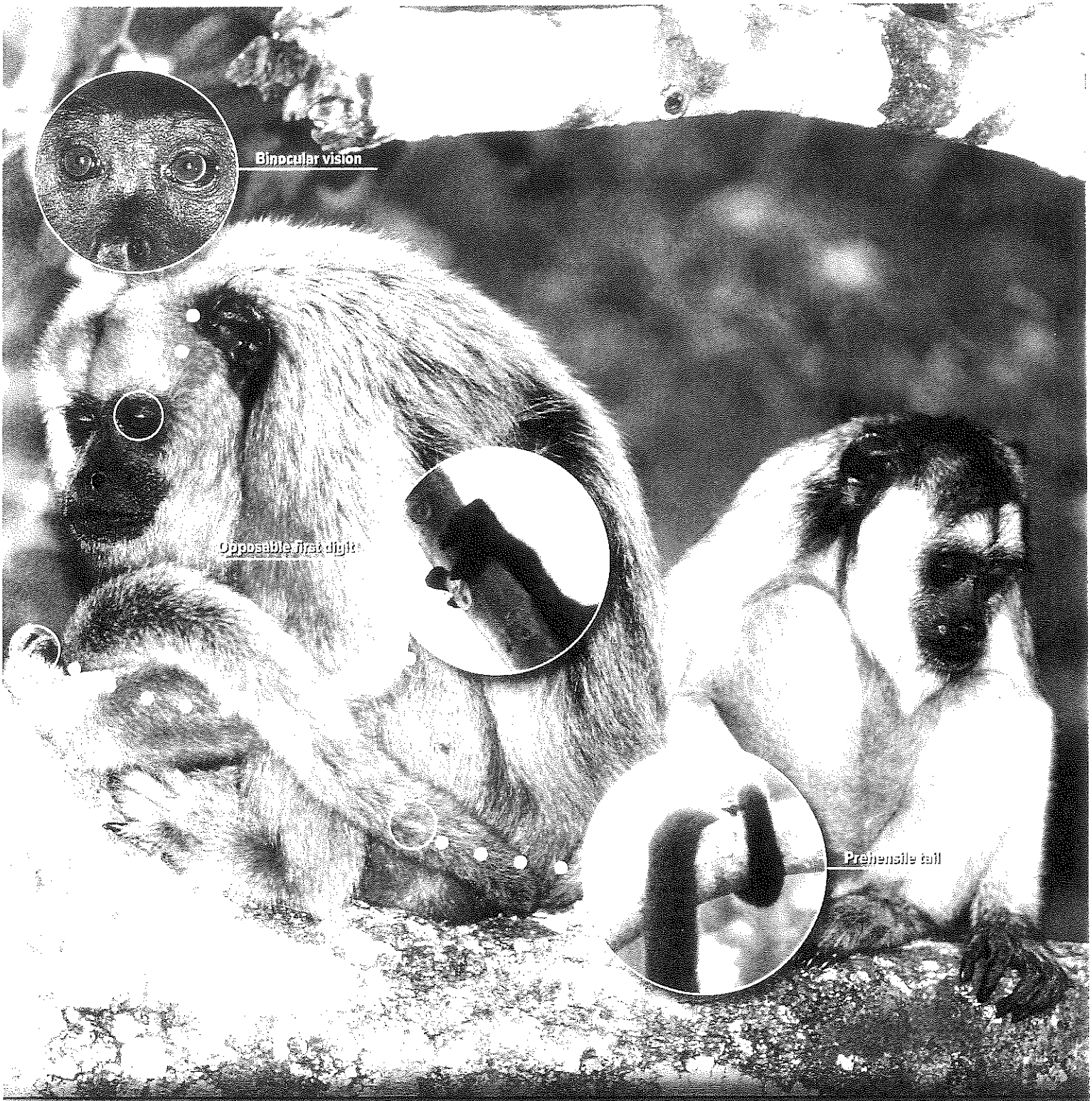


THEME FOCUS Stability and Change

The changes that separated hominins from hominoids took place over 20–25 million years.

