

# HUMAN EVOLUTION

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There is probably no other topic in evolution that is as controversial in the public's mind as human evolution. However, it is consistently the topic that students find the most interesting. After all, it is about something intrinsically interesting to us: ourselves. It is the story of how we got here. Before we dive into what evolutionary biology can tell us about human origins, it is important to keep one thing in mind: understanding human evolutionary origins is just one part of understanding what it is to be human.

*Evolutionary biology indeed has much to say about the human condition, but so do anthropology and sociology, psychology and history, philosophy and the arts. People are too complex to be understood from the narrow perspective of biology or of any other single way of knowing.*

—Douglas Futuyma, 1998

## OVERVIEW

*How do we know what we know in paleoanthropology* (the study of human evolution)? How can we tell if a particular species walked upright or lived in trees? Or if it lived in grassy savannas or tropical forests? How can we know anything about the social structure of extinct populations? As with any historical science, *clues to the past are left*, and the job of the paleoanthropologist is to find these clues and to interpret them. These clues come in many different forms; fossils of the bones and skulls of humans are the most dramatic and well publicized. The size of the skull can obviously tell us about the size of the brain. In addition, the size, shape and orientation of other bones, as well as the size of the muscle attachments on the bones tell us a lot about, for example, how the individual moved and used its hands. Other important clues about the past are tools and other archaeological items such as cave paintings and jewelry; footprints preserved in the ground; animal and plant fossils found at the same site; butchery marks found on animal bones. In addition, genetic data from modern humans and even some fossil specimens, can tell us about how groups are related and how long ago they are likely to have diverged from each other.

The archaeological record of **hominids**<sup>1</sup> is in many ways amazingly complete, showing many transitions between species. Yet in other ways, it is entirely inadequate to fully answer all of the questions we have about human origins. Some questions may never be answered to our complete satisfaction. The archaeological record does, however, allow us to make several statements with extremely high confidence. First, *modern humans evolved from apelike ancestors, through a series of intermediate steps*. Humans and the great apes—chimpanzees in particular—diverged from a common ancestor as recently as about 7 – 8 million years ago (Mya); the transition from this common ancestor to modern humans has been well documented. Second, *hominid evolution has been mosaic*—important features have evolved at different times, some sooner than others, and at different rates. For example, large brains and bipedalism (the ability to walk upright) are both hallmarks of human evolution; however, bipedalism evolved several million years sooner than increased brain size.

There have been many different **transitions in hominid evolution**. Here are some of the important ones:

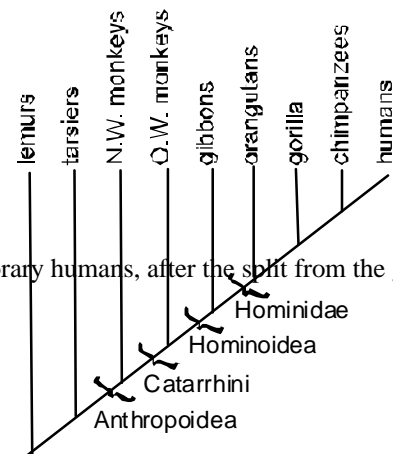
- 1) hominids diverged from the great apes, ~7 – 8 Mya
- 2) bipedalism, at least 4 Mya (probably much earlier)
- 3) simple stone tools, ~2.5 Mya
- 4) more sophisticated tools (hand axes), ~1.5 Mya
- 5) fire mastered, spears and other tools, ~0.5 Mya
- 6) symbols and signs of abstract thought (jewelry, paintings, ritualized burials), starting ~40,000 ya
- 7) agriculture, ~10,000 ya

## OUR PRIMATE ORIGINS

In The Descent of Man, Charles Darwin summarized the mass of evidence for our common

<sup>1</sup> For our purposes, hominids is the group of species, including contemporary humans, after the split from the great apes.

