

## 5. *Homo sapiens* Arrives

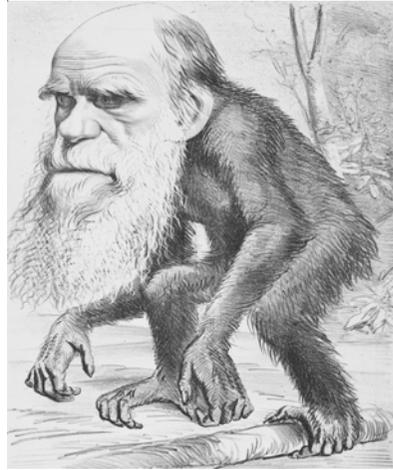
No aspect of evolution has been more contentious than the idea that humans evolved from an ape-like ancestor. The evolution of humans from a primitive form strikes at the heart of the widely-held religious notion that we are uniquely created by and in the image of the Supreme Being and thus hold a special place in the Universe. Evolution is the principle over which the confrontation between science and religion is most explosive. Some folks, mainly writers without science credentials (such as those from the British Broadcasting Corporation, or BBC), contribute to this contentiousness by using words like "ape-man" ("Near complete ape-man skull found", BBC, Wednesday, 26 April 2000; "'Oldest' ape-man fossils unearthed", BBC, Monday, 4 December 2000; "Ape-man ate termites", BBC, Monday, 16 January 2001).

Some early paleoanthropologists such as Robert Broom (*The South African Fossil Ape-Men. The Australopithecinae* published by the Transvaal Museum in 1946), insensitive to the dispute raised by religious folks or perhaps seeking to capitalize on the instant recognition the dispute offers, also contributed to this contentiousness. Perhaps because they refuse to be cowed, more modern scientists are not adverse to stoking the contentiousness of the debate (e.g., The Upright Ape: Bipedalism and Human Origins Symposium held by the Center for Academic Research & Training in Anthropogeny, or CARTA, in 2011) even though their official stance is that *Homo sapiens* is not an ape at all but rather apes and *H. sapiens* both evolved from a more primitive ancestor. "The Upright Ape" is simply throwing down a gauntlet.

Ever since Darwin published *The Descent of Man, and Selection in Relation to Sex*, foes of evolution have egregiously misstated the scientific view of human evolution by saying that Darwin believed we evolved from monkeys. The correct scientific view is that humans and the great apes both diverged from a last common ancestor (LCA in paleolingo) millions of years ago, a common ancestor more primitive than even the great apes. Monkeys are our very distant cousins, but not our ancestors. If we go back enough generations (say, 3 billion years worth), we're related to all life on the planet, even plant life. "Evolution" is simply the name given to the process by which the tree of life branches through genetic mutations. It's an inevitable consequence of the laws of nature operating on biological systems.

### Charles Darwin as a Monkey

This 1871 cartoon depicting Charles Darwin as a monkey is typical of the hysterical, egregious misrepresentation of evolution to which detractors have resorted ever since Darwin published *The Descent of Man, and Selection in Relation to Sex*.

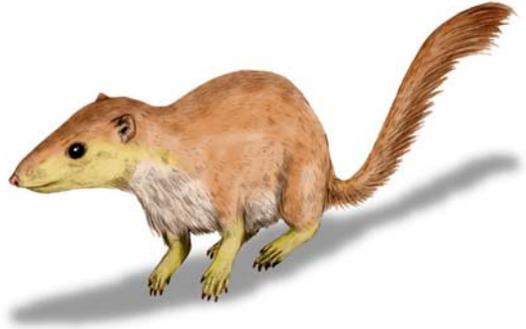


We humans (the word “human” is not a scientific term) belong to a group of animals called primates, which have a number of characteristics that are different from all other mammals:

- Primates have a unique set of teeth.
- Primates have forward-facing eyes on the front of the skull, giving them binocular vision which allows accurate depth perception.
- Primates are more dependent on vision and therefore have a smaller nose and a smaller volume of their brain devoted to the sense of smell.
- With the exception of spider monkeys, which don’t have thumbs, primates have five digits on each limb with keratin nails instead of claws on the end of the first digit although other digits can have claws. This makes manipulating bits of food and other objects much easier.
- Primates have opposable thumbs, a characteristic primate feature, although this feature is not limited to primates (opossums, for example, also have them). An increasing refinement of the hands and feet for grasping objects has been a hallmark of primate evolution.
- Primates’ hands and feet have sensitive pads on the tips of their digits.
- Primates are unique in having fingerprints.
- Primates have a clavicle, or collarbone.
- Primates have particularly flexible and limber shoulders and hip joints. The shoulders help them to have overarm movement, ideal for swinging through trees (and throwing a baseball) and being able to climb up and down quickly. Their hips are just as mobile, allowing them greater range of motion in their legs.
- Compared to most other animals, primate brains are large relative to their body size.
- Primates tend to live a relatively long time.
- Primates have a long period of growth & development before they are considered mature.
- Primates tend to live in long-lasting groups.

### *Purgatorius*

This small Paleocene mammal is considered by many palaeontologists to be the first fossil with primate characteristics of any sort. Its teeth were typical of those of primates.



Not all primates have all these characteristics, but having only one of them makes a critter a primate because they're all unique to primates. For example, the earliest known primate, *Purgatorius*, which lived for an unknown length of time sometime between 65.5 and 56.8 million years ago (according to the Paleobiology Database hosted online by the University of California at Santa Barbara and the Macquarie University in Australia), is classified as a primate based solely on its teeth. It looked like a rat, but it had primate teeth. So it had one of the characteristics of a primate and was, therefore, a primate, though an early, very, very rudimentary one. *Purgatorius* is named after the place where it was found: Purgatory Hill in Montana's Tullock Formation. During the scores of millions of years since *Purgatorius*, primates added characteristics until the presently most "advanced" species, *Homo sapiens*, has them all.

Genetic analyses have suggested that a gene unique to primates first appeared in our genetic code sometime during the Cretaceous, but it's uncertain whether or not it was active ("expressed" in the lingo of biologists) so that it could manufacture its particular protein. The mere existence of a gene doesn't necessarily imply that the mechanism for its expression is in place. No Cretaceous fossil that can be recognized as a primate has been found. Thus, the Paleocene's *Purgatorius* is probably the first animal to appear that has even the barest minimum primate characteristic.

After *Purgatorius*, many primate species appeared, then disappeared in the evolutionary drift toward *Homo sapiens*, but only a few will be mentioned in these pages. *Altiatlasius koulchii* (58.7 to 55.8 million years ago) from Morocco was a primate that had evolved a few more "advanced" traits than *Purgatorius*. It was somewhat squirrel-like in size and appearance but apparently had grasping hands and feet that were more efficient in manipulating objects and climbing trees than its earlier kin. It possibly had developed effective stereoscopic vision.

*Siamopithecus* (37.2 to 33.9 million years ago) had a parabolic mandibular dental arch like humans have; relatively small, highly convergent, and frontal-facing orbits (eye sockets); and a relatively short face (smaller snout than its ancestors). Gradually, over millions of years, the lobe in primates' brain associated with the sense of smell grew smaller while the

lobe associated with sight grew larger. Recent research has shown that of the approximately 1,000 human olfactory receptor genes, only 347 remain functional. The rest have accumulated mutations that deactivate them. This gradual loss of the keenness of the sense of smell from that of our ancestors didn't hamper our ancestors' ability to survive (which is the ultimate "good" in nature) because the increase in the keenness of sight and the shift in survival strategies that made use of sight more than compensated. This shift in emphasis was probably encouraged by the early primates' life in trees, which most likely included an increase in fruit as food and a certain amount of leaping from limb to limb.

The best preserved ancient primate fossil and one of the best preserved fossils of any kind ever found is 47 million year old *Darwinius masillae* from the Messel pit in Germany. *Darwinius* had grasping hands, a small snout, and forward facing eyes, suggesting that it probably had good depth perception. It was not specialized for either climbing or leaping but probably could do both with a moderate degree of skill. The contents of its stomach, which were part of the outstandingly preserved remains, revealed that it dined on fruit and leaves. There is considerable debate over where *Darwinius* lies in primate evolution.

After *Darwinius*, few fossils referable to hominidae lineages are known until around the beginning of the Late Miocene Period, 11,608 years ago. Only teeth and some bones can be found. After all, living things are biodegradable, and given enough time, even teeth and bones will disappear, especially in the acid rich soils of equatorial Africa. That fossils are found at all is probably simply a tribute to the huge amount of life in the biosphere.

Mutations that primates, indeed all life, accumulate are the result of random errors in the chemical processes that control life. The Appendix explains this in more detail. All forms of life accumulate different mutations that are then passed on to their progeny unless the mutations prove to be unfavorable for survival. They don't necessarily have to be beneficial (benign changes, such as the hundreds of deactivated human olfactory genes, can be retained), but they can't be unfavorable. The slow accumulation of mutations that deactivate genes such as the deactivated human olfactory genes is probably one of the factors that causes a species to become extinct. Thus, primates, and indeed all life, have branched from one another repeatedly. Some branches die out, sometimes leaving no record of their existence, while others continue. (The technical term for the study of how all life has branched from one another is "cladistics". Cladistics is a modern method of describing the relationships all life have to one another and replaces the kingdom-to-species organization system introduced by Carl Linnaeus.)

The first separation of primate branches occurred during the early Eocene, before the time of *Darwinius*, when enough mutations accumulated to separate primates into Haplorhini, (which include tarsiers, monkeys, apes, and humans) and Strepsirrhini (which include lemurs and lorises). The exact mutations that identify early fossils as belonging to one branch or the other

### Eocene Primate *Darwinius masillae*

This hypothetical representation of *Darwinius*, which was discovered in the Messel pit in Germany, was drawn by Bogdon Bocianowski as part of the discovery paper that was published on the Public Library of Science Web site. *Darwinius* had several more primate characteristics than *Purgatorius* did and looked more like a primate.



is the subject of lively debate. Representatives of both Haplorhini and Strepsirrhini are extant (still living). Shortly thereafter, Haplorhini split into Tarsiiformes and a group sometimes called Anthropoidea. Tarsiiformes are still around, but have only three extant genera encompassing nine species of *Tarsius*, one species of *Cephalopachus*, and one species of *Carlito*. Anthropoidea include monkeys, apes, and humans.

Shortly after the Haplorhini split, Anthropoidea split into catarrhines (which include macaques, gibbons, orangutans, gorillas, chimpanzees, and humans) and platyrrhines (which are often called New World monkeys and encompass five families of primates found in South America). A fossil analysis by Richard F. Kay places the separation sometime before 36 million years ago, and a molecular analysis places it around 46 million years ago.

