Early Transitional Humans

Humans are members of the genus *Homo*. Modern people are *Homo sapiens*. However, we are not the only species of humans who have ever lived. There were earlier species of our genus that are now extinct. In the past, it was incorrectly assumed that human evolution was a relatively straight forward sequence of one species evolving into another. We now understand that there were times when several species of humans and even other hominins were alive. This complex pattern of evolution emerging from the fossil record has been aptly described as a luxuriantly branching bush on which all but one twig has died off. Modern humans are that last living twig.

The striking similarities in appearance between the human genus *Homo* and our distant ancestors, the genus *Australopithecus*, is sufficient reason to place us both into the same biological tribe (*Hominini*). Both genera are bipedal and habitually upright in posture. Humans have been somewhat more efficient at this mode of locomotion. Like gracile australopithecines, early humans were light in frame and relatively short. The evolution of larger bodies occurred later in human evolution. The differences between australopithecines and early humans are most noticeable in the head. Humans developed significantly larger brains and relatively smaller faces with progressively smaller teeth and jaws. In addition, humans became ever more proficient in developing cultural technologies to aid in their survival, while the australopithecines did not.

Late gracile australopithecine

Early transitional human

The immediate ancestors of early humans were most likely late gracile australopithecines. At present, the leading contender for that ancestral species is *Australopithecus garhi* or possibly *Australopithicus africanus*.

There may have been one or possibly two species of the first humans living in East Africa--***Homo rudolfensis*** and ***Homo habilis*** (literally "able or skilled human"). The few *rudolfensis* fossils that have been found are somewhat earlier, dating about 2.4-1.6 million years ago, while the more common *habilis* remains are around 2.0-1.6 million years old. *Rudolfensis* apparently was a bit taller and relatively larger brained on average. However, many paleoanthropologists consider the differences to be too slight to warrant a separate species designation. Some have suggested that *rudolfensis* were males and *habilis* were females. As a result, they classify them both as a single species--*Homo habilis*. That is the approach taken in this tutorial.

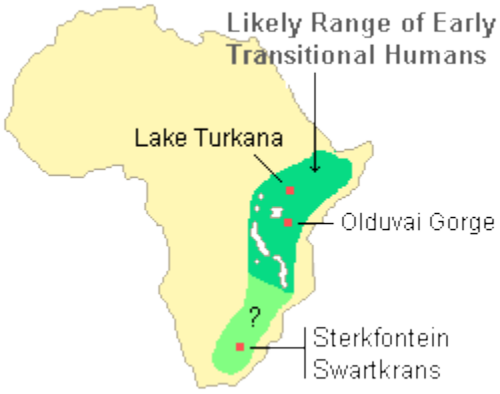
The evolution of the genus *Homo* and the robust australopithecines beginning around 2.5 million years ago coincides with the beginning of a prolonged cooling climate trend in East Africa. It is

likely that this significant environmental change was largely responsible for the rapid evolutionary changes among the hominins at that time.

Homo habilis

Early transitional human fossils were first discovered in 1960 by **Louis and Mary Leakey** at **Olduvai Gorge** in Tanzania. The Leakeys named them *Homo habilis* (Latin for "handy or skilled human") because they apparently made stone tools. Similar fossils were found at East **Lake Turkana** in Kenya by **Richard Leakey's** team of fieldworkers that began searching there in 1969. These latter specimens were named *Homo rudolfensis* after Lake Rudolf (i.e., the former name for Lake Turkana).

So far, conclusive evidence of *Homo habilis* has been found only in the Great Rift Valley system of East Africa. However, their ultimate geographic and time ranges may have been somewhat larger. Early transitional human fossils also have been found in South Africa in the caves at **Sterkfontein** and **Swartkrans** in apparent association with australopithecines. However, not all paleoanthropologists agree that these fossils should be considered *Homo habilis*.



Early transitional humans had brains that on average were about 35% larger than those of *Australopithecus africanus*. In fact, it is beginning with *Homo habilis* that our ancestors finally had brains that were consistently bigger than those of the great apes. Ajit Varki and his team of geneticists at the University of California San Diego campus have discovered a small genetic difference between humans and apes that may account for the progressive increase in the size of human brains. People, but not apes, have a gene that stops the production of N-glycolylneuramine acid. Using "molecular clock analysis," the U.C.S.D. researchers determined that this gene entered the human evolutionary line as a result of a mutation 2.7 million years ago. While it is presumed that the australopithecines lacked this gene, there is no direct evidence.

	Adult cranial capacity (range in cm^3)
chimpanzees	300-500
australopithecines	390-545
early transitional humans	509-752
modern humans	900-1880

As the early human cranium, or brain case, began to enlarge in response to increased brain size, the mouth became smaller. In comparison to the australopithecines, the early humans had smaller teeth, especially the molars and premolars. This suggests that they were eating somewhat softer foods. However, the body size of *Homo habilis* was not significantly larger than the early hominins that preceded them. Likewise, the arms of habilis and their australopithecine ancestors were relatively long compared to ours. The modern human body size and limb proportions began to appear with the next species in our evolution--*Homo erectus*.

