



IN-DEPTH FILM GUIDE

DESCRIPTION

Paleontologists have studied the fossil record of human evolution just as they have done for that of other major transitions—including the transition from fish to tetrapods and dinosaurs to birds. The short film *Great Transitions: The Origin of Humans* highlights the most important hominid fossil discoveries of the past 50 years and the insights they provide into human evolution, focusing on three key traits: bipedality, tool use, and larger brains.

KEY CONCEPTS

- The fossil record details the history of life on Earth, including transitions from one major group of animals to another.
- DNA evidence indicates that the human lineage split from that of our closest relative, the chimpanzee, about 7 million years ago—a timing that is consistent with fossil evidence.
- Traits that distinguish modern humans from modern chimpanzees include bipedality (the ability to walk upright on two legs), extensive tool use, and larger brains. Fossil evidence provides information about when and where each of these traits evolved.
- Tracing the evolution of distinct traits shows that, like other major transitions, the evolution of humans from quadrupedal apes occurred in distinct phases.
- Fossil evidence reveals that bipedalism arose over 4 million years ago and predates tool use and the evolution of larger brains by at least a million years.
- Fossils also provide evidence about the environment in which a species lived. For example, bipedalism evolved when our human ancestors were still living in forests and climbing trees.
- Finding and identifying fossils is difficult and time-consuming work. Almost every individual that lived on Earth left no fossil evidence of its existence.

CURRICULUM AND TEXTBOOK CONNECTIONS

Curriculum	Standards
NGSS (2013)	MS-LS4-1, MS-LS4-2, MS-ESS1-4, HS-LS4-1
AP Biology (2012–13)	1.A.4, 1.B.2
IB Biology (2009; 2016)	5.4.2, D.3.5, D.3.6, D.3.7–3.10; 5.1
Textbook	Chapter Sections
Miller and Levine, <i>Biology</i> (2010 ed.)	16.4, 19.1, 26.3
Reece <i>et al.</i> , <i>Campbell Biology</i> (AP ed., 9th ed.)	22.3, 25.2, 34.8

PRIOR KNOWLEDGE

It would be helpful for students to

- be familiar with the tree of life and know that humans are part of the primate group and that chimps are our species' closest living relative
- have a basic understanding of the concept that species descend from other species, and
- know that scientists have methods to determine the ages of fossils.



Short Film
Great Transitions: The Origin of Humans

PAUSE POINTS

The *Great Transitions* film may be viewed in its entirety or paused at specific points to review content with students. The table below lists suggested pause points, indicating the beginning and end times in minutes in the film.

	Begin	End	Content Description	Review Questions	Standards
1	0:00	5:02	<ul style="list-style-type: none"> Larger brains, bipedalism, and tool use are traits that characterize humans. Each of these traits distinguishes living humans from their closest living primate relatives. Charles Darwin predicted that fossils would one day be found in Africa that support the hypothesis that humans and great apes share a common ancestor. The fossils of early hominids and the tools they likely used were found in Africa, just as Darwin predicted they would be. Hominids living 1.8 million years ago already had brains larger than those of modern chimpanzees, were bipedal, and used tools. 	<ul style="list-style-type: none"> Why did the Leakeys decide to look for hominid fossils in Africa? What evidence suggests that more than one hominid species was living in Africa 1.8 million years ago? 	<p>NGSS (April 2013) MS-LS4-1, MS-LS4-2</p> <p>AP Biology (2012–13) 1.A.4</p> <p>IB Biology (2009) 5.4.2, D.3.5, D.3.6</p> <p>IB Biology (2016) 5.1</p>
2	5:03	11:53	<ul style="list-style-type: none"> Using biomolecules, including DNA, researchers have estimated that modern humans and chimpanzees have been evolving independently for almost 7 million years. Only fossils and their ancient environments can address questions about where and when the traits that distinguish humans first emerged. The volcanic geology of eastern Africa enables geologists to accurately date sediment layers and therefore fossils. Lucy (<i>Australopithecus</i>) lived 3.2 million years ago and was bipedal, but she did not use tools or have a large brain. 	<ul style="list-style-type: none"> What features of Lucy's skeleton suggest that she was bipedal? Besides bones, what other evidence is there to suggest that <i>Australopithecus</i> was bipedal? Which evolved first among hominids: tool use or bipedality? How do we know? 	<p>NGSS (April 2013) MS-LS4-1, MS-ESS1-4</p> <p>AP Biology (2012–13) 1.A.4</p> <p>IB Biology (2009) 5.4.2, D.3.5</p> <p>IB Biology (2016) 5.1</p>
3	11:54	15:23	<ul style="list-style-type: none"> Ardi (<i>Ardipithecus ramidus</i>) lived 4.4 million years ago, and like Lucy, she had a small brain, did not use tools, and was bipedal—but unlike Lucy, Ardi could climb well. 	<ul style="list-style-type: none"> Why did Dr. Tim White and his team search for fossils in sediments so much older than those in which Lucy was found? What evidence suggests that Ardi could climb well? What does Dr. White mean when he calls Ardi a “mosaic”? 	<p>NGSS (April 2013) MS-LS4-1</p> <p>AP Biology (2012–13) 1.A.4</p> <p>IB Biology (2009) 5.4.2, D.3.5</p> <p>IB Biology (2016) 5.1</p>



