26.3 Primate Evolution

THINK ABOUT IT Carolus Linnaeus placed our species, *Homo sapiens*, in an order he named Primates, which means "first" in Latin. But what are primates "first" in? When primates appeared, there was little to distinguish them from other mammals, aside from an increased ability to use their eyes and front limbs together. As primates evolved, however, several other characteristics became distinctive.

What Is a Primate?

What characteristics do all primates share?

Primates, including lemurs, monkeys, and apes, share several adaptations for a life spent in trees. **In general, a primate is a mammal that has relatively long fingers and toes with nails instead of claws, arms that can rotate around shoulder joints, a strong clavicle, binocular vision, and a well-developed cerebrum.** The lemur in **Figure 26–14** shows many of these characteristics. DOL•64

Fingers, Toes, and Shoulders

Primates typically have five flexible fingers and toes on each hand or foot that can curl to grip objects firmly and precisely. This enables many primates to run along tree limbs and swing from branch to branch with ease. In addition, most primates have thumbs and big toes that can move against the other digits. This allows many primates to hold objects firmly in their hands or feet. Primates' arms are well suited for climbing because they can rotate in broad circles around a strong shoulder joint attached to a strong clavicle, or collar bone.

Binocular Vision

Many primates have a broad face, so both eyes face forward with overlapping fields of view. This facial structure gives primates excellent binocular vision. **Binocular vision** is the ability to combine visual images from both eyes, providing depth perception and a three-dimensional view of the world. This comes in handy for judging the locations of tree branches, from which many primates swing.

Well-Developed Cerebrum

In primates, the "thinking" part of the brain—the cerebrum—is large and intricate. This well-developed cerebrum enables more-complex behaviors than are found in many other mammals. For example, many primate species create elaborate social systems that include extended families, adoption of orphans, and even warfare between rival troops.

Key Questions

- ***What characteristics do all primates share?***
- ***What are the major evolutionary groups of primates?***
- ***What adaptations enabled later hominine species to walk upright?***
- ***What is the current scientific thinking about the genus* Homo?**

Vocabulary

binocular vision • anthropoid • prehensile tail • hominoid • hominine • bipedal • opposable thumb

Taking Notes

Outline Before you read, outline this lesson. As you read, add details to your outline.

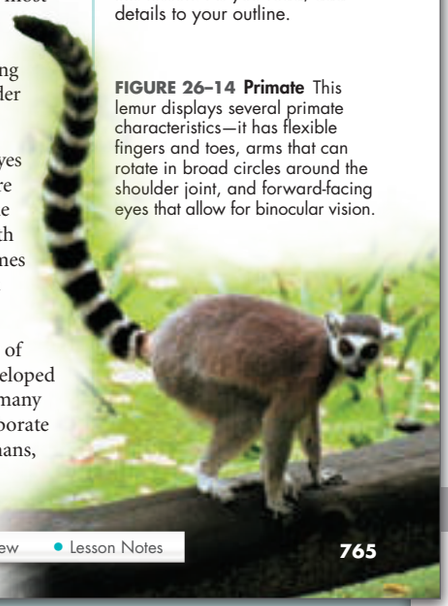


FIGURE 26–14 Primate This lemur displays several primate characteristics—it has flexible fingers and toes, arms that can rotate in broad circles around the shoulder joint, and forward-facing eyes that allow for binocular vision.

Teach for Understanding

ENDURING UNDERSTANDING Animals have evolved diverse ways to carry out basic life processes and maintain homeostasis.

GUIDING QUESTION How did primates evolve?

EVIDENCE OF UNDERSTANDING *The following assessment, to be given after the lesson is finished, should show student understanding of the characteristics of primates and how hominines evolved.* Have students work in small groups to make a poster that includes a labeled drawing showing the characteristics all primates share and a time line of hominine evolution that includes when important hominine species lived.

Getting Started

Objectives

26.3.1 Identify the characteristics that all primates share.

26.3.2 Describe the major evolutionary groups of primates.

26.3.3 Describe the adaptations that enabled later hominine species to walk upright.

26.3.4 Describe the current scientific thinking about the genus *Homo*.

Student Resources

Study Workbooks A and B, 26.3 Worksheets

Spanish Study Workbook, 26.3 Worksheets

Lab Manual B, 26.3 Hands-On Activity

BIOLOGY.com Lesson Overview • Lesson Notes • Activities: Art Review, Data Analysis • Assessment: Self-Test, Lesson Assessment

For corresponding lesson in the **Foundation Edition**, see pages 634–637.

Build Background

Show students several pictures of living primates, such as gorillas, gibbons, spider monkeys, and baboons. Then, have students work in small groups to make a list of characteristics all primates share and discuss it with the class. After students have finished this lesson, have them look at their lists again and correct any errors.

NATIONAL SCIENCE EDUCATION STANDARDS

UNIFYING CONCEPTS AND PROCESSES

I, II, III, IV, V

CONTENT

C.3.a, C.3.b, C.3.c, C.3.d, C.3.e, C.6.a, C.6.c, C.6.d, G.2, G.3

INQUIRY

A.1.b, A.1.c, A.2.e, A.2.f

Teach

Use Visuals

Use the cladogram in **Figure 26–15** to introduce students to the major groups of modern primates.

Ask If you were to draw a bracket similar to the Hominoids bracket that would include all the anthropoids, where would the bracket begin and end? *(It would begin with the New World monkeys and end with humans.)*

Ask Which primate group does this cladogram show is most closely related to humans? *(chimpanzees)*

DIFFERENTIATED INSTRUCTION

LPR Less Proficient Readers Some students may have difficulty differentiating the relationships among the different primate groups. Work with students to draw a **Concept Map** on the board that shows the relationships among these groups. (Primates is written at the top, with the linking word *include* beneath it; two subgroups directly beneath Primates include Lemurs, Lorises and Bush Babies; Tarsiers and Anthropoids; beneath Anthropoids are the three groups New World Monkeys, Old World Monkeys, and Hominoids; beneath Hominoids are Gibbons, etc.)

Study Wkbks A/B, Appendix S21, Concept Map.
Transparencies, GO4.

ELL Focus on ELL: Extend Language

BEGINNING AND INTERMEDIATE SPEAKERS
Before reading, have students make a **T-Chart**, and place the following terms on the left side of the chart: primate, anthropoid, hominoid, and hominine. As students read, have them fill in the right side of the chart with important information about the terms, including definitions and examples. Students can draw illustrations or write phrases in their native language to help remember the meanings of the terms.