Sometime after the Anthropoidea split, catarrhines branched into Cercopithecoidea, which includes such extant genera as macaques and baboons, and Hominoidea, which includes apes and humans. Much of our understanding of the evolutionary divergences that lead to the various branches of the primate family tree comes from genomic analyses. As discussed in Chapter 4, palaeontologists have begun since the 1990s to supplement the fossil record with estimates based on genomic data. In 2004, Michael E. Steiper, Nathan M. Young, and Tika Y. Sukarna published a paper in the *Proceedings of the National Academy of Science* (PNAS) in which they use genomic data to estimate the divergence of catarrhines into the hominoid and cercopithecoid superfamilies. Their analysis suggests that this divergence occurred between 29.2 and 34.5 million years ago, around the early Oligocene. A number of genomic analyses published before 2000 have estimated the hominoid/cercopithecoid split to have occurred between 20 and 25 million years ago. Unfortunately, genomic analyses don't yield pre-

cise times of divergence events because different genes accumulate mutations at different rates, so estimates depend on the specific genes chosen to analyze and their calibration with the fossil record. Nevertheless, such analyses give good ballpark figures.

Around the end of the Oligocene, Hominoidea separated into Hominidae, which encompass humans and the great apes such as gorillas and chimpanzees, and Hylobatidae, or the lesser apes such as gibbons. This is the time when our ancestors began to accumulate the mutations that separate *Homo sapiens* from the great apes.

It might be instructive at this point to identify the set of general traits that are more restrictive than those merely defining primates and that separate humans from our primate brethren.

- Humans are unspecialized. We're not very strong and are not particularly fast runners, climbers, or swimmers, but we do them all moderately well.
- Humans have a suite of skeletal characteristics that allows bipedalism to be our primary way of getting around, and any of these can suggest, but not prove, that a specific fossil is the remains of a bipedal hominid.
- Humans have a larger, more complex brain for our size than any other animal.

The most obvious human characteristic that separates us from our primate brethren is that we are bipedal; moving on only two legs is our primary mode of locomotion. Some paleoanthropologists have opened up membership in the club of humans to a wide range of species by taking the point of view that being a bipedal primate is all that's necessary to be called human. For example, Aaron Filler has written, "What defines a 'human?' I have taken the position that it is a body plan (bauplan). Video from a recent study showing that chimpanzees consistently outperform human college students on a complex computer based eidetic [photographic] memory task shows that the common ancestor's intellect was at least respectable. However, despite being 'human,' australopithecines almost certainly did not have articulate speech or 'superior' mental development. It seems that we are unavoidably forced to abandon articulate language and superior intellect as requirements for our critical definition of a human." This reflects a minimal definition of "intellect" as merely being able to remember something.

The memory test that was conducted in the experiment to which Dr. Filler refers involved teaching chimpanzees to recognize the symbols and proper order for the numbers one through nine. The test subject was shown the symbols in a random arrangement on a computer screen and was required to touch the symbols on the screen in the proper sequence. As soon as the subject touched the first symbol, the rest were replaced with blank squares which then had to be touched in the proper numeric sequence to complete the test. Thus, the subject had to remember where the symbols had been located. A key element in the test was that the random arrangement was initially shown only briefly, often for less than a second. The chimpanzees consistently performed this test better than college students,

and the briefer the initial view of the arrangement, the wider the disparity between the chimpanzee's performance and that of college students, although Kim Peek might have been able to match the chimpanzee's performance.

The position here is that such rote memory capability is not a measure of intellect at all. Intellect is much, much more complicated than that; it involves understanding, at the very least, an understanding of what the symbols mean, that the symbol "8", for example, signifies a quantity of things, any sort of things, toys, people, stars, anything. The test doesn't measure the subject's amount of understanding of anything. Thus, the test is not a measure of intellect at all and in no way eliminates intellect as a measure of humanness.

The term "human" has no scientific meaning: Hominidae, yes; Homininae, yes; Hominini, yes; but human, no. In order to be clear about what is "human", we are going to follow the Oxford dictionary's definition of "human" as "of or belonging to the species *Homo sapiens*." All other ancestors are simply placed in an extinct side branch or in the lineage that leads to "human" and are called prehumans or protohumans. Thus, these scribblings will consider a human to be a bipedal primate that's capable of understanding abstract ideas to some degree. Humans are "the thinking bipedal animal" and not simply an animal that's bipedal as the primary means of locomotion. In the precision of mathematics, bipedalism is a necessary, but not sufficient, condition to be human. It's thinking that makes us human, not simply that we are upright bipedalists. To be human is to lift our eyes from the dirt beneath our feet and gaze upon the far reaches of the Universe.

Biology supports this definition. There is a gene called *SRGAP2* that is only active when life is being organized in the womb. *Homo sapiens* is the only animal with four copies of it. *SRGAP2* controls the migration of neurons to their final locations in the brain, and it's during this migration that the neurons' dendrites grow spikes that are important in communication between brain cells. Around 3 million years ago, *SRGAP2* was duplicated in one of our ancestors, giving it two copies: the ancestral *SRGAP2A* and an additional *SRGAP2B*, which somewhat slows down this migration allowing a little more time for more spikes to grow. That was about the same time that our ancestors began to use, but not make, tools. Prior to that time, our ancestors such as *Sahelanthropus tchadensis*, for example, looked at the world around them for either danger or food in response to the prime directive of survival: to eat but not be eaten. Around 3 million years ago, at the same time *SRGAP2B* appeared, our ancestors left animal bones that bore definite marks that stone scrapers were used to remove meat from the bone though no evidence of tool manufacture has been found. Apparently, *SRGAP2B* allowed us to begin to look at the world around us with a little more curiosity than before, and we noticed that certain stones would help us remove meat from bones.

Around 2.4 million years ago, *SRGAP2* was duplicated again, giving us three copies: ancestral *SRGAP2A* plus *SRGAP2B* and a newer *SRGAP2C*.

*SRGAP2C* is more strongly expressed than *SRGAP2B* and seems to attach itself to *SRGAP2A* and slow even more the migration of neurons to their final place in the brain, giving them time to grow more spikes. That was the same time we began to make tools, and we were on our way to gazing upon the far reaches of the Universe. A fourth copy, *SRGAP2D*, appeared around 1 million years ago. Thus, we should probably define "human" as a bipedal primate with four copies of the gene *SRGAP2*, but that doesn't help with fossils, which are merely bones.

In this, the first decades of the third millennium, all paleoanthropologists agree on the broad course of human evolution, but often disagree on its specifics. For example, a UCLA Web page on paleoanthropology suggests that there's little agreement on the organization of the hominid family: "The terminology of our immediate biological family is currently in flux". This state of uncertainty derives partly from paleoanthropological knowledge expanding faster than it can be organized, or probably more accurately, faster than folks can agree on what that organization should be. The uncertainty is also at least partly due to new finds often creating (as the UCLA Web page says) "an opportunity for reinterpreting the existing data, and this reinterpretation appears at times to favor placing one's own remains at the root of the human tree, rather than in the line of descent of the chimpanzees, our closest living relatives" or even an extinct prehuman side branch. This sort of reinterpretation is only natural; we all want our stuff to be the best. We'll probably have a definitive organization of the hominid family tree (or bush, as some prefer) only some time in the future when those with an ax to grind are no longer involved and cooler heads can prevail.

Because the "terminology of our immediate biological family is currently in flux", we will create our own informal island of clarity in a sea of confusion by defining Hominidae to consist of orangutans, gorillas, chimpanzees, humans, and all the various ancestors and relatives thereof extending back to the separation of Hominidae from the lesser apes such as gibbons; Homininae to be composed of gorillas, chimpanzees, humans, and all the various ancestors and relatives thereof extending back to the separation of Homininae from orangutans; Hominini to be made up of chimpanzees and humans and all the various ancestors and relatives thereof extending back to the separation of Hominini from gorillas; and Hominina to be made up of *Homo* and all the various ancestors and relatives thereof extending back to the separation of Hominina from chimpanzees. "Hominid" is almost universally used as a general, nonspecific term for any member of Hominidae (orangutans, gorillas, chimpanzees, and humans). Few, if any, scientists will agree with these definitions, which is okay because there isn't any other system with which they agree anyway. These definitions themselves are unimportant for this work; they serve only to identify how orangutans, gorillas, chimpanzees, and humans relate to one another.

There are several hypotheses proposed to explain why bipedalism enabled our ancestors to flourish, and they all are centered on characteristics that enabled our bipedal ancestors to withstand the selection pressures

that nature applies in the fight to survive. Some of the bipedalism advantages are the ability to carry food or other portable items over longer distances; freeing forelimbs for foraging, tool use, or protection; a method of locomotion that's more energy-efficient than that of primate quadrupedalism; long distance running; an enhanced detection of food, water, and threats through the improved long-distance perception that results from a higher focal plane; and improved thermoregulation, which is important in tropical climates.

Over the past 20 or so million years, the ancestors of *Homo sapiens* slowly accumulated mutations in their skeleton that enabled bipedalism to be our primary way of getting around. The most fundamental of these, and often the only clue to the degree to which an ancestor was bipedal, is the location of the foramen magnum (literally, "big hole") in the skull. The foramen magnum is the hole in the skull through which the spinal chord attaches to the brain. In quadrupeds, the foramen magnum is located toward the back of the skull (anteriorly in technical lingo) so a vertical skull can connect with a horizontal spine. In bipeds, the foramen magnum is located more toward the base of the skull.

Other mutations involved changes in the skeleton that helped maintain balance and carry the weight while walking on two legs. A biped must balance on one leg while lifting the other foot off the ground and swinging it forward during the walking cycle. Thus, when *Homo sapiens* evolved five relatively larger lumbar vertebrae compared with an ape's four relatively smaller ones, it gave *Homo sapiens* a more flexible lower back that lets the hips and trunk swivel when walking. When walking bipedally, each side of an ape's hips move more forward rather than swivel like ours because its lower back is less flexible. *Homo sapiens* has also accumulated mutations in the sacrum, pelvis, femur, knee, ankle, and foot, that all help solve problems of balance and bearing weight while on one leg during the walking cycle.

Our ancestors' arms gradually grew shorter because longer arms were no longer necessary since climbing trees was less important for finding food or escaping predators. Other mutations in the hands have changed *Homo sapiens* fingers from curved, which enabled our tree-dwelling (arboreal) ancestors to hold branches, to flat, which enable a firm, precision grip for manipulating and manufacturing tools. These mutations were retained because they helped our ancestors withstand nature's selection pressures. An ape's big toe is orientated at somewhat of an angle relative to its other toes to allow it to grip branches with its toes. Our ancestors acquired a mutation that draws the big toe in line with the other toes ("adducted" in technical lingo). This mutation helps *Homo sapiens* to "push off" more efficiently when walking or running.