Figure 1: Phylogenetic tree of primates



ancestry with the apes. As there had been no hominid fossils discovered at the time, his evidence came from embryological, physiological, anatomical and behavioral comparisons of modern humans with vertebrates (including the apes). For example, humans and apes have a similar skeletal structure, and they go through the same embryonic stages (it is only late in development that they differ, with different body parts growing at slightly different rates). From these data, Darwin concluded that humans are vertebrates, and more specifically primates, and that we share a common ancestor with the apes. Since we were more similar to the African apes (gorillas and chimps) than to the Asian apes (orangutans), he also predicted that Africa was the place where humans originated.

Today, we have access to a tremendous breadth of accumulated evidence, and all of it supports both of Darwin's predictions. We now know, for example, that modern humans share a number of characteristics with the modern apes. Both groups have shoulders with a wide range of movement, dexterous hands with fingers that are capable of strong grasping, nails instead of claws, relatively large brains and greater cognitive abilities than other animals, and large, complex social groups. These characteristics are shared between humans and apes, and are older than the split between these groups (*shared primitive traits*). Since humans and apes diverged (about 7 – 8 Mya), both groups have evolved unique characteristics that distinguish and that define their particular groups (*derived traits*). Humans, for example, have evolved the ability to walk upright (bipedalism), a much larger and more complex brain, a much greater intellectual capacity, language (spoken and written), and the ability to precisely manipulate very small objects with their hands, among others traits. Likewise, chimps also have evolved new traits of their own during the time from the split with hominids and the present.

Perhaps the strongest evidence that we are related to the great apes comes from studies of our DNA. Today we know that humans and chimpanzees are genetically extremely similar, sharing 98% of the same genes. More specifically, the base pair sequences of our DNA are 98% identical to the sequences of chimp DNA. Modern humans and chimps are sister species, each being more closely related to each other than to any other extant species (Figure 1). Chimps are actually more closely related to humans than they are to gorillas!

Darwin was also right about Africa being the place of origin of humans. We now have a multitude of fossils documenting early lineages of hominids, and all of the oldest hominid fossils have indeed been found in Africa. Africa is the place where humanity originated.

## THE FIRST HOMINIDS

According to DNA comparisons, humans are thought to have diverged from the apes ~ 7 – 8 Mya. Until recently, however, the oldest hominid fossil ever found was about 4.4 million years old (Myo): *Ardipithecus ramidus*. Skeletal evidence indicates this species was bipedal, able to walk upright on two legs. Recently (2000), a 6 Myo fossil, *Orrorin tugenensis*, was found and classified as a hominid: it had small teeth, like later hominids, with hard enamel on their cheek teeth (indicating a diet of tough plants, rather than the soft fruit diet of chimps). There is also some skeletal evidence (e.g. where the muscles attach to the leg bones) that indicate this species was also bipedal. Even more recently (July 2002), an even older fossil hominid, close to 7 Myo, was found, and is different enough from the other two ancient species to be classified in its own genera: *Sahelanthropus tchadensis*, nicknamed “Toumai.” *S. tchadensis* is thought to have lived close to the time of the divergence between chimps and humans. This fossil is further support of the close evolutionary relationship between these humans and chimps: it has a mix of characters that are associated with early chimps and early hominids. There is even some evidence (the way the spine connects to the skull) that this species may have been bipedal, although this cannot be concluded with confidence at this time.

**Bipedalism** is a distinguishing characteristic of humans that is thought to be one of the traits that evolved very early in the human lineage. In fact, it is thought to have been a critical step in the evolution of hominids, and it entails a suite of skeletal changes. Compared to non-bipedal organisms, in bipeds the pelvis is more bowl-shaped (to help support the internal organs), the upper legs are angled inward from the hip joints (which puts the knees in a better position to support the body), the foot is shorter with more rigid toes (to help push off), the spine is shortened and S-shaped (for rigidity and balance), and the opening of the bottom of the skull is more anterior (to set the head more directly over the spine). All of these skeletal adjustments are part of the evolutionary modifications that gradually evolved in our ancient ancestors as they became increasingly upright in stature.