Big Idea Evolutionary change in a group of small, tree-living mammals eventually led to a diversity of species that includes modern humans.

Section 1

Reading Preview

Essential Questions

- What are the characteristics of primates?
- What are the similarities and differences between major primate groups?
- How can the evolution of primates be traced?

Review Vocabulary

extinction: the disappearance of a species when the last of its members dies

New Vocabulary

opposable first digit
binocular vision
diurnal
nocturnal
arboreal
anthropoid
prehensile tail
hominin

Multilingual eGlossary

Figure 1 This squirrel monkey is using its opposable digits to hold its dinner—a lantern fly. ***Infer other ways that a primate might use an opposable digit.***

Primates

MAIN Idea **Primates share several behavioral and biological characteristics, which indicates that they evolved from a common ancestor.**

Real-World Reading Link You can often tell that your aunts, uncles, or cousins are related to you. Perhaps they have the same color hair or similar features, or they are as tall as you are. Just as you can tell that you are related to your biological family, characteristics of primates show that they are also a related family.

Characteristics of Primates

Humans, apes, monkeys, and lemurs belong to a group of mammals called primates. Though primates are highly diverse, they share some general features. Some primates have a high level of manual dexterity, which is the ability to manipulate or grasp objects with their hands. They usually also have keen eyesight and long, highly movable arms. Compared to other animals, they have large brains. The primates with the largest brains, which includes humans, have the capacity to reason.

Manual dexterity Primates are distinguished by their flexible hands and feet. All primates typically have five digits on each hand and foot; as you know, humans have fingers and toes. Most have flat nails and sensitive areas on the ends of their digits. The first digits on most primates' hands are opposable, and the first digit on many primates' feet are opposable. An **opposable first digit,** either a thumb or a great toe, is set apart from the other digits. This digit can be brought across the palm or foot so that it touches or nearly touches the other digits. This action allows the primate to grasp an object in a powerful grip. Some primates also have lengthened first digits that provide added dexterity. **Figure 1** shows a monkey using its opposable thumbs to grasp its food.

Senses Though there are exceptions, primates rely more on vision and less on their sense of smell than other mammals do. Their eyes, protected by bony eye sockets, are on the front of their face. This creates overlapping fields of vision, often called **binocular vision.** Forward-looking eyes allow for a greater field of depth perception and enable primates to judge relative distance and movement of an object.