Study Wkbks A/B, Appendix S30, T-Chart.
Transparencies, GO15.

Quick Lab GUIDED INQUIRY

Binocular Vision

1. Throw a paper ball to your partner, who should try to catch the ball with one hand. Record whether your partner caught the ball.
2. Now have your partner close one eye. Repeat Step 1.

Analyze and Conclude

1. Use Tables and Graphs Exchange results with other groups. Make a bar graph for the class data comparing the results with both eyes open and one eye shut.

2. Draw Conclusions How is binocular vision useful to primates?

Evolution of Primates

What are the major evolutionary groups of primates?

Humans and other primates evolved from a common ancestor that lived more than 65 million years ago. One recently discovered fossil, *Carpolestes,* which lived 56 million years ago in Wyoming, has been proposed as an example of the first primate. Early in their history, primates split into two groups. **Primates in one of these groups look very little like typical monkeys. This group contains the lemurs and lorises. The other group includes tarsiers and the anthropoids, the group that includes monkeys, great apes, and humans.** Refer to **Figure 26–15** as you read about the evolutionary relationships between these groups.

Lemurs and Lorises With few exceptions, lemurs and lorises are small, nocturnal primates with large eyes adapted to seeing in the dark. Many have long snouts. Living members include the bush babies of Africa, the lemurs of Madagascar, and the lorises of Asia.

Tarsiers and Anthropoids Primates more closely related to humans than to lemurs belong to a different group, members of which have broader faces and widely separated nostrils. This group includes the tarsiers of Asia and the anthropoids. **Anthropoids** (AN thruh poydz), or humanlike primates, include monkeys, great apes, and humans. Anthropoids split into two groups around 45 million years ago, as the continents on which they lived moved apart.

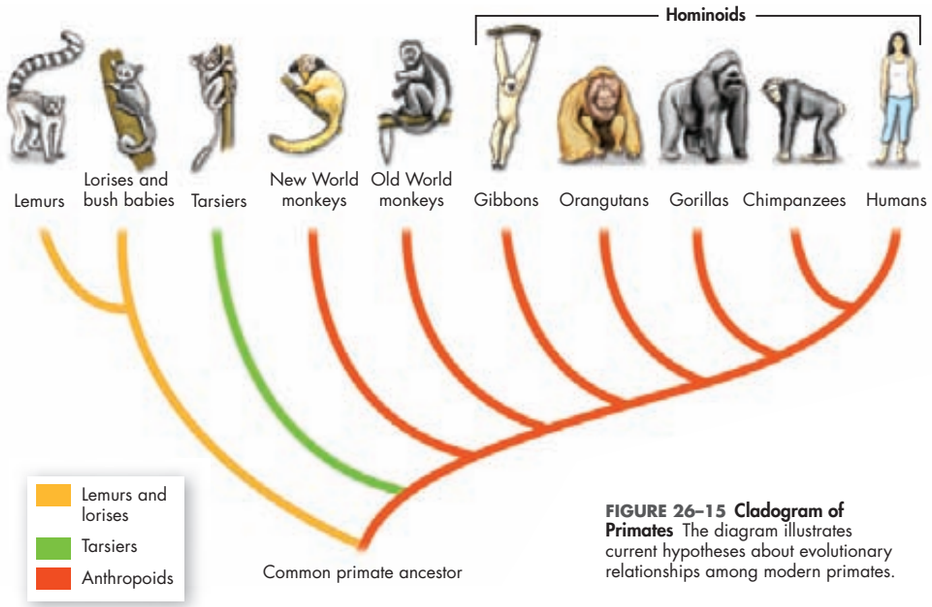


FIGURE 26–15 Cladogram of Primates The diagram illustrates current hypotheses about evolutionary relationships among modern primates.

Quick Lab

PURPOSE Students investigate the usefulness of binocular vision.

MATERIALS sheet of notebook paper, graph paper

SAFETY Warn students not to throw the ball hard or aim the ball at their partner's face.

PLANNING Have students read the procedure and discuss any questions they have about what to do.

ANALYZE AND CONCLUDE

1. Graphs should show that more students were able to catch the ball with both eyes open than with one eye closed.
2. Many primates move by swinging through trees. The ability to judge distances accurately enables them to grasp branches quickly and securely.

▶ ***New World Monkeys*** Members of one anthropoid branch, the New World monkeys, are found in Central and South America. (Europeans used the term *New World* to refer to North and South America.) Members of this group, which includes squirrel monkeys and spider monkeys, live almost entirely in trees. They have long, flexible arms that enable them to swing from branch to branch. New World monkeys also have a long, **prehensile tail** that can coil tightly enough around a branch to serve as a "fifth hand."

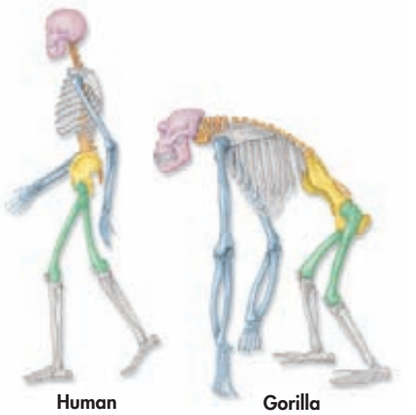
▶ ***Old World Monkeys and Great Apes*** The other anthropoid branch, which evolved in Africa and Asia, includes the Old World monkeys and great apes. Old World monkeys, such as langurs and macaques (muh KAHKS), spend time in trees but lack prehensile tails. Great apes, also called **hominoids,** include gibbons, orangutans, gorillas, chimpanzees, and humans. Recent DNA analyses confirm that, among the great apes, chimpanzees are humans' closest relatives.

Hominine Evolution

What adaptations enabled later hominine species to walk upright?

Between 6 and 7 million years ago, the lineage that led to humans split from the lineage that led to chimpanzees. The hominoids in the lineage that led to humans are called **hominines.** Hominines include modern humans and all other species more closely related to us than to chimpanzees. Hominines evolved the ability to walk upright, grasping thumbs, and large brains. **Figure 26–16** shows some ways in which the skeletons of modern humans differ from those of hominoids such as gorillas. **The skull, neck, spinal column, hip bones, and leg bones of early hominine species changed shape in ways that enabled later species to walk upright.** The evolution of this **bipedal,** or two-footed, locomotion was very important, because it freed both hands to use tools. Meanwhile, the hominine hand evolved an **opposable thumb** that could touch the tips of the fingers, enabling the grasping of objects and the use of tools.