*What may have led to the evolution of bipedalism?* In other words, what kind of advantage did individuals who were more bipedal have over those who were less bipedal? Over the years, there has been a lot of speculation about this question, and for a long time, the

“savanna” hypothesis was in favor. This hypothesis stated that the earliest hominids evolved during a period of climate change, on the newly formed African savannas (tall grasslands). The ability to stand upright was thought to be advantageous because it allowed them to look over the tall grass, presumably to detect predators. However, it appears that the earliest hominids did not live in savannas (which are now thought to have not been common in Africa until much more recently), but rather in forested environments. Other possible advantages of bipedalism include: it allowed individuals to carry food back to their family group, it enabled individuals to walk for long distances more efficiently, it made it easier for individuals to reach food from low branches, and standing upright decreased the amount of skin exposed to the hot African sun. At present, the existing data are inadequate to convincingly discriminate among these alternatives.

## THE AUSTRALOPITHS

The first species that was undoubtedly bipedal was *Australopithecus afarensis*. One of the reasons for this high level of confidence (besides many skeletal characteristics) is the Laetoli footprints, made by an *A. afarensis* individual 3.6 Myo. *A. afarensis* is a well-documented species, with hundreds of fossils, including one of the most famous hominid fossils: “Lucy,” an incredibly complete skeleton of a young female who lived 3.2 Mya. *A. afarensis* is thought to have lived from ~3.9 – 3 Mya, and is probably an ancestor to the later australopiths and maybe even to the genus *Homo*. Members of this species still had a relatively small brain (~400 cubic centimeters, roughly the same size as modern apes), and long powerful arms, suggesting that although they were definitely bipedal, they also were skilled at climbing trees.

The australopiths are commonly divided into two major groups: the early or “gracile” australopiths, which arose more than 3 Myo, and the late or “robust” australopiths, which arose after 3 Myo. The graciles had smaller teeth and jaws, while the robusts had much larger faces, with large jaws and teeth. *Ardipithecus ramidus* and *Australopithecus afarensis* are both gracile australopiths, as are a later species: *Australopithecus africanus*, which lived ~3 – 2 Mya. This species had a slightly larger brain (~500 cc), a more rounded skull, and more modern-looking face and teeth than *A. afarensis*, suggesting that it may have been the ancestor to the genus *Homo*. Whether *A. ararensis* or *A. africanus* was ancestral to *Homo* has yet to be determined.

The robust australopiths are a separate lineage from that which eventually evolved into *Homo*. The robusts had evolved by 2.7 Mya, and were extinct by ~1 Mya. They are referred to as “robust” because of their large face, broad thick cheek teeth, and prominent sagittal crest (a raised area of bone along the top of the skull, used for jaw muscle attachment) all indicating that they were very strong chewers, probably of tough, fibrous plants. The robusts are usually separated into their own genus, and three species are generally recognized: *Paranthropus aethiopicus* (the earliest), *Paranthropus robustus*, and *Paranthropus boisei*.

### THE GENUS *HOMO*

Members of our own genus, *Homo*, made their first appearance ~2.5 Mya. The key innovations that distinguish members of the genus *Homo* are considered to be: 1) a gradual increase in **brain size** (from a cranial capacity of ~400 – 500 cc in the australopith ancestors of *Homo* to an average of 1350 cc in modern humans), and 2) the **advent of toolmaking** (the first stone tools appeared 2.5 Mya). Some scientists think that a change in the climate of Africa during this time period from hot and wet to fluctuations between dry and wet environments may have given toolmaking individuals an advantage in obtaining alternative food (underground tubers and roots, as well as meat obtained from scavenging and hunting), as their old food (vegetation) became more unpredictable.

***Why did brain size increase?*** In other words, what factor selected for increased intelligence? It is possible that the advantage of being able to make tools selected for increased intelligence, and therefore, increased brain size. Or it is possible that increased sociality (larger group size) selected for increased intelligence (the larger the group size the more intelligence it takes to keep track of alliances, deceptions, etc.). In this scenario, the consequent increased intelligence led to the advent of tool-making. Whatever the reason, selection for greater intelligence resulted in larger brain size, and a suite of other traits as well: a larger birth canal; since brain development continues after birth, a prolonged period of time between birth and maturity, and a longer period of parental care of infants. These traits may have then led to changes in social structure as well (e.g. a greater need for more extended parental care may have led to a sharper division of labor between males and females).