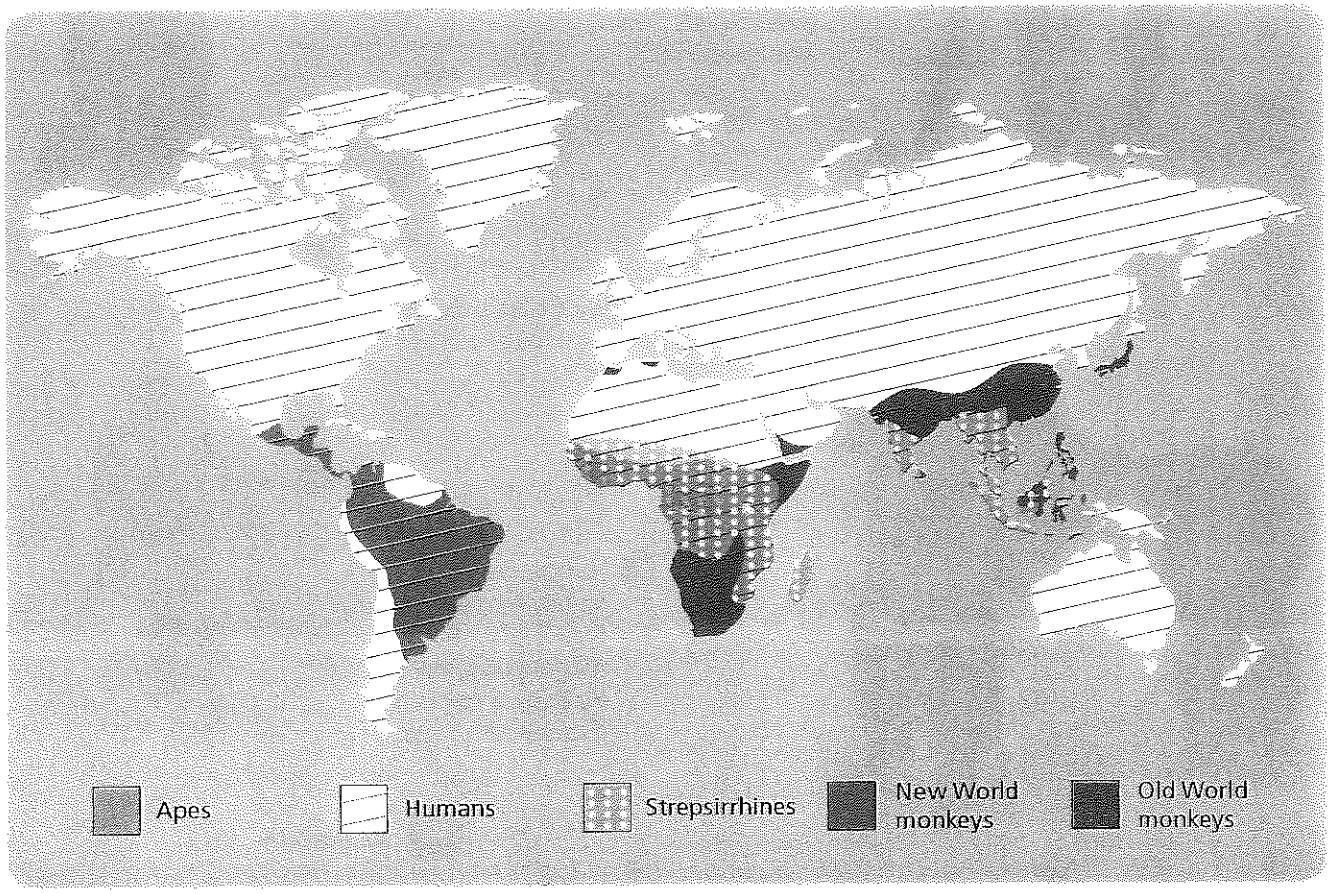
Most primates are **diurnal** (di YUR nul), which means they are active during the day. Because these primates are active in daylight, most also have color vision. Primates that are **nocturnal** (nahk TUR nul) are active at night. They see only in black and white. An increased sense of vision is generally accompanied by a decreased sense of smell. Nocturnal primates' snouts are smaller and their faces tend to be flattened, which increases the degree of binocular vision. Their teeth are reduced in size and usually are unspecialized, meaning that they are suitable for many different types of diets.

Gary Retherford/Photo Researchers

Locomotion Another characteristic of primates is their flexible bodies. Primates have limber shoulders and hips and primarily rely on hind limbs for locomotion. Most primates live in trees and have developed an extraordinary ability to move easily from branch to branch. When on the ground, all primates except humans walk on all four limbs. Many primates can walk upright for short distances, and many have a more upright posture compared to four-legged animals.

Complex brains and behaviors Primates tend to have large brains in relation to their body size. Their brains have fewer areas devoted to smell and more areas devoted to vision. They also tend to have larger areas devoted to memory and the coordination of arm and leg movement. Along with larger brains, many primates have problem-solving abilities and well-developed social behaviors, such as grooming and communicating. Most diurnal primates spend a great deal of time socializing by spending time grooming each other. In addition, many primates have complex ways of communicating to each other, which include a wide range of facial expressions.

Reproductive rate Most primates have fewer offspring than other animals. Usually, primates give birth to one offspring at a time. Compared to other mammals, pregnancy is long, and newborns are dependent on their mothers for an extended period of time. For many primates, this time period allows for the increased learning of complex social interactions. A low reproductive rate, the loss of tropical habitats, and human predation has threatened some primate populations. Many are endangered. **Figure 2** illustrates the tropical areas of the world, such as Africa and Southeast Asia, where primates live.