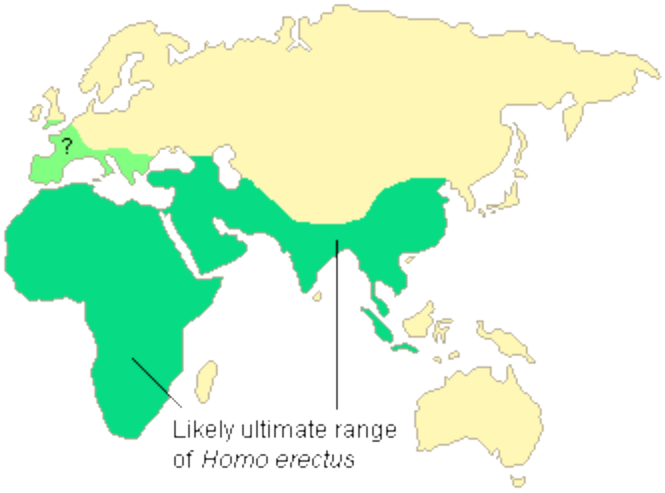
Homo erectus

By 1.8 million years ago, some of the early transitional humans had evolved into a new, fully human species in Africa. Most paleoanthropologists refer to them as ***Homo erectus*** (literally "upright human"). However, a few researchers split them into two species--***Homo ergaster*** (literally "working human") and *Homo erectus.* The *ergaster* fossils were presumably somewhat earlier and have been found for the most part in Africa. The *erectus* discoveries have been found widespread in Africa, Asia, and Europe. In this tutorial, *ergaster* and *erectus* will be considered one species--*Homo erectus*.

Homo erectus from Southeast Asia

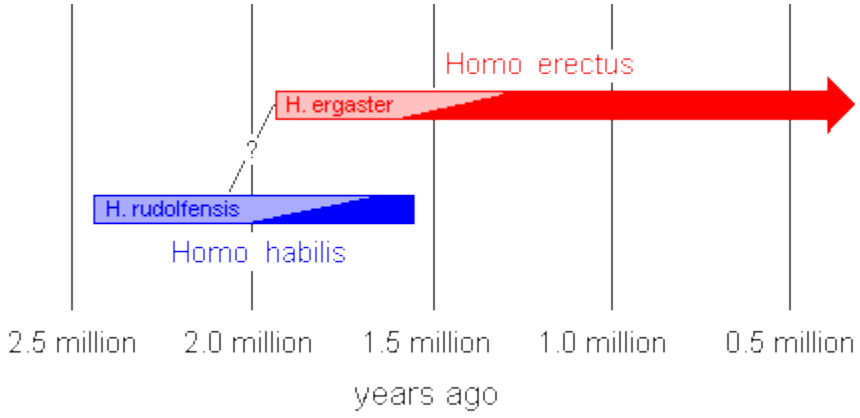
Homo ergaster from East Africa

Homo erectus were very successful in creating cultural technologies that allowed them to adapt to new environmental opportunities. They were true pioneers in developing human culture and in moving out of Africa to populate tropical and subtropical zones elsewhere in the Old World. This territorial expansion most likely began around 1.8-1.7 million years ago, coinciding with progressively cooler global temperatures. Surprisingly, however, *Homo erectus* remained little changed anatomically until about 800,000-700,000 years ago. After that time, there apparently were evolutionary developments in features of the head that would become characteristic of modern humans. By half a million years ago, some *Homo erectus* were able to move into the seasonally cold temperate zones of Asia and Europe. This migration was made possible by greater intelligence and new cultural technologies, probably including better hunting skills and the ability to create fire.



Evolutionary Relationships

The earliest *Homo erectus* were contemporaries of the late *Homo habilis* in East Africa for several hundred thousand years. This suggests that the immediate ancestor of *Homo erectus* was an early *Homo habilis* or possibly another yet to be discovered species of early humans. *Homo erectus* was a very successful human species, lasting at least 1.5 million years, though their numbers apparently remained relatively low. Some of them eventually evolved into our species, *Homo sapiens*. That evolutionary transition was well under way by 400,000 years ago but was not complete until 200,000-100,000 years ago and possibly even later in some regions.



History of Discovery


Eugene Dubois
(1858-1940)

In the late 19th century, our knowledge of human fossil ancestors did not go back beyond that of the Neandertals in Europe, less than 100,000 years ago. There was no inkling of our much earlier ancestors in Africa. A few scientists speculated that the most ancient humans would be found somewhere in tropical regions of East Asia. One of the people who strongly held this view was a Dutch anatomist and medical doctor named **Eugene Dubois**. Late in 1887, he went to the Dutch East Indies (now Indonesia) as a military doctor. This job allowed him enough spare time to pursue his passion, the search for early human fossils. He first explored the big island of Sumatra. Excavating in several caves, he found a hominid jaw fragment in 1890. However, this was not convincing evidence of early human ancestry. He then moved on to Java. During excavations in the eastern part of that island in 1891-1892, he recovered a *Homo erectus* brain case and femur (upper leg bone). Since he had discovered an unknown species, he took the liberty of naming it in an 1894 publication. He called it ***Pithecanthropus erectus*** (literally "ape man who stands erect"). He returned to Holland with his fossils in 1895 and proclaimed them to be from our earliest ancestor. Unfortunately for Dubois, most of the leading paleontologists of his day were not convinced.

Dubois' claims for his Java *Homo erectus* finds were not widely accepted until the 1930's, when the German/Dutch paleontologist Gustav von Koenigswald made similar discoveries in the Dutch East Indies. By that time, there had also been even more convincing discoveries of *Homo erectus* in China. Dubois stubbornly refused to accept any of these fossils as being from the same species as his "Java Man" specimens. He died at the outset of World War II, apparently as a rather lonely maverick scientist frustrated by the inability to convince many people that his conclusions had been correct.