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4	15:24	19:44	<ul style="list-style-type: none"> For a long time, scientists predicted that bipedality evolved in a grassland environment, but fossil evidence suggests that it evolved while our ancient ancestors were living in a woodland habitat and still spending time in trees. Stone tools enabled early humans (genus <i>Homo</i>) to compete with scavengers and predators, to broaden their diets, and to ultimately expand their geographic range out of Africa. Paleontologists continue to discover hominid fossils that reveal further details about human evolution. We now have thousands of hominid fossils from the past 6 million years that document how modern humans evolved—through a series of small steps, over a long geological time span—from small-brained, quadrupedal apes. 	<ul style="list-style-type: none"> What evidence did Dr. White's team collect that suggests Ardi lived in a woodland? What are the three major phases of human evolution? What does Dr. White mean when he says that members of the genus <i>Homo</i> are "technological primates"? How has paleontology informed us about how we became human? 	<p>NGSS (April 2013) MS-LS4-1, MS-LS4-2</p> <p>AP Biology (2012–13) 1.A.4</p> <p>IB Biology (2009) 5.4.2, D.3.5</p> <p>IB Biology (2016) 5.1</p>
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BACKGROUND

It wasn't until the publication of *The Descent of Man* in 1871, 12 years after *On the Origin of Species*, that Charles Darwin wrote about the evolution of humans. In *The Descent of Man*, he hypothesized that humans and modern apes share a common ancestor that lived in Africa. He predicted that fossil evidence would one day be found in Africa to support his hypothesis—and he was right. The film *Great Transitions: The Origin of Humans* explores several key fossil discoveries from Africa and what they reveal about human evolution.

What Are Humans?

Humans, along with familiar species such as lemurs, gibbons, and chimpanzees, are primates (Figure 1). Primates are hundreds of species that form a mammalian order, characterized by many traits, including forward-facing eyes, generalized teeth, collarbones, and nails instead of claws on their fingers and toes.

In the film, Dr. Sean Carroll explains that members of our own species, *Homo sapiens*, are distinguished from other primates by three primary traits: large brains, bipedalism, and tool use. These traits must have evolved after the lineage leading to modern humans split from the one that would eventually split into modern chimpanzees and bonobos, our closest living relatives.



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Scientists have examined the fossil record to understand when and where these three distinctly human characteristics evolved. The film describes fossils of species that were either side branches of our immediate family tree or ancestors on the evolutionary lineage that led to modern humans (Figure 2). In the film, these species are referred to as hominids (the nontechnical form of the zoological family name Hominidae). As used in the film and in this guide, “hominid” is synonymous with the alternative term “hominin,” increasingly used in the scientific literature and many textbooks.

Figure 1. The Primate Family Tree. Humans belong to the primate order, and Darwin had observed that humans shared many similarities with the African great apes. DNA studies have since shown that chimpanzees and bonobos are humans’ closest living relatives; we shared a common ancestor with them about 7 million years ago.