In summary, some physical characteristics that paleontologists use to determine degree of humanness are:

- humerus (long arms imply arboreal abilities, or climbing; Lucy's arms hung to about the knee),
- femora, tibia (shape indicates bipedal abilities),

- pelvis that is structured for straight-line walking as opposed to the side-to-side rocking gate of a chimpanzee,
- an arched foot (a minor indicator of bipedalism; there are always individual variations; for example, some humans have flat feet),
- shape of the hand (Apes have long fingers for grasping branches or for use in locomotion and have short thumbs relative to the length of fingers that make it very difficult for them to grasp like a human.),
- brain size (we humans have large brains relative to our size),
- skull shape (brow ridge, face flatness, etc.),
- tooth size (we humans have small teeth relative to our size),
- jaw shape (parabolic in humans, more “U” shaped in apes),
- thickness of tooth enamel, which relates to diet such as hard or soft foods (*Homo sapiens* has thick tooth enamel),
- body size,
- less sexual dimorphism (the size difference between males and females); in *Homo erectus*, the size difference was smaller than it was in the australopithecines of half a million years earlier).

These more human characteristics can be loosely considered to have been accumulated in four stages. First stage protohumans were forest tree dwellers that lived on fruits, leaves, and insects. The males had large canine teeth like chimpanzees that were used in displays of aggression in defense of the clan or in social status competition within the clan. Second stage protohumans were facultative (optional) bipeds that were partly arboreal. Male canine teeth were smaller, possibly signifying reduced intraclan competition. Third stage protohumans were fully terrestrial bipeds that lived in a wide range and occupied a wide ecological niche. Fourth stage protohumans had a larger brain, were technology reliant, and ranged throughout Africa and Eurasia.

First stage:

- arborealist
- dimorphic canines (female’s canines smaller than those of the male)
- forest frugivore/omnivore

Second stage:

- partly arboreal
- facultative (optional) biped
- feminized canines (male canines are smaller)
- woodland omnivore

Third stage:

- striding terrestrial biped
- pan-African
- wide ecological niche

Fourth stage:

- enlarged brain
- technology reliant
- old-world range

As of 2013, no clear human ancestral line can be identified among the

remains of the twenty-five or more currently known fossil hominids. As quoted in *ScienceDaily*, "The fossil record for early *Homo* is a mess," said Steven Churchill, from Duke University in Durham, North Carolina, a co-author of an *Australopithecus sediba* paper ('A Partial Pelvis of *Australopithecus sediba*'). This is partly because various species have different characteristics that exhibit different degrees of humanness; for some, the teeth might be more like ours, whereas for others the shape of the skull might be more like ours; currently, there's no known clear line of fossils that have sequentially accumulated human features one after the other. Currently known fossils record a random display of human characteristics rather than a continuous accumulation; some fossils have one set of human characteristics while others have a different set. This is partly because we've not yet discovered fossils of enough ancestors and partly because we haven't discovered complete remains of most of the ancestors that we know. We know enough to get a picture, but not enough to get a complete picture.

There are a few fossils that record the post-Oligocene divergence of the various branches of the primate family tree that lead to *Homo sapiens*, and some of these attest to a progressive development of bipedalism. Whether or not any of these specific forms are direct human ancestors is irrelevant; they simply mark the progress of generations toward bipedalism. Paleoanthropologists continue to debate the relationships between the various *H. sapiens* ancestors, which continue to be combined and then separated again as new discoveries are made and old discoveries are reexamined. There is no universal agreement on the specifics of the development of bipedalism, and there probably never will be. As mentioned before, paleoanthropology is, to some extent, subjective like gymnastics and not objective like track and field, so we most likely will never have complete understanding of our evolutionary heritage. But that's no deficiency. The magic of science has always been that, even in the face of knowing that complete understanding will forever elude us, we continue to strive to get closer and closer to it. Science is a journey, not a goal.

At least 21 Stage 1 hominid species are known to have lived and died between 20 and 8 million years ago, and more will probably be found in the years to come. But so few complete remains have been found that their relationship to each other and to *Homo sapiens* is unclear. Only a few of these early protohuman ancestors will be included in these pages.

*Morotopithecus bishopi*, which lived 20.6 million years ago, is possibly one of the first of our ancestors to have stood upright. However, this conclusion is based solely on analysis of a lumbar vertebra because remains of *Morotopithecus* are scant, so whether or not *Morotopithecus* had enough skeletal characteristics (other than that lumbar vertebra) to be bipedal or whether it simply could stand upright is uncertain. No complete skull has been found, so the location of its foramen magnum is unknown. However, the general consensus among paleoanthropologists is that *Morotopithecus* spent nearly all of its time in trees and that, if it stood upright at all, it was on tree branches.

An enigmatic species called *Proconsul* was possibly contemporaneous with *Morotopithecus*. *Proconsul* is enigmatic because it had features of both monkeys and apes, which has made it difficult to determine its place, if any, in human evolution. Like all extant apes, it lacked a tail and had more mobile hips, shoulders, wrists, ankles, hands, and feet than those of monkeys. On the other hand, it had monkey-like features that include thin tooth enamel (indicative of a soft diet such as leaves and fruit), light build with narrow chest and short forelimbs relative to hind limbs, curved metacarpals, long flexible back and a quadrupedal lifestyle better suited to traveling along the tops of tree branches like a monkey rather than hanging and swinging from limb to limb like an ape. Currently, *Proconsul* is considered to be a dead end and related to neither modern monkeys nor apes although it might be an ancestor of both.

A couple of million years after *Proconsul*, *Afropithecus turkanensis* (18 to 16 million years ago) appeared in northern Kenya. *Afropithecus* is thought to be the earliest ape that had teeth with thick enamel like we have. Some paleontologists suggest that *Afropithecus* may have "affinities" ("affinities" is paleo-lingo for "some similarities that may, or may not, suggest a relationship") with *Kenyapithecus*. *Kenyapithecus wickeri* (~14 million years ago, or approximately 14 million years ago), *Kenyapithecus africanus* (~15.5 million years ago), and *Equatorius africanus* (~15 million years ago) form an uncertain triumvirate. *Kenyapithecus wickeri* was discovered by Louis Leakey in 1961 at a site called Fort Ternan in Kenya. In a 27 August 1999 issue of *Science*, Carl Zimmer said Leakey was so impressed by its modern-looking teeth that he declared *Kenyapithecus* to be "a very early ancestor of man himself." Discoverers customarily make such grandiose claims for their discoveries. After considerable analysis, *K. africanus* was determined to be a little more primitive than *K. wickeri* and is now considered to be the same species as *Equatorius africanus*. In a paper presented at the 82<sup>nd</sup> Annual Meeting of the American Association of Physical Anthropologists in 2013, Arney, McCrossin, and Benefit said that an analysis of *K. africanus'* foot suggests that it was the first hominid to walk plantigrade (e.i., the heel touches the ground first followed by the whole foot and, lastly, the toes). In other words, *K. africanus* might have been the first hominid to have a human-like step.

In the time frame of 15 to 16 million years ago, the combined effect of lower sea level from increased Antarctic glaciation and the northward movement of the African plate created a land bridge between Africa and Eurasia through the Arabian peninsula. This allowed several African mammals such as elephants, pigs, antelopes, and aardvarks to migrate from Africa to Eurasia, and some primates such as, perhaps, *Afropithecus* joined them. This migration was probably sparked by climate change in eastern Africa. A University of California at Berkeley web page on the Miocene describes the climate change thusly: "Africa also encountered some tectonic movement, including rifting in East Africa and the union of the African-Arabian plate with Eurasia. Associated with this rifting, a major uplift in East Africa created a rain shadow effect between the wet Central-West Africa and dry

East Africa. The union of the continents of Africa and Eurasia caused interruption and contraction of the Tethys Sea, thereby depleting the primary source of atmospheric moisture in that area. Thus rainfall was significantly reduced, as were the moderating effects of sea temperature on the neighboring land climates."

The view that early hominids migrated from Africa through the Arabian peninsula is supported by the 1978 discovery of *Heliopithecus*, who lived around 16 million years ago in Saudi Arabia. Although there are few *Heliopithecus* remains, there is enough of them for paleoanthropologists to see a similarity between it and *Afropithecus*, and some paleoanthropologists even suggest that they are the same species. Both have teeth with thick enamel. From Saudi Arabia, the *Afropithecus/Heliopithecus* clan moved west into Europe, but its (their) relationship to other mid-to-late Miocene European hominids such as *Ouranopithecus* and *Dryopithecus* is unclear. This was the first migration of the hominid line out of Africa.

In spite of having teeth with intermediate thin enamel (as opposed to the thick enamel of later African hominids), *Dryopithecus* is thought by some paleontologists, such as David R. Begun, professor at the St. George Campus of the University of Toronto, to have migrated back to Africa and become one of *Homo*'s direct or indirect ancestors. John Hawks, Professor of Anthropology at the University of Wisconsin-Madison, has written, "Other features link *Dryopithecus* to the living apes. The elbow joint was capable of a full range of extension, which is not possible in quadrupeds like monkeys." He wrote that "these features do not necessarily show that *Dryopithecus* was ancestral to African apes and humans. Nevertheless, they illustrate the presence of almost every component of the ape anatomy in these Late Miocene fossils, which set the stage for the later rise of the hominids."

As Merceron and coworkers wrote on pages 331 to 349 in volume 53 of the *Journal of Human Evolution*, "While in Southeast Asia hominoids appear to have evolved without discontinuity until today, most fossil apes within the large geographic range from Spain to the Indian sub-continent disappeared at the end of the Vallesian, about 8.7 Ma [Mya]. Among them, two genera, *Ouranopithecus* and *Dryopithecus*, have been recently proposed as the roots of the Mio-Pliocene hominid clade. In spite of their possible phylogenetic relationship, many cranial characters indicate different feeding and habitat preferences between the two. For instance, molar enamel thickness in *O. macedoniensis* suggest a feeding adaptation consistent with hard object consumption. On the contrary, species assigned to the genus *Dryopithecus* have thinner enamel on the cheek teeth and longer shearing molar crests, indicating a diet based on fruits."

Thus, the prevailing view among many paleoanthropologists is that climate change in eastern Africa encouraged early, rudimentary bipedal apes to migrate to Eurasia around 15 million years ago. Then, around 8 million years ago, climate change in Europe encouraged them to return. This view is supported by the richness of bipedal ape fossils in Europe and the scanti-

ness of them in Africa between 15 and 8 million years ago. Martin Pickford, who holds a Chair in Paleoanthropology and Prehistory at the Collège de France, has noted that a major faunal change occurred between 8 and 7 million years ago, which was probably the result of Arctice Ice Sheet growth "to a size where it started to impinge on global climatic patterns, in particular squeezing the northern climatic zones (arctic, taiga, boreal, subtropical) equatorwards." This was the time when our ancestors returned to Africa, and a group of Stage 2 hominids that bore more human characteristics began to appear.