*Homo habilis* (“tool man”) lived between ~2.5 – 1.6 Mya, at the same time as *A. africanus* and the later robust australopiths, and resembled the australopiths in their dentition. However, the brains of individuals of this species (~650 cc) were larger than those of the australopiths. Members of this species had hands capable of producing tools, and some of the oldest tools have been found with fossil *H. habilis*, suggesting this was the first species to make simple stone tools. The first stone tools were made by banging rocks together to chip off the edges, creating a simple blade, which could chop or scrape.

*H. habilis* is intermediate in many characteristics between *A. africanus* and ***Homo erectus***, suggesting a transition between these species. *H. erectus*<sup>2</sup> (1.6 – 0.3 Mya) had a cranial capacity of ~900 cc (which increased over the lifetime of the species), made more sophisticated stone tools (called handaxes), was the first to master fire (by 0.5 Mya), and was the first species to leave Africa and spread throughout Asia and Europe (between 1.7 – 1.0 Mya).

## THE ORIGIN OF MODERN HUMANS

There are two species of late *Homo*: ***Homo neanderthalensis***, and our own species, ***Homo sapiens***. *H. neanderthalensis* lived from about 250,000 – 30,000 years ago, and actually had a larger brain (~1500 cc) than *H. sapiens* (~1350 cc), although this may just be due to an overall larger body size. They most likely evolved from *H. erectus* populations in Europe, and as they lived in the cold northern climates of western Europe, they had many facial and skeletal characteristics that were probably adaptations to cold: powerful, compact bodies that helped conserve heat and withstand cold temperatures. They also had protruding mid faces, low foreheads, prominent brow ridges, and weak chins. Neanderthals produced relatively sophisticated stone blades and spears.

*H. sapiens*, or anatomically modern humans, is a relatively new species, with the first fossils appearing ~130,000 years ago. Modern humans have a much smaller brow ridge, a rounded braincase, high foreheads (resulting from the frontal lobe of the brain positioned directly

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<sup>2</sup> Note that some authors will call geographical populations of *H. erectus* different species: *H. ergaster* (Africa), *H. erectus* (Asia) and *H. heidelbergensis* (Europe). A recent (March 2002) paper documenting a new fossil find argues that these were all actually one species: *H. erectus*; with the African population probably giving rise to *H. sapiens*, the European population giving rise to *H. neanderthalensis*, and the Asian population going extinct.

over the face), prominent chins, and a flat face. Modern humans also have a much lighter bone structure than Neanderthals.

*H. sapiens* invented tools that required a much higher degree of sophistication and skill than any other species, including spears that were much more efficient to use and that put the person using it in less danger from the animal than Neanderthal spears. They also used new types of materials, such as bones and antlers. Starting about 40,000 years ago, ornamentation, such as jewelry, began to appear in the archaeological record, as did other fine artwork, such as cave paintings, ivory carvings, clay figurines, and musical instruments. These signaled a big change in *H. sapiens* society: new ways of thinking—symbolic and abstract thought. Now, at least some people had the time to spend on skills that had nothing to do with basic survival.

***Where and when did modern humans evolve?*** There are two hypotheses that attempt to explain where modern humans originated. The **“out of Africa” hypothesis** (also called the “replacement” hypothesis) states that about 200,000 years ago, modern humans originated in a small region in Africa from a population of *H. erectus* that had been isolated from the main population. Subsequently, the new species *H. sapiens* migrated out of Africa into Asia and Europe. Eventually, *H. sapiens* replaced other species of hominids (*H. neanderthalensis* in Europe and *H. erectus* in Africa and Asia).