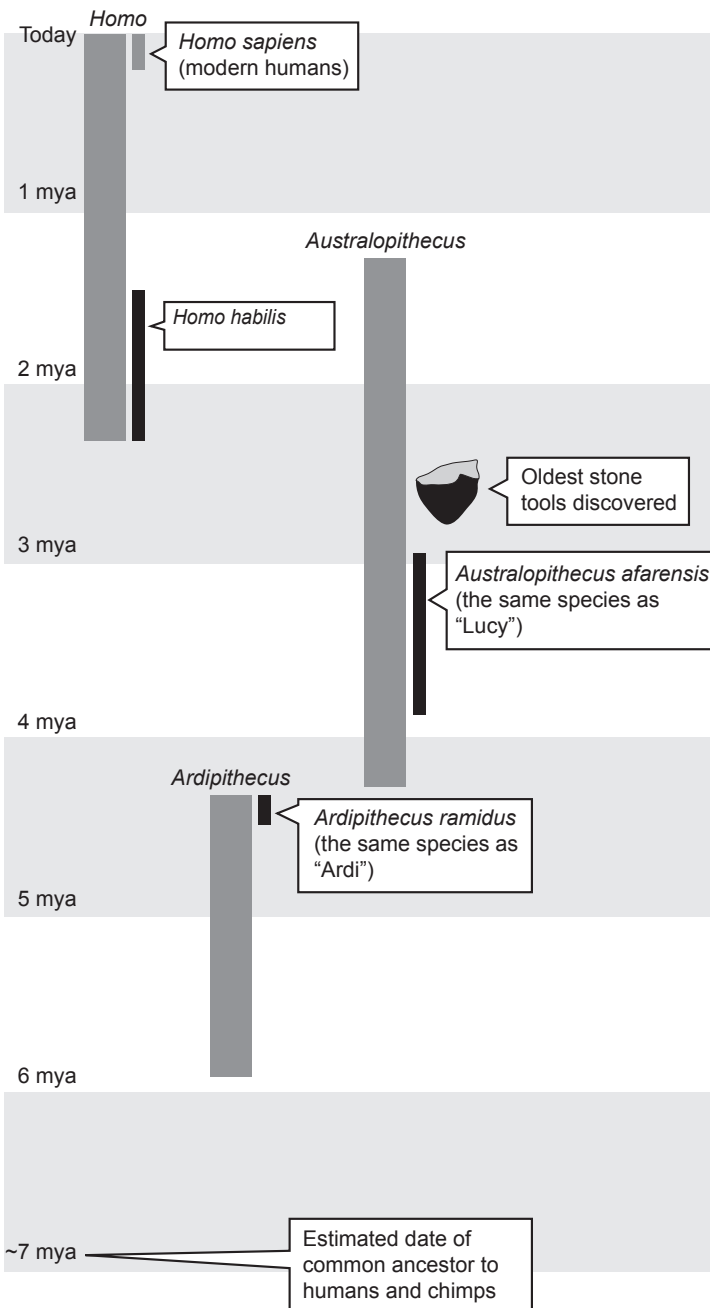
The Earliest Fossil Finds

“On July 17, at Olduvai Gorge in Tanganyika Territory, at site FLK, my wife found a fossil hominid skull, at a depth of approximately 22 ft. below the upper limit of Bed I.” This is the first line in a now-famous paper written by Dr. Louis Leakey and published in the journal *Nature* in 1959 announcing the discovery of the 1.76-million-year-old *Zinjanthropus boisei* (today classified as *Australopithecus boisei* or *Paranthropus boisei*). For three decades, the Leakeys had been searching for evidence of human evolution in the Olduvai Gorge in Tanzania, but they found only stone tools. Finally, they thought they had the toolmaker. In the *Nature* paper, Dr. Leakey proposed that this species was “the oldest yet discovered maker of stone tools,” but later finds would soon cause him to rethink this inference.



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The Leakeys concluded that *Zinjanthropus* was the toolmaker because the skull was found with stone tools in the same layer of sediment. Further analysis of the skull, however, indicated that its large back teeth and sagittal crest for the attachment of large jaw muscles put it on a specialized and now-extinct “side branch” of the human family tree.



Two years after the *Zinjanthropus* discovery, the Leakeys' son, Jonathan, discovered a new, slightly older (1.8 million years old) fossil, dubbed “Olduvai Hominid Number 7,” or “OH7.” The new fossil, with jaw and skull pieces more similar to those of modern humans, led the Leakeys to conclude that this was the real “toolmaker,” and they named it *Homo habilis*, or “handy man.”

How can we know for sure that *Homo habilis* was the toolmaker? The answer is we cannot. The fact that *Homo habilis* appeared to be more closely related to modern humans and had a larger brain than *Zinjanthropus* made it the more likely candidate for the toolmaker. However, even today we cannot exclude the possibility that *Zinjanthropus* may also have been making and/or using tools.