In 2001, the skull of *Sahelanthropus tchadensis* was discovered in Chad and dated to between 6 and 7 million years ago. Informally known as Toumaï ("hope of life" in the Dazaga language of Chad), *Sahelanthropus* is considered by many paleoanthropologists to be an early hominid, a protohuman. On its Web page titled "What does it mean to be Human?", the Smithsonian Institution has written, "*Sahelanthropus tchadensis* is one of the oldest known species in the human family tree." Toumaï probably habitually stood upright because its foramen magnum is located more on the underside of the cranium than in apes or any other primate except humans. However, the extent to which *Sahelanthropus* was bipedal is unknown as of 2013 because only a skull has been found. No post-cranial material that would measure skeletal adaptations to bipedalism has been discovered. According to analyses of fossils of other animals that had lived with *Sahelanthropus*, the area where it lived was a savannah mixed with woodland and a lake between 6 and 7 million years ago.

A few hundred thousand years or so after *Sahelanthropus* lived in Chad, *Orrorin tugenensis*, another protohuman, was living in "a wooded to forested environment" in what is now Kenya's Tugen Hills. It was first described by Brigitte Senut and coworkers in the January 2001 issue of *Comptes Rendus de l'Académie des Sciences, Sciences de la Terre et des planètes* (Rendered accounts of the Academy of Sciences, Earth and Planetary Science), Paris. *Orrorin* fossils are dated between 6.1 and 5.7 million years ago and include femora parts (the long bone that extends from the hip to the knee), sections of the humerus (upper arm bone), isolated teeth, and some finger bones. But no skull has been found, so we don't know where the foramen magnum was located. The original analysis by Senut and coworkers led them to conclude that *Orrorin* was bipedal and was in the direct line of *Homo*, although its relationship with *Homo* is the subject of considerable controversy. Analysis of the femur that was published by Richmond and Jungers in the 21 March 2008 issue of *Science* confirmed that *Orrorin* walked upright but concluded that it is most closely related to australopithecines, the group that includes "Lucy", and not directly related to *Homo*. Richmond said, "Frankly, I was surprised to see how similar it was to australopithecines, since it was twice as old." Although the femur suggests that *Orrorin* was bipedal on the ground, analysis of the humerus suggests that it was still comfortable in trees. The relationship, if any, between *Sahelanthropus* and *Orrorin* is unclear. The controversy over *Orrorin* continues.

Around 5.8 million years ago, *Ardipithecus* (informally called Ardi) appeared in what is now called the Middle Awash area of Ethiopia. This particular Stage 2 species is variously called *Ardipithecus kadabba* or *Ardipithecus ramidus kadabba*, a subspecies of *Ardipithecus ramidus*, which was found near the Awash River and first described in 1994. *Ar. ramidus* is dated at 4.4 million years ago, so Ardi existed for quite a while. As Suwa and coworkers noted in the 2 October 2009 issue of *Science* that described *Ar. ramidus* at length, the upper canine teeth are important to modern male monkeys and apes in their struggle for position (and all the rights concomitant with position) in the power structure of the clan. Thus, their smaller size in *Ar. ramidus* and other Stage 2 hominids "suggests that sexual selection played a primary role in canine reduction. Thus, fundamental reproductive and social behavioral changes probably occurred in hominids long before they had enlarged brains and began to use stone tools." Stage 2 hominids were beginning to become civilized. *Ar. ramidus'* big toe was separated from its other four to enable it to grip branches with its feet as well as its hands, so it spent a lot of time in trees. However, its pelvis tells us that it could walk upright and perhaps even run for short distances. Its brain was about the size of a modern female chimpanzee's.

*Ardipithecus* is the last Stage 2 protohuman known because around 4.2 to 4.1 million years ago *Australopithecus anamensis*, the first Stage 3 protohuman and the oldest known species of the genus *Australopithecus* (which includes the famous "Lucy") appeared in Ethiopia's Middle Awash only 9.7 kilometers (6 miles) from an *Ar. ramidus* site. That *Australopithecus anamensis* appeared so soon after *Ardipithecus* marks a rapid change from Stage 2 to Stage 3 protohumans. Such rapid changes can occur if a mutation occurs in a Hox gene.

The suite of Hox genes are active only during formation of an animal between egg fertilization and "birth". They turn on cascades of other genes that control the development of the characteristics of each longitudinal region from the "head" to the "foot". For example, they place the brain in the head and the toes on the foot. Hox genes are essentially an animal's BIOS (Basic Input/Output System) that begins a computer's boot sequence. In the 1990s, some researchers noticed that modern houseflies, which have one pair of wings, have a structure on the forward part of their abdomen that appears to be the place where a second pair of wings would attach. They knew that, like modern dragonflies, early flies had two pair of wings and surmised that sometime in the houseflies' evolution, that second pair of wings was lost by a mutation in their Hox gene. They performed an experiment in which a housefly's Hox gene was modified to grow a second pair of wings at that "empty" attach point thereby validating their hypothesis. They had created a housefly with two pair of wings instead of one. Later they modified a housefly's Hox gene to have it grow a leg from its head.

There are six known species of *Australopithecus*, *Au. anamensis* being the oldest and most primitive. Originally, three other species, called "robust" (or hefty) as opposed to "gracile" (or slender), were included in the

### *Australopithecus afarensis* ("Lucy")

This is the partial skeleton of the *Australopithecus afarensis* individual known informally as "Lucy", which was discovered by Donald Johanson's team in November 1974 at Hadar, Ethiopia.



*Australopithecus* genus, but subsequent analyses identified enough differences to give the robust varieties their own genus, *Paranthropus*, leaving the six gracile varieties as the *Australopithecus* genus. The six *Australopithecus* species and three *Paranthropus* species have enough similarities with one another to be lumped together in a group called australopithecines. Thus, the australopithecines include both the *Australopithecus* and *Paranthropus* genus. Apparently *Au. anamensis* was a short-lived species of *Australopithecus* because no fossils more recent than 3.9 million years ago have been found, so *Au. anamensis* seems to have lived for only 200,000 to 300,000 years before giving way to *Australopithecus afarensis*. The features of *Au. anamensis* that are more primitive relative to other australopithecines are concentrated in the teeth, which are larger and more ape-like than those of its later australopithecine kin but are less ape-like than those of *Ardipithecus*, suggesting a transitional species. The post-cranial (skeletal) features of *Au. anamensis* are much less primitive than those of *Ardipithecus* and are fairly similar to all other australopithecines. The post-cranial features of *Australopithecus* indicate a habitual biped typical of a Stage 3 protohuman.

*Australopithecus afarensis*, another gracile australopithecine, appeared just as *Au. anamensis* disappeared from the fossil record, and many paleoanthropologists subscribe to the view that *afarensis* is a direct descendant of *anamensis*. *Au. anamensis* lived only briefly, but *Au. afarensis* was one of our longest-lived ancestors. The earliest *afarensis* remains go back 3.85 million years, and the youngest are dated at 2.95 million years ago. Many paleoanthropologists think that *Au. afarensis* is a direct ancestor of *Homo*, but the evidence is inclusive so far. What is conclusive is that

## The Laetoli Footprints

These are the footprints left by *Australopithecus afarensis* individuals as they walked through damp volcanic ash 3.6 million years ago and were preserved by the chance occurrences of a volcanic eruption, a light rain, and another ashfall. The entire footprint trail is almost 27 m (88 ft) long and includes impressions of about 70 early human footprints. The individuals that left these prints were bipedal and had big toes in line with the rest of their foot (adducted). This means that these individuals' feet were more human-like than chimp-like because chimps have highly divergent big toes that help them climb and grasp materials like a thumb does. The footprints also show that the gait of these individuals was "heel-strike" (the heel of the foot hits first) followed by "toe-off" (the toes push off at the end of the stride) the way modern humans walk. The trail was left by an adult with a child walking on his or her left side.



*afarensis* had many human characteristics, most related to an upright, bipedal walk. The pelvis, leg bones, and foot are remarkably human-like and are consistent with an erect stride far more like that of humans than that of chimps. The foot had an arch and a fully adducted big toe that indicates *afarensis* was not strongly wedded to an arboreal life although its shoulder, curved fingers, and long arms relative to the length of its legs were chimp-like and indicate that it was also a good climber, or that the gene(s) controlling these lengths had yet to "modernize" (the inference of life style from mere bones is somewhat tenuous). Thus, *afarensis* had a mix of chimp-like and human-like characteristics.

The most famous *Au. afarensis* remains are a 3.2 million year old partial female skeleton found by Donald Johanson's team in November 1974 at Hadar, Ethiopia and formally identified as AL 288-1 but informally nicknamed "Lucy". In 1975, Donald Johanson's team discovered another site in Hadar that contained remains of 13 *afarensis* individuals, including both adults and juveniles, who appear to have all died at the same time. This discovery is sometimes called the "first family" and reveals that *afarensis* lived in groups that were probably based on family relationships.

A set of footprints called the Laetoli footprints, discovered by Mary Leakey in 1978 and called by one writer "one of the most evocative traces of humanity's ancestors ever found", further suggest, but don't prove, that *Au. afarensis* lived in family groups. These footprints were made in damp volcanic ash 3.6 million years ago (about 400,000 years before Lucy) by three individuals, one large individual who was accompanied by a small individual on its left. Close inspection revealed that a third individual walked behind the large one, stepping in its tracks. These footprints are usually, but not exclusively, interpreted to be a family of three individuals, a male

with a female walking behind and a child beside. The tracks show a human-like step and stride. The prints show a step with an initial heel strike and a final push-off with a fully adducted big toe and were made with a foot that had an arch. These are all characteristics of a human step, and the length of the stride is typical of a human walk. The footprints are generally, but not universally, considered to have been made by *Au. afarensis* because it was the only hominid known to be living at the time.

Another significant find was published by Shannon P. McPherron and coworkers in the 12 August 2012 issue of *Nature*. They reported scanning electron microscope examinations of ungulate bones from the Sidi Hakoma Member of the Hadar Formation in Dikika, Ethiopia that are radiometrically dated at between 3.42 and 3.24 million years ago. Their examinations of the bones "show unambiguous stone-tool cut marks for flesh removal and percussion marks for marrow access." They further say that "this behaviour can now be attributed to *Australopithecus afarensis*." Although they found evidence of the use of stone tools, they didn't find evidence of tool manufacture. This fossil evidence indicates that *Au. afarensis* used but didn't manufacture tools at roughly the same time genomic analyses identifies the mutation of *SRGAP2* into *SRGAP2A* and *SRGAP2B*.

