

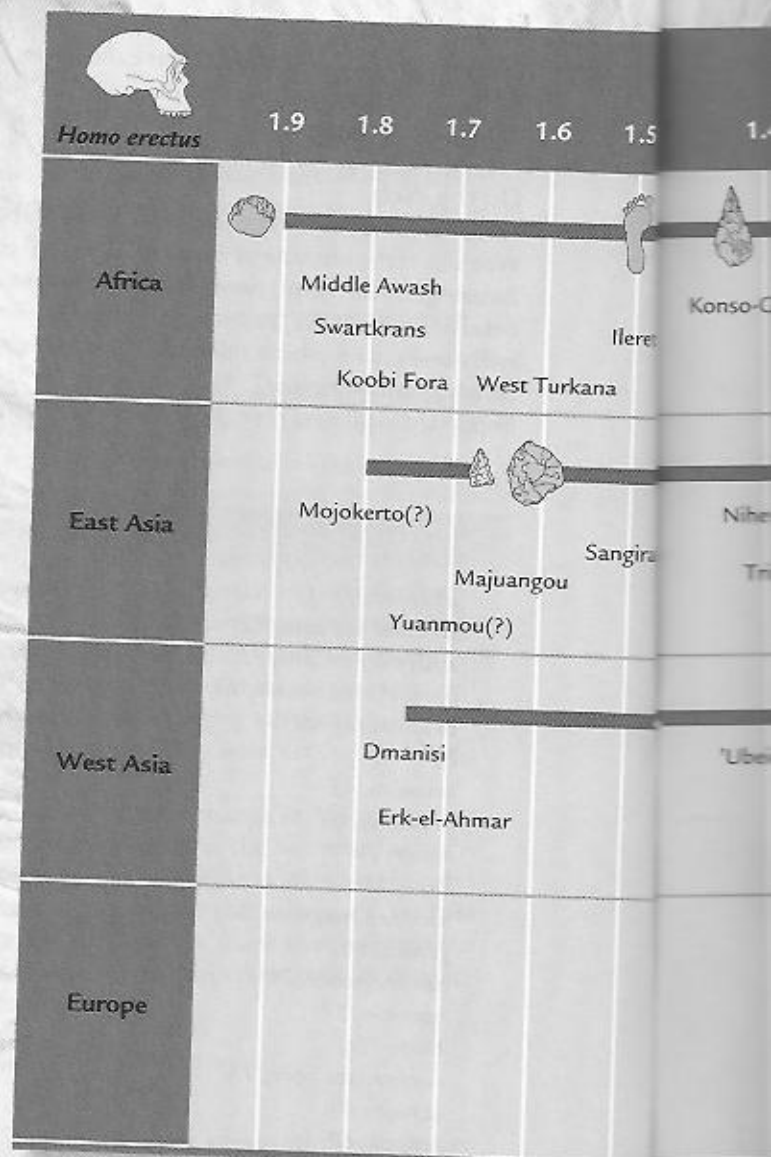
4

The Human Lineage

CHAPTER OVERVIEW

Close to 1.8 million years ago, another great change is seen in the fossil record of Africa. A new hominid makes its appearance on the evolutionary stage—*Homo erectus*. *Homo erectus* possessed a brain larger than that of *Homo habilis* from which it evolved; the *Homo erectus* brain is two-thirds the size of modern humans.

Homo erectus exhibits increasing intelligence as well as an increasing reliance on cultural adaptations. Though born in an African nursery and possessing an anatomy best suited to life in the tropics, culture allowed *Homo erectus* to expand into other regions with very different climates soon after it first appeared in Africa. Tools found in Israel and bones found in the Republic of Georgia reflect the existence of a likely corridor of hominid expansion beyond Africa beginning soon after 1.8 million years ago. Remarkably, *Homo erectus* fossils have been found that date to nearly the same time far to the east, on the



island of Java. They appear not to have entered into Europe until after 1 million years ago.

A sophisticated stone tool technology, cooperative hunting, the controlled use of fire, clothing, and the possible construction of shelters were all a part of the *Homo erectus* adaptation. A reliance on culture is a hallmark of this human ancestor.

Prelude



AS FAMED PALEOANTHROPOLOGIST RICHARD LEAKEY (Leakey and Lewin 1992) admits, it sometimes is easy to forget that the shards and slivers of fossilized bone paleoanthropologists hold in their hands, place under their microscopes, and mount in museum displays were connected to actual, thinking, feeling beings. Sometimes, however, paleoanthropologists get lucky and recover the nearly complete skeleton of an individual and it becomes impossible to forget they are looking at the remnants of a once-living creature. The remains of the boy from Nariokotome, west of Lake Turkana, in Kenya, is one case that makes it impossible to forget (R. Leakey and Walker 1985a; Walker and R. Leakey 1993; Figure 4.1).

The age at death of the West Turkana boy is judged by paleoanthropologists in much the same way that modern parents gauge the progress of their own children's physical development, by looking at his teeth (F. Brown et al. 1985:789; B. H. Smith 1993). As timeposted for a modern human child, all of the West Turkana boy's first (6-year) and second (12-year) molars had erupted; that is, they are above where the gum line would have been and, therefore, must have been


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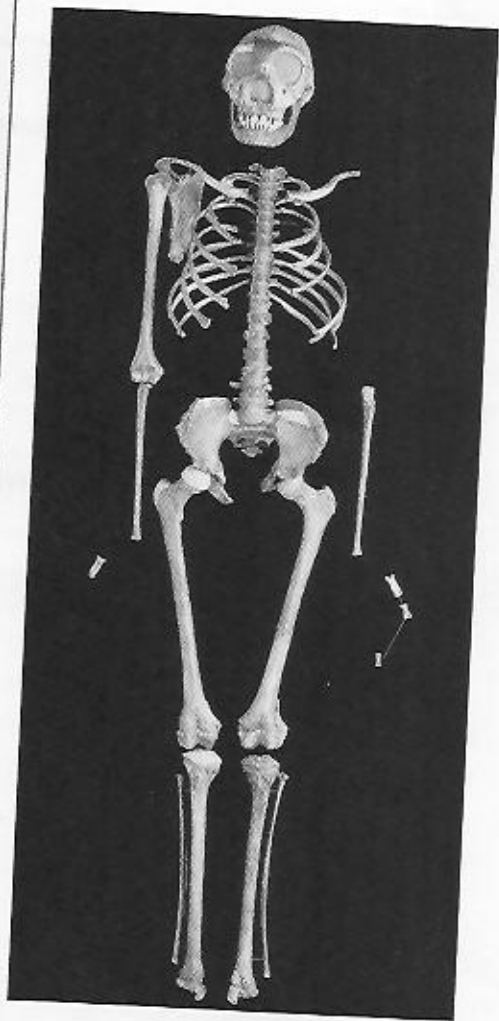
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► **Figure 4.1**
One of the most complete fossil hominid skeletons ever found: WKT-15000, the 12-year-old *Homo erectus* boy from Nariokotome.
(© David L. Brill)

exposed in his mouth when he was alive. Both of his upper deciduous canines (these are baby teeth) were still in place, and his permanent upper canine on the right side had been poised to replace its baby-tooth predecessor. None of his third molars (the wisdom teeth that erupt at age 18 in modern people) were yet in the West Turkana boy's mouth at the time of his death. So, if he were a modern child, an archaeologist would conclude that he had been about 12 years old when he died. Because of other skeletal development indicators suggesting a more rapid maturation process for the West Turkana boy, some researchers have concluded that he may have been closer to 8 (Gibbons 2008a). In any event, he was just a kid when he died.

The cause of death of the West Turkana boy is a sad mystery. His remarkably well preserved, nearly complete skeleton shows great health and vigor. Alan Walker, one of the fossil's excavators, describes the Nariokotome boy as a "strapping youth" and estimates his height at between 5 feet 4 inches and 5 feet 8 inches (R. Leakey and Lewin 1992). That is considerably taller than a modern human boy of the same age in most populations.

The West Turkana boy died on the edge of a lagoon near a lake. The position of his bones indicates that his body floated face down in the shallow water after he died. Fortunately, no scavengers picked at his corpse as it decayed, so most of the body remained pretty much in place, if not intact. Animals coming to the lagoon for a drink may have walked on the body, breaking one of the legs and scattering the rest of the bones as the flesh, muscle, and tissue that had once been a boy were washed away. After the soft parts had decayed, a gentle current dispersed the bones across a linear distance of about 7 m (slightly more than 21 ft). The bones were then covered in the mucky lake bottom by water-borne silt and ash from a nearby volcano, where they rested for close to 1.55 million years.

In August 1984, Kenyan paleontologist Kamoya Kimeu was scouting for fossils in Nariokotome, in an area that is now a dry lake bed. Kimeu was looking for fossils on his day off before the camp of paleontologists moved to another locality as planned because so little of importance had been found in the area. Within a short time, he spotted a skull fragment, and an excavation was initiated. Soon the nearly complete skeletal remains of a boy were uncovered, revealing, with unprecedented clarity, an enormously ancient ancestor.

It is ironic that by dying in the right place at the right time, a young boy achieved an immortality that likely none of us will attain. Even 1.55 million years after he lived, in a time and world we can barely imagine, people still ponder his life. We place him in the taxonomic category *Homo erectus*, and his people are the focus of this chapter.

AS INDICATED BY A SERIES OF FOSSIL SPECIMENS, soon after 1.8 million B.P. in Africa, and nearly as long ago in Asia and somewhat later in Europe, an acceleration of human evolution took place. The new fossils are different enough from *Homo habilis* to warrant a new name or names for the reasons enumerated in our discussion of species designation in Chapter 3. The new specimens have skeletal anatomies so different from that of *habilis* that they cannot reasonably be placed in the same group. But what to name the new fossils, and should they all be placed together in the same group?



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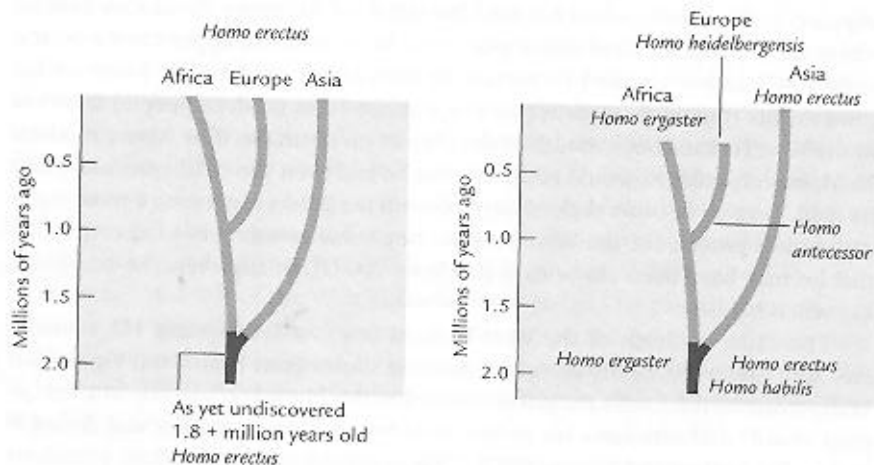
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Chronicle



► Figure 4.2

Two competing models for the number of species, evolution, and spread of hominids after 2 million years ago (mya). In the more traditional model (left), *Homo habilis* gave rise to *Homo erectus* in Africa sometime after 2 mya. From there, *Homo erectus* populations quickly spread into Asia and, later, western Europe. In the competing model (right), *Homo habilis* gave rise to *Homo ergaster* in Africa sometime after 2 mya. *Homo habilis* or a descendant also spread into Asia soon after 2 mya, where it evolved into *Homo erectus*. *Homo ergaster* may have spread into Europe, where it gave rise to yet another hominid species, *Homo antecessor*, which later evolved into *Homo heidelbergensis*.



Many paleoanthropologists believe that all of the hominins that follow *Homo habilis* and predate *Homo sapiens*—from after 1.8 million B.P. until about 400,000 B.P. or even later—belong to a single species: *Homo erectus* (Potts et al. 2004). When the sample of specimens recovered for this group was small and anatomical variation seemed quite limited among those fossils found from Africa all the way to east Asia, this assumption was reasonable. A recent spate of discoveries has convinced others, however, based on highly technical analyses of the morphology of the various specimens, that this period of human evolution instead presents us with a number of related but more or less geographically separate species (Schwartz 2004): *Homo ergaster* in Africa, *Homo erectus* in central and east Asia, and *Homo antecessor* in Europe.

