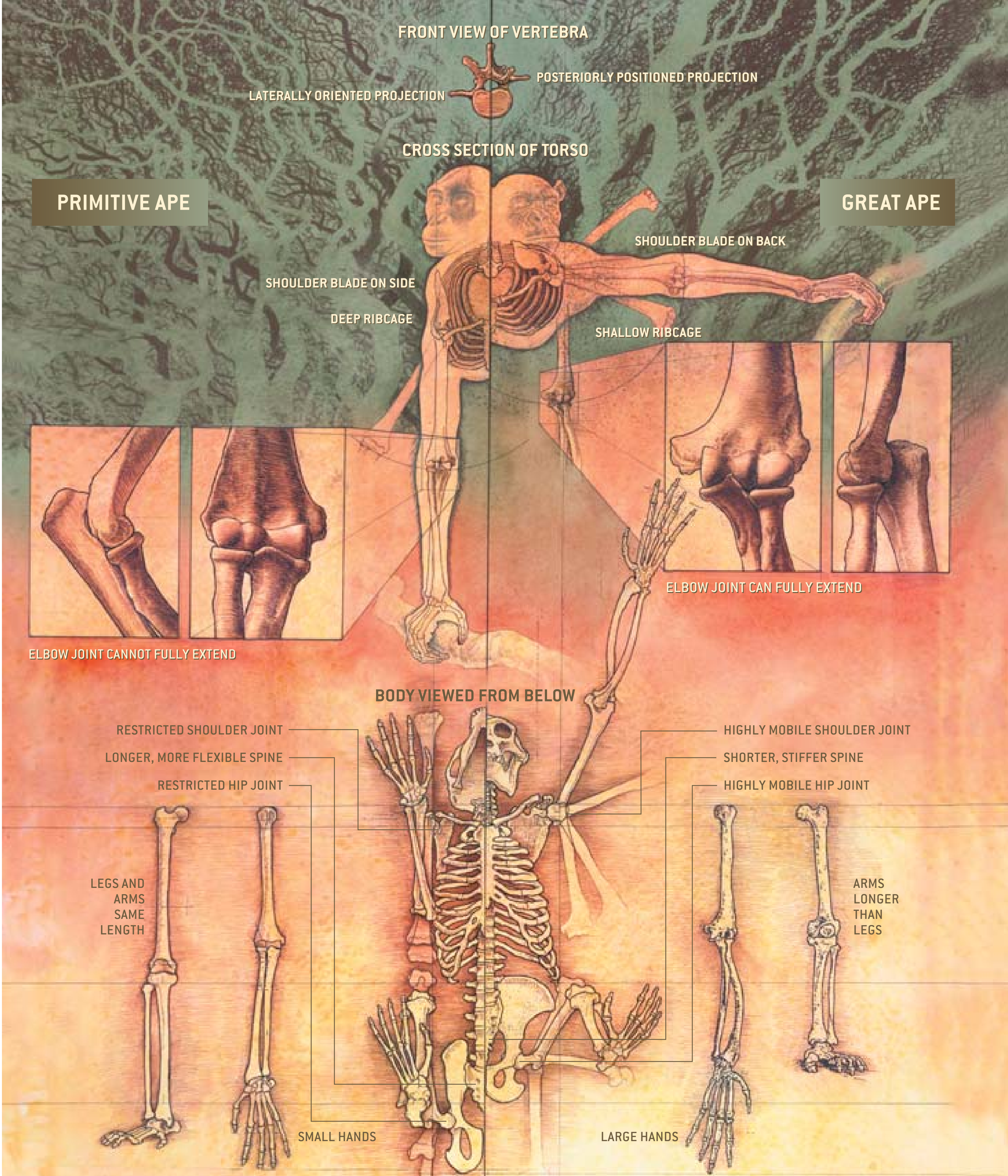
MOST OF THE EARLY Miocene apes went extinct. But one of them—perhaps *Afropithecus* from Kenya—was ancestral to the species that first made its way over to Eurasia some 16.5 million years ago. At around that time global sea levels dropped, exposing a land bridge between Africa and Eurasia. A mammalian exodus ensued. Among the creatures that migrated out of their African homeland were elephants, rodents, ungulates such as pigs and antelopes, a few exotic animals such as aardvarks, and primates.

The apes that journeyed to Eurasia from Africa appear to have passed through Saudi Arabia, where the remains of *Heliopithecus,* an ape similar to *Afropithecus,* have been found. Both *Afropithecus* and *Heliopithecus* (which some workers regard as members of the same genus) had a thick covering of enamel on their teeth—good for processing hard foods, such as nuts, and tough foods protected by durable husks. This dental innovation may have played a key role in helping their descendants establish a foothold in the forests of Eurasia by enabling them to exploit food resources not available to *Proconsul* and most earlier apes. By the time the seas rose to swallow the bridge linking Africa to Eurasia half a million years later, apes had ensconced themselves in this new land.

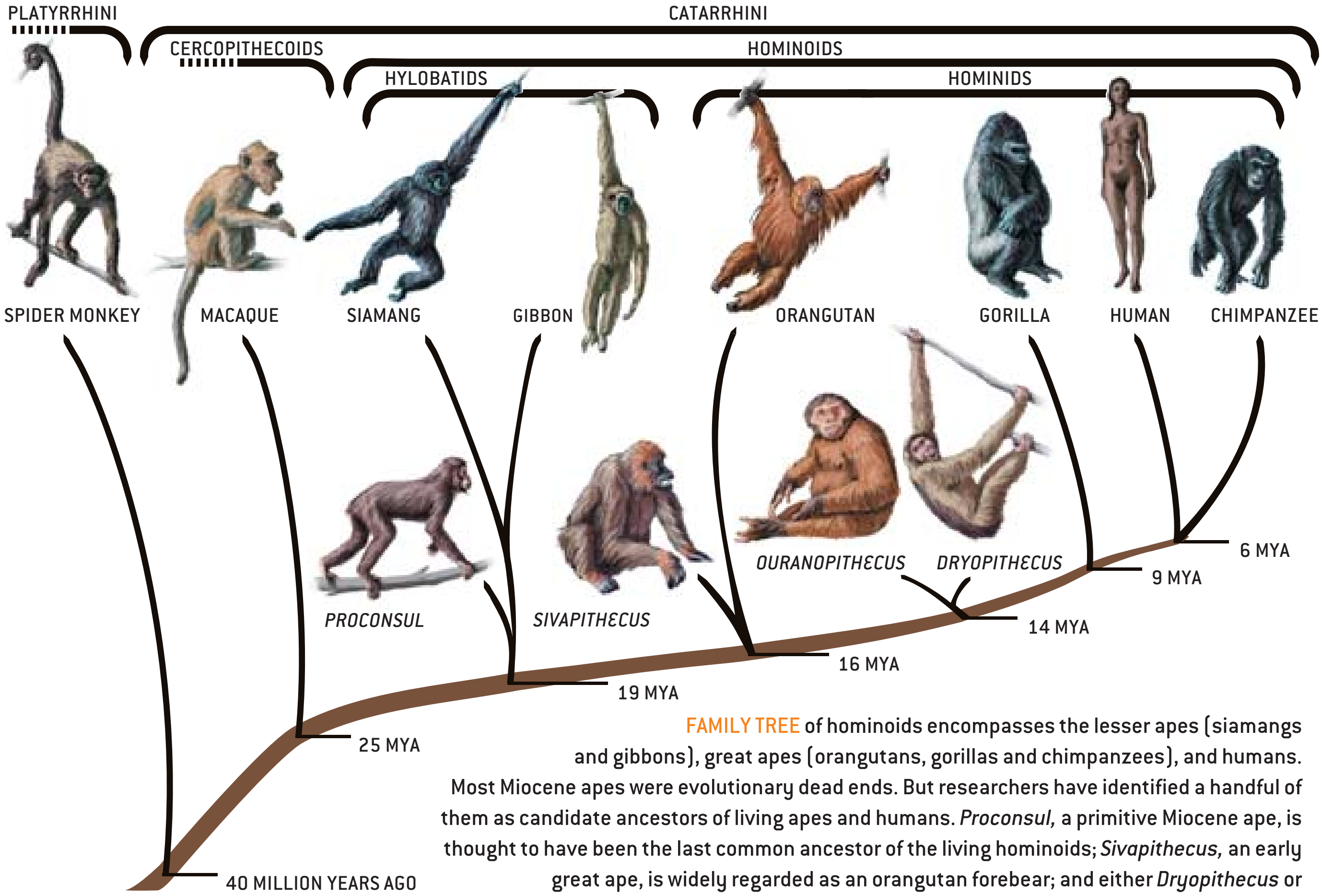
The movement of organisms into new environments drives speciation, and the arrival of apes in Eurasia was no exception. Indeed, within a geologic blink of an eye, these primates adapted to the novel ecological conditions and diversified into a plethora of forms—at least eight known in just 1.5 million years. This flurry of evolutionary activity laid the groundwork for the emergence of great apes and humans. But only recently have researchers begun to realize just how important Eurasia was in this regard. Paleontologists traditionally thought that apes more sophisticated in their food-processing abilities than *Afropithecus* and *Heliopithecus* reached Eurasia about 15 million years ago, around the time they first appear in Africa. This fit with the notion that they arose in Africa and then dispersed northward. New fossil evidence, however, indicates that advanced apes (those with massive jaws and large, grinding teeth) were actually in Eurasia far earlier than that. In 2001 and 2003 my colleagues and I described a more modern-looking ape, *Griphopithecus,* from 16.5-million-year-old sites in Germany and Turkey, pushing the Eurasian ape record back by more than a million years.

The apparent absence of such newer models in Africa between 17 million and 15 million years ago suggests that, contrary to the long-held view of this region as the wellspring of all ape forms, some hominoids began evolving modern cranial and dental features in Eurasia and returned to Africa changed into more advanced species only after the sea receded again. (A few genera—such as *Kenyapithecus* from Fort Ternan, Kenya—may have gone on to develop some postcranial adaptations to life on the ground, but for the most part, these animals still looked

PORTIA SLOAN (*this page*); JOHN GURCHE (*opposite page*)



GOING GREAT APE: Primitive ape body plan and great ape body plan are contrasted here. The earliest apes still had rather monkeylike bodies, built for traveling atop tree limbs on all fours. They possessed a long lower back; projections on their vertebrae oriented for flexibility; a deep rib cage; elbow joints designed for power and speed; shoulder and hip joints that kept the limbs mostly under the body; and arms and legs of similar length. Great apes, in contrast, are adapted to hanging and swinging from tree branches. Their vertebrae are fewer in number and bear a configuration of projections designed to stiffen the spine to support a more vertical posture. Great apes also have a broader, shallower rib cage; a flexible elbow joint that permits full extension of the arm for suspension; highly mobile shoulder and hip joints that allow a much wider range of limb motion; large, powerful, grasping hands; and upper limbs that are longer than their lower limbs.



FAMILY TREE of hominoids encompasses the lesser apes (siamangs and gibbons), great apes (orangutans, gorillas and chimpanzees), and humans. Most Miocene apes were evolutionary dead ends. But researchers have identified a handful of them as candidate ancestors of living apes and humans. *Proconsul,* a primitive Miocene ape, is thought to have been the last common ancestor of the living hominoids; *Sivapithecus,* an early great ape, is widely regarded as an orangutan forebear; and either *Dryopithecus* or *Ouranopithecus* may have given rise to African apes and humans.

like their early Miocene predecessors from the neck down.)

Rise of the Great Apes

BY THE END of the middle Miocene, roughly 13 million years ago, we have evidence for great apes in Eurasia, notably Lartet's fossil great ape, *Dryopithecus,* in Europe and *Sivapithecus* in Asia. Like living great apes, these animals had long, strongly built jaws that housed large incisors, bladelike (as opposed to tusklike) canines, and long molars and premolars with relatively simple chewing surfaces—a feeding apparatus well suited to a diet of soft, ripe fruits. They also possessed shortened snouts, reflecting the reduced importance of olfaction in favor of vision. Histological studies of the teeth of *Dryopithecus* and *Sivapithecus* suggest that these creatures grew fairly slowly, as living great apes do, and that they probably had life histories similar to those of the great apes—maturing at a leisurely rate, living long lives, bearing one large offspring at a time, and so forth. Other evidence hints that were they around today, these early great apes might have even matched wits with modern ones: fossil braincases of *Dryopithecus* indicate that it was as large-brained as a chimpanzee of comparable proportions. We lack direct clues to brain size in *Sivapithecus,* but given that life history correlates strongly with brain size, it is likely that this ape was similarly brainy.

Examinations of the limb skeletons of these two apes have revealed additional great ape–like characteristics. Most important, both *Dryopithecus* and *Sivapithecus* display adaptations to suspensory locomotion, especially in the elbow joint, which was fully extendable and stable throughout the full range of motion. Among primates, this morphology is unique to apes, and it figures prominently in their ability to hang and swing below branches. It also gives humans the ability to throw with great speed and accuracy. For its part, *Dryopithecus* exhibits numerous other adaptations to suspension, both in the limb bones and in the hands and feet, which had powerful grasping capabilities. Together these features strongly suggest that *Dryopithecus* negotiated the forest canopy in much the way that living great apes do. Exactly how *Sivapithecus* got around is less clear. Some characteristics of this animal's limbs are indicative of suspension, whereas others imply that it had more quadrupedal habits. In all likelihood, *Sivapithecus* employed a mode of locomotion for which no modern analogue exists—the product of its own unique ecological circumstances.

The *Sivapithecus* lineage thrived in Asia, producing offshoots in Turkey, Pakistan, India, Nepal, China and Southeast Asia. Most phylogenetic analyses concur that it is from *Sivapithecus* that the living orangutan, *Pongo pygmaeus,* is descended. Today this ape, which dwells in the rain forests of Borneo and Sumatra, is the sole survivor of that successful group.

In the west the radiation of great apes was similarly grand. From the earliest species of *Dryopithecus, D. fontani,* the one found by Lartet, several other species emerged over about three million years. More specialized descendants of this lineage followed suit. Within two million

PORTIA SLOAN

Bigfoot Ballyhoo

A FEW INDIVIDUALS, including some serious researchers, have argued that the *Sivapithecus* lineage of great apes from which the orangutan arose has another living descendant. Details of the beast's anatomy vary from account to account, but it is consistently described as a large, hirsute, nonhuman primate that walks upright and has reportedly been spotted in locales across North America and Asia. Unfortunately, this creature has more names than evidence to support its existence (bigfoot, yeti, sasquatch, nyalmo, rimi, raksi-bombo, the abominable snowman—the list goes on).

Those who believe in bigfoot (on the basis of suspicious hairs, feces, footprints and fuzzy videotape) usually point to the fossil great ape *Gigantopithecus* as its direct ancestor. *Gigantopithecus* was probably two to three times as large as a gorilla and is known to have lived until about 300,000 years ago in China and Southeast Asia.

There is no reason that such a beast could not persist today. After all, we know from the sub-fossil record that gorilla-size lemurs lived on the island of Madagascar until they were driven to extinction by humans only 1,000 years ago. The problem is that whereas we have fossils of 20-million-year-old apes the size of very small cats, we do not have even a single bone of this putative half-ton, bipedal great ape living in, among other places, the continental U.S. Although every primatologist and primate paleontologist I know would love for bigfoot to be real, the complete absence of hard evidence for its existence makes that highly unlikely. *—D.R.B.*

years four new species of *Dryopithecus* would evolve and span the region from northwestern Spain to the Republic of Georgia. But where *Dryopithecus* belongs on the hominoid family tree has proved controversial. Some studies link *Dryopithecus* to Asian apes; others position it as the ancestor of all living great apes. My own phylogenetic analysis of these animals—the most comprehensive in terms of the number of morphological characteristics considered—indicates that *Dryopithecus* is most closely related to an ape known as *Ouranopithecus* from Greece and that one of these two European genera was the likely ancestor of African apes and humans.

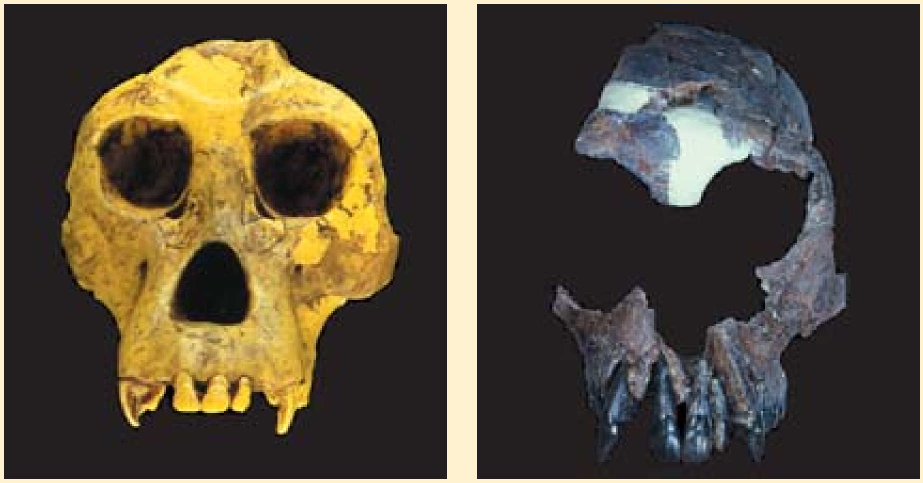
A *Dryopithecus* skull from Rudabánya, Hungary, that my colleagues and I discovered in 1999 bolsters that argument. Nicknamed "Gabi" after its discoverer, Hungarian geologist Gabor Hernyák, it is the first specimen to preserve a key piece of anatomy: the connection between the face and the braincase. Gabi shows that the cranium of *Dryopithecus,* like that of African apes and early fossil humans, had a long and low braincase, a flatter nasal region and an enlarged lower face. Perhaps most significant, it reveals that also like African apes and early humans, *Dryopithecus* was klinorhynch, meaning that viewed in profile its face tilts downward. Orangutans, in contrast—as well as *Proconsul,* gibbons and siamangs—have faces that tilt upward, a condition known as airorhinchy. That fundamental aspect of *Dryopithecus*'s cranial architecture speaks strongly to a close evolutionary relationship between this animal and the African apes and humans lineage. Additional support for that link comes from the observation that the *Dryopithecus* skull resembles that of an infant or juvenile chimpanzee—a common feature of ancestral morphology. It follows, then, that the unique aspects of adult cranial form in chimpanzees, gorillas and fossil humans evolved as modifications to the ground plan represented by *Dryopithecus* and living African ape youngsters.

One more Miocene ape deserves special mention. The best-known Eurasian fossil ape, in terms of the percentage of the skeleton recovered, is seven-million-year-old *Oreopithecus* from Italy. First described in 1872 by renowned French paleontologist Paul Gervais, *Oreopithecus* was more specialized for dining on leaves than was any other Old World fossil monkey or ape. It survived very late into the Miocene in the dense and isolated forests of the islands of Tuscany, which would eventually be joined to one another and the rest of Europe by the retreat of the sea to form the backbone of the Italian peninsula. Large-bodied and small-brained, this creature is so unusual looking that it is not clear whether it is a primitive form that predates the divergence of gibbons and great apes or an early great ape or a close relative of *Dryopithecus*. Meike Köhler and Salvador Moyà-Solà of the Miquel Crusafont Institute of Paleontology in Barcelona have proposed that *Oreopithecus* walked bipedally along tree limbs and had a humanlike hand capable of a precision grip. Most paleoanthropologists, however, believe that it was instead a highly suspensory animal. Whatever *Oreopithecus* turns out to be, it is a striking reminder of how very diverse and successful at adapting to new surroundings the Eurasian apes were.

So what happened to the myriad species that did not evolve into the living great apes and humans, and why did the ancestors of extant species persevere? Clues have come from paleoclimatological studies. Throughout the middle Miocene, the great apes flourished in Eurasia, thanks to its then lush subtropical forest cover and consistently warm temperatures. These conditions assured a nearly continuous supply of ripe fruits and an

Lucky Strikes

FOSSIL FINDS often result from a combination of dumb luck and informed guessing. Such was the case with the discoveries of two of the most complete fossil great ape specimens on record. The first of these occurred at a site known as Can Llobateres in the Vallès Penedès region of Spain. Can Llobateres had been yielding fragments of jaws and teeth since the 1940s, and in the late 1980s I was invited by local researchers to renew excavations there. The first year I discovered little other than how much sunburn and gazpacho I could stand. Undaunted, I returned for a second season, accompanied by my then seven-year-old son, André. During a planning session the day before the work was to begin, André made it clear that, after enduring many hours in a stifling building without air-conditioning, he had had enough, so I took him to see the site. We went to the spots my team had excavated the year before and then wandered up the hillside to other exposures that had looked intriguing but that we had decided not to investigate at that time. After poking around up there with André over the course of our impromptu visit, I resolved to convince my collaborators to dig a test pit in that area at some point during the season.



STELLAR SPECIMENS of *Dryopithecus,* one of the earliest great apes, have come from sites in Spain (*left*) and Hungary (*right*).

DAVID R. BEGUN

The next day we returned to the spot so that I could show a colleague the sediments of interest, and as we worked to clear off some of the overlying dirt, a great ape premolar popped out. We watched in amazement as the tooth rolled down the hill, seemingly in slow motion, and landed at our feet. A few days later we had recovered the first nearly whole face of *Dryopithecus* (*top*) and the most complete great ape from Can Llobateres in the 50-year history of excavations at the site. We subsequently traced the same sedimentological layer across the site and found some limb fragments in another area, which, when excavated more completely in the following year, produced the most complete skeleton of *Dryopithecus* known to this day.