A little over 3 million years ago, *Australopithecus africanus* lived in southern Africa, so *africanus* in southern Africa and *Au. afarensis* in eastern Africa might have overlapped for a few hundred thousand years. Some paleoanthropologists have the view that *africanus* is a descendent of *afarensis*; perhaps *afarensis* had spread to southern Africa. As so often happens when members of a species becomes isolated from one another, enough mutations accumulated in both groups for them to become separate species. *Au. africanus* was actually the first *Australopithecus* to be discovered. In 1924, Raymond Dart discovered remains that have become known as the Taung Child in a limestone quarry at Taung near Kimberley, South Africa; we know this individual was a child because its first molar teeth were in the process of erupting from the jaw. *Au. africanus* has been found at four sites in southern Africa: Taung (1924), Sterkfontein (1935), Makapansgat (1948), and Gladysvale (1992). *Au. africanus* has enough technical differences from *afarensis*, primarily in its skeleton and teeth, to warrant being a separate species. Analyses of tooth wear patterns suggests that *Australopithecus africanus* had a diet that included fruit and leaves. Chemical analysis of the teeth also suggests that some meat was included in their diet but not in significant amounts. It is likely that they may have scavenged for meat rather than hunted. *Australopithecus africanus* was once considered a "killer ape" because its remains were often found with predator bones. However, the current consensus is that predators such as lions, leopards, and hyenas left the *africanus* bones, and *africanus* was probably just one of their kills. This shouldn't be surprising, or even shocking, because lions, tigers, and hyenas still prey on unwary humans.

It's instructive to get a feel for the level of detail that paleoanthropologists use when examining fossils. As an example, here is a description of only a

few of the technical characteristics used to compare *afarensis*, *africanus*, and *Homo*. They are included here merely to illustrate the depth of comparison and need not be understood; they are quoted from ArchaeologyInfo.com.

“Human-like locomotor capacity include:

- The iliac blade is short and wide.
- There is a well-developed sciatic notch.
- There is a strong anterior inferior iliac spine.

*Africanus* [tooth] material shows several important differences when compared to *afarensis* that include:

- Postcanine teeth are larger, more bulbously cusped, and relatively broader (the size difference is greater in the later erupting teeth of each type), and may have somewhat thicker enamel, especially on the tooth walls.
- Dm1 [a technical designation of a specific tooth according to a specific numbering system] is larger and more squared, with more equal sized cusps.
- The anterior lower premolars are always bicuspid, usually with equal or close to equal sized cusps, and wear more similarly to the other premolars.
- The anterior lower premolars have greater enamel thickness.
- Compared intrasexually, *africanus* central incisors show no reduction but the other anterior teeth are usually smaller. The ranges almost completely overlap, however, and there are very large canines and incisors in both samples.

The facial features of *africanus* are a mixture of archaic and somewhat modern ones, with similarity to (and important differences between) *afarensis*. Some of these features (relative to *afarensis*) include:

- Retraction of the palate from a position in front of the face to under it.
- Forward shift of the zygomatic processes of the maxilla, the zygomatic bone, and the front of the masseter muscle, creating the zygomatic prominence.
- Expansion of the anterior part of the temporalis muscle.
- A broader nasal aperture.
- Anterior pillars extending above the canine roots, of variable expression creating thickened lateral nasal margins.
- Structural changes in the jaw related to expanding premolars and molars, as well as incisor and (especially) canine reduction and decreased emphasis on anterior loading.”

These characteristics help us to understand that analyses of fossil remains of any sort, hominid or any other, use a very specific and detailed set of characteristics.

In 2008, a collection of remains was found by Lee Berger in a cave at a South African place called Malapa. The remains include a male, a female, and three children, all of whom had apparently fallen to their death slightly less than 2 million years ago. The cave had apparently been a natural trapping pit at the time they fell in because the bones of animals were also

there. The remains were remarkably complete and well preserved. After extensive analyses, Berger and his team decided that the remains exhibited enough characteristics sufficiently different from *Australopithecus africanus* to classify them as a new species, *Australopithecus sediba*. Moreover, he proposed that *Au. sediba* is the direct ancestor to *Homo habilis* or *Homo erectus* because it has certain characteristics (in the hand, for example) that are more like those of *Homo* than does *africanus* or *afarensis* species such as Lucy have. The declaration of a new species is almost always controversial, and not all paleoanthropologists agree that a new species is warranted for *sediba* or that the remains are of a direct ancestor of *Homo*. Detractors point out that *Homo habilis* predates the Malapa remains by around 300,000 years although Berger expressed doubt that the early date for *H. habilis* is accurate. Detractors also feel that the characteristics of *Au. sediba* are within the normal variation expected of *africanus*, so the remains are those of *Au. africanus* and not a new species at all. Moreover, no other similar remains have yet been found. But even if the Malapa remains are not a new species, they're significant because they extend the presence of *africanus* in time to 2 million years ago. The find is very new and will spark considerable debate for several years, but in the future, *sediba* will probably be considered just another *africanus*.

*Australopithecus garhi* is another controversial species. It was discovered in 1996 in the Bouri Formation, located in the Middle Awash of Ethiopia's Afar Depression. The remains are clearly those of an *Australopithecus*, and the discovery team hypothesized them to be a human ancestor species and possibly the direct ancestor to the human genus, *Homo*. The remains consist of merely one cranium and four other skull fragments, although a partial skeleton found nearby, from about the same layer of rock, is usually included as part of the *Au. garhi* sample, the scattering being attributed to erosion. Thus, the Bouri remains are considerably less extensive than those of *sediba*, and much less can be said about them, and in the future, they will probably be considered just another *afarensis*. Like the Malapa remains, the *garhi* discovery is merely a snapshot of a single point in time (approximately 2.5 million years ago), and no conclusions can be drawn about how long these two particular *Australopithecus* forms lived.

*Australopithecus bahrelghazali* is another controversial species that has left very few remains (teeth and a jaw fragment). It was first discovered in 1995 in Chad's Bahr el Ghazal valley near Koro Toro, which is roughly 2,500 kilometers (1550 miles) west from the East African Great Rift Valley. The fragmentary remains are radiometrically dated at approximately 3.6 million years ago. The find is very sparse, consisting entirely of a fragment of mandible and some lower teeth, and no other fossils attributable to *bahrelghazali* have been found. The discoverer's claim that *Au. bahrelghazali* is a species separate from *Au. afarensis* is seriously challenged. Other paleoanthropologists have the view that the characteristics of *Au. bahrelghazali* are within normal variations within a species (like the difference between a basketball player and a jockey) and it is probably simply

another *Au. afarensis*. Thus, in the future, it too will probably be considered another *afarensis*. Nevertheless, the find is important because it significantly extends the range of *Australopithecus*.

*Paranthropus* is a genus that coexisted with *Australopithecus* for around 700,000 years and with *Homo* for, perhaps, more than a million years. It's represented in the fossil record by three species: *Paranthropus aethiopicus*, *Paranthropus boisei*, and *Paranthropus robustus*. All three species share similar physical characteristics: a relatively small body and a 'robust', or strongly built, skull including large lower jaws with extremely large molar teeth. The genus is otherwise very similar to *Australopithecus*, and for a long time, was actually considered to be simply a "robust" *Australopithecus*. Both names, *Australopithecus* and *Paranthropus*, are now generally accepted and used interchangeably for these three species. However, modern analyses with advanced, modern equipment have identified enough differences between *Australopithecus* and the three *Paranthropus* species to warrant designating *Paranthropus* to be a separate genus although we must remember that the definition of what constitutes a species and genus is still unclear.

*P. aethiopicus* lived in east Africa between 2.7 and 2.5 million years ago, suggesting that it shared the east African biosphere with *Australopithecus garhi*, but the remains of both species are so scanty that no conclusions can be made about how long they coexisted. The general, though not universal, consensus is that *P. aethiopicus* descended from *Australopithecus afarensis*. *Paranthropus boisei* appeared in Eastern Africa 2.3 million years ago and apparently lived there until about 1.2 million years ago. Most, but not all, paleoanthropologists have the view that *P. boisei* is a descendent of *P. aethiopicus*. *P. boisei* coexisted in eastern Africa with *Homo habilis*, *Homo rudolfensis*, and *Homo ergaster* for various lengths of time. Around 2 million years ago, *Paranthropus robustus* appeared in southern Africa and dwelled there until approximately 1.2 million years ago. The general, though not universal, consensus is that *robustus* descended from *boisei*. Paleoanthropologists almost universally believe that *Paranthropus* is a dead end genus and has no direct relationship with *Homo*. It's simply a cousin.

Around 2.4 or 2.3 million years ago, what is generally, but not universally, considered to be the first Stage 4 protohuman, a *Homo* species called *Homo habilis*, appeared in eastern Africa somewhere in the neighborhood of Kenya or Tanzania. *H. habilis* lived between approximately 2.33 and 1.44 million years ago. *Australopithecus garhi* is known to have lived in Ethiopia a couple of hundred thousand years earlier. This is close enough to *H. Habilis* in both time and space to speculate that they might briefly have been contemporaries, but there's no evidence of that. There is evidence, however, that *H. Habilis* shared eastern Africa with *Paranthropus boisei* and that *Australopithecus africanus* and *Australopithecus sediba* (if *sediba* is indeed different from *africanus*) lived at the same time in southern Africa. Thus, eastern and southern Africa were crucibles of human evolution 2 million years ago, and our ancestors were tested in those crucibles to weed out characteristics that reduce survival fitness.

*Homo habilis* Fossil KNM-ER-1813

According to the Smithsonian Institution, *Homo habilis* necessitated a redefinition of “*Homo*” to include a smaller brain size. This has resulted in a lively debate over whether or not *habilis* is really a *Homo*. This skull does have a prominent forehead that indicates a frontal cortex, the seat of higher mental processes, of respectable size.



It's fair to speculate that *Homo habilis* is the offspring of a mating between *Australopithecus garhi* and *Paranthropus boisei* and that cross-species mating occurred more than once in human history, which could explain how human-like characteristics that were individually evident in separate lines came together in *Homo*. After all, Neanderthals are known to have mated with *Homo sapiens*, giving non-African *sapiens* a few Neanderthal genes. Cross-species mating generally, but not exclusively, result in infertile young, but perhaps the several protohuman lines were not that far apart. This, of course, is sheer speculation. However, the individual characteristics came together somehow, and genetics can vie with random chance as the explanation.