Figure 2. Major Fossil Finds. The film describes three key hominid fossils: early *Homo* (*Homo habilis*), Lucy (*Australopithecus afarensis*), and Ardi (*Ardipithecus ramidus*), shown here along a geological timeline. These three species each belong to a group, or genus, that also contains other species not shown in this figure. Note: “mya” means “millions of years ago.”



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The Importance of Stone Tools

The stone tools found by Louis and Mary Leakey were simple ones. There is evidence that early humans shaped these tools to have sharp edges with which they could cut the meat off animal carcasses and then smash the bones to get at the fat-rich marrow. Although other animals are known to make and use tools, none of them modify stone in this fashion. The oldest firmly dated and diagnostically identifiable stone tools made by hominids date back to 2.6 million years ago.

Lucy

On November 24, 1974, paleoanthropologist Dr. Donald Johanson discovered almost half of the fossilized skeleton of a hominid that lived nearly 3.2 million years ago. He nicknamed the fossil “Lucy” and later included it in a new species, *Australopithecus afarensis*.

Bones of this species indicated that *A. afarensis* was bipedal. The shape of Lucy’s pelvis and knees allowed her to balance on one leg at a time, a requirement for efficient upright walking on two legs. The discovery of two trails of 3.6-million-year-old fossil footprints (called the Laetoli footprints) found on the edge of the Serengeti Plain in Tanzania lent more evidence to the conclusion that *A. afarensis* was a biped.

As for brain size, Dr. Johanson and his colleagues analyzed the skull fragments of Lucy and other *A. afarensis* fossils and determined their brain sizes to be 380 to 550 cubic centimeters (cc or cm³)—larger than the average modern chimpanzee (about 400 cubic centimeters), but much smaller than average for modern humans (about 1,300 cubic centimeters).

Ardi

An international team discovered the partial skeleton of 4.4-million-year-old *Ardipithecus ramidus* (nicknamed “Ardi”) in 1994. In the film, Dr. White described the species as “neither a chimp, nor ... human.” What does he mean by that?

Ardi had a rigid outer part of the foot, likely used as a lever for pushing off during upright walking. In contrast, the bones of chimpanzee feet are more flexible, allowing the feet to be used more like hands. But surprisingly, Ardi’s feet also had an opposable large toe that could be used for grasping while moving about in trees. The upper part of Ardi’s pelvis (the ilium) was flared out to each side, which supported muscles necessary for an upright walker to maintain balance and forward motion. However, the lower part of the pelvis (the ischium) was more like that of a chimpanzee than that of a modern human, anchoring muscles important in climbing. Ardi’s skull was small, with a brain volume of 300 to 350 cubic centimeters, similar to that of a chimpanzee.

Taken together, skeletal evidence suggests that Ardi was capable of bipedalism, but that she had climbing abilities superior to those of *Australopithecus*. Dr. White and his team had not only pushed back the origin of bipedalism to 4.4 million years ago, but they had also discovered that it evolved while our ancestors were still spending time in the trees.

Other Important Traits

Some traits that were not discussed in the film but that also differ between humans and other great apes include the shapes and sizes of teeth—and in particular the canines. Male chimpanzees have prominent, pointed canines that they display to compete with other males for social status and for females. In comparison, humans have stubby canines that are similar in size between males and



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females. Ardi's and Lucy's species had canines that were blunter than the chimpanzee's but more prominent than those of modern humans.

Table 1. Differences in Traits Among Hominids

Species	Toolmaking	Brain Volume (cm ³)	Larger Canines	Bipedal Adaptations
Modern humans	Yes	About 1,350	No	Yes
<i>Homo habilis</i>	Yes	650–680	No	Yes
<i>Australopithecus afarensis</i>	No	380–550	Yes	Yes
<i>Ardipithecus ramidus</i>	No	300–350	Yes	Some

Savanna or Woodland?

Beginning as early as the 1800s, scientists reasoned that bipedality evolved in hominids adapting to the open grasslands of eastern and southern Africa. Standing upright would have also allowed early hominids to both see potential predators as well as defend themselves with handheld weapons—advantages in an exposed, open area such as a savanna.