Hominines also evolved much larger brains. The brains of chimpanzees, our closest living relatives, typically range in volume from 280 to 450 cubic centimeters. The brains of *Homo sapiens,* on the other hand, range in size from 1200 to 1600 cubic centimeters! Most of the difference in brain size results from a radically expanded cerebrum.



Human Gorilla

Comparing Human and Gorilla Skeletons

Feature	Human	Gorilla
Skull	Atop S-shaped spine	Atop C-shaped spine
Spinal cord	Exits at bottom of skull	Exits near back of skull
Arms and hands	Arms shorter than legs; hands don't touch ground when walking	Arms longer than legs; hands touch ground when walking
Pelvis	Bowl-shaped	Long and narrow
Thigh bones	Angled inward, directly below body	Angled away from pelvis

FIGURE 26–16 Comparison of Hominoids Modern hominines walk upright on two legs; gorillas use all four limbs. The diagrams show many of the skeletal characteristics that allow hominines to walk upright. **Compare and Contrast** ***According to the chart and illustrations, what are the other skeletal differences between humans and gorillas?***

Lead a Discussion

As students begin to learn about hominine evolution, talk about differences between hominines and other hominoids. Use **Figure 26–16** in part of the discussion, but don't limit the discussion to skeletal differences. Point out that as larger brains evolved in hominines, behavior changed as well as anatomy.

DIFFERENTIATED INSTRUCTION

L1 **Special Needs** Some students may have difficulty understanding the anatomical differences between hominoids and hominines. Derive from **Figure 26–16** a list of structures that changed shape in early hominine species, and write the list on the board. Then, use the illustrations and chart in the figure to discuss how each bone in the list changed from bones in other hominoids. For example, point to the word *skull* on the board, and direct students to the first row in the chart. Read aloud what the chart says about human and gorilla skulls, and have students confirm what they have read and heard by examining the illustrations.

BIOLOGY.com Students do a drag-and-drop activity to compare human and gorilla skeletons in **Art Review: Comparison of Hominoids.**

How Science Works

NEW TERMINOLOGY

In recent years, researchers have developed many new names for groups of all sizes across all domains of organisms, including the names for groups of primates. The new terminology is a reflection of the new techniques being used to group organisms. There have been many instances where old Linnaean groups do not line up with true clades as determined by new analyses. For example, among primates the tarsiers used to be grouped with the lemurs, lorises, and bush babies under the name *prosimians.* New evidence, though, does not support that grouping, and *prosimian* is no longer a valid taxonomic term. Similarly, instead of hominid, we now use the term hominine for hominoids in the lineage that led to humans.

Answers

FIGURE 26–16 Humans have an S-shaped spine; gorillas have a C-shaped spine. The human spinal cord exits at the bottom of the skull; the gorilla spinal cord exits near the back of the skull. Human arms are shorter than the legs; gorilla arms are longer than the legs. The human pelvis is bowl-shaped; the gorilla pelvis is long and narrow. Human thigh bones are angled inward, directly below the body; gorilla thigh bones are angled away from the pelvis.

Teach continued

Build Reading Skills

Explain that it is normal if the long list of hominine fossil names and dates is confusing. One way to organize the information is to make a **Compare/Contrast Table** to organize names, dates, and characteristics. Make a three-column table on the board, with these column headings: Hominine, Approximate Age, and Description/Characteristics. Then, begin to fill in the table by pointing out the oldest probable hominine described in the text. Write *Sahelanthropus* in the first column, "7 million years ago" in the second column, and fill in the third column with characteristics of this hominine. Have students copy this information into their own table and continue to fill it in as they read.

Study Wkbks A/B, Appendix S20, Compare/Contrast Table. **Transparencies,** GO3.

DIFFERENTIATED INSTRUCTION

L3 **Advanced Students** Ask interested students to find or make a current map of Africa that can be posted on a bulletin board or the classroom wall. Also, ask them to use online resources to find out where important hominine fossils have been discovered in Africa. Then, have students make labels to affix to the map to show those locations.