Nine years later in Hungary my Hungarian colleagues and I were starting a new field season at a locality called Rudabánya. Historically, Rudabánya had yielded numerous *Dryopithecus* fossils, mostly teeth and skeletal remains. Intensive excavation over the previous two years, however, failed to turn up any material. For the 1999 season I thought we should concentrate our efforts on

easily traversed arboreal habitat with several tree stories. Climate changes in the late Miocene brought an end to this easy living. The combined effects of Alpine, Himalayan and East African mountain building, shifting ocean currents, and the early stages of polar ice cap formation precipitated the birth of the modern Asian monsoon cycle, the desiccation of East Africa and the development of a temperate climate in Europe. Most of the Eurasian great apes went extinct as a result of this environmental overhaul. The two lineages that did persevere—those represented by *Sivapithecus* and *Dryopithecus*—did so by moving south of the Tropic of Cancer, into Southeast Asia from China and into the African tropics from Europe, both groups tracking the ecological settings to which they had adapted in Eurasia.

The biogeographical model outlined above provides an important perspective on a long-standing question in paleoanthropology concerning how and why humans came to walk on two legs. To address that issue, we need to know from what form of locomotion bipedalism evolved. Lacking unambiguous fossil evidence of the earliest biped and its ancestor, we cannot say with certainty what that ancestral condition was, but researchers generally fall into one of two theoretical camps: those who think two-legged walking arose from arboreal climbing and suspension and those who think it grew out of a terrestrial form of locomotion, perhaps knuckle walking.

Your Great, Great Grand Ape

THE EURASIAN FOREBEAR of African apes and humans moved south in response to a drying and cooling of its environs that led to the replacement of forests with woodlands and grasslands. I believe that adaptations to life on the ground—knuckle walking in particular—were critical in enabling this lineage to withstand that loss of arboreal habitat and make it to Africa. Once there, some apes returned to the forests, others settled into varied woodland environments, and one ape—the one from which humans descended—eventually invaded open territory by committing to life on the ground.

Flexibility in adaptation is the consistent message in ape and human evolution. Early Miocene apes left Africa because of a new adaptation in their jaws and teeth that allowed them to exploit a diversity of ecological settings. Eurasian great apes evolved an array of skeletal adaptations that permitted them to live in varied environments as well as large brains to grapple with complex social and ecological challenges. These modifications made it possible for a few of them to survive the dramatic climate changes that took place at the end of the Miocene and return to a dark layer of sediments suggestive of a high organic content often associated with abundant fossils. That layer was visible in a north-south cross section of the site, becoming lighter and, I thought, less likely to have fossils, toward the north. I asked Hungarian geologist and longtime amateur excavator Gabor Hernyák to start on the north end and work his way south toward the presumed pay dirt. But within less than a minute, Gabor excitedly summoned me back to the spot where I had left him. There, in what appeared to be the fossil-poor sediment, he had uncovered a tiny piece of the upper jaw of *Dryopithecus*. By the time we finished extracting the fossil, we had the most complete cranium of *Dryopithecus* ever found and the first one with the face still attached to the braincase (*bottom*).

This skull from Rudabánya—dubbed "Gabi" after its discoverer—illustrates more clearly than any other specimen the close relation between *Dryopithecus* and the African apes. I will always remember the look on my friend and co-director László Kordos's face when I went back to the village. (I made the 15-minute car trip in five minutes at most.) He was in the middle of e-mailing someone and looked up, quite bored, asking, "What's new?" "Oh, nothing much," I replied. "We just found a *Dryopithecus* skull." —*D.R.B.*

Africa, around nine million years ago. Thus, the lineage that produced African apes and humans was preadapted to coping with the problems of a radically changing environment. It is therefore not surprising that one of these species eventually evolved very large brains and sophisticated forms of technology.

As an undergraduate more than 20 years ago, I began to look at fossil apes out of the conviction that to understand why humans evolved we have to know when, where, how and from what we arose. Scientists commonly look to living apes for anatomical and behavioral insights into the earliest humans. There is much to be gained from this approach. But living great apes have also evolved since their origins. The study of fossil great apes gives us both a unique view of the ancestors of living great apes and humans and a starting point for understanding the processes and circumstances that led to the emergence of this group. For example, having established the connection between European great apes and living African apes and humans, we can now reconstruct the last common ancestor of chimps and humans: it was a knuckle-walking, fruit-eating, forest-living chimplike primate that used tools, hunted animals, and lived in highly complex and dynamic social groups, as do living chimps and humans.

Tangled Branches

WE STILL HAVE MUCH to learn. Many fossil apes are represented only by jaws and teeth, leaving us with little or no idea about their posture and locomotion, brain size or body mass. Moreover, paleontologists have yet to recover any remains of ancient African great apes. Indeed, there is a substantial geographic and temporal gap in the fossil record between representatives of the early members of the African hominid lineage in Europe (*Dryopithecus* and *Ouranopithecus*) and the earliest African fossil hominids.

Moving up the family tree (or, more accurately, family bush), we find more confusion in that the earliest putative members of the human family are not obviously human. For instance, the recently discovered *Sahelanthropus tchadensis,* a six-million- to seven-million-year-old find from Chad, is humanlike in having small canine teeth and perhaps a more centrally located foramen magnum (the hole at the base of the skull through which the spinal cord exits), which could indicate that the animal was bipedal. Yet *Sahelanthropus* also exhibits a number of chimplike characteristics, including a small brain, projecting face, sloped forehead and large neck muscles. Another creature, *Orrorin tugenensis,* fossils of which come from a Kenyan site dating to six million years ago, exhibits a comparable mosaic of chimp and human traits, as does 5.8-million-year-old *Ardipithecus ramidus kadabba* from Ethiopia. Each of these taxa has been described by its discoverers as a human ancestor [see "An Ancestor to Call Our Own," by Kate Wong; SCIENTIFIC AMERICAN, January]. But in truth, we do not yet know enough about any of these creatures to say whether they are protohumans, African ape ancestors or dead-end apes. The earliest unambiguously human fossil, in my view, is 4.4-million-year-old *Ardipithecus ramidus ramidus,* also from Ethiopia.

The idea that the ancestors of great apes and humans evolved in Eurasia is controversial, but not because there is inadequate evidence to support it. Skepticism comes from the legacy of Darwin, whose prediction noted at the beginning of this article is commonly interpreted to mean that humans and African apes must have evolved solely in Africa. Doubts also come from fans of the aphorism "absence of evidence is not evidence of absence." To wit, just because we have not found fossil great apes in Africa does not mean that they are not there. This is true. But there are many fossil sites in Africa dated to between 14 million and seven million years ago—some of which have yielded abundant remains of forest-dwelling animals—and not one contains great ape fossils. Although it is possible that Eurasian great apes, which bear strong resemblances to living great apes, evolved in parallel with as yet undiscovered African ancestors, this seems unlikely.

It would be helpful if we had a more complete fossil record from which to piece together the evolutionary history of our extended family. Ongoing fieldwork promises to fill some of the gaps in our knowledge. But until then, we must hypothesize based on what we know. The view expressed here is testable, as required of all scientific hypotheses, through the discovery of more fossils in new places. SA

MORE TO EXPLORE

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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

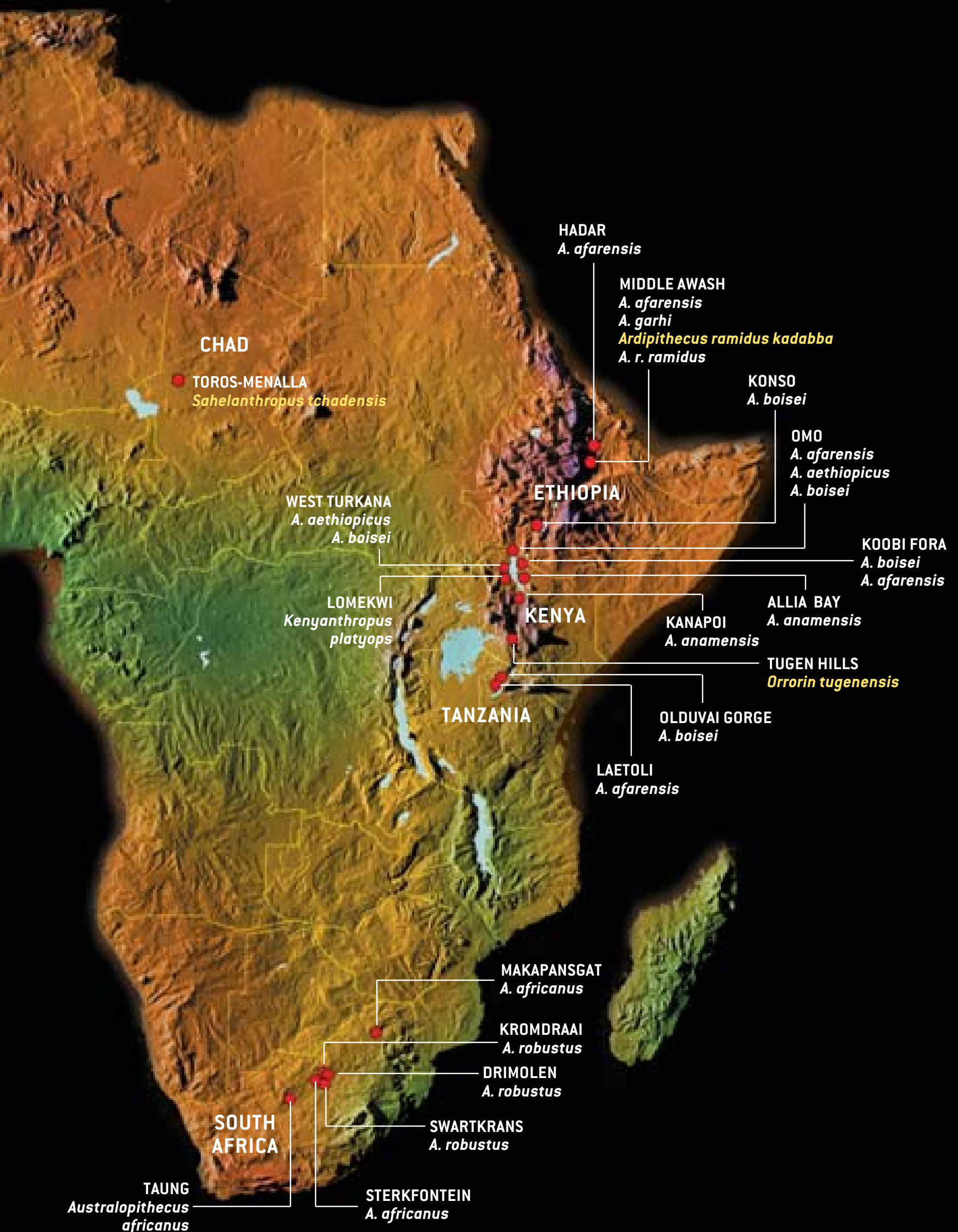
Overview/*The Oldest Hominids*

- 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

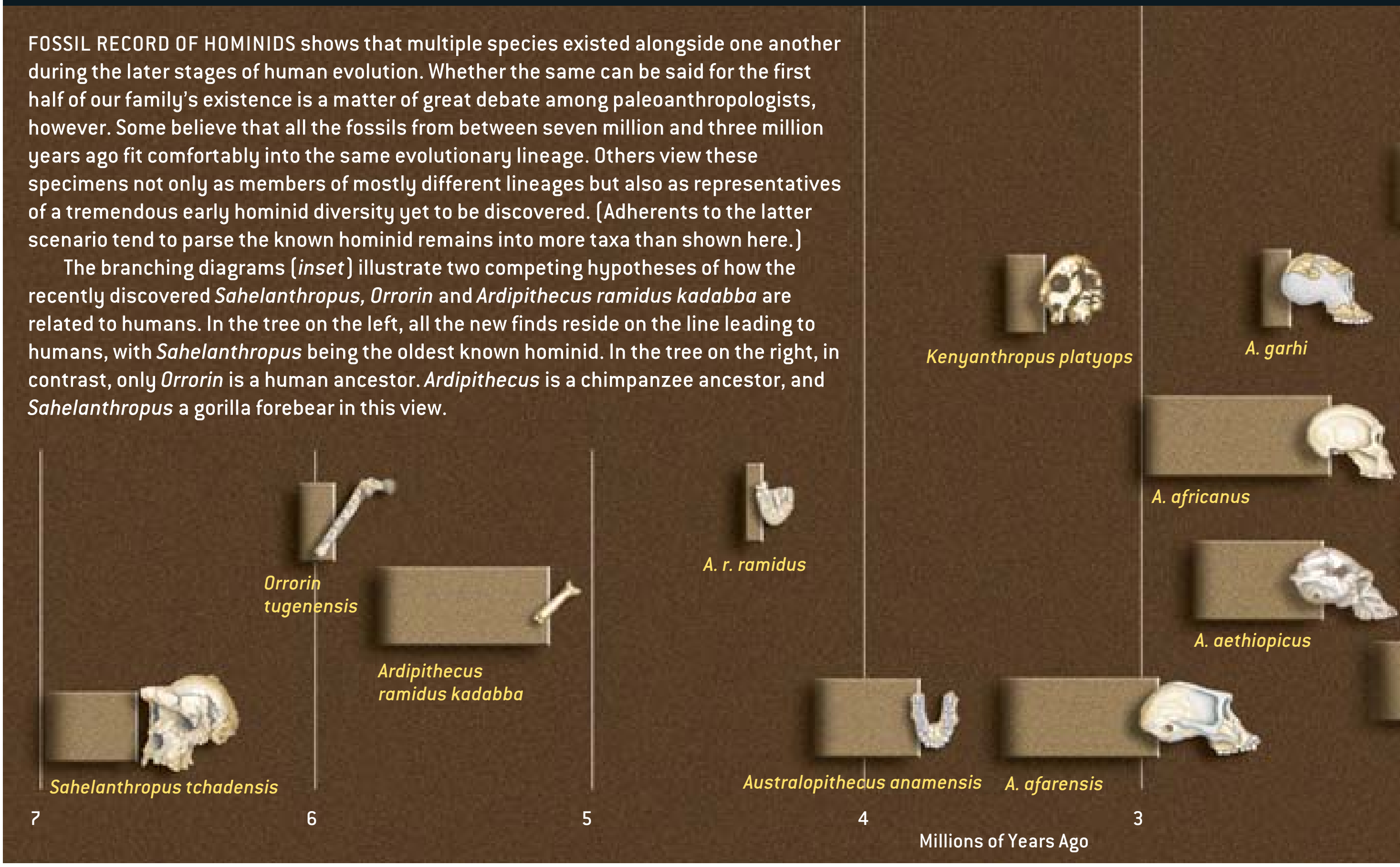
RECENT FINDS from Africa could extend in time and space the fossil record of early human ancestors. Just a few years ago, remains more than 4.4 million years old were essentially unknown, and the oldest specimens all came from East Africa. In 2001 paleontologists working in Kenya's Tugen Hills and Ethiopia's 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

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."



EDWARD BELL

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.

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.

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 hu-

ILLUSTRATIONS BY PATRICIA J. WYNNE AND CORNELIA BLIK
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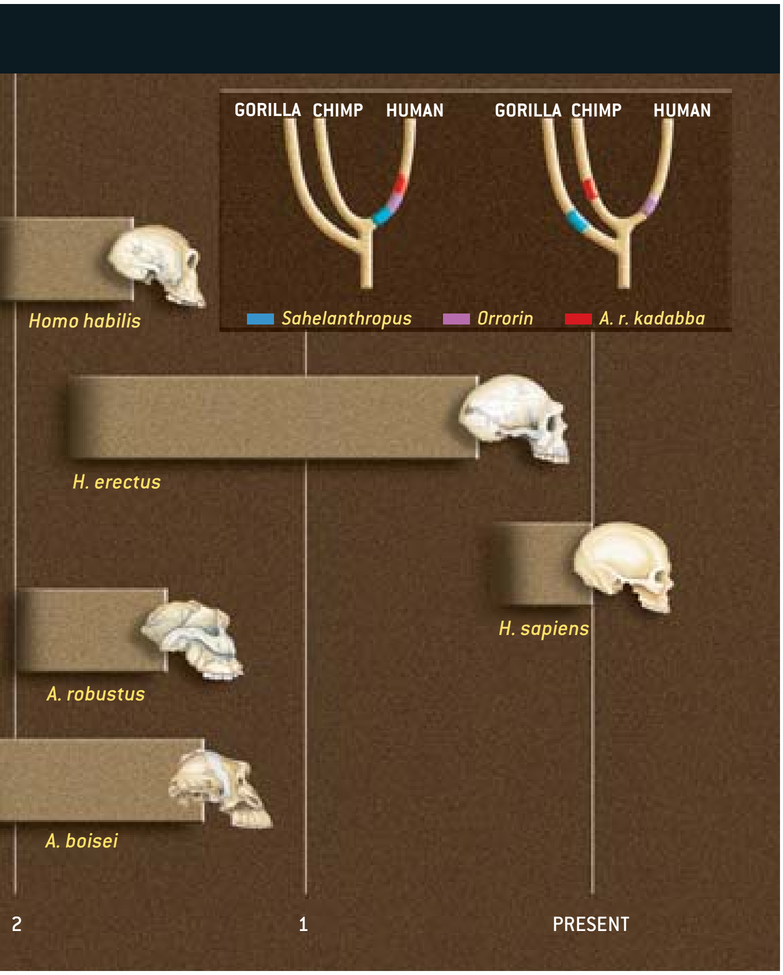


manlike gait than the much younger Lucy did. Breaking with paleoanthropological dogma, the team posits that *Orrorin* gave rise to *Homo* via the proposed genus *Praeanthropus* (which comprises a subset of the fossils currently assigned to *A. afarensis* and *A. anamensis*), leaving Lucy and her kin 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.

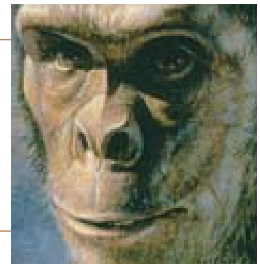
Differing anatomical interpretations notwithstanding, if either *Orrorin* or *A. r. kadabba* were a biped, that would not only push the origin of our strange mode of locomotion back by nearly 1.5 million years, it would also lay to rest a popular idea about the conditions under which our striding gait 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 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 ques-

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.



tions. 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, including *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 gorilla 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 editorial director of ScientificAmerican.com

MORE TO EXPLORE

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Early Hominid Fossils from Africa

A new species of Australopithecus, *the ancestor of* Homo, *pushes back the origins of bipedalism to some four million years ago*

by Meave Leakey and Alan Walker

The year was 1965. Bryan Patterson, a paleoanthropologist from Harvard University, unearthed a fragment of a fossil arm bone at a site called Kanapoi in northern Kenya. He and his colleagues knew it would be hard to make a great deal of anatomic or evolutionary sense out of a small piece of elbow joint. Nevertheless, they did recognize some features reminiscent of a species of early hominid (a hominid is any upright-walking primate) known as *Australopithecus,* first discovered 40 years earlier in South Africa by Raymond Dart of the University of the Witwatersrand. In most details, however, Patterson and his team considered the fragment of arm bone to be more like those of modern humans than the one other *Australopithecus* humerus known at the time.

The age of the Kanapoi fossil proved somewhat surprising. Although the techniques for dating the rocks where the fossil was uncovered were still fairly rudimentary, the group working in Kenya was able to show that the bone was probably older than the various *Australopithecus* specimens previously found. Despite this unusual result, however, the significance of Patterson's discovery was not to be confirmed for another 30 years. In the interim, researchers identified the remains of so many important early hominids that the humerus from Kanapoi was rather forgotten.

Yet Patterson's fossil would eventually help establish the existence of a new species of *Australopithecus*—the oldest yet to be identified—and push back the origins of upright walking to more than four million years (Myr) ago. But to see how this happened, we need to trace the steps that paleoanthropologists have taken in constructing an outline for the story of hominid evolution.

Evolving Story of Early Hominids

Scientists classify the immediate ancestors of the genus *Homo* (which includes our own species, *Homo sapiens*) in the genus *Australopithecus*. For several decades, it was believed that these ancient hominids first inhabited the earth at least three and a half million years ago. The specimens found in South Africa by Dart and others indicated that there were at least two types of *Australopithecus*—*A. africanus* and *A. robustus*. The leg bones of both species suggested that they had the striding, bipedal locomotion that is a hallmark of humans among living mammals. (The upright posture of these creatures was vividly confirmed in 1978 at the Laetoli site in Tanzania, where a team led by archaeologist Mary Leakey discovered a spectacular series of footprints made 3.6 Myr ago by three *Australopithecus* individuals as they walked across wet volcanic ash.) Both *A. africanus* and *A. robustus* were relatively small-brained and had canine teeth that differed from those of modern apes in that they hardly projected past the rest of the tooth row. The younger of the two species, *A. robustus,* had bizarre adaptations for chewing—huge molar and premolar teeth combined with bony crests on the skull where powerful chewing muscles would have been attached.

Paleoanthropologists identified more species of *Australopithecus* over the next several decades. In 1959 Mary Leakey unearthed a skull from yet another East African species closely related to *robustus*. Skulls of these species uncovered during the past 40 years in the northeastern part of Africa, in Ethiopia and Kenya, differed considerably from those found in South Africa; as a result, researchers think that two separate *robustus*-like species—a northern one and a southern one—existed.