Dating the Java *Homo erectus* fossils has been difficult. In the past, it was generally accepted that most of these bones are 700,000-200,000 years old, based roughly on what was the presumed date for the geological strata in which they were found. In 1994, however, radiometric dating of sand particles attached to two of the fossils indicated that they were actually 1.8 and 1.6 million years old. These dates indicate that some *Homo erectus* left Africa soon after they evolved from early transitional humans.

In 1911, a revolution in China overthrew the last emperor of the Manchu Dynasty and set up a Western-style republic under the American-educated Dr. Sun Yat-Sen. In imitation of western nations, the Geological Survey of China was established in 1917 with a Swedish geologist named **J. Gunnar Anderson** as its advisor. Among the many tasks of the Survey was a search for the source of "dragon bones." This is a Chinese generic term for the fossil bones that end up in apothecary shops as medicines. They are still popularly used in a ground up form for healing wounds and fractures and treating cramps and dizziness. Some older men in China use them as sexual stimulants, though they are being replaced by modern drugs such as Cialis, Viagra, and Levitra.

Davidson Black
(1884-1934)

In 1921, Gunnar Anderson discovered that one of the important sources of "dragon bones" in North China was an abandoned limestone quarry near the village of **Zhoukoudian**. This was only a day's drive over rough dirt roads from Beijing. In 1927, a fossil was found in an ancient cave at the base of the quarry that turned out to be a *Homo erectus* molar tooth. It was examined by **Davidson Black**, a Canadian anatomy professor at Peking Union Medical College. He identified the tooth as being from an earlier species of human which he named ***Sinanthropus pekinensis*** (literally "Chinese man from Peking", or Beijing as it is now called). This discovery sparked 10 years of intense excavations by Anderson, Black, and others (especially Pei Wenshong after 1929 and Franz Weidenreich in the mid-1930's). The bones of 40 individual *Homo erectus* were eventually found at Zhoukoudian.

"Peking Man" skull

The *Homo erectus* skeletal evidence at the "Peking Man" site of Zhoukoudian is especially important because it is from a population of men, women, and children rather than just a single individual. There was considerable sexual dimorphism and individual variability. The human remains were associated with large quantities of animal bones that apparently were mostly food refuse, though many of them had been chewed by large carnivores. A few of the bones had been burned in a way that suggests cooking. In addition, more than 100,000 stone, bone, antler, and horn tools were excavated. The cave was intermittently occupied by late *Homo erectus* for around 100,000 years, beginning around 550,000 years ago.

With the exception of two teeth, all of the *Homo erectus* bones from Zhoukoudian were lost in the chaos of late 1941 when the Japanese Army invaded Beijing and other urban centers in eastern China. There have been a number of intriguing guesses about what happened to the bones. The last time they were accounted for was when they were turned over to a U.S. Marine detachment, placed in wooden foot-lockers and possibly taken 140 miles from Beijing to Camp Holcomb. They were to be transported by ship to the U.S. for safety on an American freighter named the President Harrison. However, after the U.S. entered the war on December 7, 1941, Japanese forces quickly seized Camp Holcomb. At that point in time, the Zhoukoudian fossils disappeared and have never reappeared. In 1949, the Peoples Republic of China established a $100,000 reward for their return. Unfortunately, it has not been claimed. The only surviving bones were the two teeth that had not been turned over to the Marines in 1941.

The loss to science of the Zhoukoudian bones was not as great as it may initially seem. Earlier, they had been measured, photographed, and excellent casts of them had been successfully sent to the U.S. In addition, other *Homo erectus* skeletal material has been excavated in China since the mid 1960's. Most notably are the finds that were recovered from **Lantian** County, Shensi Province. These fossils from several Chinese sites date to about 800,000 years ago. In contrast, the Zhoukoudian cave site was occupied from about 550,000 to 450,000 years ago.

In 1960, **Louis and Mary Leakey** found a 1.25 million year old Homo erectus partial cranium at **Olduvai Gorge**. Subsequently, more *Homo erectus* fossils were discovered there and at other sites in East, South, and Northwest Africa. The oldest known *Homo erectus* date to nearly 2 million years ago in East Africa. This strongly suggests that *Homo erectus* originated there. In 1984, **Richard Leakey's** team working at **Nariokotome** on the western side of Lake Turkana found a nearly complete *Homo erectus* skeleton of a 12 year old boy dating to 1.6 million years ago. It was named the "**Turkana Boy**." The significance of this discovery will be discussed below.


"Turkana Boy"

Three surprisingly early *Homo erectus* skulls were found during the 1990's on the fringes of Eastern Europe at **Dmanisi** in the Republic of Georgia. They date to 1.75 million years ago and look very much like the earliest *Homo erectus* from Africa--i.e., those that have been classified by some researchers as *Homo ergaster*. This discovery lends credence to the 1.8 and 1.6 million year old dates for *Homo erectus* from Java and to an early rather than late *Homo erectus* expansion out of Africa.

Homo erectus-like bones were also discovered during the 1990's from several other sites in Western Europe and Africa that date 800,000-400,000 years ago. It has been difficult to assign these fossils to specific species due to the fact that they have characteristics of both *Homo erectus* and archaic *Homo sapiens*. Some paleoanthropologists consider them to be late transitional *Homo erectus*. Others suggest that they are from a subsequent species (***Homo heidelbergensis***) that preceded modern humans in some areas. This difference of species assignment is not particularly important and it does not detract from our growing understanding of the broad evolutionary trends. It is a result of our evolving conceptualization of the past as more data become available. It also partly reflects the fact that the picture of human evolution looks somewhat dissimilar in different regions of the World. It is now becoming clear that our evolution was not as straight forward as it once was commonly thought. Humans in some areas lagged behind. This was particularly true on some islands of Indonesia. At **Ngandong** on Java, for instance, *Homo erectus* may have survived to 53,000 years ago or even somewhat later.