Answers

IN YOUR NOTEBOOK about 7 million years ago

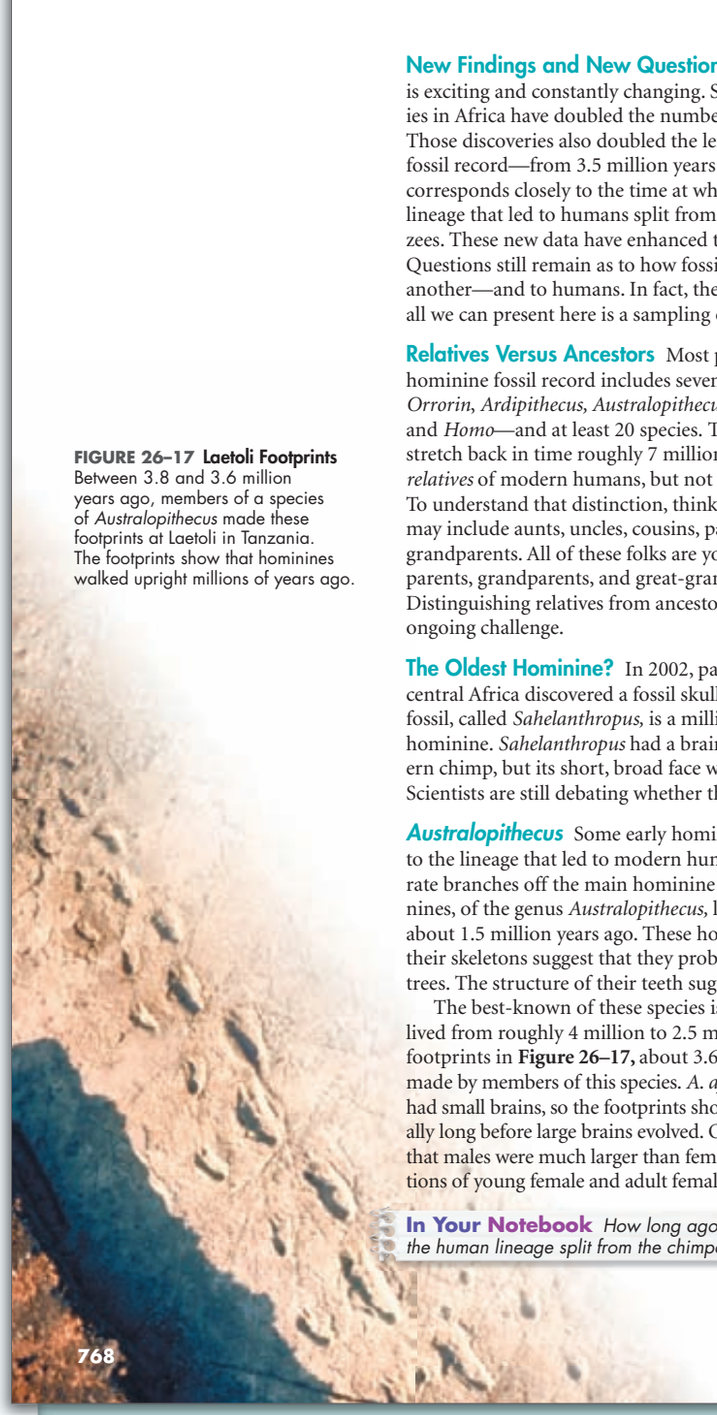


FIGURE 26–17 Laetoli Footprints Between 3.8 and 3.6 million years ago, members of a species of *Australopithecus* made these footprints at Laetoli in Tanzania. The footprints show that hominines walked upright millions of years ago.

New Findings and New Questions The study of human ancestors is exciting and constantly changing. Since the 1990s, new discoveries in Africa have doubled the number of known hominine species. Those discoveries also doubled the length of the known hominine fossil record—from 3.5 million years to 7 million years, a time that corresponds closely to the time at which DNA studies suggest that the lineage that led to humans split from the lineage that led to chimpanzees. These new data have enhanced the picture of our species' past. Questions still remain as to how fossil hominines are related to one another—and to humans. In fact, the field is changing so rapidly that all we can present here is a sampling of current hypotheses.

Relatives Versus Ancestors Most paleontologists agree that the hominine fossil record includes seven genera—*Sahelanthropus, Orrorin, Ardipithecus, Australopithecus, Paranthropus, Kenyanthropus,* and *Homo*—and at least 20 species. These diverse hominine fossils stretch back in time roughly 7 million years. All these species are *relatives* of modern humans, but not all of them are human *ancestors.* To understand that distinction, think of your family. Your relatives may include aunts, uncles, cousins, parents, grandparents, and great-grandparents. All of these folks are your relatives, but only your parents, grandparents, and great-grandparents are your ancestors. Distinguishing relatives from ancestors in the hominine family is an ongoing challenge.

The Oldest Hominine? In 2002, paleontologists working in north-central Africa discovered a fossil skull roughly 7 million years old. This fossil, called *Sahelanthropus,* is a million years older than any known hominine. *Sahelanthropus* had a brain about the size of that of a modern chimp, but its short, broad face was more like that of a human. Scientists are still debating whether this fossil represents a hominine.

Australopithecus Some early hominine fossil species seem to belong to the lineage that led to modern humans, while others formed separate branches off the main hominine line. One early group of hominines, of the genus *Australopithecus,* lived from about 4 million to about 1.5 million years ago. These hominines were bipedal apes, but their skeletons suggest that they probably spent at least some time in trees. The structure of their teeth suggests a diet rich in fruit.

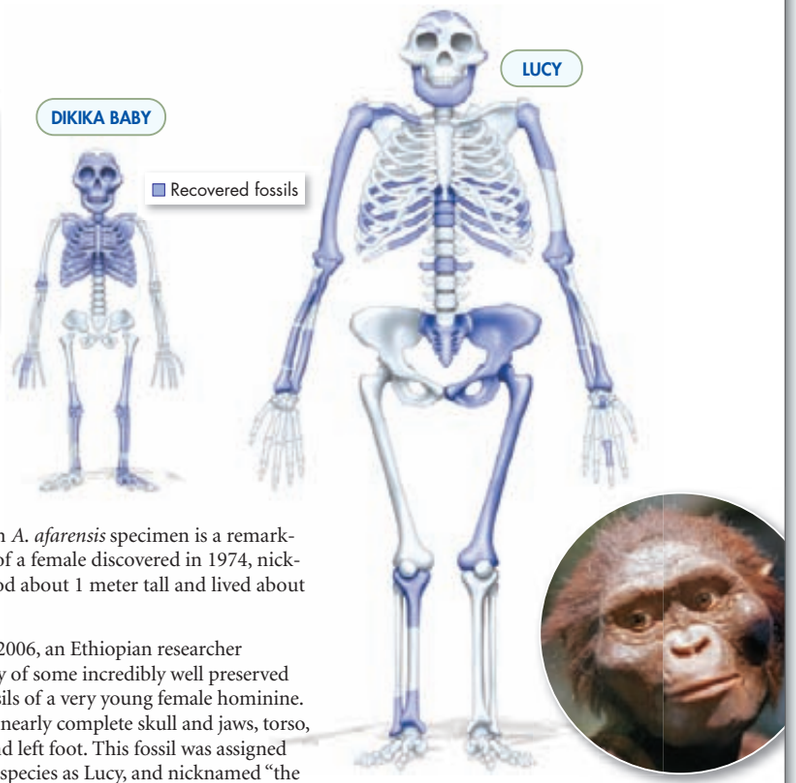
The best-known of these species is *Australopithecus afarensis,* which lived from roughly 4 million to 2.5 million years ago. The humanlike footprints in **Figure 26–17,** about 3.6 million years old, were probably made by members of this species. *A. afarensis* fossils indicate the species had small brains, so the footprints show that hominines walked bipedally long before large brains evolved. Other fossils of this genus indicate that males were much larger than females. You can see artists' conceptions of young female and adult female *A. afarensis* in **Figure 26–18.**

In Your Notebook *How long ago does DNA evidence suggest that the human lineage split from the chimpanzee lineage?*

Biology In-Depth

CHANGING AFRICAN CLIMATE AND PRIMATE EVOLUTION

Modern studies of primate evolution involve more than just primate fossils. Researchers also study fossils of other organisms and the history of climate over the last 10 million years. Several hypotheses link primate evolution to climate change and changes in ancient ecosystems in Africa. In general, many areas became drier, and forests gave way to grasslands. Some primates remained in forests, while others adapted to open grasslands. Savannah species gradually added meat to their diets, and began walking upright on two feet. Data show that climate in some parts of Africa switched back and forth several times between wet and dry. These changes in climate caused rapid shifts in plant and animal communities. New hypotheses link these repeated changes in climate and ecology to the evolution of body form, brain size, and behavior of hominines—including early members of the genus *Homo.*



▶ ***Lucy*** The best-known *A. afarensis* specimen is a remarkably complete skeleton of a female discovered in 1974, nicknamed "Lucy." Lucy stood about 1 meter tall and lived about 3.2 million years ago.