Launch Lab

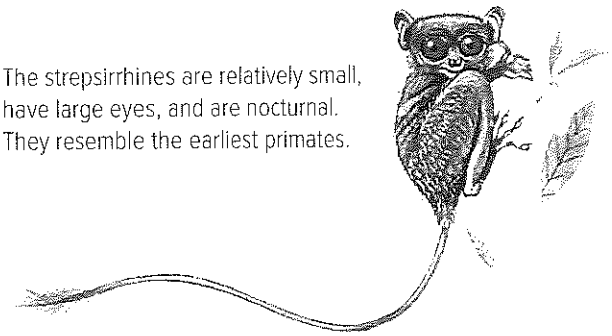
Review Based on what you have read about primate characteristics, how would you now answer the analysis questions?

Figure 2 Nonhuman primates live in a broad area spanning most of the world's tropical regions. Use this map as you read about the different primates.

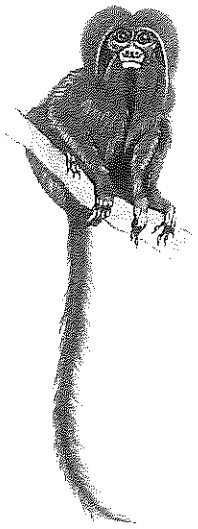
Visualizing Primates

Figure 3

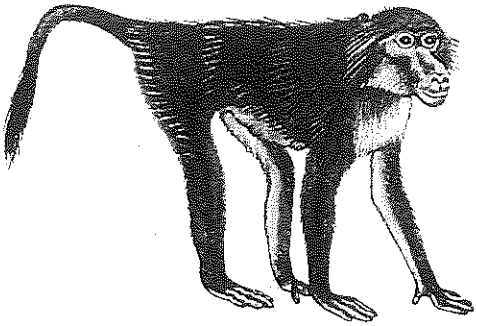
Primates are members of a highly diverse order of mammals. Most primates share common features such as binocular vision and opposable digits.



A The strepsirrhines are relatively small, have large eyes, and are nocturnal. They resemble the earliest primates.

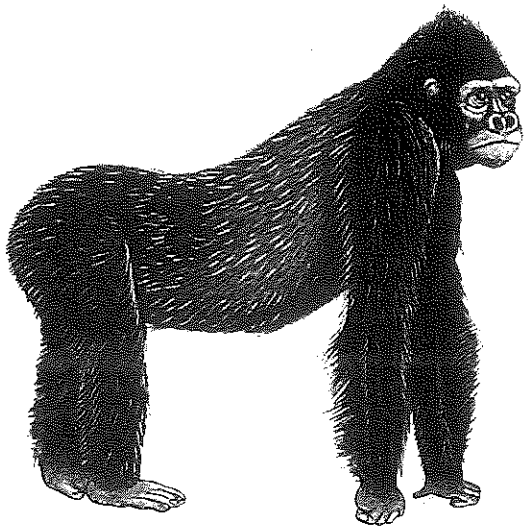


B New World monkeys are characterized by relatively long tails. Many have prehensile tails.



C Old World monkeys resemble New World monkeys but lack prehensile tails. Some have reduced tails.

D Asian apes are long-armed and inhabit tropical rain forests. Apes lack tails.



E African apes live in family groups or small bands and display complex social behavior.

F Humans, *Homo sapiens*, are the only living species in the hominin group. Hominins are unique because they possess the ability to walk for long distances on two legs.

Animation

Jeff Cadge/Getty Images

Primate Groups

Primates are a large, diverse group of more than 200 living species. Examine **Figure 3** as you read about this diverse group. Most primates are **arboreal** (ar BOHR ee uhl), or tree-dwelling. Arboreal primates live in the world's tropical and subtropical forests. Primates that live on the ground are considered terrestrial primates.

Primates are classified into two subgroups based on characteristics of their noses, eyes, and teeth. The most basic subgroup is the strepsirrhines (STREP sihr ines) (also called "wet-nosed primates"), such as the lemur. The second subgroup consists of the haplorhines (HAP lohr ines), also called "dry-nosed primates." The haplorhines include the **anthropoids** (AN thruh poydz), a group of large-brained, diurnal monkeys and hominoids.