Important Homo erectus Sites

	Date of Fossil (years ago)	Cranial Capacity (in cm.^{3})
Africa:		
East Turkana	1,800,000-1,600,000	850-900
West Turkana	1,500,000	
Olduvai Gorge	1,300,000-700,000	1067
Bouri	1,000,000	
Swartkrans	1,800,000-1,500,000	
Ternifine	700,000-500,000	
Salé	400,000	900
Java:		
Modjokerto	1,800,000	----
Sangiran	1,800,000-1,600,000	813-1059
Trinil	900,000 ?	----
Ngandong	400,000	
China:		
Lantian	800,000	780
Zhoukoudian	550,000-450,000	850-1250
Hexian	400,000	1025
Europe:		
Dmanisi	1,750,000	
Atapuerca	1,200,000	

Note: Several human fossils found in Europe dating 800,000-400,000 years ago are controversial. They are classified as *Homo erectus* by some researchers and *Homo heidelbergensis* (a later human species) by others. They will be presented in the next tutorial of this series.

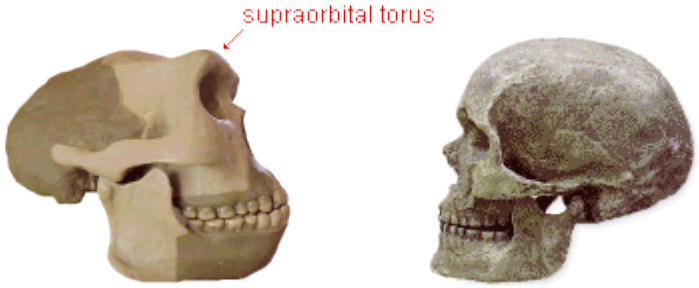
Homo erectus Anatomy

Below the neck, *Homo erectus* were anatomically much like modern humans. Their arm and leg bones were essentially the same as modern people in shape and relative proportions. This strongly supports the view that they were equal to us in their ability to walk and run bipedally. However, their leg bones were apparently denser than ours. This may be partly a result of developmental adjustment differences. Unlike us, these early humans did not spend much of their lives sitting behind desks or on a sofa watching TV. They actively used their legs more throughout the day. It also has been suggested that the pelvis in early *Homo erectus* may have been a bit narrower than in modern humans, which would require the infant brain to be smaller at birth and to then undergo

considerable growth in childhood. However, we must be careful to not make too much of these differences because the number of existing specimens is low and there were minor regional variations as well. This becomes apparent especially when comparing *Homo erectus* from Asia and Africa.

With the evolution of *Homo erectus*, there was a significant increase in body size compared to earlier hominids. Past estimates of *Homo erectus* stature frequently were in the 5-5½ feet (1.5-1.7 m.) range for adult males and around 100-110 pounds (45-50 kg.). The discovery of the "Turkana Boy" in 1984 brought this into question. This is not only the most complete specimen of this species so far discovered, but it is one of the earliest. The boy was only about 12 years old when he died but already 5 feet 3 inches (1.6 m.) tall. If he had lived to adulthood, he very likely would have grown to 6 feet (1.8 m.). As the number of nearly complete *Homo erectus* skeletons increases in the future, a clearer understanding of the range of their stature and body shape will likely emerge.

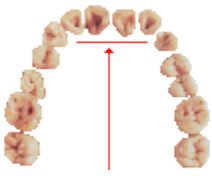
Homo erectus heads were strikingly different from ours in shape. They had relatively strong muscles on the back of their necks. Their foreheads were shallow, sloping back from very prominent bony brow ridges (i.e., **supraorbital tori**). Compared to modern humans, the *Homo erectus* brain case was more elongated from front to back and less spherical. As a consequence, the frontal and temporal lobes of their brains were narrower, suggesting that they would have had somewhat lower mental ability.



Homo erectus
(from Java)

Homo sapiens
(modern human)

The adult *Homo erectus* brain size ranged from around 750 to 1250 cm^3, averaging about 970 cm^3. While this was only around 72% the size of modern human brains on average, the upper end of the *Homo erectus* brain size range overlapped that of modern people. However, the larger brained *Homo erectus* mostly were relatively late in time and are considered by some paleoanthropologists to be a more recent human species (*Homo heidelbergensis* or early archaic *Homo sapiens*).



shovel-shaped
incisors

Homo erectus teeth were generally intermediate between modern humans and the australopithecines in shape and size. The teeth of later *Homo erectus* were generally smaller than the earlier members of this species. This was particularly true of molars. This evolutionary trend probably reflects a progressive change in diet to softer foods, including more meat and eventually cooked food. The incisor teeth of *Homo erectus* generally have a "scooped out" appearance on the tongue side. These "shovel-shaped" incisors are also found

among many Asians and Native Americans today.

Homo floresiensis

In 2003, a team of Australian paleoanthropologists led by Peter Brown discovered a skeleton from what may be a dwarf *Homo erectus* or related species that lived 18,000 years ago on Flores Island, Indonesia. This 30 year old adult female was only a little over 3 feet (1.0 m.) tall and had a brain size of 380 cm^3 (barely 1/3 as big as modern human brains, like those of australopithecines). This find implies that a population of exceptionally small *Homo erectus* or *Homo erectus*-derived humans survived on this relatively isolated island east of Java until far later than previously believed. Brown refers to this new discovery as ***Homo floresiensis***. The bones of 8 additional individuals of this cave dwelling population were subsequently found on Flores Island.