▶ ***The Dikika Baby*** In 2006, an Ethiopian researcher announced the discovery of some incredibly well preserved 3.3 million-year-old fossils of a very young female hominine. The skeleton included a nearly complete skull and jaws, torso, spinal column, limbs, and left foot. This fossil was assigned to *A. afarensis*, the same species as Lucy, and nicknamed "the Dikika Baby," after the region in Africa where it was discovered. Leg bones confirmed that the Dikika Baby walked bipedally, while her arm and shoulder bones suggest that she would have been a better climber than modern humans. Researchers will be extracting information from these bones for years.

FIGURE 26–18 Lucy and the Dikika Baby "Lucy" and "the Dikika Baby" are nicknames of two very important fossils of the hominine *A. afarensis*. Lucy is a partial skeleton of an adult female. The Dikika Baby is the most-complete fossil yet found of this species. These two fossils were discovered just 6 miles apart in Ethiopia. **Interpret Visuals** ***Given the fossils recovered, which face shape would you expect scientists to be more confident about—the Dikika Baby's or Lucy's?***

Paranthropus

Three more-recent species, which grew to the size of well-fed football linebackers, have been placed in their own genus, *Paranthropus*. These *Paranthropus* species had huge, grinding back teeth. Their diets probably included coarse and fibrous plant foods like those eaten by modern gorillas. Paleontologists now place *Paranthropus* on a separate, dead-end branch of our family tree.

Hominine Relationships

Researchers once thought that human evolution took place in relatively simple steps in which hominine species, over time, became gradually more humanlike. But it is now clear that a series of hominine adaptive radiations produced a number of species whose relationships are difficult to determine. As a result, what once looked like a simple hominine "family tree" with a single main trunk now looks more like a shrub with multiple trunks.

Quick Facts

LUCY

The discovery of the fossil nicknamed Lucy was a sensational find at the time. Here are a few facts about Lucy.

- She was a fully grown woman, probably in her 30s.
- She probably weighed 60–65 pounds.
- She lived in an area that was wooded, though by the time her skeleton was found the area was arid.
- The fossil was discovered by paleontologist Donald Johanson. As Johanson and his colleagues were celebrating the discovery, they listened to the Beatles song, "Lucy in the Sky With Diamonds."

Use Visuals

Use **Figure 26–18** to compare and contrast two fossils of *Australopithecus afarensis.*

Ask In which species do scientists classify both Lucy and the Dikika Baby? *(Australopithecus afarensis)*

Ask Where and when did these hominines live? *(They both lived in Africa in what is present-day Ethiopia. Lucy lived about 3.2 million years ago, and the Dikika Baby lived about 3.3 million years ago.)*

Ask What kind of food did Lucy probably eat? *(fruit, because the teeth of* Australopithecus *suggest a diet rich in fruit.)*

DIFFERENTIATED INSTRUCTION

L1 Struggling Students Make sure students understand that the illustrations in **Figure 26–18** are both reconstructions. The darker bones in the drawings represent the fossils that were discovered. Scientists inferred what the lighter bones likely looked like based on characteristics of the recovered fossils. Explain that the faces are artists' renditions of what these individuals might have looked like, given what the face bones suggest.

L3 Advanced Students Ask interested students to do further research about the technique of forensic facial reconstruction as it is used both in fossil reconstruction and in police work. In an oral presentation to the class, students might show examples of forensic reconstructions and explain why the technique is controversial.

Answers

FIGURE 26–18 the Dikika Baby, because many more fossils of her skull were recovered

Teach continued

VISUAL SUMMARY

After students have studied **Figure 26–19,** ask them to find species included in the time line that they have already learned about in the text. Explain that they may have learned the genus name, but not the species name. (e.g. *Sahelanthropus* and *Paranthropus*) Then, discuss why the fossil record is not complete. Explain that fossil formation happens only under special conditions; most bones deteriorate naturally after the death of the animal.

DIFFERENTIATED INSTRUCTION

L1 **Special Needs** Call on students to choose a species listed on the time line, read its name, and tell when it lived. *(Sample answer:* Homo ergaster *is shown to have lived from about 2 million years ago to about 1.4 million years ago.)* After several examples have been read aloud, emphasize that the fossil record of hominine evolution does not show a straight-line of descent to modern humans. Much is yet to be discovered about the details of human evolution.

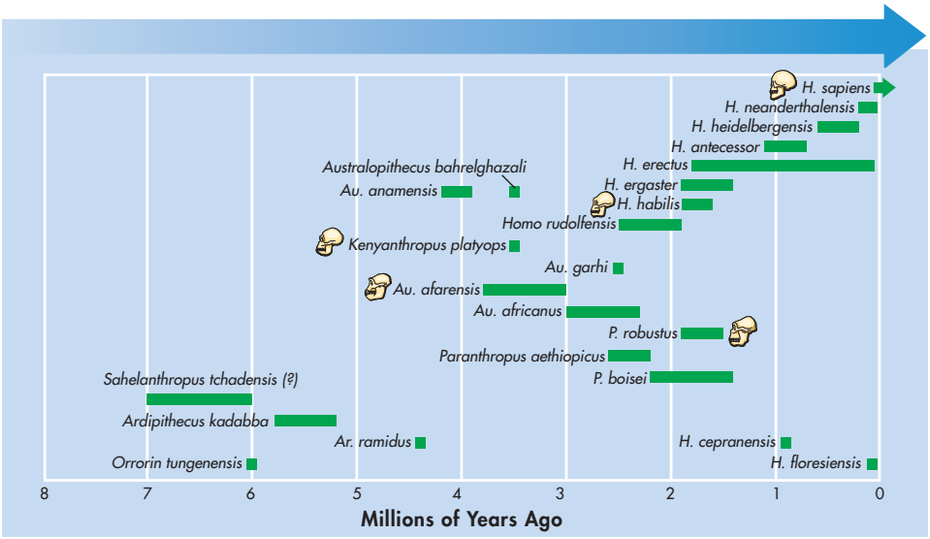
BIOLOGY.com In **Data Analysis: Who Is *H. floresiensis?*** students look at data on the *H. floresiensis* fossils. Students can then use this data to weigh in on the debate of whether these fossils represent a separate species or a population of *H. sapiens.*