Reading Check **Differentiate** between strepsirrhines and haplorhines.

VOCABULARY

WORD ORIGIN

Lemur
comes from Latin, meaning *spirit of the night*

Strepsirrhines

Strepsirrhines can be identified by their large eyes and ears. However, they are the only primates that rely predominantly on smell for hunting and social interaction. Some members of this primate group can be found in tropical Africa and Asia. Most are found in Madagascar and nearby islands. As Madagascar drifted away from the African mainland, these animals evolved which left them reproductively isolated. This isolation resulted in their diversification. **Table 1** lists characteristics of some strepsirrhine groups.

Table 1 **Characteristics of Strepsirrhines**

Interactive Table

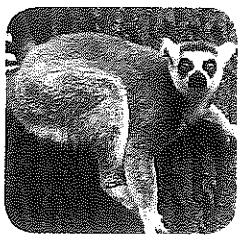
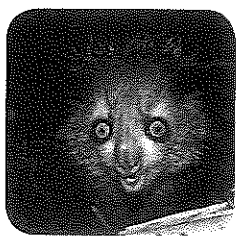
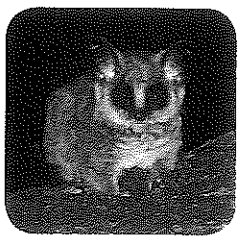
Group	Lemurs	Aye-Ayes	Lorises	Galagos
Example				
Active Period	Large—diurnal Small—nocturnal	Nocturnal	Nocturnal	Mostly nocturnal
Range	Madagascar	Madagascar	Africa and Southeast Asia	Africa
Characteristics	• Vertical leaper • Uses long bushy tail for balance • Herbivores and omnivores	• Taps bark, listens, fishes out grubs with long third finger	• Small and slow climber, solitary • Lack tails • Some have toxic secretions	• Small and fast leaper • No opposable digit • Long tail

Figure 4 Lemurs vary in their size and color. Some lemurs spend time on the ground.

FOLDABLES
Incorporate information from this section into your Foldable.

Figure 5 This spider monkey uses its prehensile tail as a fifth limb.

Most small lemurs are nocturnal and solitary. Only a few large species are diurnal and social. The indri is unique because it does not have a tail, unlike most lemurs that use their bushy tails for balance as they jump from branch to branch. Lorises are similar to lemurs but are found primarily in India and Southeast Asia. Galagos (ga LAY gohs), also called bushbabies, are found only in Africa.

Haplorhines

The second group of primates is a much larger group. The haplorhines include tarsiers, monkeys, and apes. The apes, in turn, include gibbons, orangutans, gorillas, chimpanzees, and humans.

The tarsier is found only in Borneo and the Philippines. It is a small, nocturnal creature with large eyes. It has the ability to rotate its head 180 degrees like an owl. It lives in trees, where it climbs and leaps among the branches. The tarsier shares characteristics with both lemurs and monkeys. Scientists once classified it with the lemurs, but new evidence suggests that it is more closely related to anthropoids, which makes it part of the haplorhine group.

Anthropoids are generally larger than strepsirrhines, and they have large brains relative to their body size. They are more likely to be diurnal, with eyes adapted to daylight and sometimes to color. Anthropoids also have more complex social interactions. They tend to live longer than lemurs and other strepsirrhines. The anthropoids are split into the New World monkeys and the Old World monkeys. "New World" refers to the Americas; "Old World" refers to Africa, Asia, and Europe. New World monkeys are the only monkeys that live in the Americas.

New World monkeys The New World monkeys are a group of about 60 species of arboreal monkeys that inhabit the tropical forests of Mexico, Central America, and South America. New World monkeys include the marmosets and tamarins. These are among the smallest and most unique primates. Neither species has fingernails or opposable digits.