For the sake of clarity and to make this part of the human story more straightforward, we will take the simpler approach here, labeling all of the specimens to be discussed in this chapter *Homo erectus*. (Figure 4.2 presents two different phylogenies, one based on the simpler view followed here and one on the multispecies model.) Of course, the number of hominin species alive at any given time is of enormous importance. But for our purposes, it is not as important as understanding that—one species, two, three, or more—during the period from 1.8 million to after 400,000 B.P., populations of intelligent hominins, relying on cultural adaptations, spread throughout much of the Old World, using their intelligence to successfully adjust to a series of widely different environments.

Homo erectus

Potassium/argon dating has placed the oldest *Homo erectus* specimen—a skull labeled ER 3733 (Figure 4.3) from a rich fossil locality called Koobi Fora, east of Lake Turkana (R. Leakey and Walker 1985b)—at about 1.78 million years ago (Feibel, Brown, and McDougal 1989). Physically and culturally, *Homo erectus* is recognizably human, yet it is intriguingly different from us.

The cranium of this new member of the human lineage was quite different from that of its evolutionary antecedent, *Homo habilis* (Figure 4.4). To



◀ **Figure 4.3**

The fossil cranium designated ER 3733. At nearly 1.8 million years of age, this is the oldest known specimen of the fossil species *Homo erectus*. (© National Museums of Kenya)

begin with, its skull, and by implication its brain, was significantly larger. Most specimens have cranial volumes in excess of 800 cc, and the species as a whole has a mean cranial capacity of about 960 cc (Table 4.1). This is an increase of more than 37% over *Homo habilis*, whose mean cranial capacity was only about 700 cc. The Nariokotome boy's cranial capacity was 880 cc; it is estimated that his brain size, had he lived to adulthood, would have been a little over 900 cc (Begun and Walker 1993:346). The largest members of the species have skulls with volumes of over 1,200 cc. This measurement places the brain size of the species far above that of *Homo habilis* and within the lower range of the size of the modern human brain.

The skull of *erectus* was not just larger than that of *habilis*, but it was also differently configured and differently proportioned in ways that signify a shift toward a more modern human appearance. For example, the forehead of *erectus* is somewhat flatter and less sloping than that of *habilis*, a bit more similar to the modern, virtually vertical human forehead. The back, or **occipital**, portion of the *erectus* skull is rounder than that of *habilis*, with a much larger area for muscle attachment. Larger and stronger muscles were needed to support its much larger, heavier skull.

Analysis of cranial endocasts of a number of *Homo erectus* specimens (Holloway 1980, 1981) shows intriguing similarities to the modern human brain. Most significantly, anthropologist Ralph Holloway discovered

▼ **Figure 4.4**

Comparison of the skulls of *Homo habilis* and *Homo erectus*. The skull of *erectus* is larger and more modern (less ape-like) than that of *habilis*.

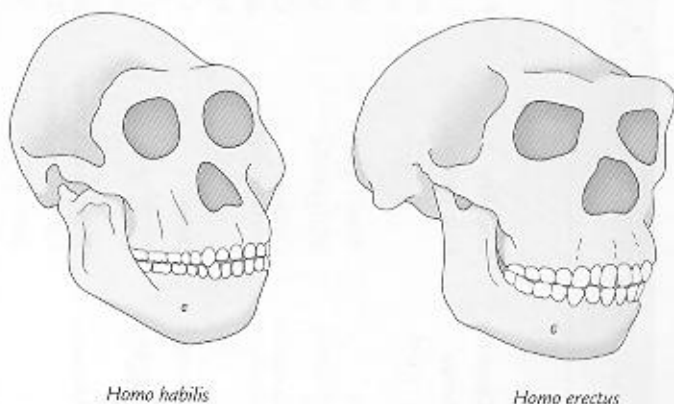


TABLE 4.1 Major *Homo erectus* Fossils Discussed in Chapter 4

Country	Locality	Fossils	Crania	Age	Brain size (cc, sub-adults in italics)
Kenya	East Turkana	Cranial and postcranial fragments including mandibles and pelvis and long bone fragments	KNM-ER 3733	1.78 million yrs	850
			KNM-ER 3883	1.57 million yrs	800
Tanzania	West Turkana	Nearly complete juvenile individual	KNM-WT 15000	1.6 million yrs	880
	Ologesailie	Cranial fragments	KNM-OL 45500	0.97-0.90 million yrs	<800
Ethiopia	Olduvai	Cranial and postcranial fragments including mandibles and pelvis and long bone fragments	OH 9	1.25 million yrs	1,060
			OH 12	0.6-0.8 million yrs	800
Algeria	Daka	Cranium		1 million yrs	995
	Ternifene	Three mandibles and a skull fragment		0.5-0.7 million yrs	
Morocco	Thomas Quarries	Mandible and skull fragments		0.5 million yrs	
	Sidi Abderrahman	Two mandible fragments			
Java	Salé	Skull fragments	Salé	0.4 million	880
		Skull cap, femur	"Java Man"	<1 million yrs	940
		Cranial and postcranial fragments from ~40 individuals	S-2	0.7-1.6 million yrs	800
			S-4	0.7-1.6 million yrs	900
			S-10	0.7-1.6 million yrs	850
			S-12	0.7-1.6 million yrs	1,050
			S-17	0.7-1.6 million yrs	1,000
			1993 Cranium	1.1-1.4 million yrs	856
			N-1	<1 million yrs	1,170
			N-6	<1 million yrs	1,250
	N-11	<1 million yrs	1,230		
Flores	Sambungmachan Mojokerto	Three partial crania Child's cranium	N-12	<1 million yrs	1,090
			Sm3	<.5 million yrs	917
				1.8 million yrs?	663
			LB1 or "Hobbit"	18,000 yrs	417

continued

TABLE 4.1 (continued)

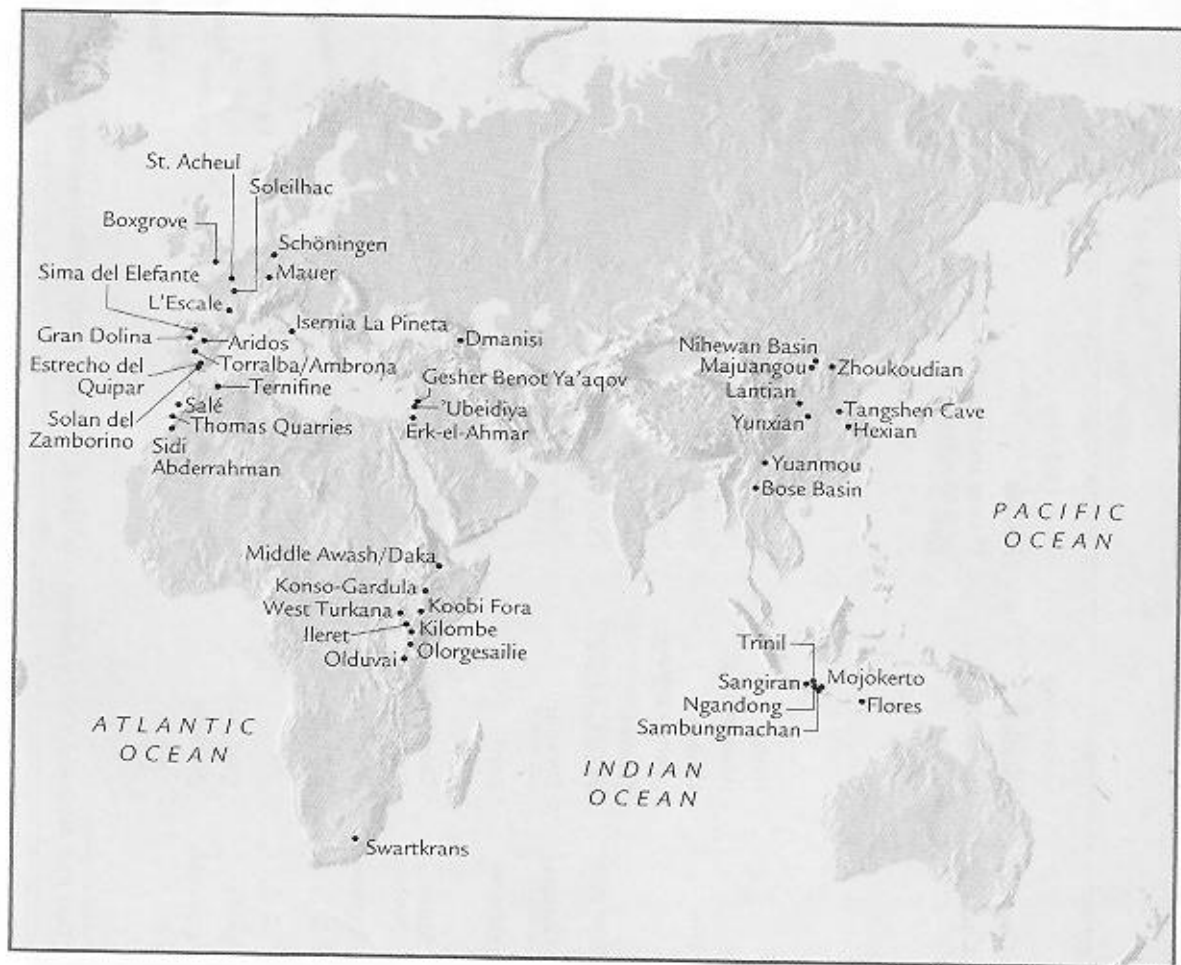
Country	Locality	Fossils	Crania	Age	Brain size (cc, sub-adults in italics)	
China	Zhoukoudian	Cranial and postcranial remains of >40 individuals	II	<0.46 million yrs	1,030	
			III	<0.46 million yrs	915	
			VI	<0.46 million yrs	850	
			X	<0.46 million yrs	1,225	
			XI	<0.46 million yrs	1,015	
			XII	<0.46 million yrs	1,030	
			Locality 13	0.7 million yrs		
			"Hexian Man"	0.27 million yrs?		1,000
Georgia	Dmanisi	Two crania	"Nanjing Man"	>0.35 million yrs		
			Young male	>0.60 million yrs	775	
		Three crania	Female teen	1.75 million yrs	650	
			Young female	1.75 million yrs	600	
Spain	Gran Dolina	Mandible fragment and 16 teeth				
		Remains of six individuals	Partial skull of child	.8 million yrs		
England	Boxgrove Quarry	Tibia		0.48-0.51 million yrs		
				Mean (excluding subadults and "Hobbit")	960	
				Mean (excluding sub-adults but including "Hobbit")	941	
			Standard Deviation (excluding sub-adults and "Hobbit")	142		
			Standard Deviation (excluding sub-adults but including "Hobbit")	268		

Data from Asfaw et al. (2002); Gabunia et al. (2000); Holloway (1980, 1981); Rightmire (1990); Vekua et al. (2002).

hemispheric asymmetry in the *erectus* brain, similar to that seen in modern human beings. The different halves, or hemispheres, of the human brain regulate different tasks; in particular, human speech is ordinarily controlled by the left hemisphere. As a result, the two halves of a human brain are of slightly different shape, proportion, and size. Whether the asymmetry in the endocasts of the *erectus* brain means they were capable of humanlike speech cannot be determined. But the configuration of the *erectus* brain was definitely more like that of modern human beings and different from that of the chimp, gorilla, orangutan, australopithecine, and *habilis* specimens to which Holloway compared them.

Beneath the intriguingly humanlike brain, the *erectus* face itself is somewhat flatter, projecting less than the *habilis* face, though it still is far more **prognathous** than that of a modern human. Above the eye orbits, *Homo erectus* crania display a ridge of bone called a **supraorbital torus**. This “brow ridge” is present in the skulls of all ape species and is generally absent in the modern human form, though some people, especially males, exhibit relatively smaller but discernible ridges above their eyes.

▼ **Figure 4.5**
Fossil localities of
Homo erectus.



From the front, the *erectus* skull presents a flattened trapezoidal shape as opposed to the corresponding very round appearance of a modern human skull. The sides of the *erectus* skull begin nearly parallel at the base and then angle inward toward the top. Also, preserved nasal bones indicate that *erectus* was the first of our ancestors to possess the modern human form of a projecting nose rather than the inset nostrils that characterize the living apes and earlier hominins (Franciscus and Trinkaus 1988).

Below the skull, the bones of *Homo erectus* bear witness to a creature that indisputably walked upright, in a manner similar, if not identical, to that of modern human beings. The recent discovery of hominin footprints in Ileret, Kenya, dating to 1.5 million years ago clearly support this conclusion (Bennett et al. 2009). Preserved in two sedimentary layers at the site, the Ileret footprints are indistinguishable from those of a modern human being.