Address Misconceptions

Humans Descended From Monkeys Some students will persist in the misconception, heard often, that the evolution of *Homo sapiens* essentially means humans descended from monkeys. As students begin to read about the road to modern humans, have them turn back to **Figure 26–15.** Point out that the cladogram shows humans and monkeys share a common primate ancestor, *not* that humans evolved from monkeys.

Answers

FIGURE 26–19 *Homo habilis, H. ergaster,* and *H. erectus* lived at the same time. *H. erectus, H. cepranensis,* and *H. antecessor* lived at the same time. *H. erectus* and *H. heidelbergensis* also lived at the same time. *H. sapiens, H. neanderthalensis, H. erectus,* and *H. floresiensis* lived at the same time.



VISUAL SUMMARY

HOMININE TIME LINE

FIGURE 26–19 The diagram shows hominine species known from fossils and the time ranges during which each species probably existed. These time ranges may change as paleontologists gather new data. At this writing, several competing hypotheses present different ideas about how these species are related to one another and to *Homo sapiens.* So far, there is no single, universally accepted hypothesis, so we present these data as a time line, rather than as a cladogram. The fossil record shows that hominine evolution did not proceed along a simple, straight-line transformation of one species into another. Rather, a series of adaptive radiations produced a number of species, several of which display a confusing mix of primitive and modern traits. **Interpret Graphs** ***According to this time line, which species in the genus* Homo *lived at the same time?***

The Road to Modern Humans

***What is the current scientific thinking about the genus* Homo?**

The hominines discussed so far lived millions of years before modern humans. **Many species in our genus existed before our species, *Homo sapiens*, appeared. Furthermore, at least three other *Homo* species existed at the same time as early humans.** Paleontologists still do not completely understand the relationships among species in our own genus.

The Genus *Homo* About 2 million years ago, a new group of hominine species appeared. Several of these fossils resemble modern human bones enough that they have been classified in the genus *Homo.* One set of fossils from this time period was found with tools made of stone and bone, so it was named *Homo habilis* (HAB uh luhs), which means "handy man" in Latin. The earliest fossils that most researchers agree can be definitely assigned to the genus *Homo* have been called *Homo ergaster. H. ergaster* was larger than *H. habilis* and had a bigger brain and downward-facing nostrils that resemble those of modern humans. *Homo rudolfensis* appeared before *H. ergaster,* but some researchers choose to classify it in the genus *Australopithecus* instead of *Homo.*

Out of Africa—But When and Who? Researchers agree that our genus originated in Africa and migrated from there to populate the world. But many questions remain. When did hominines first leave Africa? Did more than one species make the trip? Which of those species were human ancestors and which were merely relatives? You can see some of the current hypotheses in **Figure 26–20.**

How Science Works

THE STUDY OF HUMAN ANCESTORS

There is almost no scientific field that is as crowded, as contentious, and as constantly changing as the study of human ancestry. The information provided in this lesson is a best effort to present current consensus hypotheses. The noted professor and author Steven Jay Gould once said that every year when he prepared to lecture on this topic, he would throw his previous year's notes into the trash and start from scratch. So, if you and your students research the literature for more information, do not be surprised when you find genuine disagreements about the identification, age, and relationships of hominine fossils. These debates provide an excellent demonstration of how science works.

▶ ***The First to Leave*** Fossil and molecular evidence suggest that some hominines left Africa long before *Homo sapiens* evolved. It also appears that more than one *Homo* species made the trip in waves. Again, researchers differ as to the identity of various fossils, but agree that hominines began migrating out of Africa at least 1.8 million years ago. Hominine remains from that period were found in the Republic of Georgia, which is north of Turkey and far from Africa. Some researchers who have examined those remains argue that they might belong to a smaller-brained *Homo* species, *Homo habilis*.

▶ **Homo erectus *in Asia*** According to some researchers, groups of *Homo erectus* left Africa and traveled all the way across India and through China to Southeast Asia. In fact, some of the oldest known specimens of *H. erectus* were uncovered on the Indonesian island of Java. This suggests that these ancient wanderers spread very rapidly once they left Africa. These *H. erectus* populations continued to survive and evolve across Asia for as long as 1.5 million years.

▶ ***The First* Homo sapiens** Paleontologists have long debated where and when *Homo sapiens* arose. One hypothesis, called the multiregional model, suggests that, in several parts of the world, modern humans evolved independently from widely separated populations of *H. erectus*. Another hypothesis, the "out-of-Africa" model, proposes that modern humans evolved in Africa about 200,000 years ago, migrated out of Africa through the Middle East, and replaced the descendants of earlier hominine species.

Recently, molecular biologists analyzed mitochondrial DNA from living humans around the world to determine when they last shared a common ancestor. The estimated date for that African common ancestor is between 200,000 and 150,000 years ago. More recent DNA data suggest that a small subset of those African ancestors left northeastern Africa between 65,000 and 50,000 years ago to colonize the world. These data strongly support the out-of-Africa model.

BUILD Vocabulary

MULTIPLE MEANINGS The word *sapient* means "wise." It is also used as an adjective referring to *Homo sapiens*.

FIGURE 26–20 Out of Africa Data show that relatives and ancestors of modern humans left Africa in waves. But when—and how far did they travel? By comparing the mitochondrial DNA of living humans and by continuing to study the fossil record, scientists hope to improve our understanding of the complex history of *Homo sapiens*. (Note: Skulls on the map do not indicate that skulls were found at each location.)

Check for Understanding

ONE-MINUTE RESPONSE

Write the following question on the board, and give students about a minute to write a quick response.