As early as 1981, however, anthropologist Dr. C. Owen Lovejoy suggested that, given the risk of predation in the savanna ecosystem and the variety of habitats available to early hominids, the most likely habitat for the evolution of upright walking was forest habitat or a combination of forest and grassland, not grassland alone. The tens of thousands of plant and animal fossils recovered from the ancient environment in which Ardi lived provided convincing evidence that her species was adapted to a woodland existence.

DISCUSSION POINTS

- Are the fossils shown in the film the only hominid fossils that have been found? Explain to your students that many more hominid fossils have been discovered. The film focuses on three key fossils because they illustrate distinct phases in human evolution and also because these fossils were remarkable in being nearly complete. Many times, scientists only find parts of a fossil. Discuss with students how rare it is to find fossils. Most organisms are eaten or rot away before they can become fossilized.
- Your students will likely pick up on the fact that modern humans (*Homo sapiens*) and other hominids are not the only species that use tools. Primate biologist Dr. Jane Goodall was the first to document wild chimps using modified twigs to extract termites back in 1960. Other animals, such as dolphins, sea otters, and orangutans, have also been known to use tools, and the characteristic isn't even limited to mammals, as many birds and octopuses are tool users, too. So how, then, can tool use be considered one of the hallmark characteristics of modern humans? The multistep process early hominids used to make a stone tool by modifying the object in a complex way set them apart and allowed them to expand their niche. Ask students how human tool use differs from tool use by other animals. What would such use have meant for the selective pressures operating on early hominids?



- One of the other “human” characteristics—bipedalism—may also confuse students because other species (birds, for example) also walk completely on two legs. Explain that there are three major modes of locomotion on feet: unguligrade animals, such as horses, walk on the tips of their toes; digitigrade animals, such as birds and cats, walk on the flat parts of their toes (pads); and plantigrade animals, such as bears and humans, plant the entire surface of their feet while walking. Indeed, many birds are bipedal, but they are not plantigrade. And while bears and chimps are plantigrade like humans, they are not bipeds. Chimpanzees can walk for short distances on their back legs, but they wobble because their legs come straight down from their hips, they cannot put one foot in front of the other but must move their center of gravity above the supporting leg when walking bipedally, and they do not have a lumbar curve. Consequently, they are quickly fatigued when they do walk bipedally. Humans and their bipedal ancestors have legs that come down at an angle from their hips and thus can place one foot in front of the other, temporarily balancing on one leg at a time. Thus, human locomotion is different from that of a bear, monkey, or ape. The same trait, bipedalism, like many traits, arose more than once in the history of life. Along the human lineage, a peculiar type of bipedality evolved as an arboreal ape adapted to life on the ground; along the bird lineage, another.
- Students (and many teachers) may have only heard of the savanna hypothesis to explain the selection for the evolution of upright walking in the ancestors of humans. Use this as an example of science’s self-correction. Ask students whether the evidence presented in the film by Dr. White has persuaded them to accept the woodland hypothesis. Get them to realize that new evidence led them to abandon a once-entrenched idea. Ask them what future evidence might cause the woodland hypothesis to itself be modified. What if, for example, an even older hominid was discovered that was capable of bipedalism but lived in an open savanna? What kind of evidence might lead your students to conclude that such a hominid actually lived in open savanna rather than somewhere in the vicinity?
- Ask your students about the claim that *Homo habilis*, and not *Zinjanthropus* (now classified as *Australopithecus boisei* or *Paranthropus boisei*), was the toolmaker. What evidence supports this claim? The Leakeys concluded that *Homo habilis* was most likely the toolmaker given its resemblance to modern humans, but both *Homo habilis* and *Paranthropus boisei* were found in the same sediment layers as the stone tools.
- In the film, Dr. Tim White says, “Human feet, we’re all used to them, but they’re really strange.” What does he mean by this? Here Dr. White is describing the discovery of the Laetoli footprints that indicate that *Australopithecus afarensis* had the same kind of “weird feet” as modern humans. Nowhere else among modern primates can we find feet with prominent arches and no grasping big toe.