To be sure, the West Turkana boy and other, more fragmentary postcranial *Homo erectus* remains exhibit a skeletal architecture indicative of great muscularity and strength, probably outside the range of modern human beings. Nonetheless, as more than one paleoanthropologist has stated, you would not be alarmed if a *Homo erectus*, with a cap pulled down low over his or her forehead and face and appropriately dressed, were to sit down next to you in class.

The Evolutionary Position of *Homo erectus*

The oldest *erectus* fossils are found in Africa, often in the same areas where *habilis* remains have been recovered (Figure 4.5). Current consensus, therefore, is that *Homo erectus* is the direct evolutionary descendant of the African hominin species *Homo habilis*, though not all agree on this point (see Issues and Debates).

Hominins Conquer the World

Homo erectus, like its hominin predecessors, evolved in Africa. Unlike its forebears, however, *Homo erectus*, or perhaps an immediate evolutionary descendant, was not restricted to that continent. Fossils similar to the *erectus* specimens found in Africa have been found in Asia and date to very soon after their initial appearance 1.8 million years ago.

If you look at a map or globe, it is easy to see that Africa is physically connected to the rest of its hemisphere in only at its northeastern apex where it borders southwest Asia, the place we today call the Middle East. Not surprisingly, some of the oldest hominin sites outside of Africa have been found here in the broad zone where Europe and Asia come together (see Figure 4.5).

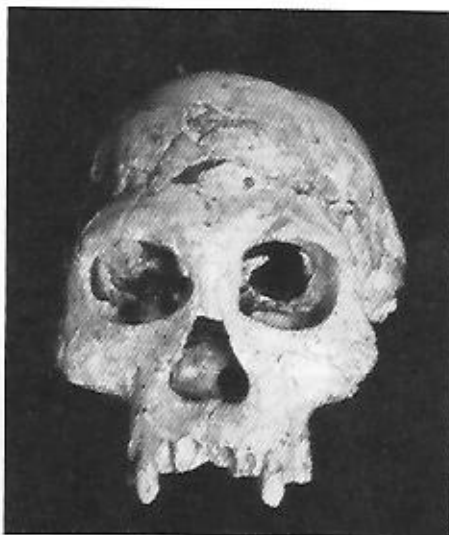
For example, at Erk-el-Ahmar in Israel an assemblage of choppers and flake tools have been excavated in a stratigraphic level bracketed between levels dated to 1.7 and 2.0 million years ago based on **paleomagnetism** (Holden 2002). Just a few kilometers north is another, somewhat younger, hominin site dating to 1.4 million years ago. Called 'Ubeidiya, it has produced a handful of choppers, picks, and flakes along with some very fragmentary remains of hominins (Belfer-Cohen and Goren-Inbar 1994).

Farther to the north, hominin fossils have been found in Dmanisi, near the shore of the Black Sea in the Republic of Georgia in what used to be the Soviet Union. Two mandibles, four relatively complete crania, a number of elements

of the post-cranial skeleton (the bones below the head) including fragments of arm, leg, shoulder, vertebral column, and bones of the foot have now been unearthed there from a deposit that has been dated to about 1.77 million years ago (Figure 4.6; Gabunia et al. 2000; Holden 2003a; Lordkipanidze et al. 2007; Vekua et al. 2002). The four Dmanisi crania range in size from 600 to 775 cc (Figure 4.6; Vekua et al. 2002).

► **Figure 4.6**

Found near the intersection of three continents—Africa, Asia, and Europe—the Dmanisi specimens—one of the crania is shown here—found in the former Soviet Republic of Georgia likely represents the remains of some of the earliest *Homo erectus* migrants out of Africa. (Photo by Gouram Tsibakhashvili. Courtesy Professor Dr. David Lordkipanidze, Deputy Director, Georgina State Museum)



All four crania are small by African *Homo erectus* standards—all of them fall closer to the mean cranial capacity of *Homo habilis* than to that of *Homo erectus*. Nevertheless, this may be explained by the fact that at Dmanisi we have the remains only of young individuals, whose heads had not reached their fully adult size; one of them is almost certainly a juvenile. Also, there is at least one small female—and possibly two—in the sample. Except for their size, the Dmanisi crania otherwise look remarkably like African *Homo erectus* crania dating to the same time period. When Pat Shipman, who had co-directed the excavation of the

Nariokotome boy, first saw one of the Dmanisi mandibles, her reaction was one of amazement; the jaws were not just similar, but could have come from twins (Shipman 2000:491).

Below the skull, the Dmanisi hominins display an interesting mosaic of characteristics. They were quite small, with a range of estimated heights of between 145 and 166 cm (about 4'8" to 5'5"); short by modern human standards and more in line with the known heights of earlier hominins like *Homo habilis* and *Australopithecus*. Though the shape and probably positioning of their arm bones differ from those of a modern human being, resembling, instead, those of an *Australopithecus*, the overall proportions of the Dmanisi hominins are quite modern, with relatively long, humanlike legs and a distinctly human, arched foot.

The tool kit of the Dmanisi hominins is another piece of evidence that links them to an African hominin heritage. Only simple chopping and flake tools have been found at the site. These tools clearly belong to the Oldowan tradition seen at *Homo habilis* and early *Homo erectus* sites in Africa (Gibbons 2009b). In other words, there is no evidence of a great leap forward in stone-tool technology that might explain the achievement of expansion beyond Africa. In fact, the tools found in Africa and in Eurasia at this early date are identical.

East Asia

It is a long way from Africa to the shore of the Black Sea, where the Dmanisi site is located, but it is not nearly the end of our journey or that of the hominin species *Homo erectus*. The next set of ancient sites we will visit are literally half a world away, at the other end of our planet's largest continent.

The fact that *Homo erectus* fossils were found first in east Asia—Java, to be more specific—is no mystery. It is simply a factor of where a scientist first looked. In a remarkable instance of intuition, Dutch physician Eugene Dubois (1894) traveled to the island of Java in the western Pacific in the late nineteenth century expressly to seek out evidence of human origins in the Asian tropics. In 1891, along the Solo River in the vicinity of the town of Trinil, he came upon a **calvarium** that looked not quite human but not quite apelike (Figure 4.7). It possessed large brow ridges like those of apes. But the cranial capacity, as best as could be judged at the time, was far larger than an ape's while still smaller than a modern human's. Dubois labeled the find *Pithecanthropus erectus*, meaning “upright ape-man.” Still popularly referred to as “Java Man,” we now include Dubois's discovery in the *Homo erectus* species. Its estimated cranial capacity of 940 cc and its age (still uncertain but probably about 1 million years old) place it firmly in the *erectus* species. A number of other *Homo erectus* specimens have been found on Java (see Table 4.1 and Figure 4.8). Though Java today is an island, during periods of lowered sea level it was part of the mainland of Southeast Asia, enabling *Homo erectus* to arrive there on foot.

Application of the argon/argon technique has provided chronological dates for a number of the Java *Homo erectus* specimens. For example, several *Homo erectus* fossils found at the very rich Sangiran locality on Java have now been dated to more than 1.0 million and perhaps as much as 1.6 million years ago (Larick et al. 2001). Additionally, the skull of a juvenile *Homo erectus* found at the Mojokerto locality on Java is now estimated to be close to 1.75 million years old, about as old as the oldest specimens in Africa, thousands of miles away (Swisher et al. 1994).

On Java, *Homo erectus* appears to have been an extremely long-lived species, surviving long after it had become extinct in Africa, Europe, and the rest of Asia. *Homo erectus* fossils recovered at the Ngandong and Sambungmachan sites have recently been dated to sometime between just 27,000 and 53,000 years ago (Swisher et al., 1996).

Homo erectus: Ocean Explorer?

As distant as all other *Homo erectus* sites are from their ultimate source in Africa, all of these places are within “walking distance” of their point of origin—at least over many generations of wandering and expansion. Remember, when *Homo erectus* arrived, the island of Java was connected to the Southeast Asian mainland as the result of lowered sea level, so members of that species walked there over dry land. However, stone tools have recently been recovered on the island of Flores, located east of Java, just below a stratigraphic level dating to 1.02 million years ago (Brumm et al. 2010). Flores is separated from Java by a deep, natural underwater trench. Even during periods of lowered sea level, Flores would still have been separated from lands to the west by approximately 19 km (12 mi) of open sea. For *Homo erectus* to get to Flores, it must have been by floating there.

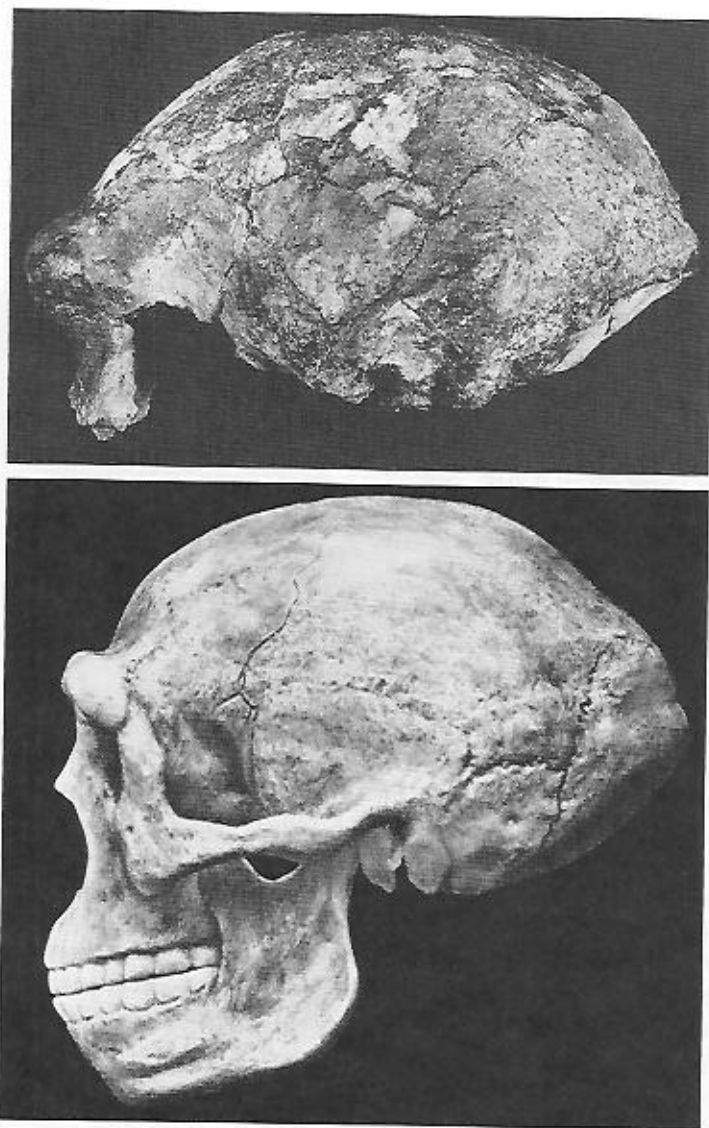


▲ **Figure 4.7**
The first skull fragment found of *Homo erectus* was this skullcap found in Java in the late nineteenth century by the Dutch scientist, Eugene Dubois. (© National Museum of Natural History)

► **Figure 4.8**

Crania of *Homo erectus* from Sangiran, Java (top) and Zhoukoudian in China (bottom).

(Top, courtesy of Ralph L. Holloway. Bottom, The Human Origins Program, Smithsonian Institution)



Robert G. Bednarik is so interested in the seafaring capability of *Homo erectus* that he has been willing to risk his reputation and even his life on its study. He has twice constructed bamboo rafts, which he has then taken to sea with hardy crews, attempting to show the seaworthiness of watercraft so elementary that perhaps *Homo erectus* would have been capable of making and sailing them (Bower 2003). Through trial and error—his first attempt at crossing the 48-km (30-mi) sea gap between the Indonesian islands of Bali and Lombok (they are in the same chain of islands as Flores) was abandoned after 6 fruitless hours of rowing—in 2000 Bednarik and his crew barely, but safely, crossed between those two islands in about 12 hours. Like all replicative archaeological experiments, this proves only that such a trip is possible, not that *Homo erectus* had actually been capable of building and then sailing a similar craft. Nevertheless, we do know that *Homo*

erectus made it to Flores, and Bednarik has provided and successfully tested one possible way in which this may have happened.