The New World monkeys also include the squirrel monkeys, spider monkeys, and capuchin monkeys. Some of these monkeys have opposable digits, and most are diurnal and live together in social bands. Most are also distinguished by their prehensile (pree HEN sul) tails. A **prehensile tail** functions like a fifth limb. It can grasp tree branches or other objects and support a monkey's weight, as shown in **Figure 5.**

Old World monkeys Old World monkeys live in a wide variety of habitats throughout Asia and Africa, from snow-covered mountains in Japan to arid grasslands in Africa. Some Old World monkeys live in Gibraltar, which is located at the southern tip of Spain. There are about 80 species in this group, including macaques and baboons in one subgroup, and colobus and proboscis monkeys in another. Old World monkeys are similar to New World monkeys in many ways. They are diurnal and live in social groups. However, their noses tend to be narrower and their bodies are usually larger. They also spend more time on the ground. None have prehensile tails, and some have no tails. Most Old World monkeys have opposable digits.

Apes Only a handful of ape species exist today. Apes generally have larger brains in proportion to their body size than monkeys. They also have longer arms than legs, barrel-shaped chests, no tails, and flexible wrists. They are often highly social and have complex vocalizations. They are classified into two subcategories: the lesser apes, which include the gibbons and siamangs, and the great apes, which include orangutans, gorillas, chimpanzees, and humans.

Lesser apes The Asian gibbons and their close relatives, the larger siamangs, are the arboreal gymnasts of the ape family. Though they have the ability to walk on either two or four legs like all great apes, they generally move from branch to branch using a hand-over-hand swinging motion called brachiation. This motion, as shown in **Figure 6,** enables an adult gibbon to move almost 3 m in one swing.

Great apes Orangutans are the largest arboreal primates and the only great ape species that lives exclusively in Asia. Orangutans are large enough that the males are often more comfortable on the ground, though they are not efficient walkers. Female orangutans give birth once every eight years and nurse their young for up to six years. A male orangutan, with prominent cheek pads, and a female orangutan with her offspring are shown in **Figure 7.**

The gorillas are the largest of the primates. Like all great apes, they are predominantly terrestrial animals. They walk on all four limbs, supporting themselves by their front knuckles. Also, like other great apes, they use sticks as simple tools in the wild, and some living in captivity have been taught to recognize written characters and numbers.

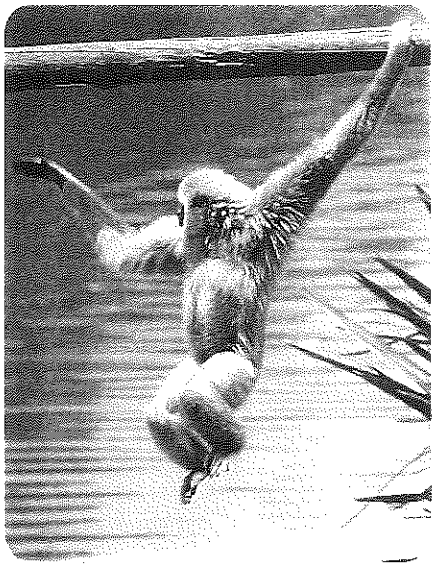
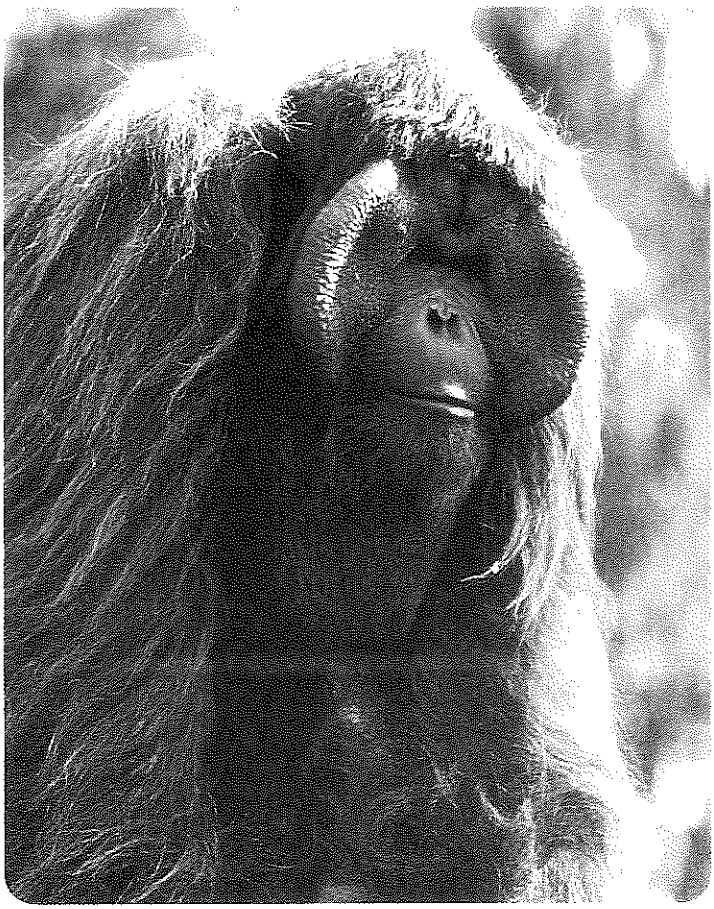