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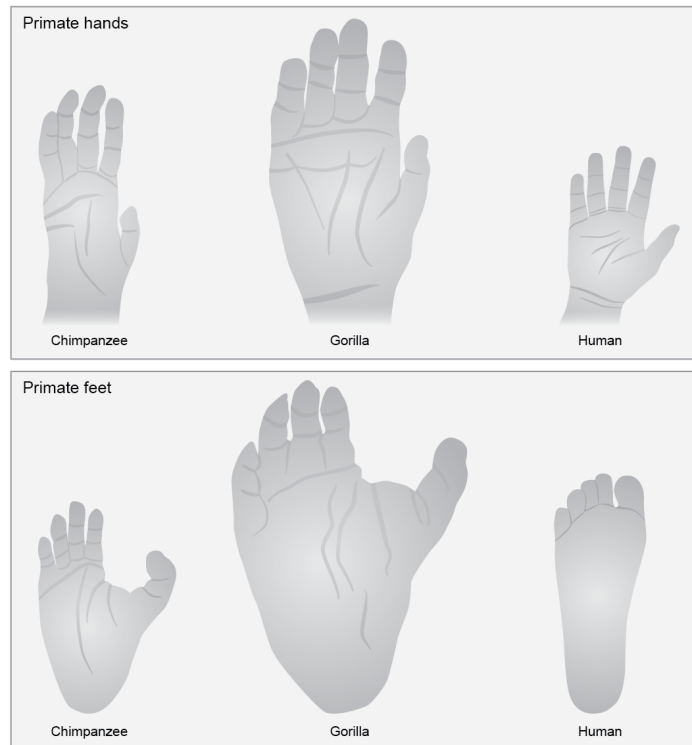


Figure 3. Human feet are strange. Primate hands look similar but human feet look very different from those of other primates, such as the chimpanzee and gorilla.

- Brain size is a good opportunity to discuss how many traits show gradual change over time rather than being either present or absent. There is no threshold after which a brain is considered “big” and all other brains are “small.” In general, brain size increased among hominids through time from the 300- to 350-cubic-centimeter brain of Ardi to the, on average, 1,350-cubic-centimeter brain of modern humans. In particular, between 800,000 and 200,000 years ago, brain size increases began to outpace body size increases. Ask your students what may have caused this period of rapid brain growth. Be on the lookout for any answers that suggest traits (such as tool use) could be summoned on demand—large brains did not evolve because humans needed to use tools! Larger brains, however, may have enabled more complex problem solving and extensive tool use.
- More important, when thinking of the evolution of certain traits, both of bipedality and enlarged brains, students tend to think only of benefits and not costs. Have them think of the costs of these adaptations. For example, larger brains consume more energy. Some of the costs of walking on two legs are discussed in the video “Your Aching Back” (https://youtu.be/FKV_tvlsYA8).
- Learning about human evolution can be challenging for some students because it has the potential to directly challenge nonscientific, but nonetheless important, ideas about human origins. These students may find it easier to accept the facts of human evolution if the evidence for human evolution from a primate ancestor is presented and interpreted just like the evolutionary evidence for any animal. Emphasize what Dr. Carroll says at the end of the



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Educator Materials

film: “Just as four-legged animals evolved from fish ancestors, and birds evolved from dinosaur ancestors over a series of small steps over a long geological time span, we evolved from small-brained quadrupedal apes over a long time span that is now well-documented in the fossil record.” Ask your students, if they do not accept the inferences presented in the film, what kind of evidence would be necessary for them to accept that humans have evolved from quadrupedal apes.

ADDITIONAL BIOINTERACTIVE RESOURCES

Holiday Lectures on Science: [Bones, Stones, and Genes: The Origin of Modern Humans](http://www.hhmi.org/biointeractive/bones-stones-and-genes-origin-modern-humans-0)

(<http://www.hhmi.org/biointeractive/bones-stones-and-genes-origin-modern-humans-0>). Dr. John Shea of Stony Brook University, Dr. Sarah Tishkoff of the University of Pennsylvania, and Dr. Tim White of the University of California, Berkeley, guide us on a global exploration spanning millions of years to illuminate the rise of modern humans.

Click and Learn: [Skeletons Reveal Human and Chimpanzee Evolution](http://www.hhmi.org/biointeractive/skeletons-reveal-human-and-chimpanzee-evolution)

(<http://www.hhmi.org/biointeractive/skeletons-reveal-human-and-chimpanzee-evolution>). This interactive learning activity compares features of a 4.4-million-year-old fossil skeleton to those of human and chimpanzee skeletons, shedding light on our evolutionary history.

Short Film: [Great Transitions: The Origin of Tetrapods](http://www.hhmi.org/biointeractive/great-transitions-origin-tetrapods) (<http://www.hhmi.org/biointeractive/great-transitions-origin-tetrapods>). The fossil *Tiktaalik* has a mix of features common to fish and four-legged animals, or tetrapods. A close look at these features helps us understand the transition from water to land more than 375 million years ago.