In 1978 Donald C. Johanson, now at the Institute of Human Origins in Berkeley, Calif., along with his colleagues, identified still another species of *Australopithecus*. Johanson and his team had been studying a small number of hominid bones and teeth discovered at Laetoli, as well as a large and very important collection of specimens from the Hadar region of Ethiopia (including the famous "Lucy" skeleton). The group named the new species *afarensis*. Radiometric dating revealed that the species had lived between 3.6 and 2.9 Myr ago, making it the oldest *Australopithecus* known at the time.

This early species is probably the best studied of all the *Australopithecus* rec-

AUSTRALOPITHECUS ANAMENSIS **(*right*) lived roughly four million years (Myr) ago. Only a few *anamensis* fossils have been found—a jawbone, part of the front of the face, parts of an arm bone and fragments of a lower leg bone—and thus researchers cannot determine much about the species' physical appearance. But scientists have established that *anamensis* walked upright, making it the earliest bipedal creature yet to be discovered.**

ognized so far, and it is certainly the one that has generated the most controversy over the past 20 years. The debates have ranged over many issues: whether the *afarensis* fossils were truly distinct from the *africanus* fossils from South Africa; whether there was one or several species at Hadar; whether the Tanzanian and Ethiopian fossils were of the same species; whether the fossils had been dated correctly.

But the most divisive debate concerns the issue of how extensively the bipedal *afarensis* climbed in trees. Fossils of *afarensis* include various bone and joint structures typical of tree climbers. Some scientists argue that such characteristics indicate that these hominids must have spent at least some time in the trees. But others view these features as simply evolutionary baggage, left over from arboreal ancestors. Underlying this discussion is the question of where *Australopithecus* lived—in forests or on the open savanna.

By the beginning of the 1990s, researchers knew a fair amount about the various species of *Australopithecus* and how each had adapted to its environmental niche. A description of any one of the species would mention that the creatures were bipedal and that they had ape-size brains and large, thickly enameled teeth in strong jaws, with nonprojecting canines. Males were typically larger than females, and individuals grew and matured rapidly. But the origins of *Australopithecus* were only hinted at, because the gap between the earliest well-known species in the group (*afarensis,* from about 3.6 Myr ago) and the postulated time of the last common ancestor of chimpanzees and humans (between 5 and 6 Myr ago) was still very great. Fossil hunters had unearthed only a few older fragments of bone, tooth and jaw from the intervening 1.5 million years to indicate the anatomy and course of evolution of the very earliest hominids.

Filling the Gap

Discoveries in Kenya over the past several years have filled in some of the missing interval between 3.5 and 5 Myr ago. Beginning in 1982, expeditions run by the National Museums of Kenya to the Lake Turkana basin in northern Kenya began finding hominid fossils nearly 4 Myr old. But because these fossils were mainly isolated teeth—no jawbones or skulls were preserved—very little could be said about them except that they resembled the remains of *afarensis* from Laetoli. But our recent excavations at an unusual site, just in-

MATT MAHURIN

land from Allia Bay on the east side of Lake Turkana [*see maps on page 24*], yielded more complete fossils.

The site at Allia Bay is a bone bed, where millions of fragments of weathered tooth and bone from a wide variety of animals, including hominids, spill out of the hillside. Exposed at the top of the hill lies a layer of hardened volcanic ash called the Moiti Tuff, which has been dated radiometrically to just over 3.9 Myr old. The fossil fragments lie several meters below the tuff, indicating that the remains are older than the tuff. We do not yet understand fully why so many fossils are concentrated in this spot, but we can be certain that they were deposited by the precursor of the present-day Omo River.

Today the Omo drains the Ethiopian highlands located to the north, emptying into Lake Turkana, which has no outlet. But this has not always been so. Our colleagues Frank Brown of the University of Utah and Craig Feibel of Rutgers University have shown that the ancient Omo River dominated the Turkana area for much of the Pliocene (roughly 5.3 to 1.6 Myr ago) and the early Pleistocene (1.6 to 0.7 Myr ago). Only infrequently was a lake present in the area at all. Instead, for most of the past four million years, an extensive river system flowed across the broad floodplain, proceeding to the Indian Ocean without dumping its sediments into a lake.

The Allia Bay fossils are located in one of the channels of this ancient river system. Most of the fossils collected from Allia Bay are rolled and weathered bones and teeth of aquatic animals—fish, crocodiles, hippopotamuses and the like—that were damaged during transport down the river from some distance away. But some of the fossils are much better preserved; these come from the animals that lived on or near the riverbanks. Among these creatures are several different species of leaf-eating monkeys, related to modern colobus monkeys, as well as antelopes whose living relatives favor closely wooded areas. Reasonably well preserved hominid fossils can also be found here, suggesting that, at least occasionally, early hominids inhabited a riparian habitat.

Where do these *Australopithecus* fossils fit in the evolutionary history of hominids? The jaws and teeth from Allia Bay, as well as a nearly complete radius (the outside bone of the forearm) from the nearby sediments of Sibilot just to the north, show an interesting mixture of characteristics. Some of the traits are primitive ones—that is, they are ancestral features thought to be present before the split occurred between the chimpanzee and human lineages. Yet these bones also share characteristics seen in later hominids and are therefore said to have more advanced features. As our team continues to unearth more bones and teeth at Allia Bay, these new fossils add to our knowledge of the wide range of traits present in early hominids.

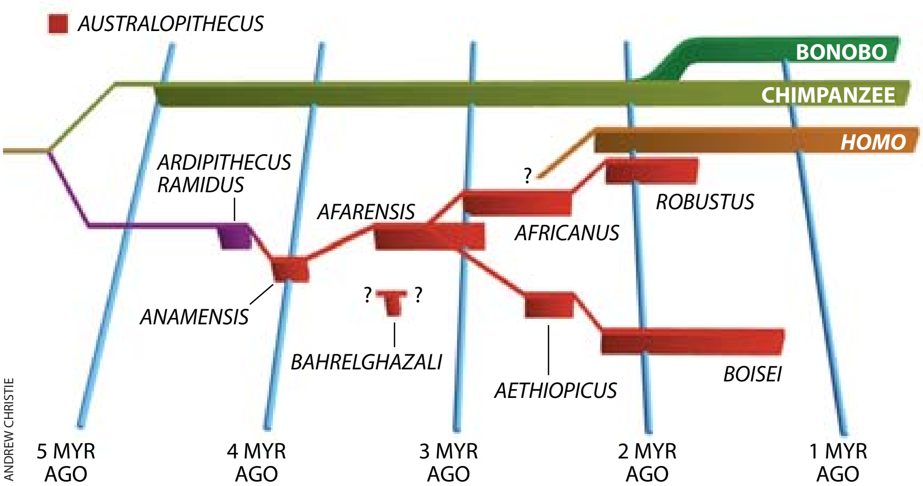
Return to Kanapoi

Across Lake Turkana, some 145 kilometers (about 90 miles) south of Allia Bay, lies the site of Kanapoi, where our story began. One of us (Leakey) has mounted expeditions from the National Museums of Kenya to explore the sediments located southwest of Lake Turkana and to document the faunas present during the earliest stages of the basin's history. Kanapoi, virtually unexplored since Patterson's day, has proved to be one of the most rewarding sites in the Turkana region.

A series of deep erosion gullies, known as badlands, has exposed the sediments at Kanapoi. Fossil hunting is difficult here, though, because of a carapace of lava pebbles and gravel that makes it hard to spot small bones and teeth. Studies of the layers of sediment, also carried out by Feibel, reveal that the fossils here have been preserved by deposits from a river ancestral to the present-day Kerio River, which once flowed into the Turkana basin and emptied into an ancient lake we call Lonyumun. This lake reached its maximum size about 4.1 Myr ago and thereafter shrank as it filled with sediments.

Excavations at Kanapoi have primarily yielded the remains of carnivore meals, so the fossils are rather fragmentary. But workers at the site have also recovered two nearly complete lower jaws, one complete upper jaw and lower face, the upper and lower thirds of a tibia (the larger bone of the lower leg), bits of skull and several sets of isolated teeth. After careful study of the fossils from both Allia Bay and Kanapoi—including Patterson's fragment of an arm bone—we felt that in details of anatomy, these specimens were different enough from previously known hominids to warrant designating a new species. So in 1995, in collaboration with both Feibel and Ian McDougall of the Australian National University, we named this new species *Australopithecus anamensis*, drawing on the Turkana word for lake (*anam*) to refer to both the present and ancient lakes.

To establish the age of these fossils, we relied on the extensive efforts of Brown, Feibel and McDougall, who have been investigating the paleogeographic history of the entire lake basin. If their study of the basin's development is correct, the *anamensis* fossils should be between 4.2 and 3.9 Myr old. Currently McDougall is working to determine the age of the so-called Kanapoi Tuff—the layer of volcanic ash that covers most of the fossils at this site. We expect that once McDougall successfully ascertains the age



ANDREW CHRISTIE

FAMILY TREE of the hominid species known as *Australopithecus* includes a number of species that lived between roughly 4 and 1.25 Myr ago. Just over 2 Myr ago a new genus, *Homo* (which includes our own species, *Homo sapiens*), evolved from one of the species of *Australopithecus*.

of the tuff, we will be confident in both the age of the fossils and Brown's and Feibel's understanding of the history of the lake basin.

A major question in paleoanthropology today is how the anatomic mosaic of the early hominids evolved. By comparing the nearly contemporaneous Allia Bay and Kanapoi collections of *anamensis,* we can piece together a fairly accurate picture of certain aspects of the species, even though we have not yet uncovered a complete skull.

The jaws of *anamensis* are primitive—the sides sit close together and parallel to each other (as in modern apes), rather than widening at the back of the mouth (as in later hominids, including humans). In its lower jaw, *anamensis* is also chimplike in terms of the shape of the region where the left and right sides of the jaw meet (technically known as the mandibular symphysis).

Teeth from *anamensis,* however, appear more advanced. The enamel is relatively thick, as it is in all other species of *Australopithecus;* in contrast, the tooth enamel of African great apes is much thinner. The thickened enamel suggests *anamensis* had already adapted to a changed diet—possibly much harder food—even though its jaws and some skull features were still very apelike. We also know that *anamensis* had only a tiny external ear canal. In this regard, it is more like chimpanzees and unlike all later hominids, including humans, which have large external ear canals. (The size of the external canal is unrelated to the size of the fleshy ear.)

The most informative bone of all the ones we have uncovered from this new hominid is the nearly complete tibia—the larger of the two bones in the lower leg. The tibia is revealing because of its important role in weight bearing: the tibia of a biped is distinctly different from the tibia of an animal that walks on all four legs. In size and practically all details of the knee and ankle joints, the tibia found at Kanapoi closely resembles the one from the fully bipedal *afarensis* found at Hadar, even though the latter specimen is nearly a million years younger.

Fossils of other animals collected at Kanapoi point to a somewhat different paleoecological scenario from the setting across the lake at Allia Bay. The channels of the river that laid down the sediments at Kanapoi were probably lined with narrow stretches of forest that grew close to the riverbanks in otherwise open country. Researchers have recovered the remains of the same spiral-horned antelope found at Allia Bay that very likely lived in dense thickets. But open-country antelopes and hartebeest appear to have lived at Kanapoi as well, suggesting that more open savanna prevailed away from the rivers. These results offer equivocal evidence regarding the preferred habitat of *anamensis*: we know that bushland was present at both sites that have yielded fossils of the species, but there are clear signs of more diverse habitats at Kanapoi.

The fossils of anamensis that we have identified should also provide some answers in the long-standing debate over whether early Australopithecus species lived in wooded areas or on the open savanna

An Even Older Hominid?

At about the same time that we were finding new hominids at Allia Bay and Kanapoi, a team led by our colleague Tim D. White of the University of California at Berkeley discovered fossil hominids in Ethiopia that are even older than *anamensis.* In 1992 and 1993 White led an expedition to the Middle Awash area of Ethiopia, where his team uncovered hominid fossils at a site known as Aramis. The group's finds include isolated teeth, a piece of a baby's mandible (the lower jaw), fragments from an adult's skull and some arm bones, all of which have been dated to around 4.4 Myr ago. In 1994, together with his colleagues Berhane Asfaw of the Paleoanthropology Laboratory in Addis Ababa and Gen Suwa of the University of Tokyo, White gave these fossils a new name: *Australopithecus ramidus.* In 1995 the group renamed the fossils, moving them to a new genus, *Ardipithecus.* Other fossils buried near the hominids, such as seeds and the bones of forest monkeys and antelopes, strongly imply that these hominids, too, lived in a closed-canopy woodland.

This new species represents the most primitive hominid known—a link between the African apes and *Australopithecus.* Many of the *Ardipithecus ramidus* fossils display similarities to the anatomy of the modern African great apes, such as thin dental enamel and strongly built arm bones. In other features, though—such as the opening at the base of the skull, technically known as the foramen magnum, through which the spinal cord connects to the brain—the fossils resemble later hominids.

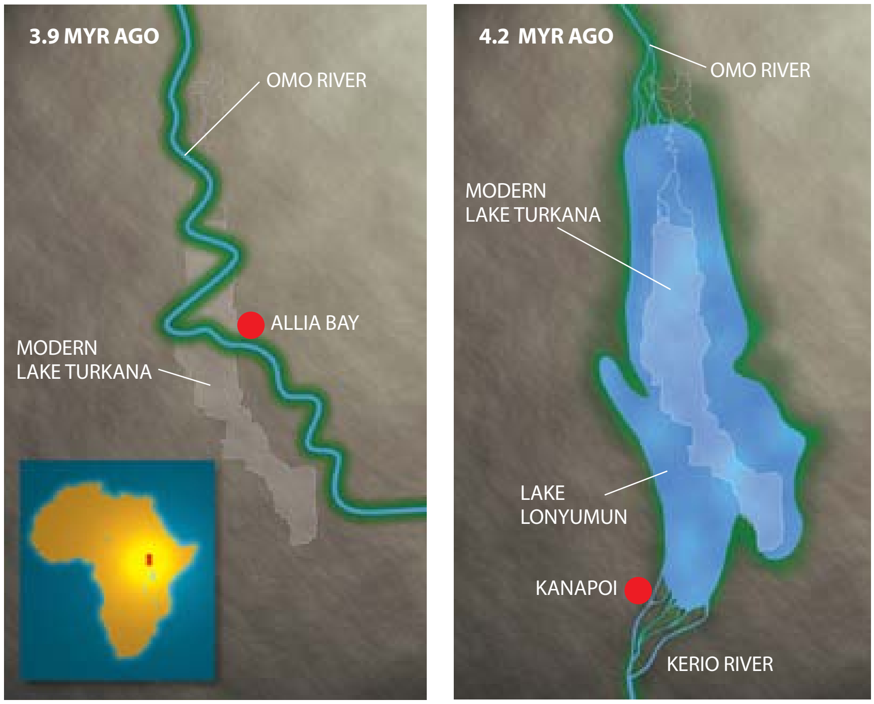
Describing early hominids as either primitive or more advanced is a complex issue. Scientists now have almost decisive molecular evidence that humans and chimpanzees once had a common ancestor and that this lineage had previously split from gorillas. This is why we often use the two living species of chimpanzee (*Pan troglodytes* and *P. paniscus*) to illustrate ancestral traits. But we must remember that since their last common ancestor with humans, chimpanzees have had exactly the same amount of time to evolve as humans have. Determining which features were present in the last common ancestor of humans and chimpanzees is not easy.

But *Ardipithecus,* with its numerous chimplike features, appears to have taken the human fossil record back close to the time of the chimp-human split. More recently, White and his group have found parts of a single *Ardipithecus* skeleton in the Middle Awash region. As White and his team extract these exciting new fossils from the enclosing stone, reconstruct them and prepare them for study, the paleoanthropological community eagerly anticipates the publication of the group's analysis of these astonishing finds.

But even pending White's results, new *Australopithecus* fossil discoveries are offering other surprises, particularly about where these creatures lived. In 1995 a team lead by Michel Brunet of the University of Poitiers announced the identification in Chad of *Australopithecus* fossils believed to be about 3.5 Myr old. The new fossils are very fragmentary—only the front part of a lower jaw and an isolated tooth. In 1996, however, Brunet and his colleagues designated a new species for their specimen: *A. bahrelghazali.* Surprisingly, these fossils were recovered far from either eastern or southern Africa, the only areas where *Australopithecus* had been found until now. The site, in the Bahr el Ghazal region of Chad, lies 2,500 kilometers west of the western part of the Rift Valley, thus extending the range of *Australopithecus* well into the center of Africa.

The *bahrelghazali* fossils debunk a hypothesis about human evolution postulated in the pages of *Scientific American* by Yves Coppens of the College of France [see "East Side Story: The Origin of Humankind," May 1994]; ironically, Coppens is now a member of Brunet's team. Coppens's article proposed that the formation of Africa's Rift Valley subdivided a single ancient species, isolating the ancestors of hominids on the east side from the ancestors of modern apes on the west side. In general, scientists believe such geographical isolation can foster the development of new species by prohibiting continued interbreeding among the original populations. But the new Chad fossils show that early hominids did live west of the Rift Valley. The geographical separation of apes and hominids previously apparent in the fossil record may be more the result of accidental circumstances of geology and discovery than the species' actual ranges.

The fossils of *anamensis* that we have identified should also provide some answers in the long-standing debate over whether early *Australopithecus* species lived in wooded areas or on the open savanna. The outcome of this discussion has important implications: for many years, paleoanthropologists have accepted that upright-walking behavior originated on the savanna, where it most likely provided benefits such as keeping the hot sun off the back or freeing hands for carrying food. Yet our evidence suggests that the earliest bipedal hominid known to date lived at least part of the time in wooded areas. The discoveries of the past several years represent a remarkable spurt in the sometimes painfully slow process of uncovering human evolutionary past. But clearly there is still much more to learn. SA



ANDREW CHRISTIE; SOURCE: FRANK BROWN AND CRAIG FEIBEL (1991)

TURKANA BASIN was home to *anamensis* roughly 4 Myr ago. Around 3.9 Myr ago a river sprawled across the basin (*left*). The fossil site Allia Bay sat within the strip of forest (*green*) that lined this river. Some 4.2 Myr ago a large lake filled the basin (*right*); a second site, Kanapoi, was located on a river delta that fed into the lake.

The Authors

MEAVE LEAKEY and ALAN WALKER, together with Leakey's husband, Richard, have collaborated for many years on the discovery and analysis of early hominid fossils from Kenya. Leakey is head of the division of paleontology at the National Museums of Kenya in Nairobi. Walker is Distinguished Professor of anthropology and biology at Pennsylvania State University. He is a MacArthur Fellow and a member of the American Academy of Arts and Sciences.