China

The oldest evidence for the presence of hominins in China has been found in the form of chert, sandstone, quartz, and andesite cores and flakes at the Majuangou site in the Nihewan River basin (Zhu et al. 2004). This site presents researchers with another example of how quickly *Homo erectus* must have spread across the face of Asia once expanding beyond its place of origin in Africa. The Nihewan is located in north-central China, and the lowest stratigraphic layer at the site that has produced stone artifacts has been dated to 1.66 million years ago. Remember that the oldest *Homo erectus* find outside of Africa dates to 1.78 million years ago at Dmanisi, located at the other side of the Asian continent from Majuangou. This implies that it took *Homo erectus* just a little more than 200,000 years to spread across several thousand miles of territory.

It is also important to point out that Majuangou is situated at 40° N latitude. Hominins living there would have been faced with a climate far different from that of Africa, where they evolved. Their ability to adapt to the very different environmental conditions of northern China is a testament to their reliance upon and the effectiveness of their cultural adaptation. The oldest hominin fossils in China with confirmed dates are all somewhat younger than this (see Table 4.1).

One of the most important *Homo erectus* sites ever discovered in China—and certainly the most widely known hominin locality—is in the village of Zhoukoudian, about 50 km (35 mi) southwest of Beijing. The cave at the site and the surrounding area produced the remains of about 45 *Homo erectus* individuals in a region possessing a continental climate (typified by hot summers and cold winters with ample precipitation spread more or less evenly throughout the year), then and now, not unlike that in the northern United States—obviously a far cry from the climate of tropical Africa, where the species originated. Occupation of the main site (Locality 1) by “Peking Man” has recently been dated to 770,000 years ago (Ciochon and Bettis 2009). Another site, located about 1 km south of the original Peking Man cave site, Locality 13, has been dated to 700,000 years ago (Jia and Huang 1990).

More details concerning the site, its discovery, and its significance—and the tragic mystery of the disappearance of the fossils more than 60 years ago—are provided in this chapter’s “Case Study Close-Up” (see Figure 4.8).

Europe

The oldest hominin fossil in Europe was found in the Sima del Elefante cave in the mountains of northern Spain. Excavators discovered part of a humanlike lower jaw in a cave deposit dating to about 1.2 million years ago (Carbonell, Bermúdez de Castro, Parés, Pérez-González, et al. 2008). Stone flakes and the cut bones of large mammalian species provide further evidence of a hominin presence in the cave at this time.

Though no indisputable *Homo erectus* remains have been found at the Solana del Zamborino and Estrecho del Quipar sites in southeastern Spain, they have produced the oldest evidence of handaxe production in Europe. Researchers

have found finely made specimens at both of these sites in stratigraphic layers dating to between .76 and .9 million years ago (Scott and Gibert 2009).

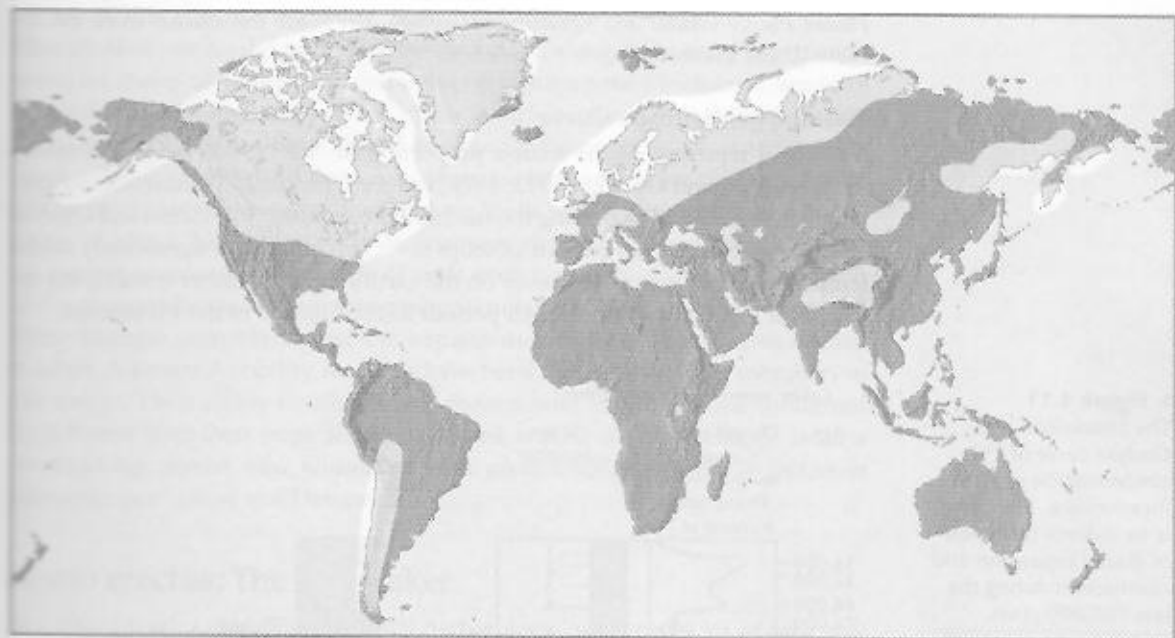
Gran Dolina in the Atapuerca Mountains in Spain is one of the most significant hominin sites in Europe (Carbonell et al. 1995). Dating to more than 800,000 and perhaps as much as 1 million years ago (Parés and Pérez-González 1995), the Gran Dolina hominin fossils include the remains of at least six individuals, including two adults, one teenager, and one 10- to 12-year-old child. The preserved lower portion of the child's body is entirely modern in its morphology and therefore quite different from that seen in *Homo erectus* fossils dating to the same period. As a result, the Gran Dolina researchers have assigned these fossils to a new species, *Homo antecessor* (Bermúdez de Castro et al. 1997). As a result of the mosaic of primitive and modern traits of the Gran Dolina fossils, the researchers suggest that *antecessor* represents a descendant of *Homo erectus* (see Figure 4.2). Whether *antecessor* possesses features sufficiently different from those of *erectus* to justify the naming of a new hominin species becomes an argument between the lumpers and the splitters again, and the details need not concern us here. Following the practice established at the beginning of this chapter, we will label these specimens as *Homo erectus*. Whatever we call them, it is reasonable to say that African hominins first entered Europe by about 1.2 million years ago. Why they arrived to colonize Europe so long after they had spread into Asia as far as the island of Java (1.75 million years ago) and northern China (1.66 million years ago) will be addressed in "Issues and Debates."

The Age of Ice

For reasons that are still uncertain, beginning at about 2.6 million years ago (Kerr 2009; Mascarelli 2009) the earth became a significantly colder place. Particularly after about 900,000 years ago, northern latitudes and higher elevations were covered by huge, expanding ice fields called **glaciers** (Shackleton and Opdyke 1973, 1976; Figures 4.9 and 4.10).

This colder period of time is called the **Pleistocene epoch** (see Figure 3.3 for a time chart placing the Pleistocene chronologically in the history of the earth). Researchers mark the end of the Pleistocene at 10,000 years ago, when worldwide temperature rose and glaciers shrank. The modern period is called the **Holocene epoch**. Many climate experts believe that the Holocene is simply a relatively warm period that is destined to end in only a few thousand years, with glacial conditions nearly certain to return. How global warming will affect this is, at this point, anybody's guess.

Though initially conceptualized and still commonly thought of as an "Ice Age" of unremitting cold, the Pleistocene actually was an epoch of fluctuating climate, with periods called **glacials** much colder than the present. These glacials were characterized by widespread ice and snow cover—imagine most of the central and northern United States and Canada and much of northern Europe looking and feeling like Greenland. But within the glacials themselves were colder and warmer periods, with attendant glacial advances (**stadials**) and retreats (**interstadials**). Between the glacials were relatively long **interglacial** periods, during which temperatures often approached, sometimes equaled, and rarely may even have exceeded the modern level.



The pattern of temperature fluctuation and glacial advance and retreat can be studied in a number of ways. Glaciers leave significant and recognizable features as they cover the land. If you live in the northern third of the United States or virtually anywhere in Canada, then you can still see the effects of the huge, moving continental sheets and rivers of ice, some a few kilometers thick, as they rode over everything in their path. Glacial geologists can read a landscape for its glacial deposits, which can then be dated to develop a chronology of glaciation, as each subsequent expansion of ice overrode the previous one. (See Richard

▲ **Figure 4.9**
Map of worldwide glacial coverage during the peak periods of glaciation during the Pleistocene epoch.



◀ **Figure 4.10**
Greenland, shown here from the air, serves as a model for conditions in much of the northern hemisphere and higher elevations during the Pleistocene epoch. (K. L. Feder)

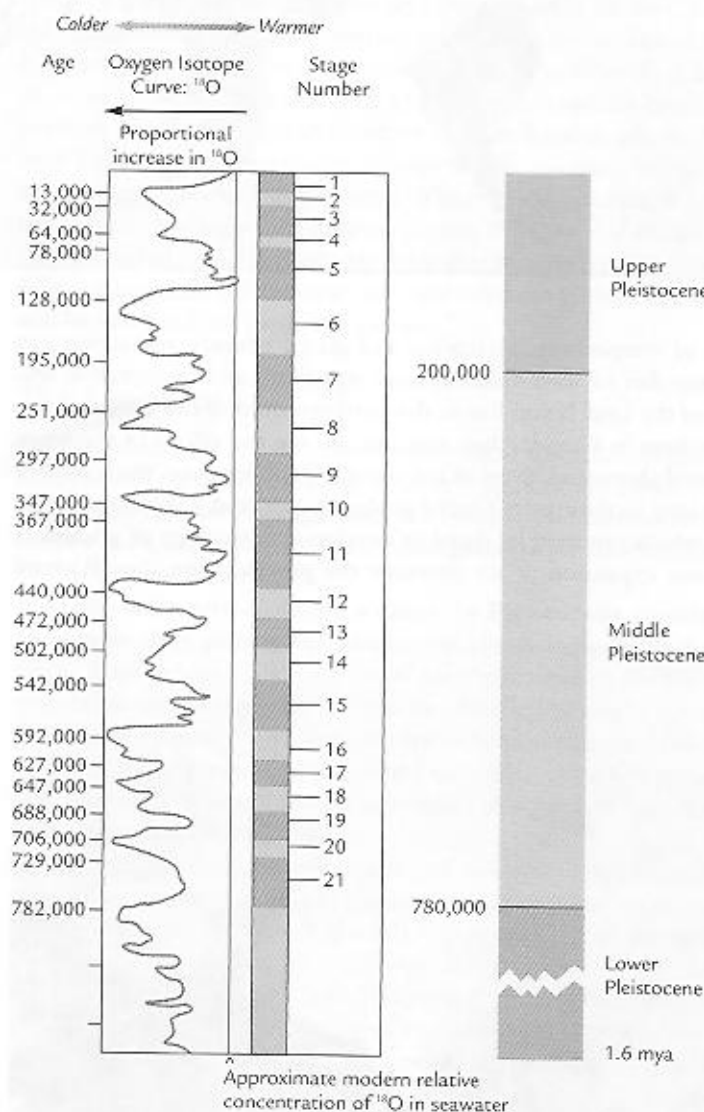
Foster Flint's *Glacial and Quaternary Geology*, 1971, for the classic work on the New World Pleistocene.)

The Oxygen Isotope Curve

The curve representing the relative proportion of ^{16}O : ^{18}O has been determined by Shackleton and Opdyke (1973, 1976; and see Chapter 2). Their results are presented in Figure 4.11. Covering the last 780,000 years, the Shackleton and Opdyke chronology exhibits ten periods of drops in ^{16}O and therefore significantly colder temperatures and greater ice cover on the earth's surface. Further research has indicated at least ten additional such periods in the first half of the Pleistocene.

► **Figure 4.11**

The Shackleton and Opdyke curve of ^{18}O concentration in fossil foraminifera. The curve is an indirect reflection of glacial expansion and contraction during the last 780,000 years.



Odd-numbered stages (in orange) = warmer periods, less glacial ice cover
 Even-numbered stages (in blue) = colder periods, more glacial ice cover

All of this climatic instability must have affected our hominin ancestors. Though *Homo erectus* did not penetrate into areas where there were large continental ice sheets, all of the earth was influenced during the Pleistocene. Sea level dropped substantially, perhaps by as much as 125 m (more than 400 ft), during glacial maxima. Such a drop altered the configuration of most of the world's coasts, exposing as dry land thousands of square kilometers that previously were and presently are under water. Lowered sea levels would have made the colonization of islands like Flores easier by lessening the distance between them and the nearest mainland. The climate of areas even far south of the farthest extent of the glaciers changed, as low-pressure systems altered their usual flow patterns. These changes certainly altered the conditions to which *Homo erectus* needed to adapt. Adaptive flexibility seems to have been a hallmark of the members of this species. Their ability to inhabit new regions with environmental conditions far different from their tropical source, as well as their ability to change as their surroundings altered, bear witness to their great intelligence and in fact their humanity (see "Issues and Debates").