At present, there is no clear consensus among paleoanthropologists as to the place of *floresiensis* in human evolution. Peter Brown and his colleague, Michael Norwood, suggest that *floresiensis* may have been a descendent of normal size *Homo erectus* who arrived in this area of Indonesia about 800,000 years ago and that they became small as a result of a well known biological phenomenon referred to as "island dwarfing". They also believe that *floresiensis* may have survived on the island until a devastating volcano wiped them out, along with dwarf elephants, around 12,000 years ago. Critics suggest that the Flores Island dwarfs were, in fact, modern people who suffered from microcephaly, a pituitary gland disorder known as Laron syndrome, or hypothyroidism due to a lack of iodine in their diet.

The short streaming video clip and the narrated slide show linked below will help you get a better understanding of this intriguing discovery.

Climate Change and Human Evolution

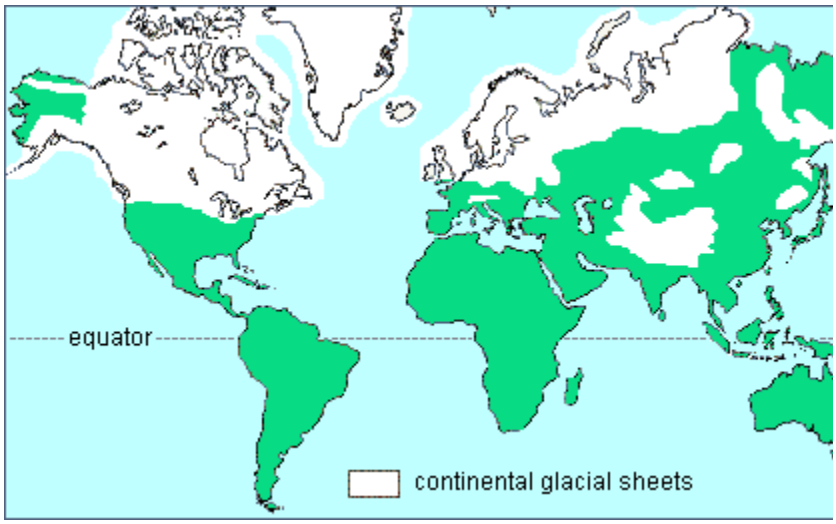
The evolutionary surge that led to *Homo habilis* began towards the end of the Pliocene Epoch around 2.5 million years ago when climates were becoming cooler. The evolution of *Homo erectus* and later species of humans occurred during the following Pleistocene Epoch (1,810,000-10,000 years ago). The Pleistocene was generally a time of more extreme world cooling and recurrent **glaciations** (ice ages). During the coldest periods, long-lasting ice sheets spread out from the poles and high mountains. Between the 4 or more major glaciations of the Pleistocene, there were interglacial warming periods with temperatures similar to now. Both the glacials and the interglacials lasted tens of thousands of years. Very likely, we are now in an interglacial that began around 10,000 years ago.

Changing Climate Patterns of the Pleistocene Epoch				
Epoch	**Climate**	**Years Ago * (approximate)**	**Regional Name**	
			European Alps	**North America**
Holocene	interglacial	10,000 to the present		
Pleistocene	glacial	110,000 to 12-10,000	Würm	Wisconsin
	interglacial	130-125,000 to 110,000	Riss-Würm	Sangamon
	glacial	200,000 to 130-125,000	Riss	Illinoian
	interglacial	380-300,000 to 200,000	Mindel-Riss	Yarmouth
	glacial	455-410,000 to 380-300,000	Mindel	Kansan
	interglacial	620,000 to 455-410,000	Günz-Mindel	Aftonian
	glacial	680,000 to 620,000	Günz	Nebraskan
	Evidence of glacial and interglacial episodes during the early Pleistocene is less clear. However, it is believed that there were 2 or more glacials with intervening interglacials. Between the Pleistocene and the preceding Pliocene Epoch was a long period of gradual cooling that began 2.6-2.5 million years ago.			
Pliocene	5.3-1.81 million years ago--mostly warmer conditions than the Pleistocene			

* These time ranges are approximations and do not reflect the fact that temperature changes between glacials and interglacials usually occurred over thousands of years. (principal source: P. Gibbard and T. Van Kolfschoten (2004) "The Pleistocene and Holocene Epochs", ch. 22, in F. M. Gradstein et.al., *A Geologic Time Scale* (2004), Cambridge University Press)

The continents of the northern hemisphere were more affected by glaciations than the southern ones, which generally remained mostly tropical and subtropical, though more humid during ice ages. The coldest regions of the world became arctic deserts. However, the great deserts of North Africa and Western North America today were mostly vast grasslands with large permanent lakes and abundant game animals during the Pleistocene ice ages. Sea levels were 300-400 feet (ca. 90-120 m.) lower than today during the coldest periods as a result of a substantial volume of the world's water being locked on the continents in 1-2 mile (ca. 1.5-3 km.) thick glacial sheets covering thousands of square miles. As a consequence, vast areas that are today shallow sea and ocean bottoms were exposed for thousands of years. Twice during the last ice age, lowered sea levels resulted in Siberia being connected to Alaska by a 1200-1300 mile (1900-2100 km.) wide corridor.

Asian hunters used this route to migrate into the western hemisphere to become the first Native Americans.