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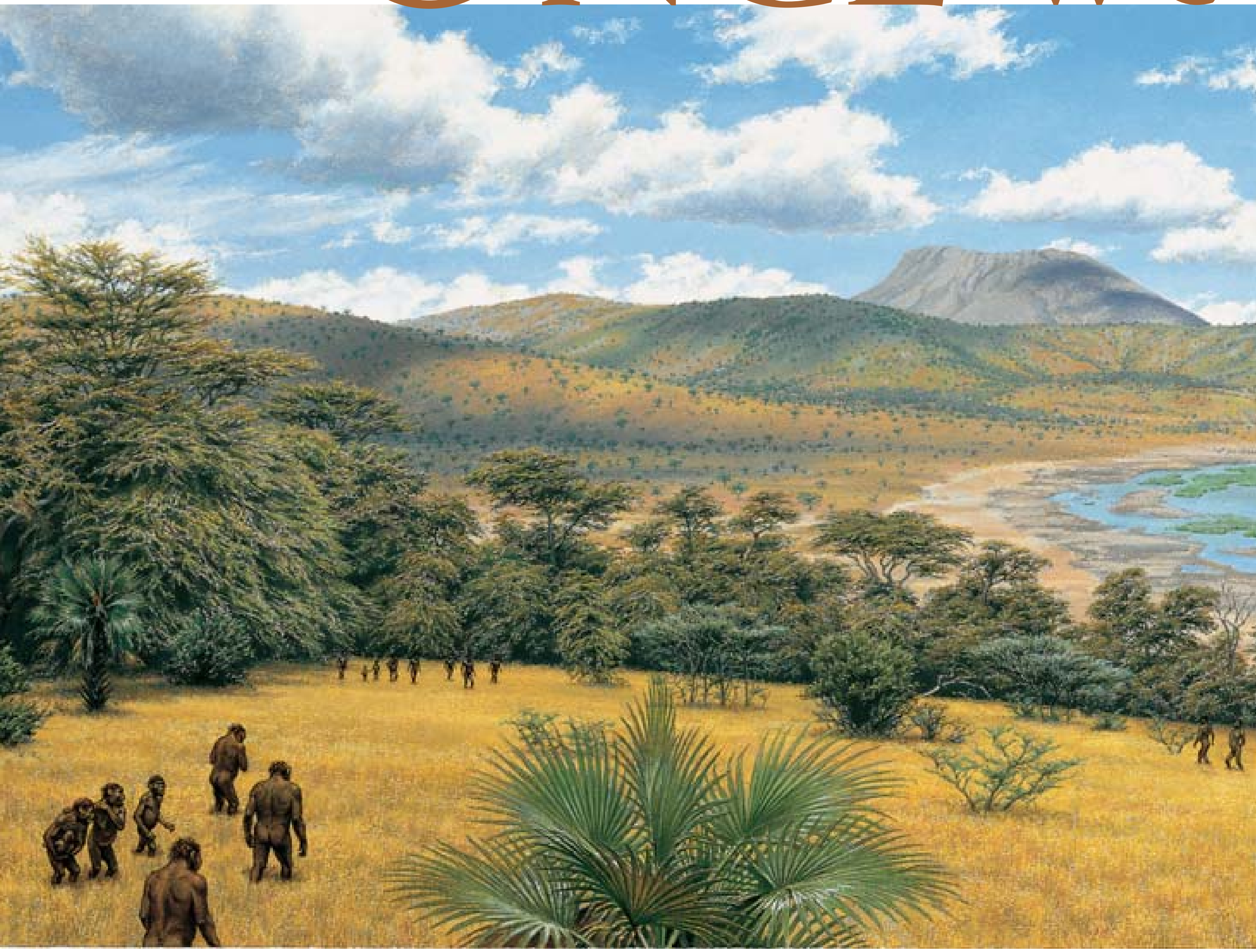
TODAY WE TAKE FOR GRANTED THAT *HOMO SAPIENS*

FOUR MILLION YEARS MANY HOMINID SPECIES

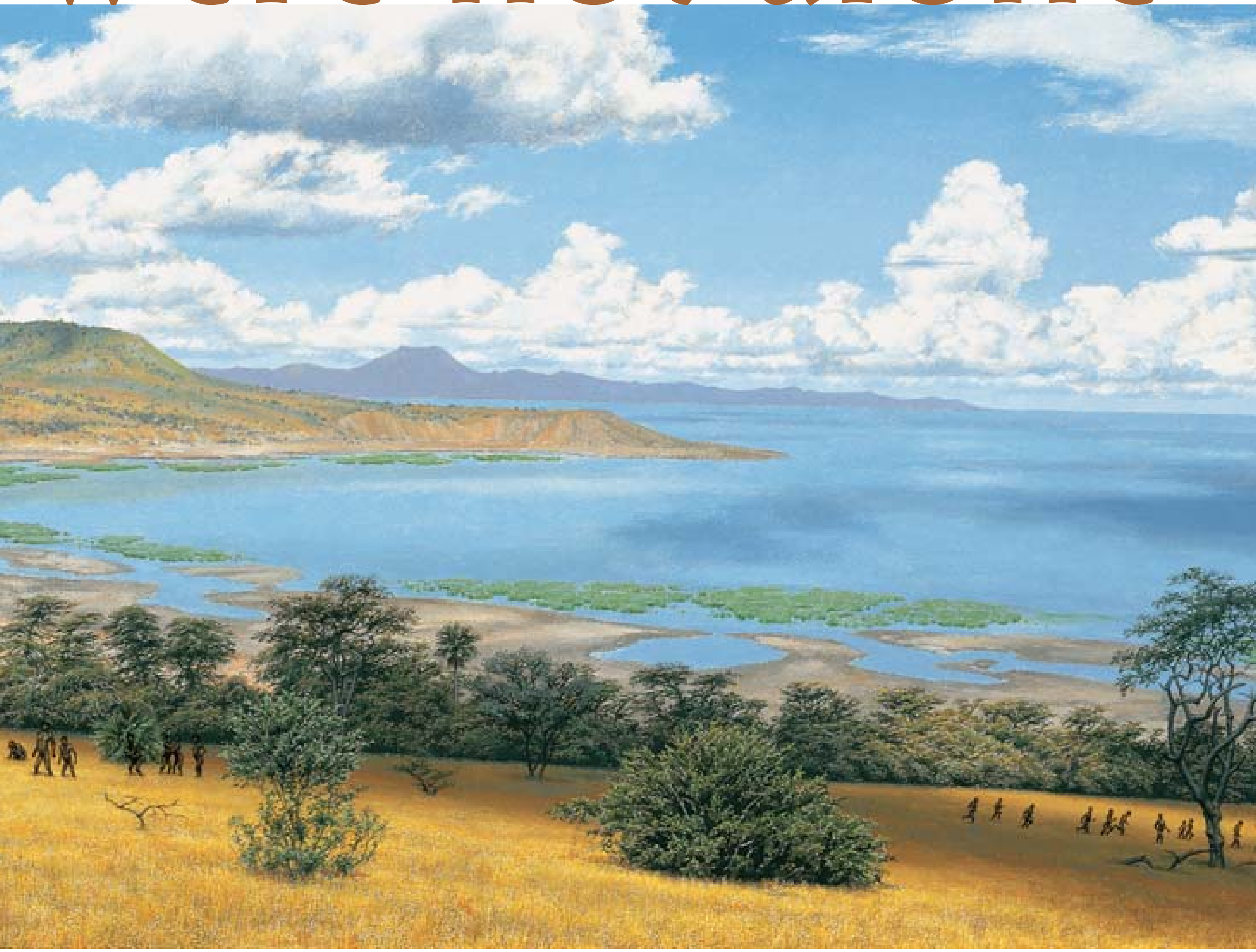
ONCE we



SHARING A SINGLE LANDSCAPE, four kinds of hominids lived about 1.8 million years ago in what is now part of northern Kenya. Although paleoanthropologists have no idea how—or if—these different species interacted, they do know that *Paranthropus boisei, Homo rudolfensis, H. habilis* and *H. ergaster* foraged in the same area around Lake Turkana.

IS THE ONLY HOMINID ON EARTH. YET FOR AT LEAST SHARED THE PLANET. WHAT MAKES US DIFFERENT?

were not alone



By Ian Tattersall • Paintings by Jay H. Matternes

Homo sapiens has had the earth to itself for the past 25,000 years or so, free and clear of competition from other members of the hominid family. This period has evidently been long enough for us to have developed a profound feeling that being alone in the world is an entirely natural and appropriate state of affairs.

So natural and appropriate, indeed, that during the 1950s and 1960s a school of thought emerged that claimed, in essence, that only one species of hominid could have existed at a time because there was simply no ecological space on the planet for more than one culture-bearing species. The "single-species hypothesis" was never very convincing—even in terms of the rather sparse hominid fossil record of 40 years ago. But the implicit scenario of the slow, single-minded transformation of the bent and benighted ancestral hominid into the graceful and gifted modern *H. sapiens* proved powerfully seductive—as fables of frogs becoming princes always are.

So seductive that it was only in the late 1970s, following the discovery of incontrovertible fossil evidence that hominid species coexisted some 1.8 million years ago in what is now northern Kenya, that the single-species hypothesis was abandoned. Yet even then, paleoanthropologists continued to cleave to a rather minimalist interpretation of the fossil record. Their tendency was to downplay the number of species and to group together distinctively different fossils under single, uninformative epithets such as "archaic *Homo sapiens*." As a result, they tended to lose sight of the fact that many kinds of hominids had regularly contrived to coexist.

Although the minimalist tendency persists, recent discoveries and fossil reappraisals make clear that the biological history of hominids resembles that of most other successful animal families. It is marked by diversity rather than by linear progression. Despite this rich history—during which hominid species developed and lived together and competed and rose and fell—*H. sapiens* ultimately emerged as the sole hominid. The reasons for this are generally unknowable, but different interactions between the last coexisting hominids—*H. sapiens* and *H. neanderthalensis*—in two distinct geographical regions offer some intriguing insights.

A Suite of Species

FROM THE BEGINNING, almost from the very moment the earliest hominid biped—the first "australopith"—made its initial hesitant steps away from the forest depths, we have evidence for hominid diversity. The oldest-known potential hominid is *Sahelanthropus tchadensis,* represented by a cranium from the central-western country of Chad [*see illustration on page 26*]. Better known is *Australopithecus anamensis,* from sites in northern Kenya that are about 4.2 million years old.

A. anamensis looks reassuringly similar to the 3.8- to 3.0-million-year-old *Australopithecus afarensis,* a small-brained, big-faced bipedal species to which the famous "Lucy" belonged. Many remnants of *A. afarensis* have been found in various eastern African sites, but some researchers have suggested that the mass of fossils described as *A. afarensis* may contain more than one species, and it is only a matter of time

PARANTHROPUS BOISEI had massive jaws, equipped with huge grinding teeth for a presumed vegetarian diet. Its skull is accordingly strongly built, but it is not known if in body size it was significantly larger than the "gracile" australopiths.

HOMO RUDOLFENSIS was a relatively large-brained hominid, typified by the famous KNM-ER 1470 cranium. Its skull was distinct from the apparently smaller-brained *H. habilis*, but its body proportions are effectively unknown.

until the subject is raised again. In any event, *A. afarensis* was not alone in Africa. A distinctive jaw, from an australopith named *A. bahrelghazali,* was found in 1995 in Chad. It is probably between 3.5 and 3.0 million years old and is thus roughly coeval with Lucy, as is the recently named new form *Kenyanthropus platyops.*

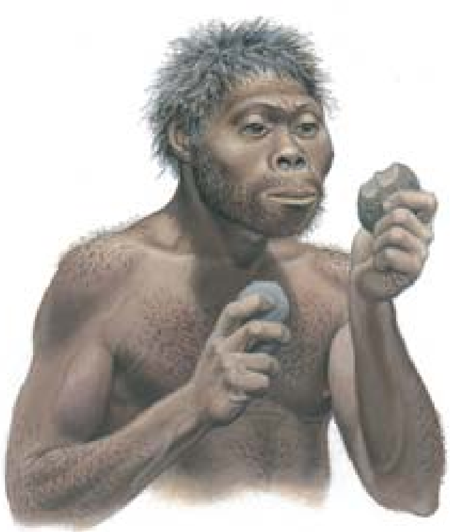
In southern Africa, scientists reported evidence in 1999 of another primitive bipedal hominid species. As yet unnamed and undescribed, this distinctive form is 3.3 million years old. At about three million years ago, the same region begins to yield fossils of *A. africanus,* the first australopith to be discovered (in 1924). This species may have persisted until not much more than two million years ago. A 2.5-million-year-old species from Ethiopia, named *Australopithecus garhi* in 1999, is claimed to fall in an intermediate position between *A. afarensis,* on the one hand, and a larger group that includes more recent australopiths and *Homo,* on the other. Almost exactly the same age is the first representative of the "robust" group of australopiths, *Paranthropus aethiopicus.* This early form is best known from the 2.5-million-year-old "Black Skull" of northern Kenya, and in the period between about 2 and 1.4 million years ago the robusts were represented all over eastern Africa by the familiar *P. boisei.* In South Africa, during the period around 1.6 million years ago, the robusts included the distinctive *P. robustus* and possibly a closely related second species, *P. crassidens.*

I apologize for inflicting this long list of names on readers, but in fact it actually underestimates the number of australopith species that existed. What is more, scientists don't know how long each of these creatures lasted. Nevertheless, even if average species longevity was only a few hundred thousand years, it is clear that from the very beginning the continent of Africa was at least periodically—and most likely continually—host to multiple kinds of hominids.

The appearance of the genus *Homo* did nothing to perturb this pattern. The 2.5- to 1.8-million-year-old fossils from eastern and southern Africa that announce the earliest appearance of *Homo* are an oddly assorted lot and probably a lot more diverse than their conventional assignment to the two species *H. habilis* and *H. rudolfensis* indicates. Still, at Kenya's East Turkana, in the period between 1.9 and 1.8 million years ago, these two species were joined not only by the ubiquitous *P. boisei* but by *H. ergaster,* the first hominid of essentially modern body form. Here, then, is evidence for four hominid species sharing not just the same continent but the same landscape [*see illustration on previous page and below*].

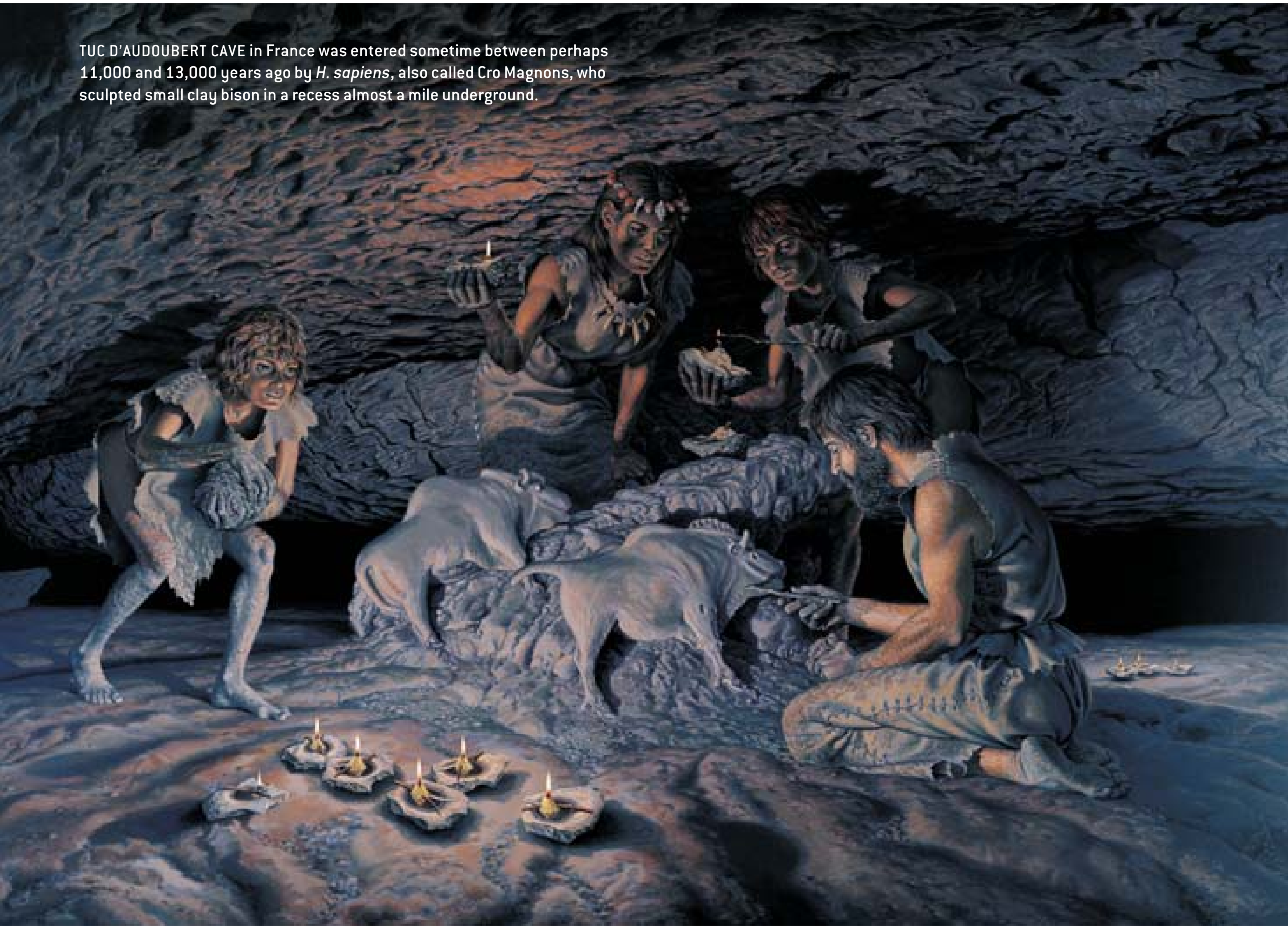
The first exodus of hominids from Africa, presumably in the form of *H. ergaster* or a close relative, opened a vast prospect for further diversification. One could wish for a better record of this movement, and particularly of its dating, but there are indications that hominids of some kind had reached China and Java by about 1.8 million years ago. A lower jaw that may be about the same age from Dmanisi in ex-Soviet Georgia is different from anything else yet found [see "Out of Africa Again … and Again?" by Ian Tattersall; SCIENTIFIC AMERICAN, April 1997]. By the million-year mark *H. erectus* was established in both Java and China, and it is possible that a more robust hominid species was present in Java as well. At the other end of the Eurasian continent, the oldest-known European hominid fragments—from about 800,000 years ago—are highly distinctive and have been dubbed *H. antecessor* by their Spanish discoverers.

About 600,000 years ago, in Africa, we begin to pick up evidence for *H. heidelbergensis,* a species also seen at sites in Europe—and possibly China—between 500,000 to 200,000 years ago. As we learn more about *H. heidelbergensis,* we are likely to find that more than one species is actually represented in this group of fossils. In Europe, *H. heidelbergensis* or a relative gave rise to an endemic group of hominids whose best-known representative was *H. neanderthalensis,* a European and western Asian species that flourished between about 200,000 and 30,000 years ago. The sparse record from Africa suggests that at this time independent develop-



HOMO HABILIS
("handy man") was so named because it was thought to be the maker of the 1.8-million-year-old stone tools discovered at Olduvai Gorge in Tanzania. This hominid fashioned sharp flakes by banging one rock cobble against another.

HOMO ERGASTER,
sometimes called "African *H. erectus,*" had a high, rounded cranium and a skeleton broadly similar to that of modern humans. Although *H. ergaster* clearly ate meat, its chewing teeth are relatively small. The best specimen of this hominid is that of an adolescent from about 1.6 million years ago known as Turkana boy.



TUC D'AUDOUBERT CAVE in France was entered sometime between perhaps 11,000 and 13,000 years ago by *H. sapiens*, also called Cro Magnons, who sculpted small clay bison in a recess almost a mile underground.

ments were taking place there, too—including the emergence of *H. sapiens*. And in Java, possible *H. erectus* fossils from Ngandong were dated to around 40,000 years ago, implying that this area had its own indigenous hominid evolutionary history for perhaps millions of years as well.

The picture of hominid evolution just sketched is a far cry from the "*Australopithecus africanus* begat *Homo erectus* begat *Homo sapiens*" scenario that prevailed 40 years ago—and it is, of course, based to a great extent on fossils that have been discovered since that time. Yet the dead hand of linear thinking still lies heavily on paleoanthropology, and even today quite a few of my colleagues would argue that this scenario overestimates diversity. There are various ways of simplifying the picture, most of them involving the cop-out of stuffing all variants of *Homo* of the past half a million or even two million years into the species *H. sapiens*.

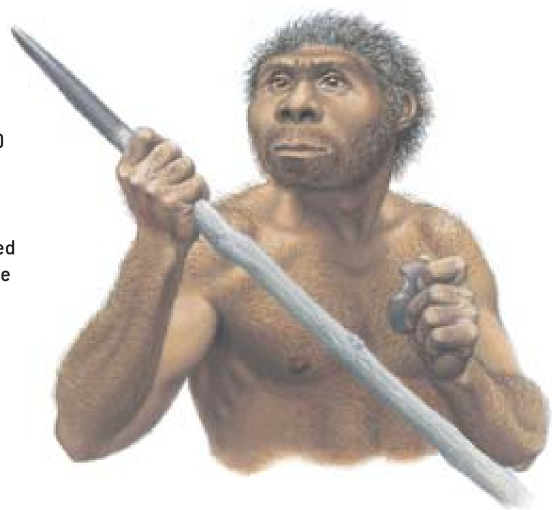
My own view, in contrast, is that the 20 or so hominid species invoked (if not named) above represent a minimum estimate. Not only is the human fossil record as we know it full of largely unacknowledged morphological indications of diversity, but it would be rash to claim that every hominid species that ever existed is represented in one fossil collection or another. And even if only the latter is true, it is still clear that the story of human evolution has not been one of a lone hero's linear struggle.

Instead it has been the story of nature's tinkering: of repeated evolutionary experiments. Our biological history has been one of sporadic events rather than gradual accretions. Over the past five million years, new hominid species have regularly emerged, competed, coexisted, colonized new environments and succeeded—or failed. We have only the dimmest of perceptions of how this dramatic history of innovation and interaction unfolded, but it is already evident that our species, far from being the pinnacle of the hominid evolutionary tree, is simply one more of its many terminal twigs.

The Roots of Our Solitude

ALTHOUGH THIS is all true, *H. sapiens* embodies something that is undeniably unusual and is neatly captured by the fact that we are alone in the world today. Whatever that something is, it is related to how we interact with the external world: it is behavioral, which

HOMINIDS of modern body form most likely emerged in Africa around 150,000 years ago and coexisted with other hominids for a time before emerging as the only species of our family. Until about 30,000 years ago, they overlapped with *H. neanderthalensis* (*left*) in Europe and in the Levant, and they may have been contemporaneous with the *H. erectus* (*right*) then living in Java.



means that we have to look to our archaeological record to find evidence of it. This record begins some 2.5 million years ago with the production of the first recognizable stone tools: simple sharp flakes chipped from parent "cores." We don't know exactly who the inventor was, but chances are that he or she was something we might call an australopith.

This landmark innovation represented a major cognitive leap and had profound long-term consequences for hominids. It also inaugurated a pattern of highly intermittent technological change. It was a full million years before the next significant technological innovation came along: the creation about 1.5 million years ago, probably by *H. ergaster*, of the hand ax. These symmetrical implements, shaped from large stone cores, were the first tools to conform to a "mental template" that existed in the toolmaker's mind. This template remained essentially unchanged for another million years or more, until the invention of "prepared-core" tools by *H. heidelbergensis* or a relative. Here a stone core was elaborately shaped in such a way that a single blow would detach what was an effectively finished implement.

Among the most accomplished practitioners of prepared-core technology were the large-brained, big-faced and low-skulled Neandertals, who occupied Europe and western Asia until about 30,000 years ago. Because they left an excellent record of themselves and were abruptly replaced by modern humans who did the same, the Neandertals furnish us with a particularly instructive yardstick by which to judge our own uniqueness. The stoneworking skills of the Neandertals were impressive, if somewhat stereotyped, but they rarely if ever made tools from other preservable materials. And many archaeologists question the sophistication of their hunting skills.