Homo erectus: The Toolmaker

In a class I teach called "Experimental Archaeology," we spend a lot of time trying to replicate, as authentically as possible, various stone tools made by prehistoric people. We follow a chronological, evolutionary sequence, first replicating the Oldowan tools of *Homo habilis* and then making copies of the Acheulean handaxe (named for the French site of Saint-Acheul, where they were first identified) that typifies *Homo erectus*, at least in Africa and Europe (Figure 4.12). The earliest and simplest handaxes have been found in Africa and can be dated to about 1.4 million years ago. Earlier tools (prior to 1.4 million years ago) made by *Homo erectus* give the appearance of advanced Oldowan choppers. There seems to have been a slow development of the far more complex handaxe from the simpler Oldowan chopper after the first appearance of *erectus* in Africa sometime after 1.8 million B.P.

Students generally have little trouble making impressive versions of Oldowan choppers and flake tools—with a little effort and after mastering the proper striking angle of hammerstone on core. This is not the case, however, for the *Homo erectus* handaxe, which is not that easy to make, at least not without lots of practice, knowledge, and time. Only a few of my students

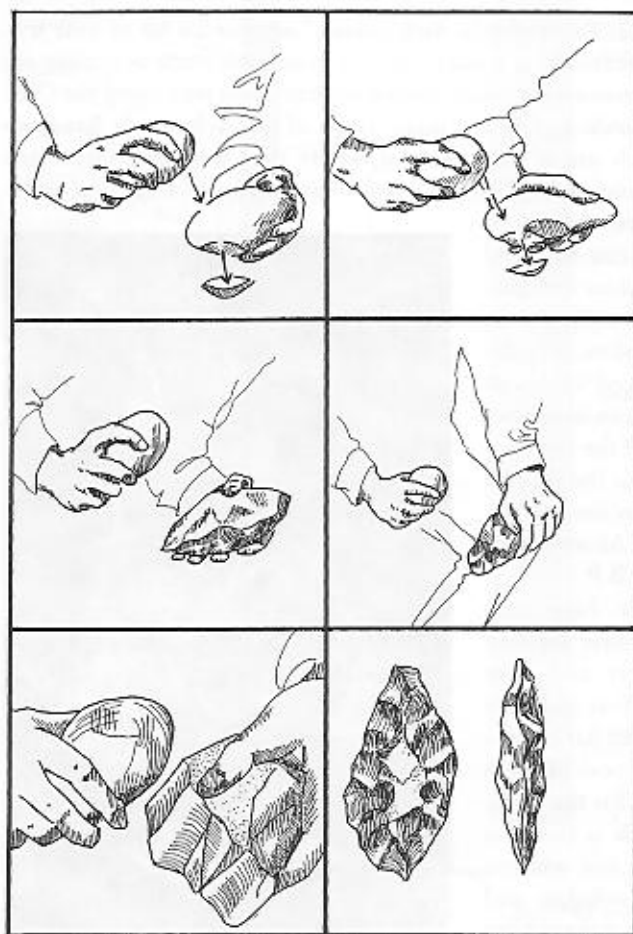


◀ **Figure 4.12**
A finely chipped, symmetrical Lower Paleolithic handaxe. Beginning about 1.4 million years ago, handaxes were sophisticated, multi-purpose tools made by members of the species *Homo erectus* in Africa, Europe, and West Asia. (© Boltin Picture Library/Bridgeman Art Library)

develop proficiency in handaxe production. Handaxes are symmetrical, finely flaked, and often aesthetically exquisite (see Figure 4.12). Dozens of flakes are removed from the core, not just a few (Figure 4.13). Even quite simple handaxes, such as the earliest known examples, from the site of Konso–Gardula in Ethiopia (Asfaw et al. 1992) and dated to 1.4 million B.P., can take 25 individual hammer strikes. The best-made examples, which date to after 1 million B.P., in Africa and more recently in Europe, took nearly three times that number (Constable 1973:128). Each flake blow must be located precisely in order to allow for the proper positioning of the next strike. The stone must be turned over again and again between hammer strikes to maintain symmetry and to keep the edge of the tool straight. All—or, at least, most—of the exterior rind, or **cortex**, of the object piece was removed in order to keep the tool relatively thin and light, so flakes needed to shoot across the face of the axe at the same time that the edge was being maintained. This takes great skill, precision, and strength.

Experimental archaeologist Mark Newcomer (1971) has replicated handaxes, determining that at least some were made in three separate steps. First, a blank, or **preform**, was roughed out with a stone hammer into the general shape of the

► **Figure 4.13**
Through a process of bifacial flaking, a symmetrical, finely made handaxe was produced. Compare this to the process of making Oldowan tools (see Figure 3.18). (Noel G. Coonce)



desired end product. Then the preform was refined via a second stage of percussion with a softer stone or even a piece of antler used in thinning the tool. Finally, the edges were straightened and sharpened in one last application of percussion. All the work was worth it: For the same mass of stone, a handaxe produces about four times more cutting edge than an Oldowan chopper and, at the same time, yields far more usable, sharp flakes. During the production of a single handaxe, Newcomer produced more than 50 flakes usable for cutting or scraping. The handaxe appears to have been an all-purpose tool (a colleague of mine calls them the “Swiss Army rocks” of the Pleistocene). Its sharp tip was used for piercing, the thin edges for cutting, and the steeper-angled edges toward the butt of the tool for scraping or chopping.

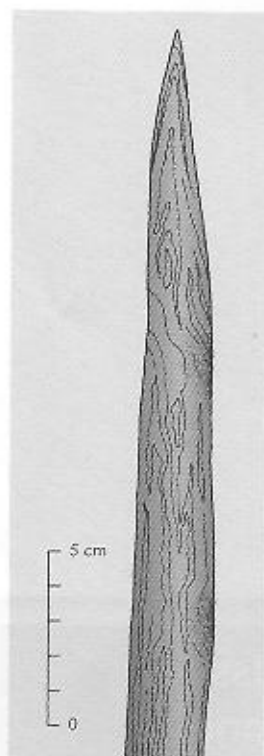
Subsistence

Remember one major issue concerning the subsistence base of *Homo habilis*: Did the members of this species hunt big game or merely scavenge remnants of kills left by carnivores? As a whole, the evidence supports the view that *Homo habilis* had a broad and opportunistic subsistence strategy: Big-game hunting was probably not preeminent, but hunting, scavenging, and gathering wild plants together provided subsistence for *Homo habilis*.

Evidence for the importance of hunting in *Homo erectus* is more substantial. For example, the remains of four butchered rhinoceroses were found at the Boxgrove Quarry site in England. The 150 handaxes found at the site, would have served well in butchering the thick-skinned rhinos (Pitts and Roberts 2000). The researchers at Boxgrove have demonstrated that butchering marks were made on the animals’ vertebrae, just where you would expect for the most efficient dismembering of the animal. Beyond this, the excavators recovered a horse scapula at Boxgrove exhibiting a wound that appears to have been made with a spear (Pitts and Roberts 2000:260).

Three remarkably well preserved wooden spears were recovered from a coal mine in Schöningen, Germany (Thieme 1997). Found in a well-understood stratigraphic sequence, the spears are approximately 400,000 years old and range in size from 1.82 to 2.30 m (about 6 to 7.5 ft) in length (Figure 4.14). These artifacts are thought to be spears, in part, on the basis of gross morphology (they have sharpened tips and certainly resemble more recent spears). Beyond this, all three spears were made the same way; each was produced from a spruce sapling with the harder, denser, and heavier wood from the base of the tree used for the spear tip, which was sharpened. The butt ends of the spears taper gently, and the balance point of each spear is located about one-third the spear length from the tip, just as it is in a modern javelin. Their form seems a clear indication that the spears were meant to be thrown, and their size implies that large game animals were the target.

There is clear evidence that *Homo erectus* butchered animals at Aridos 1 and 2, 18 km (11 mi) southeast of Madrid, Spain (Villa 1990). Both sites produced a butchered elephant, dating to probably about 350,000 years ago. Mixed in with the bones were the tools used to cut off the meat, as well as the waste flakes produced in sharpening the cutting and scraping tools. While there is no evidence of hunting at either Aridos site—no spearpoints were found, for example—there



▲ **Figure 4.14**
This 400,000-year-old throwing spear was one of three found at the Schöningen site in Germany. These spears are evidence of hunting on the part of their makers and represent a hint of the role organic materials—which preserve only under extraordinary circumstances—played in ancient tool technology. (Courtesy Harmut Thieme)

also is no evidence that *Homo erectus* gained access to the carcasses after carnivores had their fill—there are no tooth or gnaw marks on the bones.

The facts that the flint serving as the raw material for the tools at Aridos came from deposits at 3 km distance and that much of the toolmaking occurred away from the butchery site, with mostly sharpening conducted on-site, offer evidence for what researcher Paola Villa calls “planning depth.” In other words, the hominins who butchered the elephant carcasses at Aridos knew that elephants roamed the area and that there was always a chance one or more of them might die at any given time—the Aridos 1 elephant was a juvenile and Aridos 2 was an old male, both part of subpopulations with high natural mortality rates. The *Homo erectus* population in the area seems to have planned for the lucky occasions when a carcass became available by collecting the raw material and making the tools in advance. Planning ahead for a future eventuality is a human behavior, and the evidence at Aridos suggests that *Homo erectus* was capable of such behavior.

That the *Homo erectus* diet consisted of much more than meat is shown at the 800,000-year-old Geshert Benot Ya’aqov site (GBY) in Israel (Goren-Inbar et al. 2002). Among the artifacts researchers recovered at the site were chunks of stone, including cores, blocks, slabs, and flakes of hard, volcanic rock. Fifty-four of these chunks exhibited a peculiar pitting. Experimental replication indicates that the pits on these stones (and on those found at other ancient sites) are produced by using them as hammers to break open nuts.

Remember our discussion in Chapter 3 of chimpanzee nut-cracking behavior in the Taï Forest of the African nation of Côte d’Ivoire. It seems that *Homo erectus* was exploiting a similar set of resources at GBY. Because of waterlogged conditions at the site, organic preservation was quite high. The site’s researchers were able to recover the remains of seven separate species of plants that produce hard-shelled edible seeds or nuts that would have required hard hammering to break open to gain access to their nutritious kernels.

Issues and Debates



Is *Homo erectus* an Evolved *Homo habilis*?

It has long been the consensus—and it would make the story considerably simpler if it were the case—that *Homo habilis* in Africa evolved into *Homo erectus*, also in Africa, in a nice, neat evolutionary line. There is, however, a problem with this scenario; some *Homo habilis* fossils appear to be considerably younger than the oldest fossils of what should be their descendants. The oldest *Homo erectus* fossils now date to about 1.8 million years ago, while a recently excavated partial *Homo habilis* jaw has been dated to 1.44 million years ago (Spoor et al. 2007). Beyond this, another recently discovered specimen of what otherwise presents the morphology of *Homo erectus* has a cranial capacity (691 cc) that more closely matches *Homo habilis* (Spoor et al. 2007).

These fossils complicate our otherwise neat evolutionary scenario. Some suggest that, instead of representing a single line, *Homo habilis* and *Homo erectus* were evolutionary cousins, descended from a third, older and not yet discovered common ancestor. It is also possible that, while one population of *habilis* evolved into a larger brained *Homo erectus*, other *habilis* populations continued as they always had, chronologically overlapping with their larger-brained relatives. It is not yet clear and, as is always the case in paleoanthropology, scientists need more fossils to solve this issue.

Did the Pleistocene Cause the Evolution of *Homo erectus*?

We saw in the case of the earliest split between pongid and hominin at the end of the Miocene, after 8 million and probably between 7 and 5 million years ago, that a significant change in climate predated and may have inspired the evolution of our ancestors. It is tempting to suggest that the changes produced by the Pleistocene are at the root of the apparently rapid divergence of *Homo erectus* from *Homo habilis* sometime soon after 2 million years ago. However, the timing of the climate changes during the Pleistocene seems to rule out this possibility.