Figure 6 Lesser apes, such as this gibbon, move through trees primarily by brachiation—a hand-over-hand swinging motion.

Figure 7 Male orangutans are much larger and more solitary than females. The females spend most of their time raising their offspring.



(t)Tom McHugh/Photo Researchers; (b)PhotoLink/Photodisc/Getty Images; (br)©Renee Lynn/Corbis

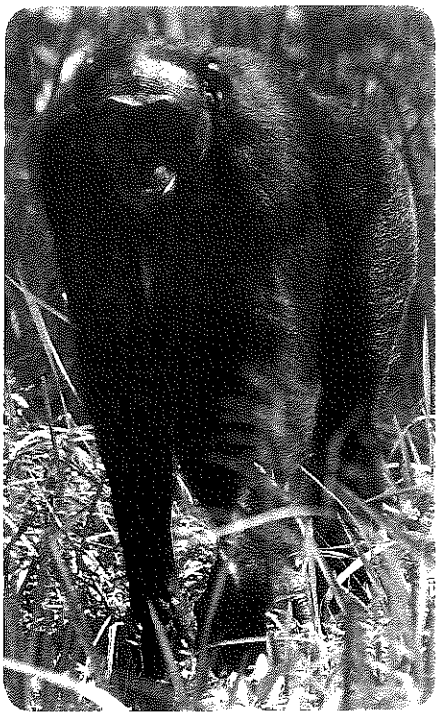


Figure 8 The bonobo is slightly smaller than the chimpanzee. Like the chimpanzee, it is structurally and behaviorally similar to humans.

Chimpanzees and their close relatives, the bonobos, are also knucklewalkers. They have well-developed communication systems, such as body positions and gestures, and social behavior, and they live in a wide variety of habitats. They are more like humans in their physical structure and behavior than any other primates are. The bonobo, shown in **Figure 8**, is slightly smaller than the chimpanzee. It was once called the "pygmy chimpanzee," but it now is considered a separate species.

Humans are included in the great ape family. They are then classified in a separate subcategory of hominids called hominins. **Hominins** are humanlike primates that appear to be more closely related to present-day humans than they are to present-day chimpanzees and bonobos. Though many species of hominins have existed on Earth, only one species—the group to which you belong—survives today. The diagram in **Figure 9** illustrates evolutionary relationships among primates.

Primate Evolution

Most primates today are arboreal. Prehensile tails, long limbs, binocular vision, brachiation, and opposable digits are traits that help them take full advantage of their forest environments.

Arboreal adaptation Some scientists suggest that primates evolved from ground-dwelling animals that searched for food in the top branches of forest shrubbery. They then evolved into additional food-gathering niches in trees. For example, the flexible hand with its opposable digits evolved not to grasp tree branches but to catch insects. Other scientists suggest that the rise of flowering plants provided new niche opportunities, and that arboreal adaptations allowed primates to take advantage of the fruits and flowers of trees.