The **“multiregional” hypothesis** (also called the “continuity” hypothesis), on the other hand, states that the evolution of modern humans began when *H. erectus* moved out of Africa ~1 – 2 Mya and spread throughout Asia and Europe. Populations of *H. erectus* evolved in response to the new situations that they encountered (leading to regional differences among populations). Gene flow between neighboring regions spread novel *H. sapiens* traits throughout the entire geographic range.

Both of these hypotheses make predictions about the genetic differences we should find among contemporary humans from different geographical regions. The multiregional hypothesis predicts that there should currently exist genetic differences between people from different geographic regions that developed more than 1 Mya, while the out of Africa hypothesis predicts that these differences should have evolved much sooner (within 200,000 years ago). Molecular studies of mitochondrial DNA (mtDNA) have yielded an estimate of the divergence time of all human populations: ~200,000 years. This means that all contemporary human mtDNA originated approximately 200,000 years ago; this supports the out of Africa hypothesis that

humans originated in Africa. These studies have also shown that contemporary African populations have a greater diversity in their mtDNA than do other geographical populations. This is expected if humans originated in Africa and then spread gradually: as new populations were founded, they were likely subject to population bottlenecks, and during these events they would lose some genetic variation (through the process of genetic drift). Today, then, we would see less variation within each of these populations than we would within the ancestors of the original source population.

In another study, mtDNA was extracted from a Neanderthal fossil and compared with contemporary human mtDNA. This study revealed that Neanderthals and modern humans are not very close genetically, with the estimated divergence time about 600,000 years ago. This also supports the out of Africa hypothesis. Overall, the [genetic evidence](#)<sup>3</sup> tends to favor the out of Africa hypothesis.

Fossil evidence also tends to favor the out of Africa hypothesis. The oldest anatomically modern human fossils have been found in Africa, and are ~130,000 years old. The next oldest come from the Near East (~90,000 years old). Modern humans are not seen in Europe until about 40,000 years ago (Cro-Magnon people). This chronological pattern would be expected with a migration pattern predicted by the out of Africa hypothesis.

On the other hand, fossil *H. erectus* and anatomically modern humans in some regions (e.g. Asia) share some physical traits, indicating that the local *H. erectus* may have given rise to (or at least contributed genes to) the modern humans in those regions. Although the balance of the evidence at this point tends to favor the out of Africa hypothesis, there is sufficient criticism of this evidence and the interpretation of the evidence that a consensus has not yet been reached.

## CULTURAL EVOLUTION

Culture is the social transfer of information from one generation to the next. Cultural evolution, or change in culture, is analogous to (but is not the same as) biological evolution. Ideas change and these new ideas are spread across populations. New ideas often compete with

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<sup>3</sup> However, some geneticists have criticized these studies for the use of mtDNA and not nuclear DNA, as well as the mutation rate used to calculate divergence time.

old ideas, a form of natural selection. The evolution of **language** had a huge impact on cultural evolution, speeding the rate of the spread of ideas.

In a way, cultural evolution has “taken over” human populations. Humans have not changed much genetically over the past 30,000 – 40,000 years, but culturally we are amazingly different from what we were then. Culture can even influence biological evolution. For example, when dairy cows were domesticated in some parts of the world, the people in those populations eventually changed genetically. Adult humans in most populations are unable to break down the sugar lactose, but in populations where dairy cows were domesticated, the gene for lactose tolerance was selected for and is now predominant. In other ways, culture may be slowing down biological evolution. In our modern society, people with genetic diseases that were probably selected against just a century ago, due to death at a young age, are now able to live full lives and even pass on those genes to their children. Culture dominates today’s human society.