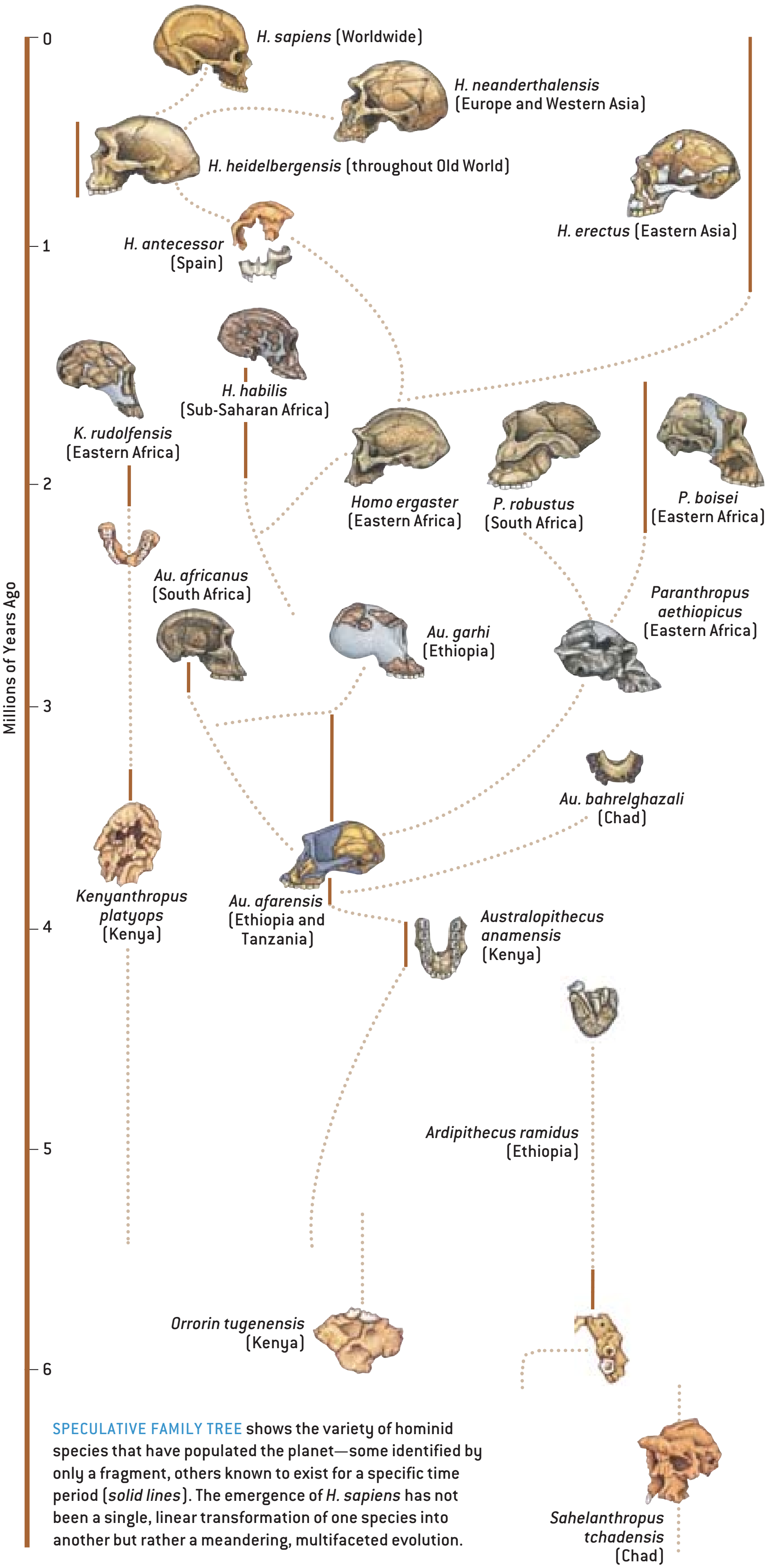
Further, despite misleading early accounts of bizarre Neandertal "bear cults" and other rituals, no substantial evidence has been found for symbolic behaviors among these hominids or for the production of symbolic objects—certainly not before contact had been made with modern humans. Even the occasional Neandertal practice of burying the dead may have been simply a way of discouraging hyenas from making incursions into their living spaces or have a similar mundane explanation. This view arises because Neandertal burials lack the "grave goods" that would attest to ritual and belief in an afterlife. The Neandertals, in other words, though admirable in many ways and for a long time successful in the difficult circumstances of the late ice ages, lacked the spark of creativity that, in the end, distinguished *H. sapiens*.

Although the source of *H. sapiens* as a physical entity is obscure, most evidence points to an African origin perhaps between 150,000 and 200,000 years ago. Modern behavior patterns did not emerge until much later. The best evidence comes from Israel and its surrounding environs, where Neandertals lived about 200,000 years ago or perhaps even earlier. By about 100,000 years ago, they had been joined by anatomically modern *H. sapiens*, and the remarkable thing is that the tools and sites the two hominid species left behind are essentially identical. As far as can be told, these two hominids behaved

THE AUTHOR AND THE ARTIST

IAN TATTERSALL and *JAY H. MATTERNES* have worked together since the early 1990s, notably on the Hall of Human Biology and Evolution at the American Museum of Natural History in New York City and at the Gunma Museum of Natural History in Tomioka, Japan (where the Tuc d'Audoubert mural on the opposite page is installed). Tattersall was born in England and raised in East Africa. He is a curator in the department of anthropology at the American Museum of Natural History. His books include *Becoming Human: Evolution and Human Uniqueness* (Harvest Books, 1999) and *The Last Neanderthal: The Rise, Success, and Mysterious Extinction of Our Closest Human Relatives* (Westview Press, 1999, revised).

Matternes is an artist and sculptor who has for more than 40 years specialized in fossil primates and hominids. In addition to his museum murals, he is well known for his illustrations for books, periodicals and television, including Time/Life Books and *National Geographic.* The research for his depictions has taken him to many parts of the U.S., Canada, Mexico, France, Colombia and Africa.



SPECULATIVE FAMILY TREE shows the variety of hominid species that have populated the planet—some identified by only a fragment, others known to exist for a specific time period (*solid lines*). The emergence of *H. sapiens* has not been a single, linear transformation of one species into another but rather a meandering, multifaceted evolution.

PATRICIA J. WYNNE (*drawings*)

in similar ways despite their anatomical differences. And as long as they did so, they somehow contrived to share the Levantine environment.

The situation in Europe could hardly be more different. The earliest *H. sapiens* sites there date from only about 40,000 years ago, and just 10,000 or so years later the formerly ubiquitous Neandertals were gone. Significantly, the *H. sapiens* who invaded Europe brought with them abundant evidence of a fully formed and unprecedented modern sensibility. Not only did they possess a new "Upper Paleolithic" stoneworking technology based on the production of multiple long, thin blades from cylindrical cores, but they made tools from bone and antler, with an exquisite sensitivity to the properties of these materials.

Even more significant, they brought with them art, in the form of carvings, engravings and spectacular cave paintings; they kept records on bone and stone plaques; they made music on wind instruments; they crafted intricate personal adornments; they afforded some of their dead elaborate burials with grave goods (hinting at social stratification in addition to belief in an afterlife, for not all burials were equally fancy); and their living sites were highly organized, with evidence of sophisticated hunting and fishing. The pattern of intermittent technological innovation was gone, replaced by constant refinement. Clearly, these people were *us*.

Competing Scenarios

IN ALL THESE WAYS, early Upper Paleolithic people contrasted dramatically with the Neandertals. Some Neandertals in Europe seem to have picked up new ways of doing things from the arriving *H. sapiens,* but we have no direct clues as to the nature of the interaction between the two species. In light of the Neandertals' rapid disappearance and of the appalling subsequent record of *H. sapiens,* though, we can reasonably surmise that such interactions were rarely happy for the former. Certainly the repeated pattern found at archaeological sites is one of short-term replacement, and there is no convincing biological ev-

*The pattern of intermittent technological innovation was gone, replaced by **constant refinement**. Clearly, these people were* us.

idence of any intermixing of peoples in Europe.

In the Levant, the coexistence ceased—after about 60,000 years or so—at right about the time that Upper Paleolithic–like tools began to appear. About 40,000 years ago the Neandertals of the Levant yielded to a presumably culturally rich *H. sapiens,* just as their European counterparts had.

The key to the difference between the European and the Levantine scenarios lies, most probably, in the emergence of modern cognition—which, it is reasonable to assume, is equivalent to the advent of symbolic thought. Business had continued more or less as usual right through the appearance of modern bone structure, and only later, with the acquisition of fully modern behavior patterns, did *H. sapiens* become completely intolerant of competition from its nearest—and, evidently, not its dearest—co-inhabitors.

To understand how this change in sensibility occurred, we have to recall certain things about the evolutionary process. First, as in this case, all innovations must necessarily arise *within* preexisting species—for where else can they do so? Second, many novelties arise as "exaptations," features acquired in one context before (often long before) being coopted in a different one. For example, hominids possessed essentially modern vocal tracts for hundreds of thousands of years before the behavioral record gives us any reason to believe that they employed the articulate speech that the peculiar form of this tract permits.

And finally, it is important to bear in mind the phenomenon of emergence—the notion that a chance coincidence gives rise to something totally unexpected. The classic scientific example in this regard is water, whose properties are wholly unpredicted by those of hydrogen and oxygen atoms alone. If we combine these various observations, we can see that, profound as the consequences of achieving symbolic thought may have been, the process whereby it came about was unexceptional.

We have no idea at present how the modern human brain converts a mass of electrical and chemical discharges into what we experience as consciousness. We do know, however, that somehow our lineage passed to symbolic thought from some nonsymbolic precursor state. The only plausible possibility is that with the arrival of anatomically modern *H. sapiens,* existing exaptations were fortuitously linked by a relatively minor genetic innovation to create an unprecedented potential.

Yet even in principle this deduced scenario cannot be the full story, because anatomically modern humans behaved archaically for a long time before adopting modern behaviors. That discrepancy may be the result of the late appearance of some key hardwired innovation not reflected in the skeleton, which is all that fossilizes. But this seems unlikely, because it would have necessitated a wholesale Old World–wide replacement of hominid populations in a very short time, something for which there is no evidence.

It is much more likely that the modern human capacity was born at—or close to—the origin of *H. sapiens,* as an ability that lay fallow until it was activated by a cultural stimulus of some kind. If sufficiently advantageous, this behavioral novelty could then have spread rapidly by cultural contact among populations that already had the potential to acquire it. No population replacement would have been necessary to spread the capability worldwide.

It is impossible to be sure what this innovation might have been, but the best current bet is that it was the invention of language. For language is not simply the medium by which we express our ideas and experiences to one another. Rather it is fundamental to the thought process itself. It involves categorizing and naming objects and sensations in the outer and inner worlds and making associations between resulting mental symbols. It is, in effect, impossible for us to conceive of thought (as we are familiar with it) in the absence of language, and it is the ability to form mental symbols that is the fount of our creativity. Only when we are able to create such symbols can we recombine them and ask such questions as "What if...?"

We do not know exactly how language might have emerged in one local population of *H. sapiens,* although linguists have speculated widely. But we do know that a creature armed with symbolic skills is a formidable competitor—and not necessarily an entirely rational one, as the rest of the living world, including *H. neanderthalensis,* has discovered to its cost. SA

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Stranger in a New Land

By Kate Wong

Stunning finds in the Republic of Georgia upend long-standing ideas about the first hominids to journey out of Africa

We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.
—T. S. Eliot, Four Quartets: "Little Gidding"

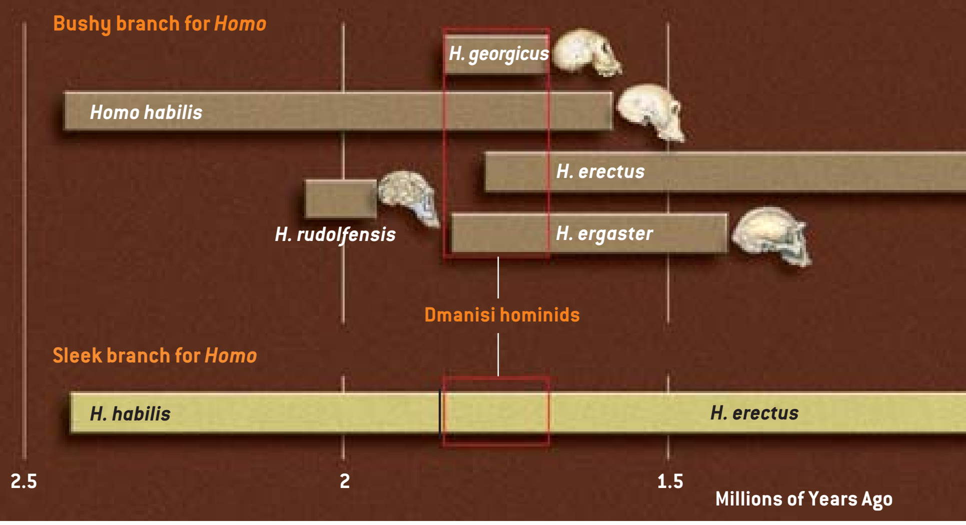
In an age of spacecraft and deep-sea submersibles, we take it for granted that humans are intrepid explorers. Yet from an evolutionary perspective, the propensity to colonize is one of the distinguishing characteristics of our kind: no other primate has ever ranged so far and wide. Humans have not always been such cosmopolitan creatures, however. For most of the seven million years or so over which hominids have been evolving, they remained within the confines of their birthplace, Africa. But at some point, our ancestors began pushing out of the motherland, marking the start of a new chapter in our family history.

JOHN GURCHE

PORTRAIT OF A PIONEER: With a brain half the size of a modern one and a brow reminiscent of *Homo habilis,* this hominid is one of the most primitive members of our genus on record. Paleoartist John Gurche reconstructed this 1.75-million-year-old explorer from a nearly complete teenage *H. erectus* skull and associated mandible found in Dmanisi in the Republic of Georgia. The background figures derive from two partial crania recovered at the site.

TRIMMING THE FAMILY TREE

SPURIOUS SPECIES? Experts vigorously debate just how many species our genus, *Homo*, comprises. The bushiest representations of the *Homo* branch of the family tree contain up to eight species, a number of which were evolutionary dead ends (*top*). Other renditions appear as a streamlined succession of just a few forms (*bottom*). The fossils from Dmanisi—categorized variously as *H. habilis, H. erectus, H. ergaster* and a new species, *H. georgicus*—could be compatible with scenarios of substantial hominid diversity. Alternatively, the anatomical range evident in the Georgian remains could just underscore how variable a species can be. Viewed that way, some pruning may be in order.



It was, until recently, a chapter the fossil record had kept rather hidden from view. Based on the available evidence—a handful of human fossils from sites in China and Java—most paleoanthropologists concluded that the first intercontinental traveling was undertaken by an early member of our genus known as *Homo erectus* starting little more than a million years ago. Long of limb and large of brain, *H. erectus* had just the sort of stride and smarts befitting a trailblazer. Earlier hominids, *H. habilis* and the australopithecines among them, were mostly small-bodied, small-brained creatures, not much bigger than a modern chimpanzee. The *H. erectus* build, in contrast, presaged modern human body proportions.

Curiously, though, the first representatives of *H. erectus* in Africa, a group sometimes referred to as *H. ergaster*, had emerged as early as 1.9 million years ago. Why the lengthy departure delay? In explanation, researchers proposed that it was not until the advent of hand axes and other symmetrically shaped, standardized stone tools (a sophisticated technological culture known as the Acheulean) that *H. erectus* could penetrate the northern latitudes. Exactly what, if anything, these implements could accomplish that the simple Oldowan flakes, choppers and scrapers that preceded them could not is unknown, although perhaps they conferred a better means of butchering. In any event, the oldest accepted traces of humans outside Africa were Acheulean stone tools from a site called ‘Ubeidiya in Israel.

Brawny, brainy, armed with cutting-edge technology—this was the hominid hero Hollywood would have cast in the role, a picture-perfect pioneer. Too perfect, it turns out. Over the past few years, researchers working at a site called Dmanisi in the Republic of Georgia have unearthed a trove of spectacularly well preserved human fossils, stone tools and animal remains dated to around 1.75 million years ago—nearly half a million years older than the ‘Ubeidiya remains. It is by paleoanthropological standards an embarrassment of riches. No other early *Homo* site in the world has yielded such a bounty of bones, presenting scientists with an unprecedented opportunity to peer into the life and times of our hominid forebears. The discoveries have already proved revolutionary: the Georgian hominids are far more primitive in both anatomy and technology than expected, leaving experts wondering not only why early humans first ventured out of Africa but how.

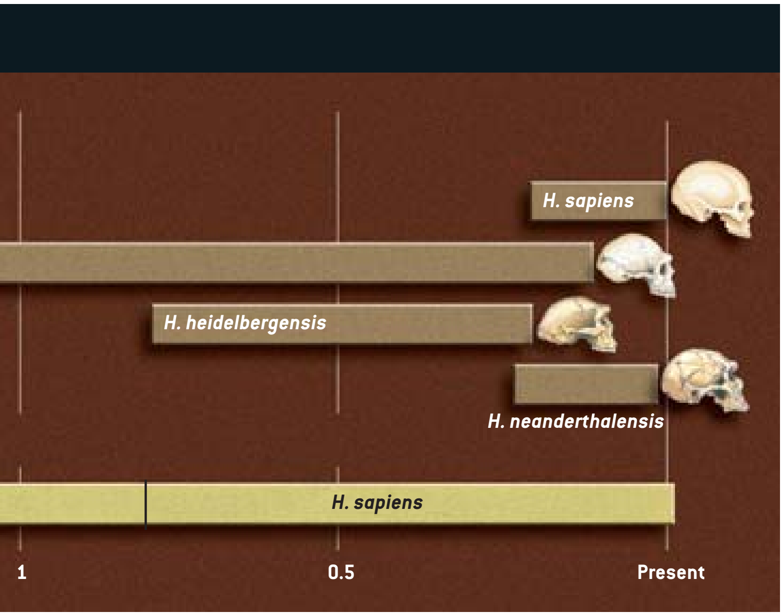
A Dubious Debut

AS THE CROW FLIES, the sleepy modern-day village of Dmanisi lies some 85 kilometers southwest of the Georgian capital of Tbilisi and 20 kilometers north of the country’s border with Armenia, nestled in the lower Caucasus Mountains. During the Middle Ages, Dmanisi was one of the most prominent cities of the day and an important stop along the old Silk Road. The region has thus long intrigued archaeologists, who

Overview/*The First Colonizers*

- Conventional paleoanthropological wisdom holds that the first humans to leave Africa were tall, large-brained people equipped with sophisticated stone tools who began migrating northward around a million years ago.
- New fossil discoveries in the Republic of Georgia are forcing scholars to rethink that scenario in its entirety. The remains are nearly half a million years older than hominid remains previously recognized as the most ancient outside of Africa. They are also smaller and accompanied by more primitive implements than expected.
- These finds raise the question of what prompted our ancestors to leave their natal land. They are also providing scientists with a rare opportunity to study not just a single representative of early *Homo* but a population.

CORNELIA BLIK, PATRICIA J. WYNNE AND EDWARD BELL



have been excavating the crumbling ruins of a medieval citadel there since the 1930s. The first hint that the site might also have a deeper significance came in 1983, when paleontologist Abesalom Vekua of the Georgian Academy of Sciences discovered in one of the grain storage pits the remains of a long-extinct rhinoceros. The holes dug by the citadel's inhabitants had apparently opened a window on prehistory.

The next year, during paleontological excavations, primitive stone tools came to light, bringing with them the tantalizing possibility that fossilized human remains might eventually follow. Finally, in 1991, on the last day of the field season, the crew found what they were looking for: a hominid bone, discovered underneath the skeleton of a saber-toothed cat.

Based on the estimated ages of the associated animal remains, the researchers judged the human fossil—a mandible, or lower jaw, that they attributed to *H. erectus*—to be around 1.6 million years old, which would have made it the oldest known hominid outside of Africa. But when David Lordkipanidze and the late Leo Gabunia, also at the Georgian Academy of Sciences, showed the specimen to some of the biggest names in paleoanthropology at a meeting in Germany later that year, their claims met with skepticism. Humans were not supposed to have made it out of Africa until a million years ago, and the beautifully preserved mandible—every tooth in place—looked too pristine to be as old as the Georgians said it was. Many concluded that the fossil was not *H. erectus* but a later species. Thus, rather than receiving the imprimatur of paleoanthropology's elite, the jaw from Dmanisi came away with question marks.

Undaunted, team members continued work at the site, refining their understanding of its geology and searching for more hominid remains. Their perseverance eventually paid off: in 1999 workers found two skulls just a few feet away from where the mandible had turned up eight years prior. A paper describing the fossils appeared in *Science* the following spring. "That year the fanfare began," recollects Lordkipanidze, who now directs the excavation. The finds established a close relationship between the Dmanisi hominids and African *H. erectus*. Unlike the earliest humans on record from eastern Asia and western Europe, which exhibited regionally distinctive traits, the Dmanisi skulls bore explicit resemblances—in the form of the browridge, for example—to the early African material.

By this time, geologists had nailed down the age of the fossils, which come from deposits that sit directly atop a thick layer of volcanic rock radiometrically dated to 1.85 million years ago. The fresh, unweathered contours of the basalt indicate that little time passed before the fossil-bearing sediments blanketed it, explains C. Reid Ferring of the University of North Texas. And paleomagnetic analyses of the sediments signal that they were laid down close to 1.77 million years ago, when Earth's magnetic polarity reversed, the so-called Matuyama boundary. Furthermore, remains of animals of known antiquity accompany the hominid fossils—a rodent called *Mimomys*, for instance, which lived only between 1.6 and 2.0 million years ago—and a second, 1.76-million-year-old layer of basalt at a nearby site caps the same stratigraphy.