Even if the Pleistocene is not at the root of the development of *erectus* as a new species of hominin, it remains an important consideration in our reconstruction of *Homo erectus*'s intelligence and cultural capability. *Homo erectus* whose origin we can trace to the tropics was able to thrive and expand geographically despite the unsettled climatic and geographic conditions produced by the Pleistocene. Its adaptability and flexibility are hallmarks of the human cultural adaptation and show how similar to us members of this different species must have been.

What Enabled the Geographic Expansion of *Homo erectus*?

The spread of members of *Homo erectus* out of Africa into new habitats with different climates, resources, and challenges was not made possible by or accompanied by any change in their physical adaptation.

Intelligence

It seems clear that what enabled *Homo erectus* to survive where human ancestors had not previously been able to penetrate was intelligence and the ability to invent new adaptations as needed. Whereas *Homo habilis* certainly was a cultural creature, as shown by its invention, manufacture, and use of stone tools, *Homo erectus* seems to have been the first human ancestor to genuinely rely for survival on the invented, learned, and passed-down adaptations of culture. In the use of sophisticated tools and ultimately in the taming of fire (see the next section), *Homo erectus* exhibits how similar the species was to us.

Consider the diversity of environments with which this one hominin species was associated across its enormous geographic range. Certainly, *Homo erectus* began its evolutionary journey in the warm and humid tropics of Africa at least 1.8 million years ago and likely possessed physical adaptations for that environment. The rapid expansion of this species across much of southern Asia may indicate a natural affinity for a tropical or subtropical climate. But physical adaptations and natural affinities cannot explain *Homo erectus* thriving in northern China more than 1.6 million years ago where the climate was cold and dry (Zhu et al. 2001). The vast extent of the longitudinal (east-west) range of *Homo erectus* evidences its ability to spread quickly from Africa to easternmost Asia. The vast extent of its latitudinal range (north-south) and the wide diversity of climates in which *Homo erectus* survived are indications of a flexibility and adaptability made possible by culture. Possession of the intelligence to invent new adaptations virtually instantaneously when the need presents

itself is usually considered a uniquely human trait. This kind of intelligence and a reliance on the cultural adaptation define what it means to be a human being and are the most important things we modern humans share with our evolutionary kin, *Homo erectus*.

Control of Fire

There is something very compelling, even to twenty-first-century humans, about a simple open flame: the smell of wood smoke, the crackling and popping of dry tinder, the warmth of the fire. For countless generations of our human ancestors, fire was more than just a diversion; it meant warmth and light, power and strength—in fact, survival itself. When did the first human ancestors make the great leap from fearing this elemental natural force to understanding and controlling it?

The best available evidence indicates that *Homo erectus* was our first ancestor able to control fire. For example, the nearly 800,000-year-old site, Geshert Benot Ya'aqov, in Israel exhibits strong evidence for the controlled use of fire by *Homo erectus* (Goren-Inbar et al. 2004). Bits of burned seeds and wood, along with burned flint, were found in discrete clusters at the site. Excavators of the site interpret the individual pockets of burning as simple hearths.

Though indisputable evidence of the use of fire by the *Homo erectus* inhabitants of Zhoukoudian in northern China is lacking, the new date derived for the cave's occupation—770,000 years—puts it right in the middle of an extremely cold glacial stadial (Guanjun et al. 2009). Without the ability to warm themselves by a controlled fire, it seems unlikely that *Homo erectus* could have survived the cold temperatures of a glacial period in northeast Asia. It seems reasonable to suggest that these hominins, in fact, had the use of fire more than three-quarters of a million years ago.

The controlled use of fire may have been the key cultural adaptation that enabled members of this tropically derived and adapted species to survive outside the tropics (Balter 2004b). Fire gives warmth and protection from animals. Fire also produces light and therefore probably played an important role in extending the usable part of the day for members of a species who, like us and most other primates, relied primarily on vision for their sensory input but who, also like us, did not see well in the dark.

Fire also enables cooking. As primatologist Richard Wrangham (2009) suggests, cooking, in a sense, helps predigest our food, decreasing the energy we might expend in actual digestion, freeing up those calories for other biological processes. Among the biological processes that would benefit from this includes those related to the brain. Our brains are consumers of energy far out of proportion to their mass: at about 1350 grams (3 pounds), the brain constitutes less than 2% of our mass but consumes, even at rest, 25% of our energy. Cooking, therefore, is advantageous for a large-brained hominin, making more calories available for those big brains.

The “Art” of Making Tools

An important point should be made about the handaxes we discussed previously: They were better made than they had to be. That is to say, the Acheulean handaxes—at least many of the later ones—have a symmetry, balance, precision,

and beauty that took a lot of work, but work that was not absolutely necessary from a utilitarian perspective (see Figure 4.12). A high level of consistency in handaxe form can be found within sites, as if the makers were adhering to a particular standard (Gowlett 1984).

That such extra care was taken in their production implies that their makers were interested in more than simple utility. *Homo erectus* toolmakers may have been producing beautiful objects for the sake of displaying their great skill or for the sheer pleasure of producing a thing of symmetry and beauty. Though the first true art is usually associated with anatomically modern humans of a much later period—the cave paintings of the European Upper Paleolithic (see Chapter 6) are clearly recognizable as art—for producing stone tools more artfully than they needed to, some of our much earlier ancestors may well deserve the credit, if not for being the first true artists, then at least for being the world's first craftspeople (Gowlett 1984). They produced useful tools in a manner so artful we recognize the “art” in their craft as much as 1.4 million years after they made them.

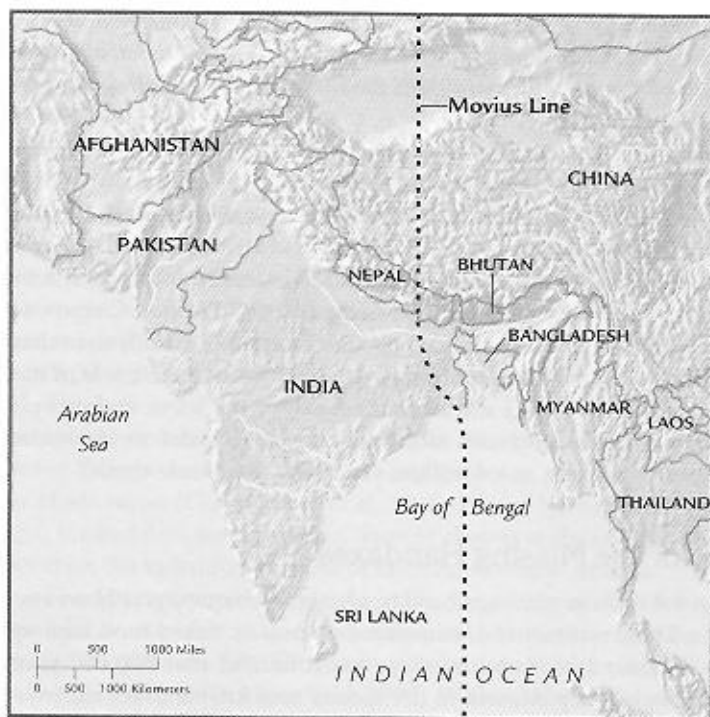
The Mystery of the Missing Handaxes

Beginning about 1.4 million years ago, handaxes become ubiquitous at *Homo erectus* sites in Africa. These symmetrical, sometimes exquisitely flaked tools turn up in Europe with the arrival of *Homo erectus* on that continent after 800,000 years ago. Though seemingly a key element in the species' tool kit, handaxes are, mysteriously, extremely rare or more commonly entirely absent from *Homo erectus* sites in Asia east of the Indian subcontinent where generally nonsymmetrical, less morphologically consistent, chipped stone tools made from stone nodules predominate. This geographic division poses an interesting puzzle: Why would a tool so common as to be diagnostic of *Homo erectus* stone tool technology in Africa and Europe be absent—or nearly so—in east Asia?

This geographically based, technological dichotomy even has a designation. The so-called **Movius line**, named for paleoanthropologist Hallam Movius, who first articulated it, separates the sites to the west of the line, where handaxes are found, from those where they do not occur to its east (Figure 4.15). The Movius line is not viewed as having been an absolute barrier. There are some sites far to the east of the line where bifacially flaked tools that resemble handaxes have been found: for example, in the Bose Basin of southern China (Yamei et al. 2000). Such examples, however, are exceptional, and the line still seems to demarcate a genuine, though not absolute, distinction between tool technologies to the west and east. So the question remains: Why? The answer to this puzzle may lie in the nature and timing of *Homo erectus* expansion beyond the confines of the African continent. Based on the very early timing of *Homo erectus* migration to west and east Asia and their altogether rather late movement into Europe, it seems that *Homo erectus* populations in Africa first expanded into Asia before they had developed Acheulean technology with its emblematic handaxe. Remember that the early stone-tool technologies at Erk-el-Ahmar in Israel, Dmanisi in the Republic of Georgia, and the Nihewan Basin sites in northern China all look a lot like the Oldowan technology in Africa as practiced by, first, *Homo habilis*, and later, the early representatives of *Homo erectus*. But *Homo erectus* did not penetrate Europe until after 1 million years ago, well after African populations of the species

► **Figure 4.15**

The Movius Line reflects an interesting but not yet fully explained aspect of the distribution of handaxe technology: handaxes are common in *Homo erectus* sites in Africa, Europe, and west Asia, but quite rare in Asia east of India. (From Kenneth Feder and Michael Park, *Human Antiquity: An Introduction to Physical Anthropology and Archaeology*, Fourth Edition, Mayfield Publishing Company, 2001. Reprinted with permission from The McGraw-Hill Companies)



had already developed handaxes. When they expanded into Europe, and when they sustained subsequent population movements into southwest Asia and Eurasia, these African migrants brought the new stone-tool technology with them. That the technology did not pass to the east, beyond the Movius line, later on is still a mystery. It may have been due to the fact that handaxes were superfluous in east Asia, their tasks already being carried out with the use of bamboo tools (G. Pope 1989).

Who Were the Hobbit Hominins?

In an interesting bit of synchronicity, I saw the MSNBC report of the discovery of what researchers (P. Brown et al. 2004; Morwood et al. 2004) were calling *Homo floresiensis* soon after watching the DVD of the third movie in the *Lord of the Rings* trilogy. I suppose that is why it struck me as mildly hilarious that some were referring to the diminutive female hominin recovered on the Indonesian island of Flores as a “hobbit.” With a tiny head, an adult height of not even 1 m (less than 3 ft), and a probable weight of about 20 kg (44 lb)—essentially the size of a four-year-old modern human child—indeed it was hobbit-sized. Brain size has been computed to have been about 417 cc, about the mean size of a chimp and equivalent to the brain size of a newborn modern human baby (Figure 4.16). Small though their brains may have been, these hobbit-sized hominins appear to have been quite intelligent; a variety of well-made stone flake tools were found alongside the fossil.

It isn't all that often that a paleoanthropological discovery is covered by the networks, every major cable news channel, and newspapers as well. The hob-

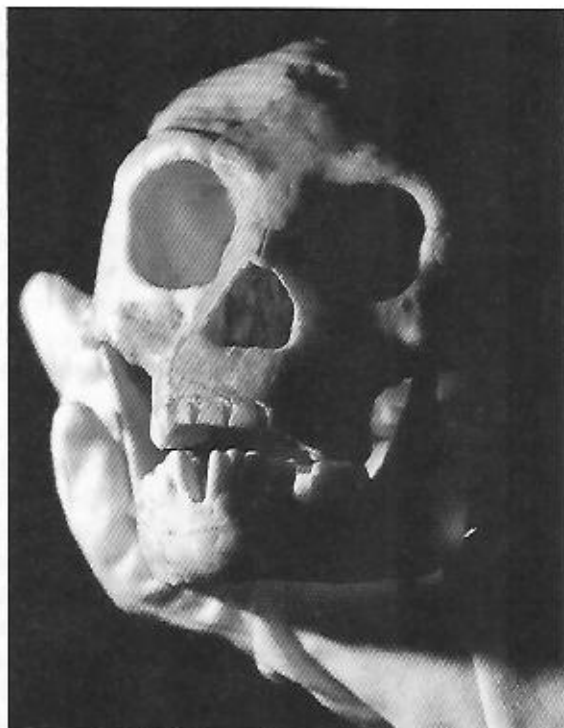
bit hook helped; and the Flores fossil—consisting of a cranium, mandible, the right half of the pelvis, the right femur and **tibia**, additional fragmented bones of the left leg, both hands and feet, and the vertebral column—was one of those rare instances that generated a tremendous amount of interest among scientists and nonscientists alike for a number of reasons beyond any *Lord of the Rings* allusions (Figure 4.17).