### **RESOURCE LIST**

- Campbell, N.A., J.B. Reece, and L.G. Mitchell. 1999. *Biology*, 5<sup>th</sup> ed. Benjamin/Cummings, California.
- Clarke, T. 2002. Skull thwarts species-splitters. *Nature News*, March 20, 2002.
- Futuyma, D. J. 1998. *Evolutionary Biology*, 3<sup>rd</sup> ed. Sinauer, USA.
- Lemonick, M.D. and A. Dorfman. 2001. One giant step for mankind: meet your newfound ancestor, a chimplike forest creature that stood up and walked 5.8 million years ago. *Time* 158 (3): 54.
- Nickels, M. 2001. Top ten lines of evidence for human evolution. *Reports of the National Center for Science Education* 21 (5-6): 27.
- WGBH. 2001. *Evolution: Teacher’s Guide*. WGBH, Boston.
- Wood, B. 2002. Hominid revelations from Chad. *Nature* 418: 133 – 135.
- Zimmer, C. 2001. *Evolution: the Triumph of an Idea*. Harper Collins Publishers, Japan.

### **USEFUL WEBSITES**

**The Institute of Human Origins:** <http://www.becominghuman.org>

**The Smithsonian Institution Human Origins Program:**

<http://www.mnh.si.edu/anthro/humanorigins/index.htm>

**PBS Evolution:** <http://www.pbs.org/wgbh/evolution/humans/index.html>

## LESSONS ON HUMAN EVOLUTION

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There are many nice classroom lessons about human evolution. The ENSI site has many lessons, as well as a two-week unit that uses human biology as an introduction to evolution, “**Human Evolution Unit.**” [[[www.indiana.edu/~ensiweb/lessons/unt.he.f.html](http://www.indiana.edu/~ensiweb/lessons/unt.he.f.html)]] This unit incorporates several of their lessons on human evolution.

### Skull Comparisons

A classic lesson on human evolution is the skull comparison, in which students compare the skull characteristics of contemporary humans and apes (such as chimps or gorillas), with fossil hominids. Students see for themselves what kind of similarities and differences there are between these species. There are a couple of lessons to choose from: ENSI’s “**Hominoid Cranium Comparison.**” [[[www.indiana.edu/~ensiweb/lessons/hom.cran.html](http://www.indiana.edu/~ensiweb/lessons/hom.cran.html)]] as well as Access Excellence’s “**Hominoid Skull Comparison.**” [[[www.accessexcellence.org/AE/AEPC/WWC/1995/hominoidscomp.html](http://www.accessexcellence.org/AE/AEPC/WWC/1995/hominoidscomp.html)]]

### Chromosome Comparisons

Another common lesson is to compare the chromosome banding patterns of contemporary humans and chimps (and sometimes gorillas). This is a nice visual way to get across their extreme genetic similarity. ENSI has one: “**Comparison of Human and Chimpanzee Chromosomes.**” [[[www.indiana.edu/~ensiweb/lessons/chromcom.html](http://www.indiana.edu/~ensiweb/lessons/chromcom.html)]] PBS’ Evolution Teacher’s Guide has also adapted this lesson, called “**Chromosome Clues.**” [[[www.pbs.org/wgbh/evolution/educators/teachstuds/unit5.html](http://www.pbs.org/wgbh/evolution/educators/teachstuds/unit5.html)]] Arizona State University’s Institute for Human Origins also has an on-line activity, “**The Chromosome Connection: Comparison of Human and Ape Chromosomes.**” [[[www.becominghuman.org](http://www.becominghuman.org)]]

### Phylogenies

There are also several activities on phylogenies that include humans. ENSI's lesson, "**Classroom Cladogram of Vertebrate/Human Evolution**," [[[www.indiana.edu/~ensiweb/lessons/c.bigcla.html](http://www.indiana.edu/~ensiweb/lessons/c.bigcla.html)]] has the students collectively work together to build a giant phylogeny of vertebrates, including humans. ENSI also has another activity, "**Molecular Sequences and Primate Evolution**," [[[www.indiana.edu/~ensiweb/lessons/mol.prim.html](http://www.indiana.edu/~ensiweb/lessons/mol.prim.html)]] that has students compare amino acid differences in beta hemoglobin from primate species, and construct a phylogeny from these data. ASU's Institute for Human Origins has a lesson, "**All in the Family: Calculating Cousins**" [[[www.becominghuman.org](http://www.becominghuman.org)]] in which students do not actually build a phylogeny, but they do examine evolutionary relatedness, by calculating what they call "approximate cousinhood" between humans and non-human primates. PBS' Evolution web site also has a web activity, "**A Tree Full of Ancestors**," [[[www.pbs.org/wgbh/evolution/educators/lessons/lesson5/index.html](http://www.pbs.org/wgbh/evolution/educators/lessons/lesson5/index.html)]] in which students examine three alternative phylogenies of extinct hominids, based on fossil data.