Together the new fossils and dating results clinched the case for Dmanisi being the oldest unequivocal hominid site outside of Africa, pushing the colonization of Eurasia back hundreds of thousands of years. They also toppled the theory that humans could not leave Africa until they had invented Acheulean technology. The Dmanisi tool kit contained only Oldowan-grade implements fashioned from local raw materials.

Pint-Size Pioneer

THE GREAT AGE of the Georgian hominids and the simplicity of their tools came as a shock to many paleoanthropologists. But Dmanisi had even more surprises in store. Last July, Lordkipanidze's team announced that it had recovered a third, virtually complete skull—including an associated mandible—that was one of the most primitive *Homo* specimens on record. Whereas the first two skulls had housed 770 cubic centimeters and 650 cubic centimeters of gray matter, the third had a cranial capacity of just 600 cubic centimeters—less than half the size of a modern brain and considerably smaller than expected for *H. erectus*. Neither was the form of the third skull entirely *erectus*-like. Rather the delicacy of the brow, the projection of the face and the curvature of the rear of the skull evoke *H. habilis*, the presumed forebear of *H. erectus*.

The discovery of the third skull has led to the startling revelation that contrary to the notion that big brains were part and parcel of the first transcontinental migration, some of these early wayfarers were hardly more cerebral than primitive *H. habilis*. Likewise, the Georgian hominids do not appear to have been much larger-bodied than *H. habilis*. Only isolated elements from below the neck have turned up thus far—namely, ribs, clavicles, vertebrae, as well as upper arm, hand and foot bones—and they have yet to be formally described. But it is already clear that "these people were small," asserts team member G. Philip Rightmire of the University of Binghamton.

"This is the first time we have an intermediate between *erectus* and *habilis*," Lordkipanidze observes. Although the fossils

DIGGING DMANISI

DMANISI, REPUBLIC OF GEORGIA, JULY—From the Republic of Georgia's capital, Tbilisi, the village of Dmanisi is just a two-hour drive, yet it seems a world apart from the bustle of the diesel- and dust-choked city. Here in the foothills of the Caucasus Mountains, donkey-drawn carts outnumber cars and the air is fragrant with hay. The locals farm the rich soil and raise sheep, pigs and goats; children spend summer afternoons racing down a stretch of paved road on homemade scooters. Even the roosters appear to lose track of time, crowing not only at daybreak but in the afternoon and evening as well.

The leisurely pace of modern life belies the region's storied past, however. Centuries ago Dmanisi was a seat of great power, situated at a crossroads of Byzantine and Persian trading routes. Today the region is littered with reminders of that bygone era. Haystacklike mounds resolve into ancient Muslim tombs on closer inspection; medieval burials erode out of a hillside after heavy rains; and looming above it all are the imposing ruins of a citadel built on a promontory that once overlooked the Silk Road.

That much about Dmanisi's past has been known for decades. Only recently have scholars learned that long before the rise and fall of the city, this was the dominion of a primitive human ancestor, the first known to march out of Africa and begin colonizing the rest of the Old World some 1.75 million years ago—far earlier than previously thought. It is a realization that still gives David Lordkipanidze pause. Just a dozen years ago he helped to unearth the first hominid bone at Dmanisi. Four skulls, 2,000 stone tools and thousands of ancient animal fossils later, the 40-year-old is deputy director of the Georgian State Museum and head of an excavation many paleo-anthropologists regard as the most spectacular in recent memory. "It is big luck to have these beautiful fossils," he reflects. But it is also "a big responsibility." Indeed, equal parts paleontologist and politician, Lordkipanidze seems to work around the clock, talking on his cell phone late into the night with colleagues and prospective sponsors.

Largely as a result of those efforts, what started as a 10-person team of Georgians and Germans has mushroomed into a 30-strong collaboration of scientists and students from around the world, a number of whom have gathered here for the annual field season. For eight weeks every summer, the Dmanisi field crew surveys, digs and analyzes new finds. It is a shoestring operation. Team members live in a no-frills house a couple miles from the site, typically sleeping four to a tiny room. Electricity is ephemeral at best, hot running water nonexistent.

Every morning at around 8:30, after a breakfast of bread and tea at the picnic tables on the porch, the groggy workers pile into a Russian army-issue lorry left over from the days of Soviet occupation and drive up to the site. In the main excavation area—the 20-meter-by-20-meter square that in 2001 yielded an extraordinarily complete skull and associated lower jaw—each person tends a square-meter plot, meticulously recording the three-dimensional position of each recognizable bone and artifact uncovered during removal of the sediments. These items are then labeled and bagged for later study. Even nondescript pebbles and sediments are saved for further scrutiny: rinsing and sieving them may expose shells, minuscule mammal bones and other important environmental clues.

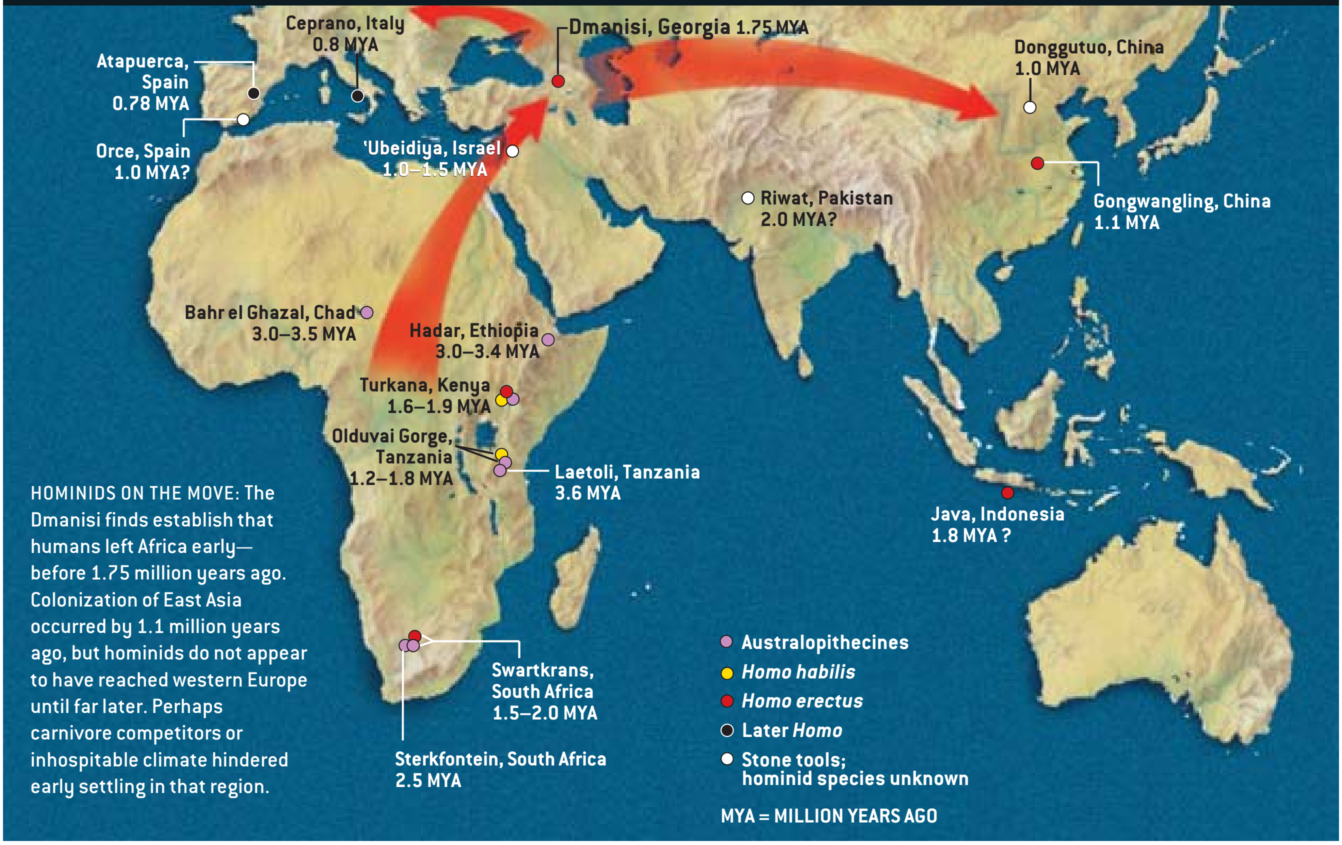
On this particular day the fossil hunters are in especially good spirits. A rare bout of soggy weather left them housebound yesterday (waterlogged bones are too fragile to extract), and this morning's skies threatened to do the same. But the mist draping the mountains has finally burned off, eliciting a chorus of Johnny Nash's "I Can See Clearly Now," sung over the taps and scrapes of trowels, hammers and spackle knives against the chalky sediments. They progress slowly. The excavators are now working in the dense upper layer, which does not yield its bones and stones easily. They must take care not to scratch the remains with their implements, lest the fresh marks be mistaken for ancient ones in later analyses. When noon arrives, the diggers break eagerly for lunch—tomatoes, cucumbers, bread, hard-boiled eggs and pungent, brine-soaked cheese (an acquired taste)—and a catnap on the grass before returning to their squares.

Meanwhile, in a makeshift lab back at camp, other crew members sort through remains brought back earlier by the excavators. Seated at metal-topped wooden tables and sharing an outmoded microscope, they identify the species to which each bone belongs and inspect it for telltale breaks, cut marks and tooth marks. Such data should eventually disclose how the bones accumulated. Preliminary findings from the main excavation suggest that denning saber-toothed cats may have collected them. In contrast, early data from another dig spot about 100 meters away, known as M6, hint that humans worked there—the abundance of smashed bone in this locale is more characteristic of hominid activity than carnivore activity. If so, M6 could provide critical insight into how the primitive Dmanisi hominids eked out an existence in this new land.

When the fossil hunters return with the day's haul at around 4:00, camp is once again the center of activity. An early dinner leaves time for a shower, a game of chess or a trip down the road to visit the enterprising village woman who vends candy, soda, cigarettes and other luxury goods from a small whitewashed building affectionately dubbed the Mall, before a final hour of lab work and the evening tea.

For Lordkipanidze, the work has come full circle. Here at the site where he cut his teeth on paleoanthropology, he hopes to establish a preeminent field school to train aspiring young archaeologists and anthropologists. In the meantime he and his colleagues have plans to test promising spots elsewhere in the region for hominid fossils. Perhaps Georgia's biggest surprises are yet to come. *—K.W.*

AFRICAN EXODUS



HOMINIDS ON THE MOVE: The Dmanisi finds establish that humans left Africa early—before 1.75 million years ago. Colonization of East Asia occurred by 1.1 million years ago, but hominids do not appear to have reached western Europe until far later. Perhaps carnivore competitors or inhospitable climate hindered early settling in that region.

EDWARD BELL

have been provisionally categorized by the team as *H. erectus* based on the presence of certain defining characteristics, he thinks the population represented by the Dmanisi hominids may have been more specifically the rootstock of the species, a missing link between *erectus* and *habilis*.

Other scholars have proposed a more elaborate taxonomic scheme. Noting the anatomical variation evident in the skulls and mandibles recovered so far (including a behemoth jaw unearthed in 2000), Jeffrey Schwartz of the University of Pittsburgh suggested that the Dmanisi fossils might represent two or more early human species. "If that's the case, I'll eat one of them," retorts Milford H. Wolpoff of the University of Michigan at Ann Arbor. A more likely explanation, he offers, is that the rogue mandible comes from a male and the rest of the bones belong to females.

For his part, Lordkipanidze acknowledges that the massive mandible "is a bit of a headache," but given that the fossils all come from the same stratigraphic layer, he reasons, they are probably members of the same population of *H. erectus*. Indeed, one of the most important things about Dmanisi, he says, is that it "gives us an opportunity to think about what variation is." Perhaps some researchers have underestimated how variable *H. erectus* was—a notion that recent discoveries from a site called Bouri in Ethiopia's Middle Awash region and another locality known as Ileret in Kenya support. Lordkipanidze suspects that as the Georgian picture becomes clearer, the sex and species of more than a few African fossils will need reassessing, as will the question of who the founding members of our lineage were. "Maybe *habilis* is not *Homo*," he muses. In fact, a number of experts wonder whether this hominid may have been a species of *Australopithecus* rather than a member of our own genus.

"It is not cladistically compelling to place *habilis* in *Homo*," comments Bernard Wood of George Washington University. Considering its brain and body proportions, characteristics of its jaws and teeth and features related to locomotion, "*habilis* is more australopithlike than it has been made out to be." If so, the emergence of *H. erectus* may well have marked the birth of our genus. What is unclear thus far, Wood says, is whether the Dmanisi hominids fall on the *Homo* side of the divide or the *Australopithecus* one.

Taxonomic particulars aside, the apparently small stature of the Dmanisi people could pose further difficulty for paleoanthropologists. Another popular theory of why humans left Africa, put forth in the 1980s by Alan Walker and Pat Shipman of Pennsylvania State University and elaborated on more recently by William R. Leonard of Northwestern University and his colleagues, proposes that *H. erectus*'s large body size necessitated a higher-quality diet—one that included meat—than that of its smaller predecessors to meet its increased energy needs. Adopting such a regimen would have forced this species to broaden its horizon to find sufficient food—an expansion that might have led it into Eurasia. The exact proportions of these primitive Georgians are pending, but the discovery of individuals considerably smaller than classic *H. erectus* outside of Africa could force experts to rethink that scenario.

Georgia on Their Minds

HOWEVER EARLY HOMINIDS got out of Africa, it is not hard to see why they settled down in southern Georgia. For one, the presence of the Black Sea to the west and the Caspian Sea to the east would have ensured a relatively mild, perhaps even Mediterranean-like, climate. For another, the region appears to have been incredibly diverse ecologically: remains of woodland creatures, such as deer, and grassland animals, such as horses, have all turned up at the site, suggesting a mosaic of forest and savanna habitats. Thus, in practical terms, if the going got tough in one spot, the hominids would not have had to move far to get to a better situation. "The heterogeneity of the environment may have promoted occupation," Ferring says. The Dmanisi site in particular, located on a promontory formed by the confluence of two rivers, may have attracted hominids with its proximity to water, which would have not only quenched their thirst but lured potential prey as well.

"Biologically this was a happening place," remarks Martha Tappen of the University of Minnesota. Of the thousands of mammal fossils that workers have unearthed along with the hominid remains, many come from large carnivores such as saber-toothed cats, panthers, bears, hyenas and wolves. Tappen, whose work centers on figuring out what led to the accumulation of bones at the site, suspects that the carnivores may have been using the water-lined promontory as a trap. "The question," she says, "is whether hominids were, too."

So far Tappen has identified a few cut marks on the animal bones, indicating that, at least on occasion, the Dmanisi settlers ate meat. But whether they scavenged animals brought down by the local carnivores or hunted the beasts themselves is not known. The matter warrants investigation. One of the few remaining hypotheses for what allowed humans to expand their range into northern lands holds that making the transition from the mostly vegetarian diet of the australopithecines to a hunter-gatherer subsistence strategy enabled them to survive the colder winter months, during which plant resources were scarce, if not altogether unavailable. Only further analyses of the mammal bones at the site can elucidate how the Dmanisi humans acquired meat. But Tappen surmises that they were hunting. "When you're a scavenger, the distribution of animals is so unpredictable," she remarks. "I don't think it was their main strategy."

That does not mean that humans were the top carnivores, however. "They could have been both the hunters and the hunted," Tappen observes. Telltale puncture wounds on one of the skulls and gnaw marks on the large mandible reveal that some of the hominids at Dmanisi ended up as cat food.

Outward Bound

THE GEORGIAN REMAINS prove that humans left Africa shortly after *H. erectus* evolved around 1.9 million years ago. But where they went after that is a mystery. The next oldest undisputed fossils in Asia are still just a bit more than a million years old (although controversial sites in Java date to 1.8 million years ago), and those in Europe are only around 800,000 years of age. Anatomically, the Dmanisi people make reasonable ancestors for later *H. erectus* from Asia, but they could instead have been a dead-end group, the leading edge of a wave that washed only partway across Eurasia. There were, scientists concur, multiple migrations out of Africa as well as movements back in. "Dmanisi is just one moment," Lordkipanidze says. "We need to figure out what happened before and after."

Echoing what has become a common refrain in paleoanthropology, the Dmanisi discoveries in some ways raise more questions than they answer. "It's nice that everything's been shaken up," Rightmire reflects, "but frustrating that some of the ideas that seemed so promising eight to 10 years ago don't hold up anymore." A shift toward meat eating might yet explain how humans managed to survive outside of Africa, but what prompted them to push into new territories remains unknown. Perhaps they were following herd animals north. Or maybe it was as simple and familiar as a need to know what lay beyond that hill, or river, or tall savanna grass—a case of prehistoric wanderlust.

The good news is that scientists have only begun plumbing Dmanisi's depths. The fossils recovered thus far come from just a fraction of the site's estimated extent, and new material is emerging from the ground faster than the researchers can formally describe it—a fourth skull unearthed in 2002 is still undergoing preparation and analysis and a new jaw, tibia and ankle bone were unearthed this summer. Topping the fossil hunters' wish list are femurs and pelvises, which will reveal how these early colonizers were proportioned and how efficiently they covered long distances. There is every reason to expect that they will find them. "They've got the potential to have truckloads of fossils," Wolpoff says enthusiastically. "There is work for generations here," Lordkipanidze agrees, noting that he can envision his grandchildren working at the site decades from now. Who knows what new frontiers humans will have explored by then? SA

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MORE TO EXPLORE

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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.

Overview/*Evolved Thinking*

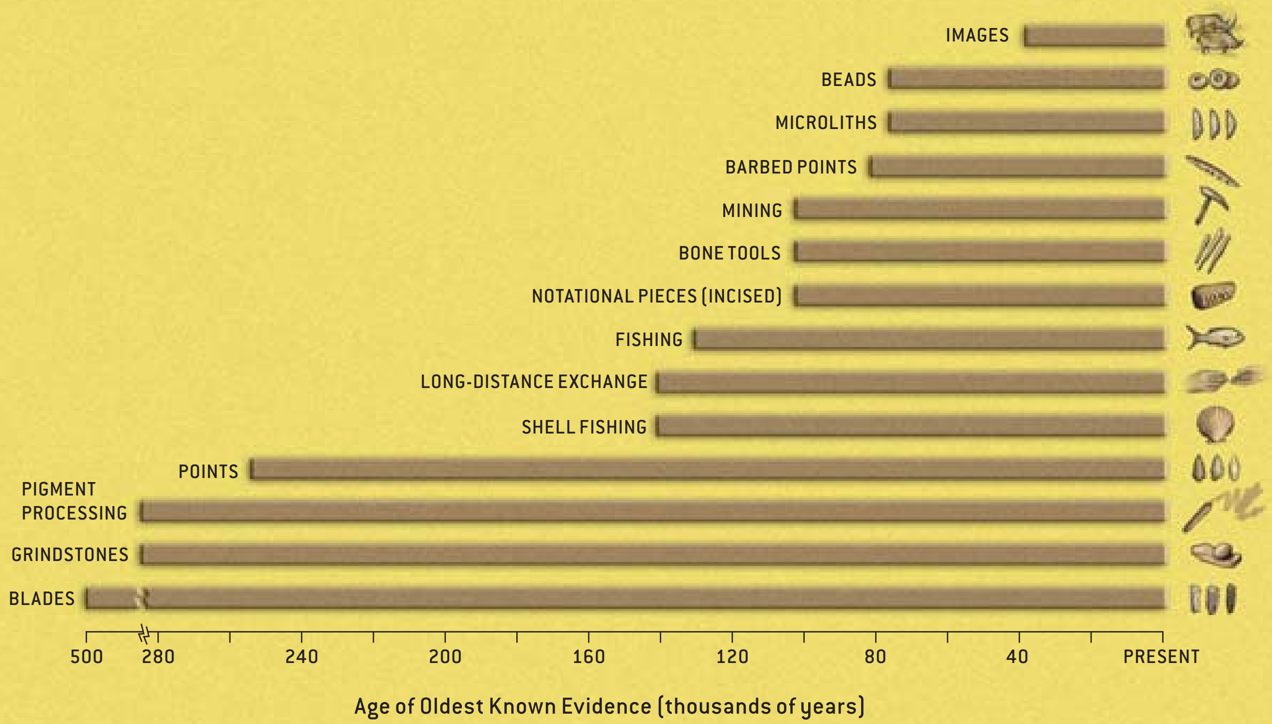
- Archaeologists have traditionally envisioned *Homo sapiens* becoming modern of mind quickly and recently—sometime in the past 50,000 years, more than 100,000 years after attaining anatomical modernity.
- New discoveries in Africa indicate that many of the elements of modern human behavior can be traced 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.

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 rec-ord 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 rela-

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.