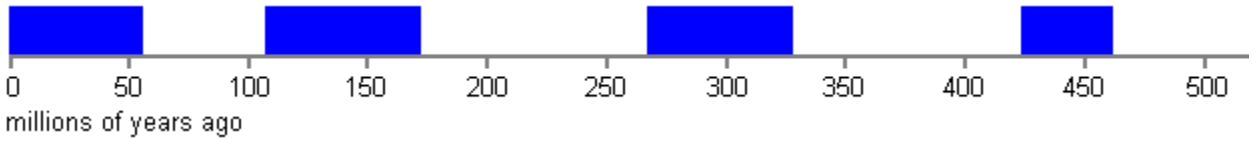
Extent of major glaciers at the height of the last ice age (20,000 b.p.)

Ice age conditions in the northern hemisphere during the Pleistocene (persistent glaciers with tundra and cold forests at lower elevations farther south)

Human evolution was very likely affected strongly by the dramatic climatic swings of the Pleistocene. These changes no doubt presented powerful new natural selection pressures. Many animal species were driven to extinction by the advancing and retreating ice ages. Humanity survived primarily by becoming more intelligent and adaptable. This allowed us to develop new cultural technology to deal with cold environments, especially during the last 1/4 million years. One of the greatest problems in the cold regions would have been the relative scarcity of plant foods that humans could eat during the winters. In response to this, our ancestors became more proficient at hunting animals, especially large ones that provided more calories. This required inventing more sophisticated hunting skills as well as better weapons and butchering tools. These changes in subsistence pattern were essential for our survival.

During ice ages, those species that were not driven to extinction by the cold commonly evolved larger, more massive bodies as a means of producing and retaining more heat. This was especially true of mammals in the northern hemisphere. This is to be expected, given the predictions of Bergmann's rule. Humans evolved larger bodies during the Pleistocene as well.

Major Long-term Cold Periods Over the Last 1/2 Billion Years
(shown in blue)



(These time ranges are approximations and do not reflect the fact that temperature changes between major cold
and warm phases of the earth's history usually occurred over long periods of time and that the cold periods varied
in temperature and were not consistently cool.}

Early Human Culture

Paralleling the biological evolution of early humans was the development of cultural technologies that allowed them to become increasingly successful at acquiring food and surviving predators. The evidence for this evolution in culture can be seen especially in three innovations:

1. the creation and use of tools
2. new subsistence patterns
3. the occupation of new environmental zones

Tool Making

Some chimpanzee communities are known to use stone and wood as hammers to crack nuts and as crude ineffective weapons in hunting small animals, including monkeys. However, they rarely shape their tools in a systematic way to increase efficiency. The most sophisticated chimpanzee tools are small, slender tree branches from which they strip off the leaves. These twigs are then used as probes for some of their favorite foods--termites and ants. More rarely, chimpanzees have been observed using sticks as short thrusting spears to hunt gallagos in holes and crevices in trees where they sleep during the day time. It is likely that the australopithecines were at least this sophisticated in their simple tool use.

The first unquestionable stone tools were evidently made and used by early transitional humans and possibly *Australopithecus garhi* in East Africa about 2.5-2.4 million years ago. While the earliest sites with these tools are from the Gona River Region of Ethiopia, simple tools of this kind were first discovered by Mary and Louis Leakey associated with *Homo habilis* at Olduvai Gorge in Tanzania. Hence, they were named **Oldowan** tools after that location. These early toolmakers were

selective in choosing particular rock materials for their artifacts. They usually chose hard water-worn creek cobbles made out of volcanic rock.

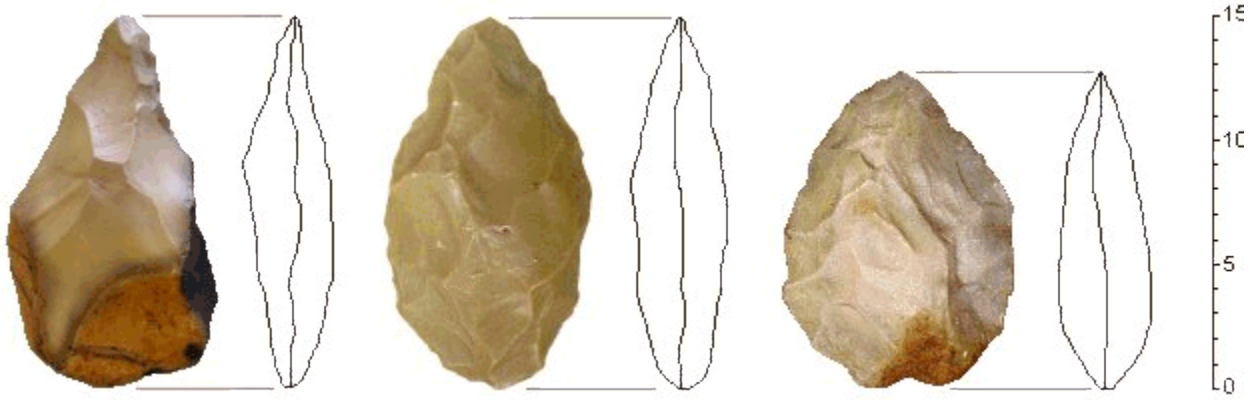
There were two main categories of tools in the Oldowan tradition. There were stone cobbles with several flakes knocked off usually at one end by heavy glancing percussion blows from another rock used as a hammer. This produced a jagged, chopping or cleaver-like implement that fit easily in the hand. These **core tools** most likely functioned as multipurpose hammering, chopping, and digging implements. Efficient use of this **percussion flaking** technique requires a strong precision grip. Humans are the only living primates that have this anatomical trait. Probably the most important tools in the Oldowan tradition were sharp-edged stone flakes produced in the process of making the core tools. These simple **flake tools** were used without further modification as knives. They would have been essential for butchering large animals, because human teeth and fingers are totally inadequate for penetrating thick skins and removing pieces of meat. Some paleoanthropologists have suggested that the core tools were, in fact, only sources for the flake tools and that the cores had little other use.