*Homo habilis* is generally (though, again, not universally) thought to have descended from *Australopithecus*, but its status is still a subject of debate. Some paleoanthropologists even go so far as to say that *habilis* is not a *Homo* descendent of *Australopithecus* at all but is, itself, just another australopithecine. Once again, we come face to face with the unanswered question that has plagued the biological sciences ever since we sought to organize our knowledge of living things: What is a species? Many years ago, in simpler times, living things were considered to be the same species if they could breed and produce fertile offspring. Animals that look slightly different, or that occupy different environmental niches, but that can breed and produce fertile offspring were considered to be subspecies of the same species. But this interbreeding criterion is inapplicable when classifying extinct life or life that doesn't propagate sexually. Thus, those in the biological sciences have sought, vainly to date, to identify universal criteria by which species can be identified. Fossils are analyzed by extensive, specific, and very detailed criteria, but what set of criteria define a species is simply a matter of definition and not at all as extensive, specific, and detailed. There is no law of nature that defines a “species”; it's an arbitrary human invention. The closest we've been able to come to a natural law is the interbreeding criterion. A further ambiguity that contributes to the “species problem” is the extent of normal variations that a species can be expected

to have. What variations exist, for example, in the humerus and femur dimensions between a modern jockey and basketball player? Chimpanzees exhibit a rather large variation of characteristics within the species compared with the variations within the human race.

The idea of a species has no intrinsic worth. It's merely a system that helps us understand how all life forms relate to one another, and it has value only in the extent to which it aids in that understanding. A species is simply a name we give to an actor in the great drama we call evolution, and in a sense, it's as arbitrary as the criteria by which gymnastics are judged. Although it has been percolating on the back burner for a long time, the "species problem" has taken on a fresh resurgence since the discovery of five skulls at Dmanisi in the country of Georgia. The five skulls are of hominids that seemingly coexisted but were different enough to suggest they might be of different species. This has led some paleontologists to suggest that the spread of characteristics defining a species should be broader than currently assumed. In his book *The First Humans: Origin and Early Evolution of the Genus Homo*, Bernard Wood, University Professor of Human Origins at George Washington University in Washington, DC, wrote, "Where does the genus *Homo* begin, and how would we know?" He continued, "Seven years after the publication of Wood and Collard (1999) ["The human genus", *Science* 284:65 to 71.], and approaching this problem afresh, there is still ambiguity about where to draw the lower boundary of the genus *Homo*."

Clifford Jolly, Professor Emeritus of Anthropology at New York University, has suggested that the range of characteristics in the Dmanisi fossils are similar to those in modern baboons. Baboons at various places in their range across Africa look different and have different survival strategies for coping with their different habitats. These differences have prompted most anthropologists to separate them into five or six species. However, if members of the different groups meet, they can breed and produce fertile offspring, prompting the question of whether they are actually separate species at all. "Maybe Dmanisi was the equivalent of that," said Dr. Disotell, a biological anthropologist at New York University, as quoted in a 2013 article in *The New York Times*. "What we need, practically, is labels for them," said Dr. Disotell. "We will never solve the species problem for fossils if we can't for living, breathing animals."

Although *Homo habilis* might have looked similar to australopithecines, it differed in one important way: its cranial capacity was between 510 and 660 cubic centimeters as opposed to 390 to 545 cubic centimeters for australopithecines. This increase in brain size, especially in the frontal lobe, was enough for *habilis* to make tools rather than use whatever stones were found lying around. Evidence of cut marks on animal bones suggests that australopithecines were using tools as early as 3.2 million years ago, but no clear evidence of tool making has been found prior to *habilis* although there are tantalizing suggestions in the fossil record that *Australopithecus garhi* might have made tools. The tool making ability of *Homo habilis* coincides with genetic evidence of the mutation of the *SRGAP2* gene to the all-

important third copy: *SRGAP2C*. Beginning with *H. habilis*, the type of technology used became an ever increasingly important criterion for determining the labels, or species, for representatives of the different levels of protohuman development.

The first tool manufacturing technology is called Olduwan (sometimes spelled Oldowan), or Mode 1; it began around 2.5 million years ago, the earliest time when *H. habilis* first appeared and *SRGAP2* mutated to form *SRGAP2C*, and lasted until approximately 1.7 million years ago. It was the first technology of the lower paleolithic, or early old stone age. This was the technology of *Homo habilis* and possibly *Australopithecus garhi*. As mentioned earlier, there is some small evidence that *Australopithecus* might have used stone tools as early as 3.3 million years ago, but there is no unambiguous evidence that *Australopithecus* manufactured them at that time. It's a huge step from using something handy to making specific and well-organized changes that improve use.

The first tool maker had to develop some sort of idea about what he wanted that was probably based on making better the rocks that he had been using among those he found lying around. His people had probably discovered that meat made their bellies full faster than fruit and leaves did, so improving the tools necessary to strip meat from bones became important. However, they had no way of knowing the importance of meat in the growth in brain size. Meat is more easily digested than plant matter and, pound for pound, has higher energy content, and a human brain is a huge consumer of energy. Humans devote 20% to 25% of basal metabolism to their brains compared with between 2% and 8% for most other vertebrates. Thus, meat as a compact, easily digested source of energy was vital to human's increase in brain size, and tools were vital to the acquisition of meat foodstuff.

Mode 1 tools were manufactured by using a roughly spherical hammerstone to strike the edge of a core stone such as quartz, flint, or chert and chip off thin pieces called flakes. The core stone would then have a sharper edge than before although the edge of flakes would be even sharper. This action was done repeatedly until the core stone attained the desired properties. The manufactured tools were used for chopping and scraping, the cores for heavy duty work and flakes for light duty work. Mode 1 tools are rather crude in the sense that they are not smoothed (reworked) very much, the chipped sites on the core stone being left somewhat large.

Numerous fossils have been discovered that cover the time between the first appearance of *Homo habilis* and *Homo sapiens*, but the relationships between them are still murky in 2013. They seem to display a mélange of physical characteristics that defy a simple explanation: *Homo erectus*, which was thought to be well understood at one time but has become enigmatic of late; newcomers *Homo gautengensis*, *Homo ergaster*, and *Homo rudolfensis*, all of whom have muddied the waters rather than clarifying them. They all appear in the fossil record about the same time (1.9

million years ago) and could be considered poster children for the “species problem”.

*Homo gautengensis* is a species proposed by biological anthropologist Darren Curnoe in 2010 after he analyzed partial skulls, several jaws, teeth and other bones found at various times (some as early as the 1930s) and cave sites at a South African location called the “Cradle of Humankind”. Very few finds have been attributed specifically to *gautengensis*, so its status in the evolution of *Homo* and whether or not it will even remain a valid taxon are open questions although *gautengensis* will probably always have its champions.

*Homo rudolfensis* is known only through a handful of representative fossils, and like *H. gautengensis*, is widely debated among paleoanthropologists. It was discovered in 1972 by a team led by anthropologist Richard Leakey and zoologist Meave Leakey at what is now Lake Turkana in Kenya. In an August 2012 issue of *Nature*, Meave Leakey’s team announced two jawbones with teeth and a face had been found in northern Kenya that they attribute to *H. rudolfensis*. The 1972 and 2012 discoveries are the only one attributed to *rudolfensis*. Like *H. gautengensis*, the status of *rudolfensis* in the evolution of *Homo* and whether or not it’s a valid taxon are open questions.

The status of *Homo erectus* seemed clear at the middle of the twentieth century but became more murky as time passed. When Darwin wrote *The Descent of Man, and Selection in Relation to Sex*, he postulated that the human race began in Africa. But there were, nevertheless, late nineteenth century paleontologists who believed we began in Asia, and some went there to search out our earliest ancestors. Their efforts were rewarded in 1891 when a skull and femur were found on Java (“Java Man”). Additional ancient hominem remains were found in China in 1921 (“Peking Man”). In April 1949, a *Homo erectus* specimen was found at Swartkrans excavations in South Africa, and search for our ancestors switched to Darwin’s Africa.

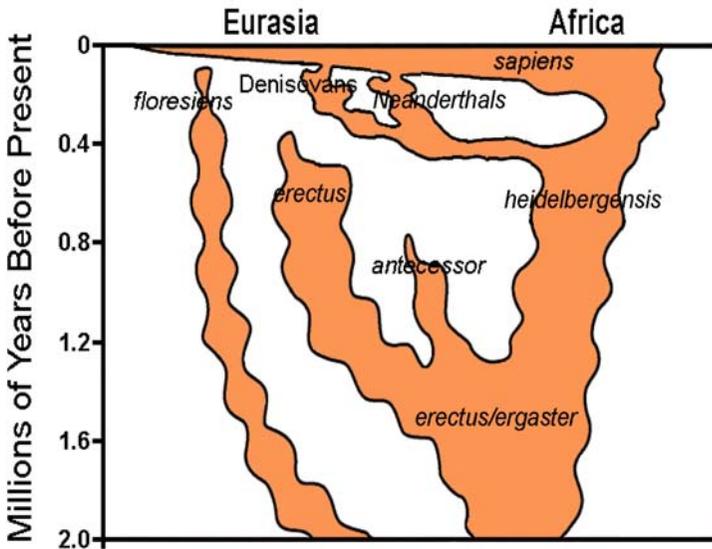
A 1.25 million year old *Homo erectus* partial cranium was found at Olduvai Gorge in 1960, and subsequently, more *erectus* fossils were discovered there and at other sites in East, South, and Northwest Africa. The oldest known *erectus* date to nearly 2 million years ago in East Africa. These discoveries led to the proposed scenario that *H. erectus* began in Africa, possibly descended from *Homo habilis*, then spread out of Africa to the Far East in a reprise of the *Afropithecus/Heliopithecus* migration 14 million years earlier. This scenario was strengthened by the discoveries of several *erectus* skulls at Ubeidiya in Israel; Atapuerca, Spain; Ceprano, Italy; and Dmanisi in the Republic of Georgia, all of which are younger than the oldest African fossil. Toward the close of the twentieth century, some paleoanthropologists began to feel that there were enough small differences between the African and Asian *Homo erectus* populations to declare them separate species and began to call the African *erectus* population *Homo ergaster*. This point of view is still debated in 2013. A species/sub-species relationship is probably more accurate.

An astounding discovery was made in 1984 at West Turkana, Kenya when Alan C. Walker, a paleontologist and human anatomy professor at the Johns Hopkins Medical School, and paleontologist Richard E. Leakey unearthed a nearly complete skeleton of an eight or nine year old *Homo erectus/ergaster* that has been nicknamed Turkana Boy. The boy has been estimated to have died around 1.6 million years ago. "We think two pieces of the root of the milk teeth were left behind and didn't resorb properly," Dr. Walker said. That appears to have led to gum disease, erosion of the jaw bone, and infection. "That would have hurt. Whether it also led to sepsis [blood poisoning] that killed him, we'll never know." But the boy was not malnourished. In life, Dr. Walker said, "he was healthy and big for his age." From the neck down, Turkana Boy is not radically different from *Homo sapiens*, which tells us that the primary path of evolution since *erectus/ergaster* has been in the brain.