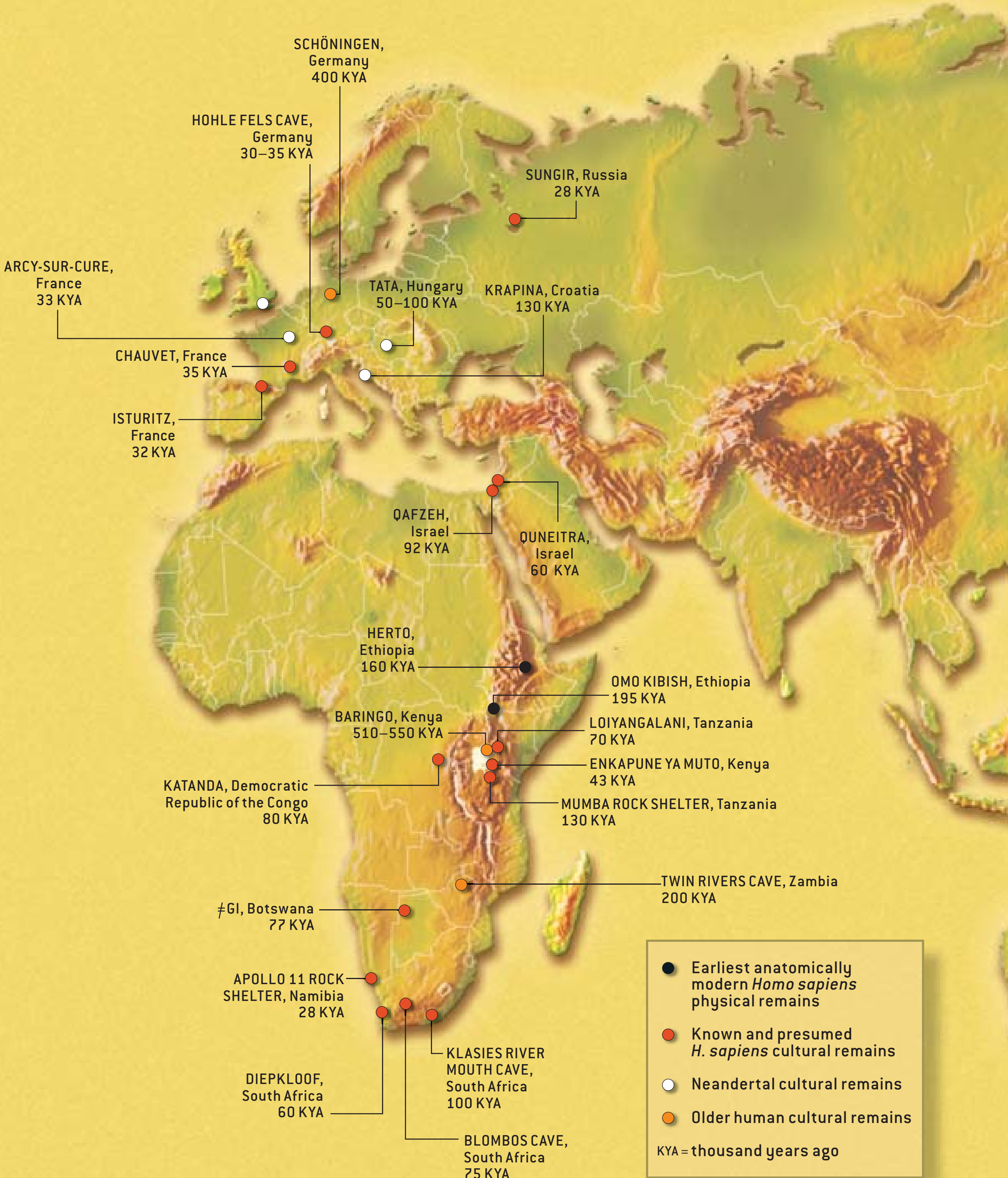
Brain mutation. A genetic mutation roughly 50,000 years ago had the lucky effect of rewiring the human brain such that it was capable of symbolic thought—including language—argues Richard G. Klein of Stanford University. Humans carrying this mutation had a considerable advantage over those who did not and quickly outcompeted and replaced them.

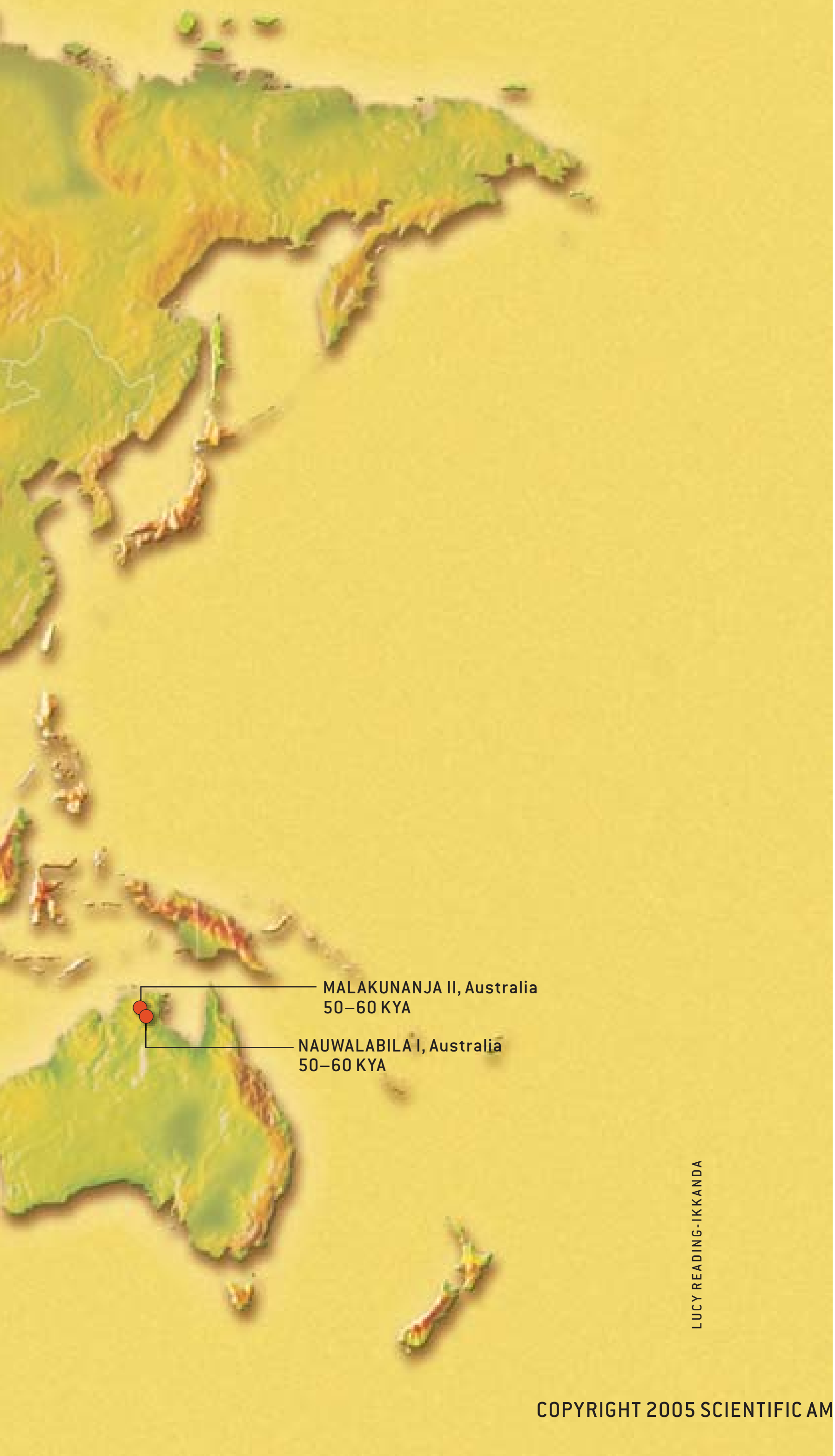
ALISON KENDALL; SOURCE: UPDATED FROM S. MCBREARTY AND A. S. BROOKS IN *JOURNAL OF HUMAN EVOLUTION*, VOL. 39, NO. 5, PAGES 453–563; NOVEMBER 2000

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.





LUCY READING-IKKANDA

tively 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.

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.

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.

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.

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.

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

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.

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.

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."

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 pigment 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

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MORE TO EXPLORE

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THE LITTLEST HUMAN

A spectacular find in Indonesia reveals that a strikingly different hominid shared the earth with our kind in the not so distant past

By Kate Wong

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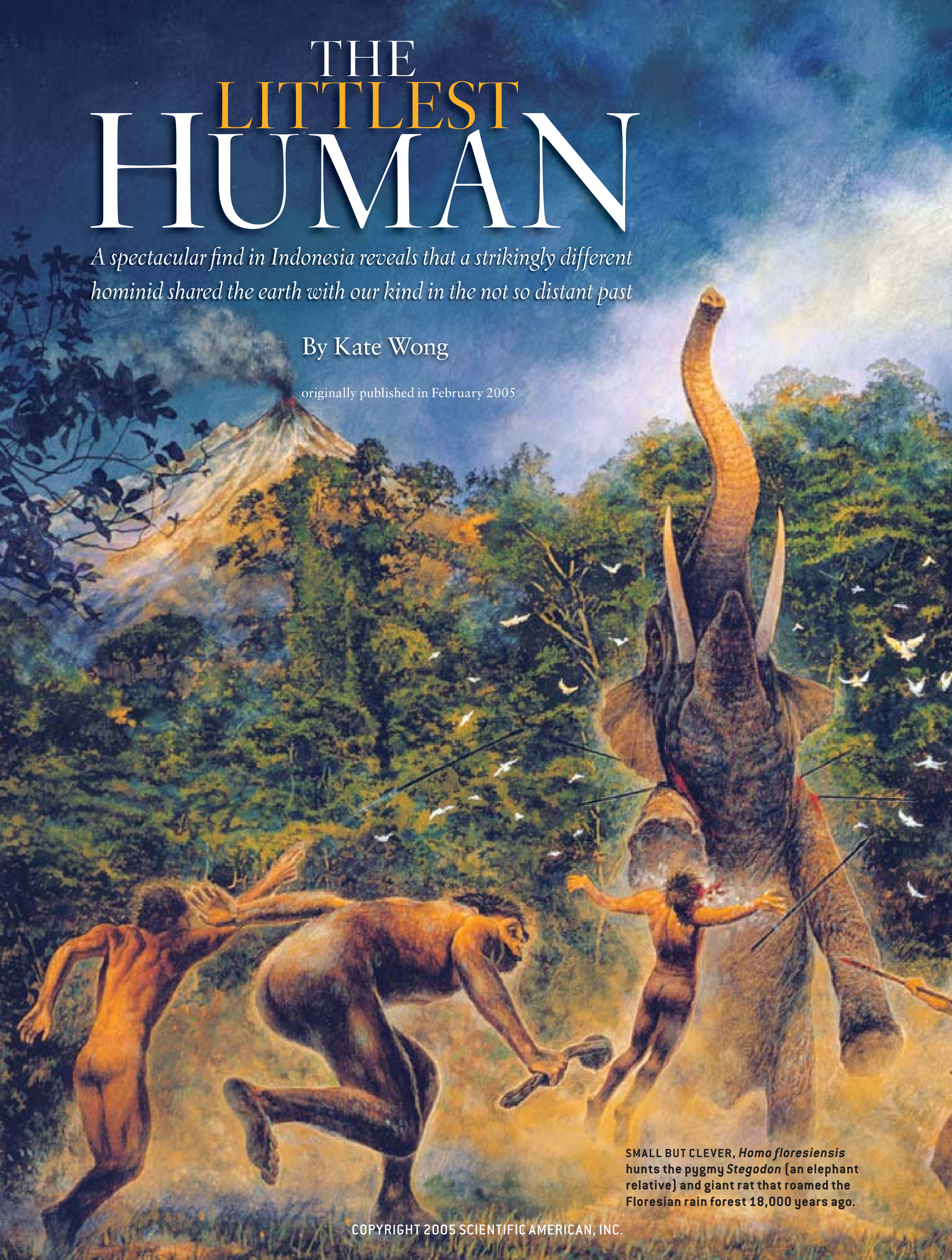


SMALL BUT CLEVER, ***Homo floresiensis*** **hunts the pygmy** ***Stegodon*** **(an elephant relative) and giant rat that roamed the Floresian rain forest 18,000 years ago.**

On the island of Flores in Indonesia, villagers have long told tales of a diminutive, upright-walking creature with a lopsided gait, a voracious appetite, and soft, murmuring speech.

They call it *ebu gogo*, "the grandmother who eats anything." Scientists' best guess was that macaque monkeys inspired the *ebu gogo* lore. But last October, an alluring alternative came to light. A team of Australian and Indonesian researchers excavating a cave on Flores unveiled the remains of a lilliputian human—one that stood barely a meter tall—whose kind lived as recently as 13,000 years ago.

The announcement electrified the paleoanthropology community. *Homo sapiens* was supposed to have had the planet to itself for the past 25 millennia, free from the company of other humans following the apparent demise of the Neandertals in Europe and *Homo erectus* in Asia. Furthermore, hominids this tiny were known only from fossils of australopithecines (Lucy and the like) that lived nearly three million years ago—long before the emergence of *H. sapiens*. No one would have predicted that our own species had a contemporary as small and primitive-looking as the little Floresian. Neither would anyone have guessed that a creature with a skull the size of a grapefruit might have possessed cognitive capabilities comparable to those of anatomically modern humans.

Isle of Intrigue

THIS IS NOT THE FIRST TIME Flores has yielded surprises. In 1998 archaeologists led by Michael J. Morwood of the University of New England in Armidale, Australia, reported having discovered crude stone artifacts some 840,000 years old in the Soa Basin of central Flores. Although no human remains turned up with the tools, the implication was that *H. erectus,* the only hominid known to have lived in Southeast Asia during that time, had crossed the deep waters separating Flores from Java. To the team, the find showed *H. erectus* to be a seafarer, which was startling because elsewhere *H. erectus* had left behind little material culture to suggest that it was anywhere near capable of making watercraft. Indeed, the earliest accepted date for boat-building was 40,000 to 60,000 years ago, when modern humans colonized Australia. (The other early fauna on Flores probably got there by swimming or accidentally drifting over on flotsam. Humans are not strong enough swimmers to have managed that voyage, but skeptics say they may have drifted across on natural rafts.

Hoping to document subsequent chapters of human occupation of the island, Morwood and Radien P. Soejono of the Indonesian Center for Archaeology in Jakarta turned their attention to a large limestone cave called Liang Bua located in western Flores. Indonesian archaeologists had been excavating the cave intermittently since the 1970s, depending

KAZUHIKO SANO (*preceding pages*)

MODERN INDIAN ELEPHANT
(*Elephas maximus*)

Overview/*Mini Humans*

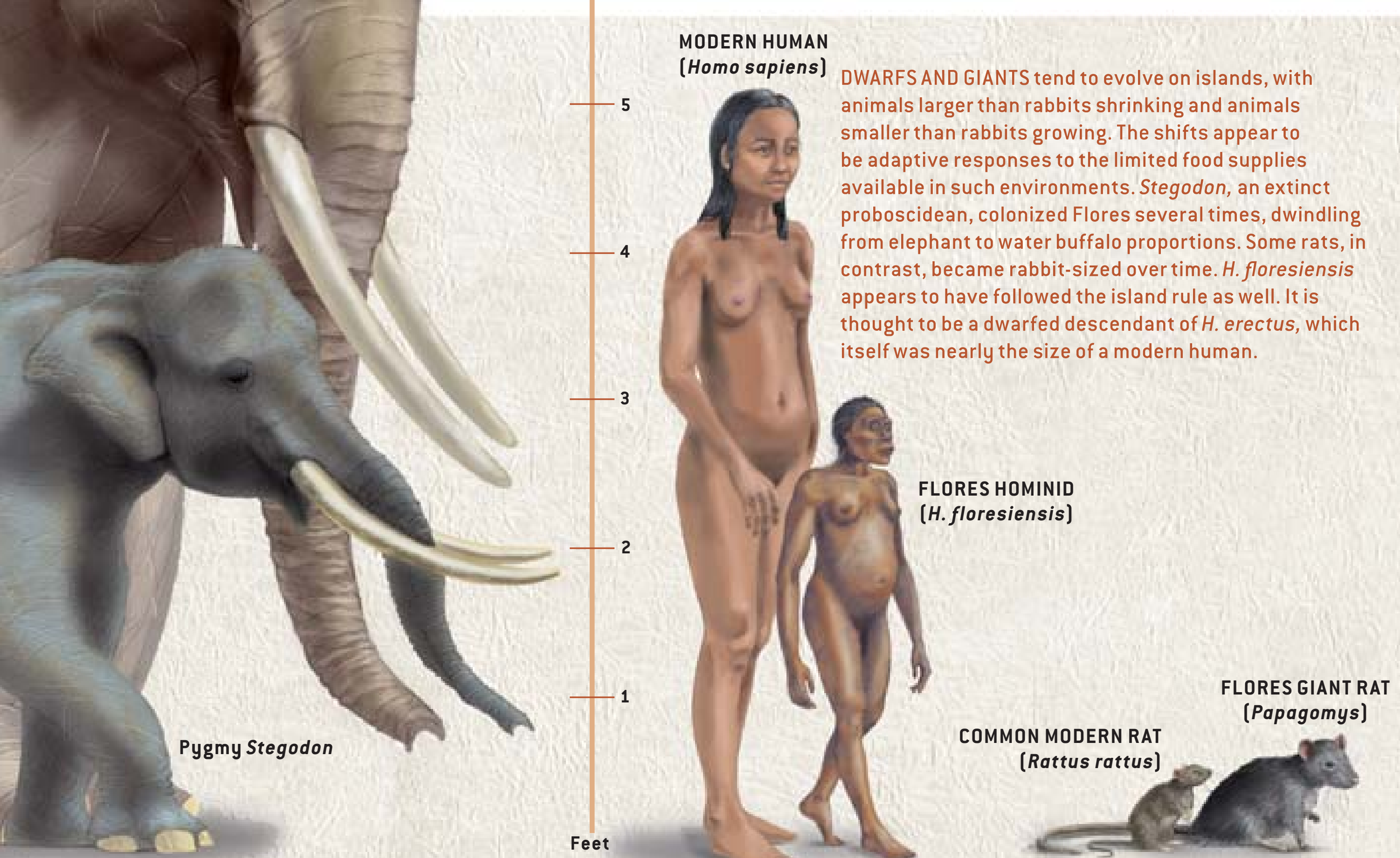
- Conventional wisdom holds that *Homo sapiens* has been the sole human species on the earth for the past 25,000 years. Remains discovered on the Indonesian island of Flores have upended that view.
- The bones are said to belong to a dwarf species of *Homo* that lived as recently as 13,000 years ago.
- Although the hominid is as small in body and brain as the earliest humans, it appears to have made sophisticated stone tools, raising questions about the relation between brain size and intelligence.
- The find is controversial, however—some experts wonder whether the discoverers have correctly diagnosed the bones and whether anatomically modern humans might have made those advanced artifacts.

on funding availability, but workers had penetrated only the uppermost deposits. Morwood and Soejono set their sights on reaching bedrock and began digging in July 2001. Before long, their team's efforts turned up abundant stone tools and bones of a pygmy version of an extinct elephant relative known as *Stegodon*. But it was not until nearly the end of the third season of fieldwork that diagnostic hominid material in the form of an isolated tooth surfaced. Morwood brought a cast of the tooth back to Armidale to show to his department colleague Peter Brown. "It was clear that while the premolar was broadly humanlike, it wasn't from a modern human," Brown recollects. Seven days later Morwood received word that the Indonesians had recovered a skeleton. The Australians boarded the next plane to Jakarta.

Peculiar though the premolar was, nothing could have prepared them for the skeleton, which apart from the missing arms was largely complete. The pelvis anatomy revealed that the individual was bipedal and probably a female, and the tooth eruption and wear indicated that it was an adult. Yet it was only as tall as a modern three-year-old, and its brain was as small as the smallest australopithecine brain known. There were other primitive traits as well, including the broad pelvis and the long neck of the femur. In other respects, however, the specimen looked familiar. Its small teeth and narrow nose, the overall shape of the braincase and the thickness of the cranial bones all evoked *Homo*.

Brown spent the next three months analyzing the enigmatic skeleton, catalogued as LB1 and affectionately nicknamed the Hobbit by some of the team members, after the tiny beings in J.R.R. Tolkien's *The Lord of the Rings* books. The decision about how to classify it did not come easily. Impressed with the characteristics LB1 shared with early hominids such as the australopithecines, he initially proposed that it represented a new genus of human. On further consideration, however, the similarities to *Homo* proved more persuasive. Based on the 18,000-year age of LB1, one might have reasonably expected the bones to belong to *H. sapiens*, albeit a very petite representative. But when Brown and his colleagues considered the morphological characteristics of small-bodied modern humans—including normal ones, such as pygmies, and abnormal ones, such as pituitary dwarfs—LB1 did not seem to fit any of those descriptions. Pygmies have small bodies and large brains—the result of delayed growth during puberty, when the

PORTIA SLOAN



DWARFS AND GIANTS tend to evolve on islands, with animals larger than rabbits shrinking and animals smaller than rabbits growing. The shifts appear to be adaptive responses to the limited food supplies available in such environments. *Stegodon,* an extinct proboscidean, colonized Flores several times, dwindling from elephant to water buffalo proportions. Some rats, in contrast, became rabbit-sized over time. *H. floresiensis* appears to have followed the island rule as well. It is thought to be a dwarfed descendant of *H. erectus,* which itself was nearly the size of a modern human.

brain has already attained its full size. And individuals with genetic disorders that produce short stature and small brains have a range of distinctive features not seen in LB1 and rarely reach adulthood, Brown says. Conversely, he notes, the Flores skeleton exhibits archaic traits that have never been documented for abnormal small-bodied *H. sapiens*.