- What is the difference between the multiregional hypothesis and the "out-of-Africa" hypothesis?

ADJUST INSTRUCTION

If students' responses are incorrect or incomplete, lead a short class discussion on the two hypotheses for the spread of *Homo sapiens* around the world. Make sure students understand that both hypotheses have advocates among scientific experts.

Use Visuals

Have students examine **Figure 26–20,** and then call on volunteers to explain what it shows. Point out that all the hominine fossils students have learned about thus far, including *Australopithecus* and *Paranthropus,* were discovered in Africa, and the skulls placed on the map of Africa represent some of those discoveries.

Ask Where does the map show that hominines first spread when they left Africa? *(to the Middle East)*

Point out that today the Middle East includes such countries as Syria, Lebanon, Israel, and Iraq.

DIFFERENTIATED INSTRUCTION

L1 Struggling Students Some students may have trouble understanding **Figure 26–20.** Work with them so they understand what the colors in the key show, what the arrows mean, and what the skull icons indicate. Explain how to interpret each arrow.

L3 Advanced Students Ask students who are interested in this topic to research any recent hominine discoveries. Have them search for information using online search engines and online or hard-copy indexes of *National Geographic* and the academic journal, *Nature*. Ask them to report back to the class on what they find.

Assess and Remediate

EVALUATE UNDERSTANDING

Call on students to define each of the lesson's vocabulary terms. Then, have them complete the 26.3 Assessment.

REMEDIATION SUGGESTION

L1 **Struggling Students** If students have trouble with **Question 3a,** have them find the highlighted sentence in their text that answers this Key Question: What adaptations enabled later hominine species to walk upright?

BIOLOGY.com Students can check their understanding of lesson concepts with the **Self-Test** assessment. They can then take an online version of the **Lesson Assessment.**

FIGURE 26–21 Cro-Magnon Art This ancient cave painting from France shows the remarkable artistic abilities of Cro-Magnons. **Infer** *How might these painted images be related to the way in which these early humans lived?*

Modern Humans The story of modern humans over the past 200,000 years involves two main species in the genus *Homo.*

▶ **Homo neanderthalensis** Neanderthals flourished in Europe and western Asia beginning about 200,000 years ago. Evidence suggests that they made stone tools, lived in complex social groups, had controlled use of fire, and were excellent hunters. They buried their dead with simple rituals. Neanderthals survived in parts of Europe until about 28,000 to 24,000 years ago.

▶ ***Modern* Homo sapiens** Anatomically modern *Homo sapiens,* whose skeletons look like those of today's humans, arrived in the Middle East from Africa about 100,000 years ago. By about 50,000 years ago, *H. sapiens* populations were using new technology to make more sophisticated stone blades. They also began to make elaborately worked tools from bones and antlers. They produced spectacular cave paintings and buried their dead with elaborate rituals. In other words, these people, including the group known as Cro-Magnons, began to behave like modern humans.

When *H. sapiens* arrived in the Middle East, they found Neanderthals already living there. Neanderthals and *H. sapiens* lived side by side in the Middle East for about 50,000 years. Groups of modern humans moved into Europe between 40,000 and 32,000 years ago. There, too, *H. sapiens* coexisted alongside Neanderthals for several thousand years. For the last 24,000 years, however, our species has been Earth's only hominine. Why did Neanderthals disappear? Did they interbreed with *H. sapiens*? No one knows for sure. What we do know is that our species, *Homo sapiens,* is the only surviving member of the once large and diverse hominine clade.

26.3 Assessment

Review Key Concepts

1. a. Review What are the characteristics of primates?
b. Apply Concepts How does each characteristic benefit primates?

2. a. Review List the two major groups of primates.
b. Sequence At what point did the two groups of anthropoids split, and why?

3. a. Review Which early hominine bones changed shape over time, allowing later hominines to walk upright?
b. Relate Cause and Effect How was bipedal locomotion important to hominine evolution?

4. a. Review Which two species are considered humans?
b. Compare and Contrast List two ways in which *Homo neanderthalensis* differed from *Homo sapiens.*

WRITE ABOUT SCIENCE

Creative Writing

5. Create a "Lost Hominine" poster for *Homo neanderthalensis.* Include its known characteristics and approximately when and where it was last seen. Illustrate the poster with a drawing or clipping.

BIOLOGY.com Search Lesson 26.3 GO • Lesson Assessment • Self-Test

Answers

FIGURE 26–21 Answers will vary. Sample answer: The animals in the paintings may be the animals that were hunted by Cro-Magnons.

Assessment Answers

1a. In general, a primate is a mammal that has relatively long fingers and toes with nails instead of claws, arms that can rotate around shoulder joints, a strong clavicle, binocular vision, and a well-developed cerebrum.

1b. The fingers and toes allow primates to swing in trees and grasp objects. The strong shoulders and clavicles are well suited for climbing. Binocular vision provides depth perception. The well-developed cerebrum enables complex behaviors.

2a. Lemurs and lorises make up one group, and tarsiers and anthropoids make up a second group.

2b. The two groups split apart around 45 million years ago as continents moved apart.

3a. the skull, neck, spinal column, hip bones, and leg bones

3b. Bipedal locomotion freed both hands to use tools.

4a. *Homo neanderthalensis* and *Homo sapiens*

4b. Sample answer: *H. neanderthalensis* flourished in areas out of Africa 100,000 years before *H. sapiens. H. neanderthalensis* did not develop the elaborate tools that *H. sapiens* developed.

WRITE ABOUT SCIENCE

5. Have students do library or online research to find out about the known characteristics and to find images of Neanderthals.

Biology & HISTORY

Human-Fossil Seekers **The study of human origins is an exciting search for our past. Piecing together this complicated story requires the skills of many scientists.**

1855 1885 1915 1945 1955 1975 2005 2035

1868
Edouard Lartet
Henry Christy
French geologist Lartet and English banker Christy unearth several ancient human skeletons in a rock shelter called Cro-Magnon in France. These hominine fossils are the first to be classified as *Homo sapiens*.

1886
Marcel de Puydt
Max Lohest
De Puydt and Lohest describe two Neanderthal skeletons found in a cave in Belgium. Their detailed description shows that Neanderthals were an extinct human form, not an abnormal form of modern human.