Though the discoverers applied a new species name to the fossil, in many ways it resembles a highly miniaturized *Homo erectus*. But how and why would an adult *Homo erectus* be so tiny? Some suggested that *Homo floresiensis* was, in fact, merely an exceptional *Homo erectus* individual, one afflicted by some rare genetic growth disorder, a sort of “Little Hominin, Big World” scenario. Others proposed that what the discoverers were calling *Homo floresiensis* was an anatomically modern human being, but one reflecting a pathology called **microcephaly**, a condition marked by a small head enclosing a small brain, usually resulting in severe mental retardation.

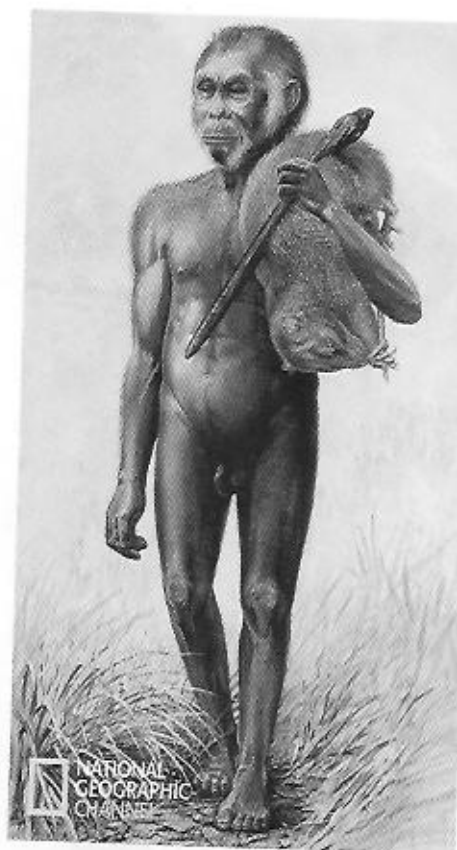
Others suggested that the small size might be an example of the well-known biological phenomenon of island dwarfing. As biologist Jared Diamond (2004) points out, there are many examples of nature selecting for smaller versions of animals who have colonized remote islands. So, conceivably, *Homo erectus* ancestors arrived on Flores by way of a very difficult and unlikely journey and managed to survive on the island for a long period. In this scenario, small individuals among those early arrivals were at an adaptive advantage, perhaps because they could survive on less food and water than their larger companions. Over time, natural selection for smaller individuals resulted in an entire population of very small hominins. Support for this hypothesis has been revealed in new excavations at the site. Along with the right arm bones from the original “Hobbit,” researchers recovered another mandible, a vertebra, a shoulder blade, as well as a mix of arm, leg, finger, and toe bones from as many as nine additional individuals, all about the same size as the first discovery (Morwood et al. 2004).

To assess the place of the Hobbit, researchers have analyzed the interior of the recovered cranium using **three-dimensional computed tomography**, a process by which they were able to produce what amounts to a “virtual brain,” or, at least, a virtual image of the surface of the Hobbit’s brain (Falk et al. 2005). They compared their results to those obtained by applying the same technology to a sample of other crania, including those belonging to various hominin and pongid species, including *Australopithecus*, *Homo erectus*, *Homo sapiens* (including a modern human pygmy and a modern microcephalic), gorilla, and chimpanzee.

The results of this research indicate that the Flores cranium is not a perfect match for any of the specimens to which it was compared. However, it was absolutely clear that the Hobbit was neither an ape nor a modern human with microcephaly. Equally clearly, the Hobbit was not a modern human pygmy. In fact,



▲ **Figure 4.16**
The tiny skull of a diminutive hominid, found on the island of Flores in the western Pacific, caught the attention of the public when it was discovered in 2004, not only for the reason that it immediately was likened to a Hobbit. Called by its discoverers *Homo floresiensis*, the very small-brained hominid produced sophisticated stone tools and lived only just 18,000 years ago, long after similar creatures had become extinct. (© The Human Origins Program, Smithsonian Institution)



▲ Figure 4.17
An artist's conception of what a living example of *Homo floresiensis* might have looked like; or, if you prefer, what a real Hobbit looks like. (© AP/Wide World Photo)

though the ratio of its brain size to its body size is similar to what is seen for *Australopithecus*, the virtual brain of *Homo floresiensis* actually was a pretty good match for that of *Homo erectus*, leading some researchers to conclude that, though not of the same species, *Homo floresiensis* shares a common ancestor with *Homo erectus*. The tiny size of the brain and the association with complex stone tools astonishes everybody and is leading to a reassessment of the significance of overall brain size in the evolution of intelligence in the hominin family.

Though the opinion of the paleoanthropological community is far from unanimous, each form of analysis seems to support the hypothesis that Flores hominin fossils are a diminutive version of *Homo erectus*. The mandibles and shoulders are dissimilar to modern humans (Culotta 2008), and a recent examination by a team led by researcher Matthew Tocheri (Tocheri et al. 2007) has shown that the bones of the Hobbit wrist shows a configuration more like ancient hominins. In keeping with the Hobbit reference, the fossil varieties seem to have had proportionally huge feet, though I can't vouch for their hairiness (Culotta 2008; Jungers et al. 2009). The fossil Hobbit's feet were differently configured from those of a modern human being and their length, proportional to their legs, is more like that seen in apes (Jungers 2009).

Just as astonishing as the creature's small size and chimp-sized brain was the date researchers determined for the stratigraphic layer in which she was found. Luminescence dating bracketed the sediments above and below the skeleton to a period between 35,000 and 14,000 years ago, and charcoal from the layer of the bones produced a date of 18,000 years ago, suggesting that the Flores fossil is even younger than the remarkably young specimens from Ngandong and Sambungmachan on Java. All three sites have produced amazingly recent dates for an extinct version of a human ancestor, but there are precedents for the continued existence on an isolated island of a remnant population of a species extinct everywhere else. This supports the possibility already mentioned that even after the evolution of anatomically modern human beings, other, older versions of human beings, in this case, *Homo erectus* or, at least, something very similar to *Homo erectus*, continued to survive in some isolated places until fairly recently.

Raising *Homo erectus*

My understanding of the care necessary for raising human babies as compared to the young of other species has been forged on the anvil of experience: I've got two kids and have raised six cats, and there simply is no comparison. We adopted the various cats when they were between 7 and 15 weeks old and ready to leave their mothers. They all could walk, could feed themselves, were litter-box trained, and were fierce hunters of blowing leaves and dust bunnies. My kids, like all baby humans, are another story. Immediately following birth and for an extended period thereafter, my kids were capable of crying, filling their diapers, sleeping, and little else.

Whereas after just several weeks of life, animals such as cats attain a reasonable level of competence at moving around, eating, and defending themselves, human children are utterly dependent on adults to satisfy all their needs for a very long time—usually years, even decades. Some specialists characterize even full-term human babies (9 months of gestation) as inherently premature and little more than embryos living outside the womb. The term **altricial** is used to characterize baby birds who are completely dependent on their parents for fulfilling their needs. Intellectually, human babies are anything but altricial; almost from birth they begin to gather and process sensory information, and they are quickly insatiably curious and experimental about their world. Physically, however, they are born at an earlier stage of development and remain immature for longer than the offspring of other species; human babies are said to be **secondarily altricial**.

There are a number of reasons why evolution would have selected for a seemingly dangerous situation in which human children are born at an early stage of physical development. A reconfiguration of the human pelvis was necessary to allow our first hominin ancestors to stand up. This change in pelvic form provided for a change in muscle positioning and shape necessary for bipedal locomotion. It also had an incidental effect: It greatly narrowed the pelvic outlet in females, making it far more difficult for a baby's body to pass through the birth canal. This difficulty can be shown by a simple statistic: Average birth labor time for a chimpanzee is about 2 hours; for a human mother it is more than 14 hours (Rosenberg 1992:99; see this study for an informative discussion of the evolution of human childbirth).

A detailed comparison by anthropologists Robert Tague and Owen Lovejoy (1986) of the reconstructed pelvis of the fossil Lucy (*Australopithecus afarensis*) with the pelvises of a chimpanzee and a modern human female indicates that, though bipedality probably complicated birth for *Australopithecus* females, it still was not as problematic as it is for modern human women (Figure 4.18). The brains of the various *Australopithecus* species were still quite small, so while there may have been a tighter fit at birth, this probably presented little problem because their heads were still no bigger than those of chimp babies. However, as natural selection began to favor greater intelligence in the hominins—made possible by an increase in brain and therefore head size—a problem did develop: A smaller pelvic outlet was forced to accommodate an increasingly large head at birth.

Nature's solution, still hardly perfect, as witnessed by the often difficult time women have in childbirth, was twofold. The first strategy was to maximize pelvic outlet size in females by fine-tuning the configuration of the pelvis. Male and female human pelvises became readily distinguishable because the pelvis exhibits sexual dimorphism. The second strategy of natural selection was timing the birth of human babies at an earlier stage in fetal development, when the head, though large, was still small enough to pass through the birth canal. Today this timing is reflected in the fact that the human newborn has a smaller head, proportional to its ultimate adult size, than do any of the living apes. A human newborn's brain is less than 25% of its ultimate adult size (Jordaan 1976:274). Compare this to the great apes, in whom a newborn's brain is more than 40% of its adult size or to a typical monkey, the macaque, whose brain at birth is 70% of its adult volume. Beyond this, a human child takes twice as long to reach adulthood than does a

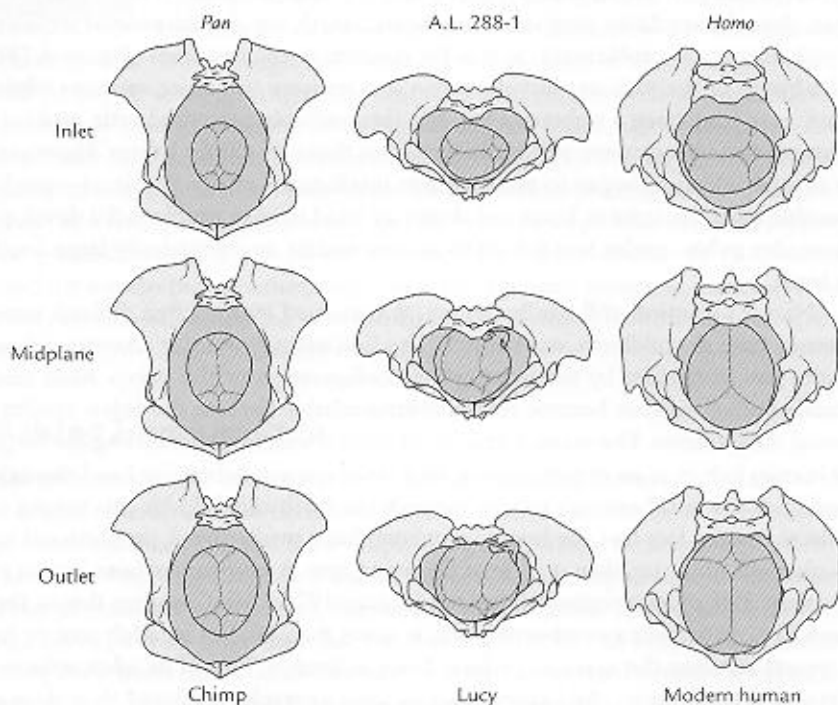
chimpanzee (Gibbons 2008b). Human beings are born at an immature stage of development and then mature much more slowly than our primate cousins.

Most human brain growth occurs outside the womb, after birth. This is fundamentally different from the situation for all the apes. For example, whereas the rate of brain growth declines dramatically in chimpanzees immediately after birth, human babies maintain what is essentially a relatively fast fetal rate of brain growth for an entire year after they are born (R. D. Martin 1989; Rosenberg 1992:106). The proportionally small size of the human baby's head at birth is what enables the baby to be born at all, given the constraints of pelvic outlet size necessitated by upright walking. But this situation presents problems, for the less developed a newborn of any species is, the more susceptible it is to trauma, infection, cold, and death.

Birth at an early stage of development for an organism with a large and complex brain has some advantages. Stimulation and learning begin earlier, while the brain is still experiencing rapid growth, and bonding between parents and children is, of necessity, stronger. This timing can be advantageous in a species that depends for its survival so thoroughly on learned behavior and social relations. It is beneficial for humans to be born at an immature stage of development and to have an extended childhood; the learning curve is simply a lot steeper and longer for us than it is for cows, cats, or even other primates.