What LB1 looks like most, the researchers concluded, is a miniature *H. erectus*. Describing the find in the journal *Nature,* they assigned LB1 as well as the isolated tooth and an arm bone from older deposits to a new species of human, *Homo floresiensis*. They further argued that it was a descendant of *H. erectus* that had become marooned on Flores and evolved in isolation into a dwarf species, much as the elephantlike *Stegodon* did.

Biologists have long recognized that mammals larger than rabbits tend to shrink on small islands, presumably as an adaptive response to the limited food supply. They have little to lose by doing so, because these environments harbor few predators. On Flores, the only sizable predators were the Komodo dragon and another, even larger monitor lizard. Animals smaller than rabbits, on the other hand, tend to attain brobdingnagian proportions—perhaps because bigger bodies are more energetically efficient than small ones. Liang Bua has yielded evidence of that as well, in the form of a rat as robust as a rabbit.

But attributing a hominid's bantam size to the so-called island rule was a first. Received paleoanthropological wisdom holds that culture has buffered us humans from many of the selective pressures that mold other creatures—we cope with cold, for example, by building fires and making clothes, rather than evolving a proper pelage. The discovery of a dwarf hominid species indicates that, under the right conditions, humans can in fact respond in the same, predictable way that other large mammals do when the going gets tough. Hints that *Homo* could deal with resource fluxes in this manner came earlier in 2004 from the discovery of a relatively petite *H. erectus* skull from Olorgesailie in Kenya, remarks Richard Potts of the Smithsonian Institution, whose team recovered the bones. "Getting small is one of the things *H. erectus* had in its biological tool kit," he says, and the Flores hominid seems to be an extreme instance of that.

Curiouser and Curiouser

H. FLORESIENSIS's teeny brain was perplexing. What the hominid reportedly managed to accomplish with such a modest organ was nothing less than astonishing. Big brains are a hallmark of human evolution. In the space of six million to seven million years, our ancestors more than tripled their cranial capacity, from some 360 cubic centimeters in *Sahelanthropus,* the earliest putative hominid, to a whopping 1,350 cubic centimeters on average in modern folks. Archaeological evidence indicates that behavioral complexity increased correspondingly. Experts were thus fairly certain that large brains are a prerequisite for advanced cultural practices. Yet whereas the pea-brained australopithecines left behind only crude stone tools at best (and most seem not to have done any stone working at all), the comparably gray-matter-impoverished *H. floresiensis* is said to have manufactured implements that exhibit a level of sophistication elsewhere associated exclusively with *H. sapiens*.

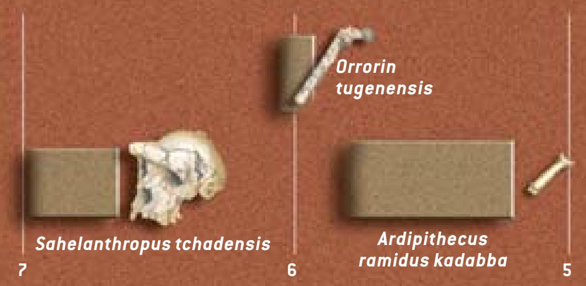
The bulk of the artifacts from Liang Bua are simple flake tools struck from volcanic rock and chert, no more advanced than the implements made by late australopithecines and early *Homo*. But mixed in among the pygmy *Stegodon* remains excavators found a fancier set of tools, one that included finely worked points, large blades, awls and small blades that may have been hafted for use as spears. To the team, this association suggests that *H. floresiensis* regularly hunted *Stegodon*. Many of the *Stegodon* bones are those of young individuals that one *H. floresiensis* might have been able to bring down alone. But some belonged to adults that weighed up to half a ton, the hunting and transport of which must have been a coordinated group activity—one that probably required language, surmises team member Richard G. ("Bert") Roberts of the University of Wollongong in Australia.

The discovery of charred animal remains in the cave suggests that cooking, too, was part of the cultural repertoire of *H. floresiensis*. That a hominid as cerebrally limited as this one might have had control of fire gives pause. Humans are not thought to have tamed flame until relatively late in our collective cognitive development: the earliest unequivocal evidence of fire use comes from 200,000-year-old hearths in Europe that were the handiwork of the large-brained Neandertals.

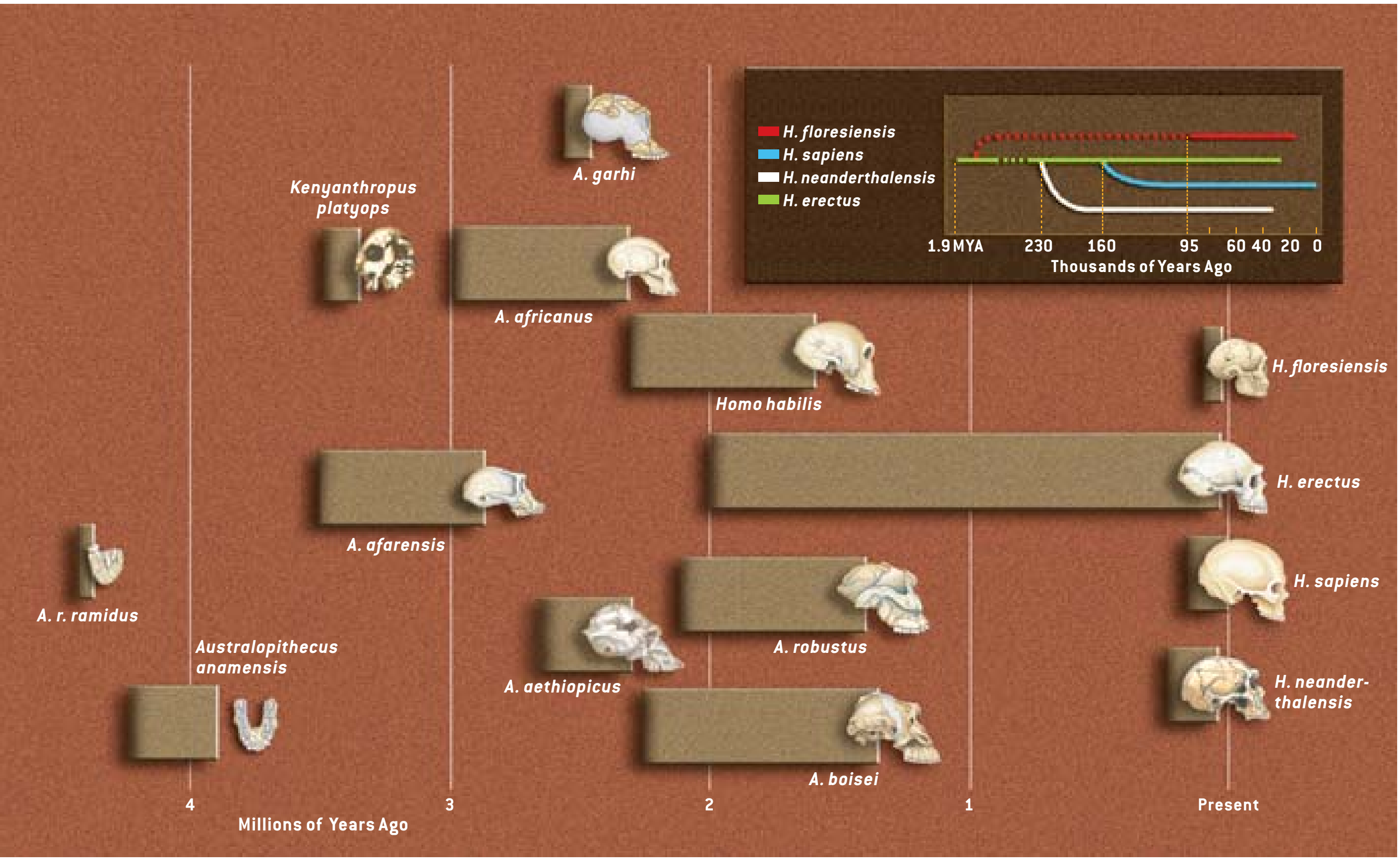
If the *H. floresiensis* discoverers are correct in their interpretation, theirs is one of the most important paleoanthropological finds in decades. Not only does it mean that another species of human coexisted with our ancestors just yesterday

The Times of Their Lives

Adding a twig to the family tree of humans, Peter Brown of the University of New England in Armidale, Australia, and his colleagues diagnosed the hominid remains from Flores as a new species of Homo, *H. floresiensis*. This brings the number of hominid forms alive at the time of early *H. sapiens* to four if Neandertals are considered a species separate from our own, as shown here. Brown believes that *H. floresiensis* descended from *H. erectus* (*inset*). Others hypothesize that it is an aberrant *H. sapiens* or *H. erectus* or an offshoot of the earlier and more primitive habilines or australopithecines.



PATRICIA J. WYNNE, CORNELIA BLIK AND EDWARD BELL



in geological terms, and that our genus is far more variable than expected, it raises all sorts of questions about brain size and intelligence. Perhaps it should come as no surprise, then, that controversy has accompanied their claims.

Classification Clash

IT DID NOT TAKE LONG for alternative theories to surface. In a letter that ran in the October 31 edition of Australia's *Sunday Mail,* just three days after the publication of the *Nature* issue containing the initial reports, paleoanthropologist Maciej Henneberg of the University of Adelaide countered that a pathological condition known as microcephaly (from the Greek for "small brain") could explain LB1's unusual features. Individuals afflicted with the most severe congenital form of microcephaly, primordial microcephalic dwarfism, die in childhood. But those with milder forms, though mentally retarded, can survive into adulthood. Statistically comparing the head and face dimensions of LB1 with those of a 4,000-year-old skull from Crete that is known to have belonged to a microcephalic, Henneberg found no significant differences between the two. Furthermore, he argued, the isolated forearm bone found deeper in the deposit corresponds to a height of 151 to 162 centimeters—the stature of many modern women and some men, not that of a dwarf—suggesting that larger-bodied people, too, lived at Liang Bua. In Henneberg's view, these findings indicate that LB1 is more likely a microcephalic *H. sapiens* than a new branch of *Homo.*

Susan C. Antón of New York University disagrees with that assessment. "The facial morphology is completely different in microcephalic [modern] humans," and their body size is normal, not small, she says. Antón questions whether LB1 warrants a new species, however. "There's little in the shape that differentiates it from *Homo erectus,*" she notes. One can argue that it's a new species, Antón allows, but the difference in shape between LB1 and *Homo erectus* is less striking than that between a Great Dane and a Chihuahua. The possibility exists that the LB1 specimen is a *H. erectus* individual with a pathological growth condition stemming from microcephaly or nutritional deprivation, she observes.

But some specialists say the Flores hominid's anatomy exhibits a more primitive pattern. According to Colin P. Groves of the Australian National University and David W. Cameron of the University of Sydney, the small brain, the long neck of the femur and other characteristics suggest an ancestor along the lines of *Homo habilis,* the earliest member of our genus, rather than the more advanced *H. erectus.* Milford H. Wolpoff of the University of Michigan at Ann Arbor wonders whether the Flores find might even represent an offshoot of *Australopithecus.* If LB1 is a descendant of *H. sapiens* or *H. erectus,* it is hard to imagine how natural selection left her with a brain that's even smaller than expected for her height, Wolpoff says. Granted, if she descended from *Australopithecus,* which had massive jaws and teeth, one has to account for her relatively delicate jaws and dainty dentition. That, however, is a lesser evolutionary conundrum than the one posed by her tiny brain, he asserts. After all, a shift in diet could explain the reduced chewing apparatus, but why would selection downsize intelligence?

Finding an australopithecine that lived outside of Africa—

not to mention all the way over in Southeast Asia—18,000 years ago would be a first. Members of this group were thought to have died out in Africa one and a half million years ago, never having left their mother continent. Perhaps, researchers reasoned, hominids needed long, striding limbs, large brains and better technology before they could venture out into the rest of the Old World. But the recent discovery of 1.8 million-year-old *Homo* fossils at a site called Dmanisi in the Republic of Georgia refuted that explanation—the Georgian hominids were primitive and small and utilized tools like those australopithecines had made a million years before. Taking that into consideration, there is no a priori reason why australopithecines (or habilines, for that matter) could not have colonized other continents.

Home of the Hobbit

Troubling Tools

YET IF *AUSTRALOPITHECUS* made it out of Africa and survived on Flores until quite recently, that would raise the question of why no other remains supporting that scenario have turned up in the region. According to Wolpoff, they may have: a handful of poorly studied Indonesian fossils discovered in the 1940s have been variously classified as *Australopithecus*, *Meganthropus* and, most recently, *H. erectus*. In light of the Flores find, he says, those remains deserve reexamination.

Many experts not involved in the discovery back Brown and Morwood's taxonomic decision, however. "Most of the differences [between the Flores hominid and known members of *Homo*], including apparent similarities to australopithecines, are almost certainly related to very small body mass," declares David R. Begun of the University of Toronto. That is, as the Flores people dwarfed from *H. erectus*, some of their anatomy simply converged on that of the likewise little australopithecines. Because LB1 shares some key derived features with *H. erectus* and some with other members of *Homo*, "the most straightforward option is to call it a new species of *Homo*," he remarks. "It's a fair and reasonable interpretation," *H. erectus* expert G. Philip Rightmire of Binghamton University agrees. "That was quite a little experiment in Indonesia."

Even more controversial than the position of the half-pint human on the family tree is the notion that it made those advanced-looking tools. Stanford University paleoanthropologist Richard Klein notes that the artifacts found near LB1 appear to include few, if any, of the sophisticated types found elsewhere in the cave. This brings up the possibility that the modern-looking tools were produced by modern humans, who could have occupied the cave at a different time. Further excavations are necessary to determine the stratigraphic relation between the implements and the hominid remains, Klein opines. Such efforts may turn up modern humans like us. The question then, he says, will be whether there were two species at the site or whether modern humans alone occupied Liang Bua—in which case LB1 was simply a modern who experienced a growth anomaly.

Stratigraphic concerns aside, the tools are too advanced and too large to make manufacture by a primitive, diminutive hominid likely, Groves contends. Although the Liang Bua implements allegedly date back as far as 94,000 years ago, which the team argues makes them too early to be the handiwork of *H. sapiens*, Groves points out that 67,000-year-old tools have turned up in Liujiang, China, and older indications of a modern human presence in the Far East might yet emerge. "*H. sapiens*, once it was out of Africa, didn't take long to spread into eastern Asia," he comments.

"At the moment there isn't enough evidence" to establish

Scholars were stunned a decade ago to learn that *H. erectus* might have survived on the island of Java in Indonesia until 25,000 years ago, well after the arrival of *H. sapiens* in the region and even after the disappearance of Europe's Neandertals. The recent revelation that a third hominid, dubbed *H. floresiensis,* lived in the area until just 13,000 years ago has proved even more provocative.

Archaeologists recovered the remains from a large limestone cave known as Liang Bua located in western Flores. No one knows exactly how humans first reached the island—they may have made the requisite sea crossings by boat, or they may have drifted over on natural rafts quite by accident.

Geographically, Javan *H. erectus* is a good candidate for the ancestor of *H. floresiensis.* But resemblances to specimens from Africa and the Republic of Georgia raise the question of whether *H. floresiensis* stemmed from a different hominid migration into Southeast Asia from the one that gave rise to Javan *H. erectus.* Future excavations on Flores and other Indonesian islands (*detail*) may cast light on these mysteries.

LAURIE GRACE AND EDWARD BELL (*maps*)

that *H. floresiensis* created the advanced tools, concurs Bernard Wood of George Washington University. But as a thought experiment, he says, "let's pretend that they did." In that case, "I don't have a clue about brain size and ability," he confesses. If a hominid with no more gray matter than a chimp has can create a material culture like this one, Wood contemplates, "why did it take people such a bloody long time to make tools" in the first place?

"If *Homo floresiensis* was capable of producing sophisticated tools, we have to say that brain size doesn't add up to much," Rightmire concludes. Of course, humans today exhibit considerable variation in gray matter volume, and great thinkers exist at both ends of the spectrum. French writer Jacques Anatole François Thibault (also known as Anatole France), who won the 1921 Nobel Prize for Literature, had a cranial capacity of only about 1,000 cubic centimeters; England's General Oliver Cromwell had more than twice that. "What that means is that once you get the brain to a certain size, size no longer matters, it's the organization of the brain," Potts states. At some point, he adds, "the internal wiring of the brain may allow competence even if the brain seems small."

LB1's brain is long gone, so how it was wired will remain a mystery. Clues to its organization may reside on the interior of the braincase, however. Paleontologists can sometimes obtain latex molds of the insides of fossil skulls and then create plaster endocasts that reveal the morphology of the organ. Because LB1's bones are too fragile to withstand standard casting procedures, Brown is working on creating a virtual endocast based on CT scans of the skull that he can then use to generate a physical endocast via stereolithography, a rapid-prototyping technology.

"If it's a little miniature version of an adult human brain, I'll be really blown away," says paleoneurologist Dean Falk of the University of Florida. Then again, she muses, what happens if the convolutions look chimplike? Specialists have long wondered whether bigger brains fold differently simply because they are bigger or whether the reorganization reflects selection for increased cognition. "This specimen could conceivably answer that," Falk observes.

Return to the Lost World

SINCE SUBMITTING their technical papers to *Nature,* the Liang Bua excavators have reportedly recovered the remains of another five or so individuals, all of which fit the *H. floresiensis* profile. None are nearly so complete as LB1, whose long arms turned up during the most recent field season. But they did unearth a second lower jaw that they say is identical in size and shape to LB1's. Such duplicate bones will be critical to their case that they have a population of these tiny humans (as opposed to a bunch of scattered bones from one person). That should in turn dispel concerns that LB1 was a diseased individual.

Additional evidence may come from DNA: hair samples possibly from *H. floresiensis* are undergoing analysis at the University of Oxford, and the hominid teeth and bones may contain viable DNA as well. "Tropical environments are not the best for long-term preservation of DNA, so we're not holding our breath," Roberts remarks, "but there's certainly no harm in looking."

The future of the bones (and any DNA they contain) is uncertain, however. In late November, Teuku Jacob of the Gadjah Mada University in Yogyakarta, Java, who was not involved in the discovery or the analyses, had the delicate specimens transported from their repository at the Indonesian Center for Archaeology to his own laboratory with Soejono's assistance. Jacob, the dean of Indonesian paleoanthropology, thinks LB1 was a microcephalic and allegedly ordered the transfer of it and the new, as yet undescribed finds for examination and safekeeping, despite strong objections from other staff members at the center. At the time this article was going to press, the team was waiting for Jacob to make good on his promise to return the remains to Jakarta by January 1 of this year, but his reputation for restricting scientific access to fossils has prompted pundits to predict that the bones will never be studied again.

Efforts to piece together the *H. floresiensis* puzzle will proceed, however. For his part, Brown is eager to find the tiny hominid's large-bodied forebears. The possibilities are threefold, he notes. Either the ancestor dwarfed on Flores (and was possibly the maker of the 840,000-year-old Soa Basin tools), or it dwindled on another island and later reached Flores, or the ancestor was small before it even arrived in Southeast Asia. In fact, in many ways, LB1 more closely resembles African *H. erectus* and the Georgian hominids than the geographically closer Javan *H. erectus,* he observes. But whether these similarities indicate that *H. floresiensis* arose from an earlier *H. erectus* foray into Southeast Asia than the one that produced Javan *H. erectus* or are merely coincidental results of the dwarfing process remains to be determined. Future excavations may connect the dots. The team plans to continue digging on Flores and Java and will next year begin work on other Indonesian islands, including Sulawesi to the north.

The hominid bones from Liang Bua now span the period from 95,000 to 13,000 years ago, suggesting to the team that the little Floresians perished along with the pygmy *Stegodon* because of a massive volcanic eruption in the area around 12,000 years ago, although they may have survived later farther east. If *H. erectus* persisted on nearby Java until 25,000 years ago, as some evidence suggests, and *H. sapiens* had arrived in the region by 40,000 years ago, three human species lived cheek by jowl in Southeast Asia for at least 15,000 years. And the discoverers of *H. floresiensis* predict that more will be found. The islands of Lombok and Sumbawa would have been natural stepping-stones for hominids traveling from Java or mainland Asia to Flores. Those that put down roots on these islands may well have set off on their own evolutionary trajectories.

Perhaps, it has been proposed, some of these offshoots of the *Homo* lineage survived until historic times. Maybe they still live in remote pockets of Southeast Asia's dense rain forests, awaiting (or avoiding) discovery. On Flores, oral histories hold that the *ebu gogo* was still in existence when Dutch colonists settled there in the 19th century. And Malay folklore describes another small, humanlike being known as the *orang pendek* that supposedly dwells on Sumatra to this day.

"Every country seems to have myths about these things," Brown reflects. "We've excavated a lot of sites around the world, and we've never found them. But then [in September 2003] we found LB1." Scientists may never know whether tales of the *ebu gogo* and *orang pendek* do in fact recount actual sightings of other hominid species, but the newfound possibility will no doubt spur efforts to find such creatures for generations to come. SA

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MORE TO EXPLORE

Archaeology and Age of a New Hominin from Flores in Eastern Indonesia. M. J. Morwood et al. in *Nature,* Vol. 431, pages 1087–1091; October 28, 2004.

A New Small-Bodied Hominin from the Late Pleistocene of Flores, Indonesia. P. Brown et al. in *Nature,* Vol. 431, pages 1055–1061; October 28, 2004.

A Q&A with Peter Brown is at **www.sciam.com/ontheweb**