Short Film: [Great Transitions: The Origin of Birds](http://www.hhmi.org/biointeractive/great-transitions-origin-birds) (<http://www.hhmi.org/biointeractive/great-transitions-origin-birds>). In the second film of the *Great Transitions* trilogy, paleontologist Dr. Julia Clarke takes us on a journey to uncover the evidence that birds descended from dinosaurs.

QUIZ QUESTIONS AND ANSWERS

This quiz was developed to supplement the viewing of the film *Great Transitions: The Origin of Humans*. Before watching the film, students are introduced to some key concepts needed to fully understand the importance of the evidence presented in the film. They then take a short prequiz, fill in a small chart as they watch the film, and take a postquiz.

Procedure

1. Before watching the film, show students the phylogenetic tree in Figure 1 in this document. Guide students on how to interpret the tree. Tell students that scientists have long recognized that humans are part of the group of vertebrates known as the primates. Primates share characteristics such as forward-facing eyes, generalized teeth, and nails instead of claws on fingers and toes.
2. Point out the lineage that leads from the split between humans and chimpanzees to humans. The film highlights some of the most important fossil finds in this lineage. (Emphasize that the illustration is a simplified version of the primate phylogenetic tree. The illustration shows the lineage that led to modern humans, but it does not show any side branches to our immediate family tree.)
3. Distribute the student handout and ask students to answer Questions 1–3 in the “Before Watching the Film” section. Students may work in pairs or small groups.



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4. Show the film to students. Consider using the “Pause Points” listed on pages 2 and 3 of this document to review content and answer any questions students may have. Encourage students to fill in the chart (question 4) and take notes that they can refer to when answering quiz questions.
5. Assign students Questions 5–17 in the “After Watching the Film” section of their handouts.
 - Alternatively, some teachers choose to have students answer questions as they watch the quiz or when stopped at the “Pause Points.”
 - Some teachers have students work in groups and stop and start the film as needed. If you wish to have students in groups take unique “real time quizzes,” you can pick and choose from use these questions to develop three different quizzes.

Answer Key

Before Watching the Film

1. Which physical and behavioral characteristics do you think distinguish humans from other primates? List three key ones.

Be open to a range of student ideas that have to do with morphology, behavior, and cognition. Eventually, students will learn that the traits that distinguish modern humans from modern chimps (that we can find evidence for in the prehistoric record) include relatively large brains, bipedalism, and extensive tool use.

2. Charles Darwin hypothesized that humans and the African great apes all descended from a common ancestor. What evidence would you expect to find in the fossil record to support this hypothesis?

Again, be open to a range of student ideas before they watch the film. Hopefully, students will suggest that fossils would be expected to show a combination of traits, some shared with modern humans and some shared with other great apes. The younger fossils would be expected to share more features with modern humans.

3. A “tool” is defined as “an instrument or device that is held by the hands and used to perform a particular task or function.” Think about the tools you have used so far today. What is the most primitive tool you have used today and why? What is the most advanced tool you have used and why?

Students may mention primitive tools such as forks, spoons, or shovels. Advanced tools will likely involve electronics, such as cellular phones or laptop computers. You may want to ask students to compare even these simple tools to the tools used by chimpanzees and other animals such as crows to make the point that humans use tools extensively and are very reliant on tools, as compared to other animals.

As you watch

4. For each fossil discovery, write the name of the scientist(s) who found it, its approximate age and what combination of human characteristics it had.



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Fossil	Scientist(s)	Fossil Age	Human Characteristic(s)
<i>Ardipithecus ramidus</i> (Ardi)	Tim White	4.4 million years ago	Bipedality
<i>Australopithecus afarensis</i> (Lucy)	Donald Johanson	3.2 million years ago	Bipedality
Olduvai Hominid No. 7 (OH7)	Louis and Mary Leakey	1.8 million years ago	Bipedality, larger brain, tool use
<i>Zinjanthropus</i>	Louis and Mary Leakey	1.76 million years ago	Bipedality, larger brain

After Watching the Film

5. At the beginning of the film, what are the three traits that Dr. Sean Carroll says make humans unique compared to our primate relatives?