An additional hypothesis holds that one of the key changes that characterized ancient hominins from *Homo habilis* onward is **neoteny**, or the “holding on” to features that are typical of newborn apes (Gould 1977). And modern human adults resemble baby chimps more than they resemble adult chimpanzees. Our

► **Figure 4.18**
The birth canals of apes and modern human beings, and the fossil pelvises of extinct hominids allow for a comparison in the birth process of these three kinds of creatures.
(Courtesy of Robert Tague)



lack of body hair, rounded skulls, flat faces, and even the point of articulation between the base of our skull and backbone are all things we share with fetal or newborn, but not adult, chimpanzees.

The pelvis of a female *Homo erectus* has been recovered from a fossil site in Gona, Ethiopia (Simpson et al. 2008). Dating to between 0.9 and 1.4 million years ago, the pelvis has a relatively large birth canal when compared to that of a modern human female. Researchers calculated that a baby with a cranial size of about 315 cc could have passed through the Gona birth canal. That's about 33% of the size of an adult *Homo erectus* cranium as calculated on Table 4.1. Compare that to the virtual reconstruction of a Neandertal newborn recovered in Mezmaiskaya Cave in Crimea, Russia. This newborn's brain size was calculated by researchers at somewhere between 381 and 416 cm (Gibbons 2008b) which is about the maximum size of a modern human newborn's brain size as well.

As stated previously, in the Great Apes, a newborn baby's brain is more developed, about 40% of its adult size. In modern humans, a newborn baby's brain is only about 25% of its adult size. In other words, *Homo erectus* babies were born at an earlier stage of development than a chimp but were not quite as immature, at least in terms of the growth of their brains, as Neandertals or human beings. So, at least based on this one *Homo erectus* pelvis (of course, we'd like to see more such pelvises in order to support this conclusion), it looks like *Homo erectus* was on the path to the modern pattern of giving birth to very immature newborns.

When Did *Homo erectus* Become Extinct?

It should be clear by this point that human evolution was not a simple, progressive process with each species thriving during its time and then giving way to the next in line, repeating this process as a series of steps leading directly to modern human beings. The human story is, instead, far more complex, characterized until fairly recently by geographically separated, multiple contemporary hominins (Figure 4.19).

We will begin the next chapter talking about a new, more modern-looking hominin species that can be dated to about 400,000 years ago. The appearance of this new species does not mean that all older species conveniently disappeared from the scene at that time. In fact, in the scenario presented in this book, only one of the *Homo erectus* populations—that in Africa—is directly ancestral to us. That African *Homo erectus* line evolved into another hominin that looked and behaved more like modern humans, while other branches of *Homo erectus*, particularly those in Europe and Asia, almost certainly continued on more or less the same as they always had perhaps into the very recent past as implied by the Ngandong, Sambungmachan, and Flores fossils.

In 1918 a fossil locality southwest of Beijing, China, was explored by Swedish geologist Johan Gunnar Andersson. Andersson took advantage of a local Chinese belief that fossil bones were actually the remnants of dragons and that powder made from ground-up “dragon bones” was a cure-all. Many local druggists collected such bones for use in their medicines. Even today, paleontologists rely on local druggists for leads in their search for fossil (“dragon”) bones (Jian and Rice 1990).

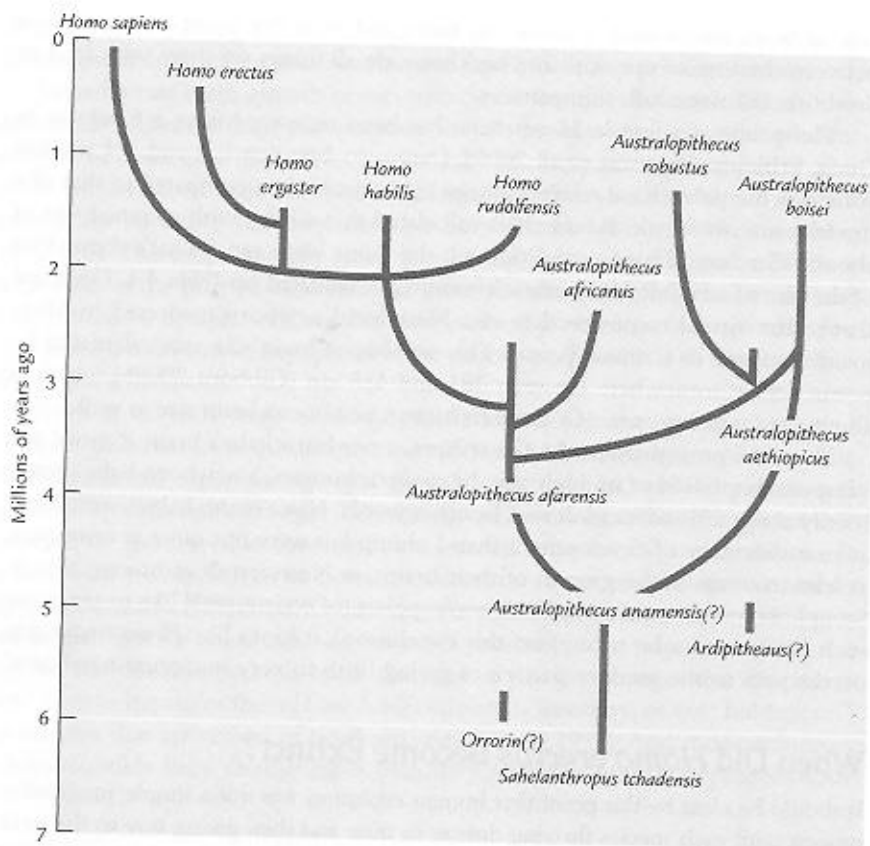
In 1918 Andersson was directed by a druggist to a hill called Jigushan (Chicken Bone Hill) near the village of Zhoukoudian (Jia and Huang 1990).

Case Study Close-up



► Figure 4.19

One phylogeny proposed for the fossil hominids.
(Based partially on Bernard Wood 1992a, 1992b)



Convinced there was a rich array of fossil bones in the surrounding region, he began excavating on another hill, called Longgoshan—Dragon Bone Hill. In 1926 two humanlike teeth were recovered; in 1929, with the dig now led by British scientist Davidson Black, a nearly intact skull was encountered in a cave at the top of the hill (Locality 1). The fossil was recognizably different from almost everything that had been found previously, with the possible exception of Java Man. A new species was named and defined: *Sinanthropus pekinensis*. The specimens from Zhoukoudian are now included in the species *Homo erectus*, but in the popular mind both then and now, they may forever be known as “Peking Man” (see Figure 4.8, bottom).

The cave at Dragon Bone Hill was spectacularly productive by any standards. By the time excavations were finished at Zhoukoudian, the expedition had recovered, along with thousands of specimens of ancient animals, 15 fragmentary skulls, 6 more complete crania, 13 fragmentary mandibles, 3 upper jaws, some postcranial bones (including pieces of femur, upper arms, toe bones, numerous teeth), and a single vertebra of Peking Man (Jia and Huang 1990:161–62). All told, the remains of more than 40 hominin individuals were recovered from deposits in the cave. Though dating of the hominin occupation of the cave has been fraught with uncertainty, a recent redating of the site shows that the cave

was first occupied approximately 770,000 years ago (Guanjun et al. 2009). Being so numerous and discovered so early in our thinking about human evolution, the Peking Man fossils played an important historical role in the scientific conceptualization of human evolution and in interpretations of the culture of ancient human beings.

Tragically, the Zhoukoudian hominin assemblage was lost during World War II when the fossils were being removed from China by U.S. Marines in an attempt to keep them away from Japanese invaders, coincidentally on the same day that Pearl Harbor was attacked. The Marines were captured and imprisoned, and to this day no one knows what became of their precious fossil cargo. (It may have been destroyed by Japanese troops or simply lost, or it may have been found later by Chinese druggists who ground the bones up for medicine. There is even a very slight possibility that some are still hidden away in China, Japan, or the United States.)

Summary

Sometime after 1.8 million years ago, *Homo habilis* was replaced by a new hominin species, *Homo erectus*. *Erectus* possessed a larger brain than *habilis*; its mean brain size of just under 1,000 cc is two-thirds the modern human mean. With its larger brain and attendant greater intelligence, *Homo erectus* was able to adapt to the changing environmental conditions posed by the Pleistocene epoch.

Homo erectus was the first ancestral human being to expand beyond the borders of our hominin family's African birthplace and nursery. Following the most reasonable trail beyond the borders of Africa, *Homo erectus* fossils and their tools are found in southwest Asia and Eurasia more than 1.7 million years ago, very soon after they first appeared in Africa. For reasons that are still debated, these African migrants did not enter into western Europe until later, perhaps about 1.2 million years ago.

It was intelligence and not any physical adaptation that enabled *Homo erectus* to adapt to the diversity of habitats offered throughout Asia. New and more sophisticated tools, new methods of hunting, and the use of fire were all part of the *Homo erectus* behavioral repertoire.

Homo erectus was a stable and long-lived species. Fossils from Africa to east Asia show a consistent morphology from close to 1.8 million to 400,000 years ago. After 400,000 years ago, brain size, relatively stable during the existence of *erectus*, exhibits a rapid increase, signifying the evolution of the first *Homo sapiens* from an *erectus* base.

To Learn More

Technical Summaries

The definitive work on the Nariokotome *Homo erectus* boy has been edited by two of its excavators, Alan Walker and Richard Leakey: *The Nariokotome Homo erectus Skeleton* (1993). A good, very descriptive, general technical work on *Homo erectus* is G. Philip Rightmire's *The Evolution of Homo erectus: Comparative Anatomical Studies of an Extinct Human Species* (1990).

Popular Summaries

Richard Leakey and Roger Lewin's (1992) *Origins Reconsidered: In Search of What Makes Us Human* discusses the discovery, excavation, and interpretation of the Nariokotome skeleton. Much information about *Homo erectus* is offered in *Ancestors: In Search of Human Origins* by Don and Lenora Johanson and Blake Edgar (1994). A very helpful, popular summary of evolution with quite a bit of information on the Lower Paleolithic is provided in Alan Walker and Pat Shipman's *The Wisdom of the Bones* (1996).

There are two great summary chapters devoted to *Homo erectus* (and fossils here called *Homo erectus* but labeled *Homo ergaster* by the authors) in the book *Extinct Humans* by paleoanthropologists Ian Tattersall and Jeffrey Schwartz (2000). Paleoanthropologist Harry Shapiro's *Peking Man* (1974) provides a riveting account of the discovery and loss of Peking Man. Also, see *The Story of Peking Man* (1990), by Jia Lanpo and Huang Weiwen, for a detailed telling of the story of Peking Man by one of its excavators (Jia Lanpo). The best popular books on science present the story of scientific discovery within the personal and cultural context of the individuals involved in those breakthroughs. Paleoanthropologist Pat Shipman (2001) has accomplished just this in her book *The Man Who Found the Missing Link: Eugene Dubois and His Lifelong Quest to Prove Darwin Right*. It is a great read about the initial discovery of a fossil we would come to label *Homo erectus*. Another useful book using the Java hominid discoveries both as a jumping-off point to discuss human evolution and to provide the personal contexts of scientists involved in this analysis is *Java Man: How Two Geologists Changed the History of Human Evolution* by Carl Swisher, Garniss Curtis, and Roger Lewin (2000).

For a summary of the discovery and interpretation of *Homo floresiensis*, take a look at a book co-authored by one of its discoverers, Mike Morwood (Morwood and van Oosterzee 2006), *The Discovery of the Hobbit: The Scientific Breakthrough that Changed the Face of Human History*.

On the Web

Unlike the Neandertals, one of the fossil populations we will be discussing in the next chapter, there aren't really any pages devoted just to *Homo erectus*. However, there's plenty of information about *Homo erectus* sites and specimens on the Internet included within Web pages on the broader topic of human evolution. For example, for details on selected *Homo erectus* fossils and sites, see the pages devoted to this fossil species on the Smithsonian Institution's *Human Origins Program* Web site at <http://www.mnh.si.edu/anthro/humanorigins/ha/erect.html>. On the PBS page *The Origins of Humankind*, you can find an interactive timeline that provides some chronological context for *Homo erectus* (<http://www.pbs.org/wgbh/evolution/humans/humankind/index.html>). You can take a QuickTime spin with one of the crania from Zhoukoudian at http://anthro.amnh.org/qtvr/peking_qtvr.mov.