Oldowan tradition core tool (chopper)

In addition to stone tools, *Homo habilis* probably made simple implements out of wood and other highly perishable materials that have not survived. In the 1940's, Raymond Dart suggested that australopithecines and early humans also used the hard body parts of animals as clubs, daggers, and other sorts of weapons. Dart proposed an entire tool making tradition which he named **osteodontokeratic**, based on the presumed use of bones (osteo), teeth (donto), and horns (keratic). This idea has been rejected by most paleoanthropologists today since there is a lack of evidence for the systematic shaping or even use of these materials for weapons or other types of tools at this early time. In addition, it is unlikely that the earliest humans were aggressive hunters. They most likely were primarily vegetarians who occasionally ate meat that was mostly scavenged from the leftovers of kills abandoned by lions, leopards, and other large predators. At times, they also may have hunted monkeys and other small game much as chimpanzees do today.

Homo habilis made and used stone tools in the Oldowan tradition for nearly a million years but with gradual improvements over time. The early *Homo erectus* also used what could be described as advanced or evolved Oldowan tool making techniques. By 1.7-1.6 million years ago, the skills of some *Homo erectus* had increased to the point that they were making more sophisticated stone implements with sharper and straighter edges. Their tool kits were sufficiently advanced by 1.5 million years ago to consider them to be a new tool making tradition now referred to as **Acheulian**. It was named after the Saint Acheul site in southwest France where these kinds of tools had been discovered in the 19th century. However, the Acheulian tool making tradition was first developed in

East Africa. Perhaps, the most important of the Acheulian tools were **hand axes**. They are rock cores or very large flakes that have been systematically worked by percussion flaking to an elongated oval shape with one pointed end and sharp edges on the sides. Since they were shaped on both faces, they are also referred to as **biface** tools. In profile, hand axes usually had a teardrop or broad leaf shape. Referring to these artifacts as hand axes may be misleading since we do not know for sure whether they were primarily axes in a modern sense or even if they were held in the hand. Based on tool edge wear patterns and the brittle fracturing lithic materials that were used to make them, it is likely that hand axes were multipurpose implements used for light chopping of wood, digging up roots and bulbs, butchering animals, and cracking nuts and small bones. In a sense, they were the Swiss Army knives of their times. They were reusable portable tools intended to be carried from place to place rather than made each time they were needed.



Acheulian biface tools (hand axes)

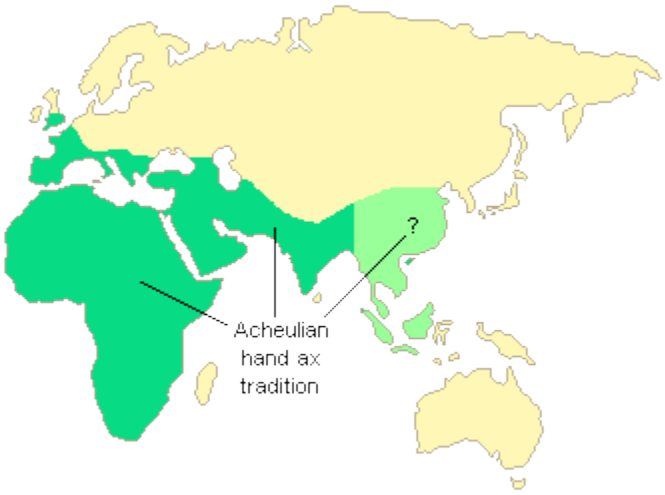
Some of the Acheulian tools were shaped by additional percussion flaking to relatively standardized forms. For instance, the surfaces of late Acheulian hand axes often had many relatively small flake scars, suggesting that these tools were not completely made with heavy hammerstones. Late *Homo erectus* or their immediate successors must have begun using softer hammers for greater control in the final shaping process. Pieces of hard wood, antler, or bone would have functioned well for this purpose.

Percussion Flaking Techniques: hard hammer (left) and soft hammer (right)

While hand axes were the most diagnostic of Acheulian tools, they usually make up only a small percentage of the artifacts found at *Homo erectus* sites. In fact, these early humans made a relatively wide variety of stone tools that were used for processing various plant and animal

materials. Their tool kits included choppers, cleavers, and hammers as well as flakes used as knives and scrapers. It is quite likely that *Homo erectus* also made many implements out of more perishable materials such as wood, bark, and even grass, which can be easily twisted together to make string and rope.

The Acheulian tradition of tool making spread from Africa into Southwest Asia by 1.4 million years ago and reached southern Europe by at least 600,000 years ago. Until recently, the lack of hand axes at Zhoukoudian and other East Asian *Homo erectus* sites suggested that the Acheulian tradition did not reach that far. It was thought likely that the same functions that hand axes performed in the west were being performed in the far East by other kinds of tools, perhaps made of bamboo. However, 24 sites in southern China have now been found to contain Acheulian tools dating back about 800,000 years. There remains controversy as to whether they include true hand axes.



Throughout most of the *Homo erectus* geographic range, there is clear evidence of progressive improvement in tool making over time. The late *Homo erectus* had more complex mental templates guiding them in the manufacture of their artifacts. In addition, the reliance on tools increased as the implements became more useful. By 400,000 years ago, major *Homo erectus* sites commonly had tens of thousands of discarded stone tools.