Traits that distinguish modern humans from modern chimps include relatively large brains, bipedalism, and tool use.

6. What evidence was missing during Darwin's time that would have supported his hypothesis that humans evolved in Africa from ancestral primates?

At the time that Charles Darwin proposed his hypothesis that humans evolved in Africa from ancestral primates, very few fossils of ancient humans had been discovered. Additionally, evidence from DNA sequencing was not available until well over 100 years later.

7. What evidence has allowed scientists to conclude that the common ancestor of modern chimps and humans lived around 7 million years ago?
- Stone tool usage began showing up in the human lineage around 7 million years ago, and chimps do not use stone tools.
 - From the changes scientists have observed in chimps over the past 200 years, they predict it will take at least 7 million years for today's chimps to evolve into more humans.
 - Biological molecules such as proteins and DNA reveal differences between humans and chimps that would have taken around 7 million years to accumulate.**
 - Scientists know from whale evolution that it takes around 3.5 million years for brain size to double in volume in a species' lineage, and chimp brains are 300 cubic centimeters, while human brains are around 1,300 cubic centimeters.

Note: Answer b addresses a misconception about human evolution. Other common misconceptions are listed in the Smithsonian Educators Guide at <http://humanorigins.si.edu/education/education-guide>.

8. Which of the following trends is illustrated by human ancestors over time?
- An increase in brain size**
 - A decrease in body size
 - A reduction in the number of toes
 - An increase in the size of the molars and the canine teeth



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9. Which of the following is an anatomical feature that defines humans as bipedal hominids?
- A hairless face
 - The absence of a prehensile tail
 - Opposable digits on all four limbs
 - A much shorter hip bone, broader front to back, that wraps around the side**
10. Which conclusion about human evolution can scientists infer from the existing *fossil* evidence?
- Humans and chimps shared a common ancestor around 7 million years ago.
 - Larger brains began evolving around 1.8 million years ago.
 - Humans began using tools at least 1.8 million years ago.
 - Bipedality evolved at least 4.4 million years ago.
- I only
 - II and IV only
 - II, III, and IV only**
 - I–IV
11. Which conclusion about human evolution can scientists currently infer from *molecular* (DNA and proteins) evidence?
- Humans and chimps shared a common ancestor around 7 million years ago.
 - Large brains began evolving around 1.8 million years ago.
 - Humans began using tools around 1.8 million years ago.
 - Bipedality in hominids evolved at least 4.4 million years ago.
- I only**
 - I and II only
 - II and IV only
 - I–IV
12. *Ardipithecus ramidus* (Ardi) is a hominid with a combination of chimplike and humanlike characteristics. Describe these characteristics.
- The Ardi fossil shared the following features with chimpanzees: a large toe that stuck out to the side and evidence that she had extensive climbing abilities. The Ardi fossil had pelvic and other anatomical evidence that suggests she was bipedal, like modern humans.**
13. Before the discovery of Ardi, what kind of habitat did most paleobiologists hypothesize bipedality evolved in?
- Most paleobiologists hypothesized that bipedality evolved in open grasslands.**
14. What did the discovery of Ardi suggest about the kind of habitat in which bipedality evolved? How do we know?
- Tens of thousands of plant and animals fossils found with Ardi suggest that she was living in a woodland setting.**



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15. How do scientists know how old the Ardi fossil is?
- The differences between Ardi's DNA and human DNA suggest that Ardi lived around 4.4 million years before modern humans.
 - The Ardi fossil was found in sediment that was sandwiched between volcanic deposits that dated to 4.4 million years ago.**
 - Ardi's teeth reveal that she ate plants that went extinct around 4.4 million years ago.
 - The stone tools found in the same sediment as Ardi date to 4.4 million years ago.

16. Explain how the Laetoli footprints found in Africa support the conclusion that *Australopithecus* was a biped.

The pattern of impressions of the Laetoli footprints is consistent with an organism walking in a fashion similar in many ways to the way modern humans walk. The big toe was in line with the other toes and there was evidence of arches in the feet. Also there was no evidence of knuckle marks.

17. What are the hallmarks of what Dr. White calls the third phase of human evolution? Check all that apply.

Broadened diets	✓
Evolution of big teeth	_____
Evolution of bipedality	_____
Evolution of genus <i>Homo</i>	✓
Expansion out of Africa	✓
Expansion within Africa	_____
Reliance on culture	✓
Stone tool technology	✓

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