The average brain size of African *H. erectus/ergaster* was in the range of 700 to 850 cubic centimeters, the smallest of any *Homo* species in the past 2 million years except for contemporaneous *Homo rudolfensis* and the diminutive *Homo floresiensis* recently discovered in Indonesia. However, remains of the Asian *H. erectus* have a brain size of as much as 1225 cubic centimeters, which is the major reason for separating *H. erectus* as the Asian representative and *H. ergaster* as the African one. Ever larger brains gave *Homo* the increasing ability to manufacture more and more complex tools that has given *Homo* its great advantage in the struggle to survive.

Around 1.8 million years ago, *Homo erectus/ergaster* began the Acheulean, or Mode 2, stone technology, which is characterized primarily by augmenting the Mode 1 choppers with larger, more finely worked tools having the misleading name "hand-axes". These hand-axes are unhafted, pear shaped, teardrop shaped, or rounded and are usually 12 to 20 centimeters (4.7 to 7.9 inches) long. They're not axes as we think of axes. Studies have suggested they were not used to chop wood but as butchery tools on a larger scale than Mode 1 choppers. Another characteristic of Mode 2 technology is that both sides of a core stone were worked equally, creating what is called a bifacial tool. Mode 2 is the technology of *Homo erectus/ergaster*. Few, if any, paleoanthropologists question that *erectus/ergaster* was a direct ancestor of *Homo sapiens*.

Equally as significant as the use of tools was *Homo erectus/ergaster's* use of fire. Francesco Berna and coworkers reported in a 2012 issue of *Proceedings of the National Academy of Sciences* that they discovered "unambiguous evidence" in the Wonderwerk Cave, South Africa, that *Homo erectus/ergaster* used controlled fire as early as 1 million years ago. Research published in a 2008 issue of the journal *Quaternary Science Reviews* even went so far as to say that occupants of a site in Israel were able to start fires by 790,000 years ago although it's possible, perhaps even likely, that the fire pits in Israel were the work of *Homo heidelbergensis*, a later species.



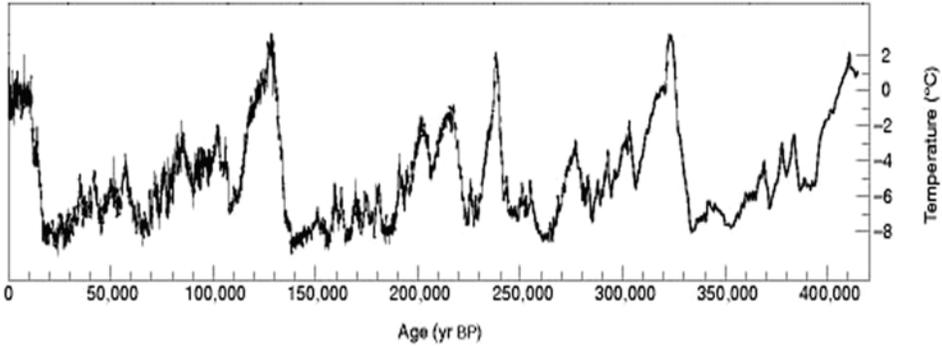
### Evolution of Neanderthals and *Homo sapiens*

This scenario, which is adapted from Chris Stringer's *Nature* article, illustrates the most logical scenario of the evolution of Neanderthals and *H. sapiens*. Both probably evolved independently from *Homo heidelbergensis*, the Neanderthals in Europe and *H. sapiens* in Africa. As usual with scenarios of ancient evolution, this one is hotly debated

*Homo rudolfensis* is known only through a handful of fossils first discovered in 1972 on the east side of Lake Rudolf (now Lake Turkana) in Kenya. In August 2012, a paper published in *Nature* announced the discovery of two *rudolfensis* jawbones with both a face and teeth in northern Kenya. All the finds were dated at around 1.9 million years ago, prompting the authors to declare, "the new fossils confirm the presence of two contemporary species of early *Homo* [that is, *habilis* and *rudolfensis*], in addition to *Homo erectus*, in the early Pleistocene of eastern Africa". Nevertheless, there is considerable debate about whether *rudolfensis* is a valid taxon because so few remains have been found. The size of *rudolfensis*'s brain was around 700 cubic centimeters, about the same as that of African *erectus/ergaster*.

*Homo antecessor*, *Homo heidelbergensis*, *Homo cepranensis*, and *Homo rhodesiensis* are four recent species whose relationship to one another is unclear although considerable consensus is building that they all are actually the same protohuman. All four had a brain volume around 1000 to 1300 cubic centimeters, which is significantly larger than the 700 to 850 cubic centimeters of African *erectus/ergaster* and *rudolfensis*. However, little of this increase in brain size was concentrated in the frontal lobe, the seat of advanced mental processing. *H. antecessor*, *H. heidelbergensis*, and *H. cepranensis* are European, and *H. rhodesiensis* is African.

*Homo cepranensis* is the most problematic of the four because it's based on only one skull cap found near Ceprano, Italy in 1994. Little can be said about this protohuman because so few remains have been found. The



### Temperature Variation over the Past 440,000 Years

This figure shows the temperature variation over the last four glacial/interglacial periods. It is excerpted from an article on a 1999 issue of *Nature* that describes the analysis of a 3.6 kilometer (2.2 mile) long ice core drilled at the Vostok station in east Antarctica. The temperature is referenced to the mean temperature during recent times. The Neanderthals had to endure a wide variation in climate, yet they persevered.

next most problematic of the four is *H. rhodesiensis*, or Rhodesian Man, which was found and named in 1921. It's known only from a skull that's formally identified as Kabwe 1 but informally called the Broken Hill skull. Since 1921, nearly all paleoanthropologists recognize this fossil find as *Homo heidelbergensis*. Interestingly, this is probably the oldest skull that has cavities in its teeth. They occur in 10 of the upper teeth, and the individual may have died from an infection, perhaps sepsis, related to dental disease.

*Homo antecessor* is the oldest of the four, going back to between 1.2 million and 800,000 years ago, but is only known from skulls and a few other bones found in two sites in Spain. This is the first *Homo* species known to have lived in Europe. Little is known about this species because few bones other than skulls have been found. Among the human bones found, however, are a few that bear unmistakable signs they had flesh removed by tools, suggesting the first indication of possible cannibalism among our ancestors. Some features of the teeth and skull suggest *antecessor* might have descended from *Homo ergaster*.

*Homo heidelbergensis* is the best known and most widely distributed of the four, and it's reasonable to speculate, as some paleoanthropologists and the Smithsonian Institution Human Origins Initiative do, that *antecessor*, *cepranensis*, and *rhodesiensis* are all simply *heidelbergensis*. Since its initial discovery near Heidelberg, Germany in 1907, it has been widely found throughout Africa, Europe, and western Asia. The oldest finds date to at least 600,000 years ago, and if *H. antecessor* is actually *heidelbergensis*, the species dates back 1.2 million years. It survived until around 250,000 years ago. There is strong consensus among paleoanthropologists that it's very likely the transition between *erectus/ergaster* and *Homo sapiens* in Africa, the Neanderthals in Europe, and perhaps also the Denisovans in Asia.

Kabwe 1, the Rhodesian *heidelbergensis*, shows features similar to *H. erectus* such as a low braincase profile, large brow ridges, and a protrusion at the back of the skull called the occipital torus. But Kabwe also resembles modern humans with a flatter, less prognathic face, and larger brain (1300 cubic centimeters).

Two important advances can be attributed to *H. heidelbergensis*. The least controversial is that *heidelbergensis* used spears to hunt large game such as rhinos, hippopotamus, bears, horses, and deer. Bones of this sort of prey have been found at *heidelbergensis* sites, implying that these animals were skillfully hunted and then butchered in such an orderly fashion as to suggest these people were working in co-operative groups. The spears were probably thrust into the prey rather than thrown. The second, and somewhat controversial, is that *heidelbergensis* might have constructed shelters. The Smithsonian Institution Human Origins Initiative says that "evidence for this comes from the site of Terra Amata, France". *H. heidelbergensis* apparently built fires in these shelters. Some paleoanthropologists speculate that European *heidelbergensis* might have worn rudimentary clothing because the climate there was variable, becoming cooler for long stretches of time, but no direct evidence of clothing has been found.

Around 600,000 years ago, climate began to play a part in *heidelbergensis*'s development. This is succinctly described by the Australian Museum: "Between 600,000 and 200,000 years ago, the climates of Africa and Europe experienced a series of warm and cool phases [ice ages] and the move from Africa to Europe subjected these people to generally colder climates. About 300,000 years ago, a severe cold, dry period began and the Sahara became a barrier to movement between Africa and Eurasia, although movement may have been possible between Europe and northern Asia. At this time, populations in Africa and in Europe were isolated from one another and regional differences began to appear."

These regional differences were probably similar to those of modern day baboons, enough that they were different populations that possibly looked slightly different and had different survival strategies but not enough to make them different species. The different populations could probably breed and produce fertile offspring. The existence of these distinct *heidelbergensis* populations has resulted in the evolutionary scenario ascribed to anthropologist Chris Stringer and published in the 3 May 2012 issue of *Nature*. This scenario suggests that the European population developed into Neanderthals (or Neandertals), the African population into *Homo sapiens*, and (perhaps) the Asian population into the Denisovans, which have been found in a cave in Russia. This is probably the most logical scenario describing the origin of Neanderthals and *Homo sapiens* and the relationship between them. This scenario is reinforced by the lack of Neanderthal remains in Africa; the closest Neanderthals ever got to Africa was Gibraltar and the Eastern Mediterranean's Levant late in their existence. Under this scenario, Neanderthals are not a subspecies of *Homo sapiens*, but share a last common ancestor (*H. heidelbergensis*) instead. The evolution of the two lines

were separate, independent events, one in Europe and one in Africa, so there's no specific date when Neanderthals and *Homo sapiens* separated because they didn't actually specifically separate from one another. Because the evolutionary lines in Europe and Africa both came from the same common ancestor, they shared an overwhelmingly large part of their DNA, but the two lines did develop a few differences because geography genetically isolated them from one another.

Neanderthals apparently separated from *H. heidelbergensis* around 250,000 years ago, in the middle of the recent series of ice ages. The recurring European ice ages encouraged the *heidelbergensis*/Neanderthal line to develop a shorter, stockier physiology than the *heidelbergensis (rhodesiensis)/sapiens* line because a more compact physiology is better able to reduce heat loss. Thus, environmental stresses favored retaining genes associated with the more compact build and encouraged Neanderthals' evolution in that direction. In other words, more Neanderthals with a short, stocky build were able to survive the cold and pass on their DNA than those with a tall, lanky physique. Conversely, the taller, more slender body of the African *heidelbergensis (rhodesiensis)/sapiens* line was better at dissipating heat in the warmer African environment. However, the more important difference was in the structure of the skull and brain.