1924
Raymond Dart
Dart, an Australian anatomist, finds an early hominine fossil—a nearly complete skull of a child—in South Africa. This specimen was placed in a new genus called *Australopithecus*.

1974
Donald Johanson
An American paleontologist and his team find 40 percent of a skeleton of *Australopithecus*, which they call Lucy, in the Afar region of Ethiopia. The skeleton is about 3.2 million years old.

1978
Mary Leakey
Mary Leakey, a British anthropologist, discovers a set of 3.6 million-year-old fossil hominine footprints at Laetoli in Tanzania. The footprints provide evidence that early hominines walked erect on two legs.

2001
Meave Leakey
Nature publishes Meave Leakey's discovery of a 3.5–3.2 million year old skull that may be a human ancestor other than *Australopithecus*.

2002
Ahounta Djimdoumalbaye
Djimdoumalbaye, a college student in Chad, discovers the cranium of what may be the oldest known hominine, *Sahelanthropus tchadensis*.

2006
Zeresenay Alemseged
Zeresenay, an Ethiopian paleoanthropologist, announces his discovery of the fossilized skeleton of a young hominine in the Dikika region of Ethiopia. It is the most complete example of *A. afarensis* ever discovered and is about 3.3 million years old.

WRITING **Use the library or Internet sources suggested by your teacher to research one of these discoveries. Present your research in a poster with images and captions.**

Quick Facts

THE LEAKEY FAMILY

The Leakey family has been in the forefront of the study of human origins since the 1920s. These are the most prominent members of the family.

- Louis Leakey (1903–1972), married to Mary Leakey, was influential in convincing anthropologists to look in Africa for fossils of human ancestors.
- Mary Leakey (1913–1996), married to Louis Leakey, made many discoveries, including the Laetoli footprints and *Australopithecus* fossils.
- Richard Leakey (b. 1944), son of Louis and Mary, discovered many fossils of human ancestors in Kenya.
- Meave Leakey (b. 1942), married to Richard, was first hired by Louis Leakey to study monkeys and apes. She later made important fossil finds.

Teach

Lead a Discussion

Discuss with students how theories about human ancestors have changed over time and how each discovery included here helped change those theories.

Ask What method are scientists increasingly using today to determine relationships among hominoids? *(DNA analysis)*

Point out that analysis of mitochondrial DNA has been used in determining when human ancestors left Africa.

DIFFERENTIATED INSTRUCTION

L3 **Advanced Students** Mary Leakey and Donald Johanson have both written books about their experiences as fossil hunters and the implications of their discoveries on hypotheses about human evolution. Students might read one of these books and then present significant information from the book to the class. Some ways that students might present this information include the following: reading a passage from the book followed by leading a class discussion or making a poster showing important events described in the book.

Answers

WRITING Have students work in small groups. Make sure not all groups decide to research the same discovery. For students' sources, suggest Web sites with reliable scientific information. Ask students to provide detailed information about the sources they use.

NATIONAL SCIENCE EDUCATION STANDARDS

UPC II, IV
CONTENT C.3.e, G.1, G.2, G.3
INQUIRY A.2.a

CHAPTER LAB

Pre-Lab

Introduce students to the concepts they will explore in the chapter lab by assigning the Pre-Lab questions.

Lab

Tell students they will perform the chapter lab *Investigating Hominoid Fossils* described in **Lab Manual A.**

L1 **Struggling Students** A simpler version of the chapter lab is provided in **Lab Manual B.**

Look online for **Editable Lab Worksheets.**

For corresponding pre-lab in the **Foundation Edition**, see page 638.

NATIONAL SCIENCE EDUCATION STANDARDS

UCP III, IV
CONTENT C.3.a, C.3.b, C.3.c., C.3.d, C.3.e
INQUIRY A.1.c

Forensics Lab

GUIDED INQUIRY

Pre-Lab: Investigating Hominoid Fossils

Problem What can a comparison of skulls and hands reveal about the evolution of humans?

Materials metric ruler, protractor

Lab Manual Chapter 26 Lab

Skills Focus Measure, Analyze Data, Compare and Contrast

Connect to the Big Idea To learn about the evolution of humans, scientists study both close relatives and possible ancestors. Fossils of possible ancestors are rare, and complete skeletons are even rarer. Yet, scientists have gained valuable information from those fossils that have been found. In this lab, you will make measurements that a paleontologist might make after finding a fossil. Then, you will use your data to make inferences about human evolution.

Background Questions

a. **Review** What are hominoids, and what are hominines?

b. **Explain** Use the examples of chimpanzees and humans to explain the difference between evolutionary relatives and ancestors.

c. **Compare and Contrast** What is the difference between the locomotion of humans and the locomotion of chimpanzees?

Pre-Lab Questions

Preview the procedure in the lab manual.

1. **Use Models** What will you use instead of actual skulls and hands to make your measurements?

2. **Interpret Visuals** The bony cavities in a skull that protect the eyes are called orbits, or eye sockets. On the skulls, what does line AC measure? What does line BC measure?

3. **Use Analogies** Shoe sizes such as 9A and 11E (or 9 narrow and 11 extra-wide) are an example of an index. What two measurements are being compared in a shoe index?

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Visit Chapter 26 online to test yourself on chapter content and to find activities to help you learn.

Untamed Science Video Join the Untamed Science crew as they talk with insect experts to better understand why there are more than a million insects.

Art Review Review your understanding of different hominoids.

InterActive Art Build a cladogram of invertebrates.

Data Analysis Compare data on the *H. floresiensis* fossil and modern *H. sapiens* and determine if they are separate species.

Pre-Lab Answers

BACKGROUND QUESTIONS

a. Hominoids are the anthropoid branch that includes gibbons, orangutans, gorillas, chimpanzees, and humans. Hominines are hominoids in the lineage that led to humans (or modern humans and all species more closely related to humans than chimpanzees).

b. Sample answer: Chimpanzees and humans are relatives who are descended from a common primate ancestor. Species that are not in the direct line of descent are not ancestors.

c. Chimpanzees walk on all four limbs while humans are bipedal, meaning that they walk upright on two limbs.

PRE-LAB QUESTIONS

1. I will be using images of skulls and hands.

2. Line AC measures the distance from the bottom of the eye socket to the top of the skull. Line BC measures the distance from the top of the eye socket to the top of the skull.

3. Sample answer: In a shoe size, the width of the shoe is being compared to the length of the shoe.