## **Real Fossil Data**

There are several other lessons that use real fossil data to address questions. PBS has a general lesson on hominid fossils, "**Fossil Finding**," [[[www.pbs.org/wgbh/evolution/educators/lessons/lesson5/index.html](http://www.pbs.org/wgbh/evolution/educators/lessons/lesson5/index.html)]] in which students examine four real fossil finds and learn how scientists interpret them and what kind of questions can be answered by the fossils. ENSI's "**Chronology Lab**," [[[www.indiana.edu/~ensiweb/lessons/chronlab.html](http://www.indiana.edu/~ensiweb/lessons/chronlab.html)]] has students chart a timeline of fossil hominids from fossil data. The teacher then makes a possible phylogeny from these data, to help make the connection that these extinct species are related. PBS' Teacher's Guide has a lesson, "**Fossil and Migration Patterns of Early Hominids**" [[[www.pbs.org/wgbh/evolution/educators/teachstuds/unit5.html](http://www.pbs.org/wgbh/evolution/educators/teachstuds/unit5.html)]] in which students use real fossil data to determine possible migration patterns of early hominids throughout the world.

## **Hominid Adaptations**

Finally, there are several lessons that explore important hominid adaptations. Again, using real fossil data, there are two lessons that explore the Laetoli footprints and bipedalism: ENSI's "**Footsteps in Time**," [[[www.indiana.edu/~ensiweb/lessons/footstep.html](http://www.indiana.edu/~ensiweb/lessons/footstep.html)]] in which students examine the fossil prints, measure their own feet and height, then use the resulting correlation to estimate the height of the individuals who created the Laetoli print. PBS' Teacher's Guide's "**Watch Your Step**," [[[www.pbs.org/wgbh/evolution/educators/teachstuds/unit5.html](http://www.pbs.org/wgbh/evolution/educators/teachstuds/unit5.html)]] is a more general lesson on the prints, exploring what kinds of questions can be addressed and how scientists choose the best explanation for these kind of data. ASU's Institute for Human Origins has an on-line activity on bipedalism and the skeletal structure that supports the ability to stand upright, "**Building Bodies: Primate Bipedalism—Understanding Standing Up**," [[[www.becominghuman.org](http://www.becominghuman.org)]] There is also a fun lesson on the key innovation of opposable thumbs, "**Thumbs Up, Thumbs Down: Grasping the Idea of Evolution**," [[[www.accessexcellence.org/AE/AEPC/WWC/1995/thumbs.html](http://www.accessexcellence.org/AE/AEPC/WWC/1995/thumbs.html)]] in which students try various tasks first using their thumbs, and then with their thumbs taped.

## Videos

There are also several videos you can use with your students. PBS' Evolution series, episode six, "**The Mind's Big Bang**" explores the later evolution of hominids, specifically the last 50,000 years or so of evolution in our own species. Also check out the PBS video "**Learning and Teaching Evolution**," [[[www.pbs.org/wgbh/evolution/educators/teachstuds/svideos.html](http://www.pbs.org/wgbh/evolution/educators/teachstuds/svideos.html)]] a companion to the series that contains short, seven-minute segments for use in the classroom. Segment five ("**Did Humans Evolve?**") summarizes "The Mind's Big Bang." Also check out Nova's three-part series: "**In Search of Human Origins**," which is a bit outdated as far as the most recent fossil evidence for our earliest ancestors (it was filmed in 1994), but it has some nice segments on the nature of this kind of historical science. ASU's Institute for Human Origins' also has an online documentary, "**Becoming Human**," [[[www.becominghuman.org](http://www.becominghuman.org)]]