The *heidelbergensis/neanderthalensis* line retained the *heidelbergensis* skull shape and brain structure, which included a pronounced bulge in the back of the skull and a forehead that sloped back from a prominent brow ridge. On the other hand, the *heidelbergensis (rhodesiensis)/sapiens* line developed a more rounded skull with a higher forehead above a much smaller brow ridge. This higher forehead creates a place for expanded brain frontal lobes, which are associated with planning, reasoning, and abstract thought and which gave the African line a greater capacity to plan and find more relationships among its stored information that are favorable for survival, which is the essence of being smart. To date, *H. sapiens* is the only known hominid with a high forehead, flat face, and thin, flat brows.

The probably slightly inferior ability of Neanderthals relative to *H. sapiens* to plan and find more relationships among their stored information that are favorable for survival placed them at a slight competitive disadvantage compared with *H. sapiens*. Curtis W. Marean of Arizona State University has said, "The key difference is that Neanderthals were just not as advanced cognitively as modern humans," although many paleoanthropologists suggest that their cognitive capacities and culture were comparable to those of *H. sapiens*. The key word here is "comparable". When living on the edge as Neanderthals and *sapiens* were 50,000 years ago, even a small advantage can be telling, as people who engage in competitive activities at the highest level know. Katerina Harvati of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany has said, "In this context, even small advantages would become extremely important and might spell the difference between survival and death." The cognitive capacities of Neanderthals and *H. sapiens* of 50,000 years ago are inferred from their cultures,



### Neanderthal and *Homo sapiens* Skulls

This figure, adapted from course material created by Dennis O'Neil at Palomar College in San Marcos, California, illustrates the shape of the Neanderthal (left) and *H. sapiens* (right) skulls. Although both have a comparable volume, *H. sapiens*' skull is more rounded and has a much larger frontal lobe, which is the seat of planning and abstract thought. Much of Neanderthal's cranial volume is in the bulge called the occipital bun at the back of the skull.

and comparable cultures suggest comparable cognitive capacities. For the Neanderthals, that culture was probably the limit of their abilities, but for *H. sapiens* with their larger frontal lobes, it was merely a way station on the road to gazing upon the far reaches of the Universe.

A slight competitive disadvantage for Neanderthals becomes more significant when we realize that, at any one time, they never numbered more than 70,000 individuals divided among numerous small bands distributed throughout Europe from the Atlantic to the Caucasus Mountains. Their higher caloric intake requirements compared with *H. sapiens* was another competitive disadvantage. For example, University of Wisconsin-Madison hominid energetics researcher Karen Steudel-Numbers has determined that Neandertals needed 32 percent more energy than *H. sapiens* to simply walk and run because of their stocky build and short shinbones, which would have shortened their stride. Andrew Froehle of the University of California, San Diego, and Duke University's Steven Churchill have determined that Neandertals would have required somewhere between 100 and 350 calories more than *H. sapiens* living in the same climate. Thus, food shortages would have been harder on Neanderthals than on *H. sapiens*.

Neanderthals were ambush hunters using spears tipped with points worked from stone and thrusting rather than throwing them. This was a dangerous strategy that sometimes resulted in injury to the hunters, but evidence of broken bones that healed tells us that Neanderthals cared for their injured for a considerable length of time. Another sign of the "advanced" nature of Neanderthal culture is that they apparently deliberately buried their dead and occasionally, such as at Iraq's Shanidar Cave, even marked their graves with offerings, such as flowers. No other primates, and no earlier human species, had ever practiced this sophisticated and symbolic behavior.

Although no clothing has been found among Neanderthal remains, there is indirect evidence that they used animal skins to make clothing of some

sort to keep warm during cold times. Stone borers or awls that are usually used to punch or drill holes in relatively soft materials such as leather have been found at many Neanderthal sites. Moreover, some Neanderthal skulls have incisor teeth with a wear pattern similar to that of older North American Inuit (or Eskimo) women who chewed their husband's boots to soften them. Needles left behind by *H. sapiens* hint that their clothing and tents were tailored, which would have been better for keeping out the cold than those made by simple lacing through punched holes. Neanderthals left behind no such signs of sewing, and some paleoanthropologists believe their clothing and shelter were more crude.

In 2007 researchers led by Johannes Krause of the Max Planck Institute reported that analyses of Neanderthal DNA have shown that they had the same version as modern humans of the speech-enabling gene *FOXP2*. In a 2013 article, Dan Dediu and Stephen C. Levinson say, "...we adduce a broad range of evidence from linguistics, genetics, paleontology, and archaeology clearly suggesting that Neanderthals shared with us something like modern speech and language." This capacity for modern speech apparently extends back to *Homo heidelbergensis*. Although Neanderthals had the same *FOXP2* gene that *Homo sapiens* carry, the question of whether or not the epigenome was able to express it is unanswered as of 2013.

Neanderthals disappear from the fossil record sometime around 28,000 years ago. No clear, single cause has been established for their extinction. Several hypotheses have been proposed, and their demise was doubtless caused by all proposed hypotheses acting together. One hypothesis is that climate change was a contributing factor. European climate became unstable, undergoing a fast series of severe and abrupt warm/cold climate swings just prior to the onset of the last ice age 40,000 years ago. Clive Finlayson of the Gibraltar Museum says that Neanderthals would have had to quickly change their way of hunting in response to these climate swings. For example, wooded areas might have become open grassland leaving ambush hunters without cover. Finlayson hypothesized that the Neanderthals' reliance on big game made it difficult for them to adapt fast enough to changing food sources that result from large, fast swings in climate.

One of these climate swings was possibly a "volcanic winter" caused by the Campanian Ignimbrite eruption of 39,000 years ago, which had a Volcanic Explosivity Index of 7 (comparable to the 1815 Tambora eruption that gave Europe, which is half a world away, the "year without a summer"). This was the first and most violent volcanic event in the Phlegrean Fields near Naples, Italy and was violent enough to cause the complete collapse of the crater into Naples Bay. Although the eruption didn't cause the demise of the Neanderthals as some claimed at the time the research article was first published, it doubtless was a stress factor in their survival. Thus, they might have already been on a steady decline when *Homo sapiens* entered their territory in force around 40,000 years ago and began to compete for resources. It was probably only at the end that *H. sapiens* out-competed them. One anthropologist has even gone so far as to propose that *H.*

*sapiens* violently destroyed them, a proposal that's not widely accepted although all known human cultures have engaged in ethnic violence against other cultures to some degree.

However, analyses of both the human and Neanderthal genomes has revealed that Neanderthals have not really completely disappeared; some of their DNA remains in the DNA of *Homo sapiens*. Sequencing Neanderthal and modern human DNA has provided the opportunity to compare them. Analyses of mitochondrial DNA (mtDNA; see Chapter 3) has shown no Neanderthal contribution to *H. sapiens* mtDNA. However, analyses of nuclear DNA has shown that modern non-African humans have a Neanderthal contribution of between 1% and 4% according to the Smithsonian Institution Human Origins Initiative. Because mtDNA is passed on by only the mother, this means that one or more matings between a Neanderthal male and a *Homo sapiens* female resulted in fertile offspring, but any mating between a modern human male and a Neanderthal female either didn't occur or resulted in sterile offspring. Because Neanderthals never made it to Africa, native sub-Saharan Africans have no Neanderthal DNA, but everyone else does, the amount depending on their distance from Europe.

Thus, sometime between 60,000 and 40,000 years ago people that are sometimes called "anatomically modern humans" entered Neanderthal territory and displaced the already-beleaguered group by one means or another within approximately 12,000 to 30,000 years.

In the neighborhood of 200,000 years ago, *Homo sapiens* evolved from *Homo heidelbergensis* (*Homo rhodesiensis*) in Africa. This was shortly after *Homo neanderthalensis* had evolved from *Homo heidelbergensis* in Europe. In a 2009 paper published in the *Proceedings of the National Academy of Science*, Ian Tattersall of the American Museum of Natural History hypothesizes that the emergence of *H. sapiens* was a two stage event: physical development followed by the appearance of cognitive function. "Evidently, then, 'becoming human' took place in two separate stages. First, the distinctive modern human morphology became established, very clearly in Africa, and probably shortly after 200 Ka [SIC; Ka = thousand years ago]. This event involved a radical departure from the primitive *Homo* body form. Only ca. 100 Ka later, again in Africa, and in a Middle Stone Age industrial context, did modern symbolic behaviors begin to be expressed, underwritten by a new capacity that had most plausibly been present but unexploited in the first anatomical *H. sapiens*." Perhaps the new capacity was not exploited in the first anatomical modern *H. sapiens* because the epigenome to facilitate it was not developed yet.

In a 2012 paper published in *Molecular Biology and Evolution*, Soares and coworkers wrote, "Although fossil remains show that anatomically modern humans dispersed out of Africa into the Near East ~100 to 130 Ka, genetic evidence from extant populations has suggested that non-Africans descend primarily from a single successful later migration."

Thus, once *H. sapiens* obtained advanced cognitive capacity, approximately 70,000 years ago, it began a successful dispersal from Africa to

populate the Earth. Analyses of global mtDNA suggests that the first movement was along the shores of Saudi Arabia, India, and southeast Asia. Approximately 50,000 to 40,000 years ago *H. sapiens* moved into Europe.

For over three billion years our ancestors fought a never-ending battle to eat but not be eaten in an environment that was sometimes hostile to life of any sort, and they persevered. Humans are an evolved species that carries the legacy of three billion years of evolution, and 50,000 years of cultural striving has done no more than cover that legacy with a thin veneer.

In the past 50,000 years, we humans have overlaid 3 billion years of our evolutionary background with a thin veneer of civilization. Nearly all of us are so thrilled with that accomplishment that we refuse to acknowledge that any remnant, however small, of our basic evolutionary nature remains as if 50,000 years of civilization can completely wipe away more than 3 billion years of evolution. A vast number of our horde simply refuses to entertain the reality that we are evolved beings at all, preferring to believe the pretty myth that the Creator of the remarkably vast and complex Universe cast us upon the Earth as we are now, fully fledged special beings without the untidy baggage of evolution. Even folks in the sciences of psychology and sociology who understand us as evolved beings say that we should not place too great an emphasis on our evolutionary past when explaining how we act. But the entire sweep of human history, from the rise and fall of nations to the rise and bankruptcy of corporations, can be explained more completely by our basic evolutionary nature than by the artificial parameters of our man-made civilization, and our steadfast refusal to acknowledge who we are prevents us from becoming who we can be.

### Song of *sapiens*

I know who I am and whence I came.

I floated in primordial oceans and swam in archaic seas.

I wiggled from ancient ooze onto dry land.

I fought unceasingly to survive, to live one more day.

I became small and could hide from the great killing stone and its all-consuming fires

To survive, to live one more day.

More slowly than slow, I grew larger and stood upright and began to know,

But my spirit still floats in primordial oceans, still swims archaic seas.