New Subsistence Patterns

Anthropologists use the term **subsistence pattern**, or **subsistence base**, to refer to sources of food and the way it is obtained. A clear measure of success in human evolution has been the progressive development of new food getting techniques and the inclusion of new food sources. These measures have made it possible for humanity to increase in numbers from a few thousand australopithecines in Africa 3 million years ago to perhaps hundreds of thousands of *Homo erectus* by ½ million years ago. This trend of expanding and diversifying subsistence patterns making it possible for population growth continues to the present. In fact, it accelerated dramatically two centuries ago and is largely responsible for our burgeoning world population of over 6.6 billion people today.

Based on the analysis of tooth wear patterns and food refuse evidence, it is likely that australopithecines and early transitional humans were primarily wild plant food collectors and occasional scavengers of meat and eggs. By the time of *Homo erectus*, small game hunting and large animal carcass scavenging were apparently becoming much more common. The evidence of this change in subsistence pattern can be seen especially at late *Homo erectus* sites such as Zhoukoudian. Literally tens of thousands of fragmentary food refuse bones were found there. They came from pigs, sheep, rhinoceros, buffalo, and especially deer. In addition, there were large numbers of bones from small animals including birds, turtles, rabbits, rodents, and fish as well as the shells of oysters, limpets, and mussels. Some of these bones ended up in the cave at Zhoukoudian as a result of large carnivorous animals rather than humans, but there is sufficient evidence to suggest that by 1/2 million years ago, some *Homo erectus* were exploiting virtually every animal in their environment for food. They undoubtedly were harvesting vast amounts of wild plant foods as well. It would be a mistake to assume that *Homo erectus* had become an efficient specialized big game hunter. That development did not occur until more advanced *Homo sapiens* had evolved, several hundred thousand years later.

Occupation of New Environmental Zones

Homo erectus was the first species in our line of evolution to expand their range beyond tropical and subtropical environments into temperate climatic zones of the Old World where they encountered relatively cold winters. This evidently occurred by at least ½ million years ago in Asia and a possibly few hundred thousand years earlier in Europe. It was made possible mainly by the success of new inventions and new subsistence strategies. The most important change may have been increased meat consumption as a result of hunting and more successful scavenging. The greatest difficulty living in temperate areas was probably not the cold weather but obtaining something to eat during the winter when fresh plant foods are scarce. It is in that season that meat would have been the most important calorie source.

The ability to use fire for cooking and heating may also have been significant in the successful colonization of colder regions. However, the first convincing evidence of regular fire use for these purposes does not come until 400,000-300,000 years ago, when *Homo erectus* were evolving into *Homo heidelbergensis* (archaic *Homo sapiens*). The earliest suggestive evidence of fire being associated with humans was found at two sites in Kenya dating to 1.5 million years ago. In both cases, soil sediments appear to have been exposed to high temperatures. However, it is not necessary to assume that early humans were responsible. The burned soil could have resulted naturally from lightning started wild fires that are common in the grasslands of East Africa even today. Similar questionable evidence has been found in South Africa dating to about 1,000,000 years ago. There is no convincing evidence of human control of fire at this early time. A 790,000 year old site in Israel has more credible evidence, though there does not seem to have been any cooking or repeated fire creation. The first reasonably good evidence of cooking is in the form of burned bones and fire altered stones at the Chinese site of Zhoukoudian dating sometime between 550,000 and 450,000 years ago. All of these sites in Africa and Asia with uncertain fire use indications presumably would have been occupied by *Homo erectus*. We have no evidence as to how *Homo erectus* might have obtained fire or even if they had the ability to create it at will.

Implications

The cultural developments of *Homo erectus* essentially began a new phase of our evolution--one in which natural selection was altered by cultural inventions. This has been referred to as **biocultural evolution**. Culture can affect the direction of human evolution by creating non-biological solutions to environmental challenges. This potentially reduces the need to evolve genetic responses to the challenges. Normally, when animals move into new environmental zones, natural selection, operating on random mutations, causes evolution. In other words, the population's gene pool is altered as a result of adapting to a new environment. When late *Homo erectus* moved into temperate environments, nature should have selected for biological adaptations that were more suited to cooler climates. Such things as increased amounts of insulating body fat and insulating hair covering most of the body would be expected. *Homo erectus* evidently achieved much of the same adaptation by occupying caves, using fires, and becoming more capable at obtaining meat. By using their intelligence and accumulated knowledge, they remained essentially tropical animals despite the fact that they were no longer living only in the tropics. However, natural selection continued to select for increased brain size and presumably intelligence. This pattern of culture altering natural selection accelerated dramatically with the evolution of modern humans. Today, most of us live in cities and towns that are essentially unnatural environments and the rate of culture change has accelerated dramatically. We have occupied most environmental zones on land, and yet we are still essentially tropical animals physically. As a result, we perish rapidly if our cultural technology is taken away from us in environments in which the temperature drops to freezing.

NEWS: In the September 27, 2001 issue of the journal Nature, Rixiang X. Zhu of the Chinese Academy of Sciences in Beijing announced that stone tools made by Homo erectus about 1.36 million years ago have been found in the Nihewan Basin of northeastern China. This is the earliest confirmed evidence of Homo erectus in temperate regions of East Asia. These artifacts imply that Homo erectus were able to adapt to relatively cold winter climates more than a half a million years earlier than previously believed. Until the discovery of additional well dated sites confirming this evidence, it would be wise to hold judgment.