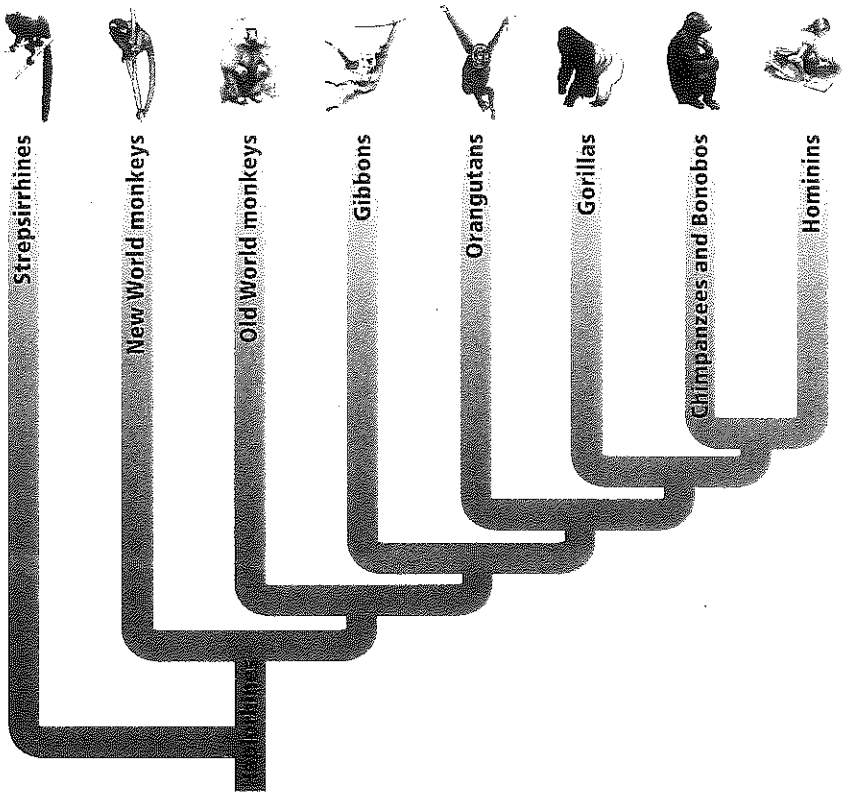


Figure 9 This branching diagram illustrates the diverging pattern of primate evolution.
Interpret *Which primate was the earliest to diverge?*

Primate ancestors Genetic data suggest that the first primates probably lived about 85 mya, when dinosaurs still roamed Earth. However, the earliest primate fossils do not appear in the fossil record until the beginning of the Eocene epoch, about 60 mya. One of the earliest fossil primates, called *Altiatlasius* (al tee aht lah SEE us), was a small, nocturnal animal that ate insects and fruits using its hands and feet for grasping. It might have resembled the tiny tree shrew in **Figure 10**, but it had some features similar to those of lemurs today. Learn more about the early evolution of primates in **Data Analysis Lab 1.**

Diverging primates Lemurlike primates were widespread by about 50 mya, and many species existed on all continents except Australia and Antarctica. Sometime around 50 mya, and possibly earlier, the anthropoids diverged from the tarsiers; this might have occurred in Asia, where the tarsiers are found today. The earliest anthropoids leaped less and walked more than the strepsirrhines and tarsiers, but they were still tiny and their brains were still small. By the end of the Eocene, 30–35 mya, the anthropoids had diverged and spread widely.

Displacement Many early strepsirrhines appear to have become extinct by the end of the Eocene. This might have been caused by a change in climate. Many major geological events took place at the end of the Eocene and temperatures became cooler. Or, it could have been caused by the divergence of the anthropoids. The anthropoids of this time generally were larger and had bigger brains than the strepsirrhines did. Thus, the anthropoids might have outcompeted some of the strepsirrhines for resources. This idea is supported by the observation that today, the nocturnal strepsirrhines do not interact with the diurnal anthropoids when the habitats of these two groups overlap.

Figure 10 The earliest primate ancestor might have looked like this tree shrew.

FLPA/Alamy

DATA ANALYSIS LAB 1

Based on Real Data*

Interpret Scientific Illustrations

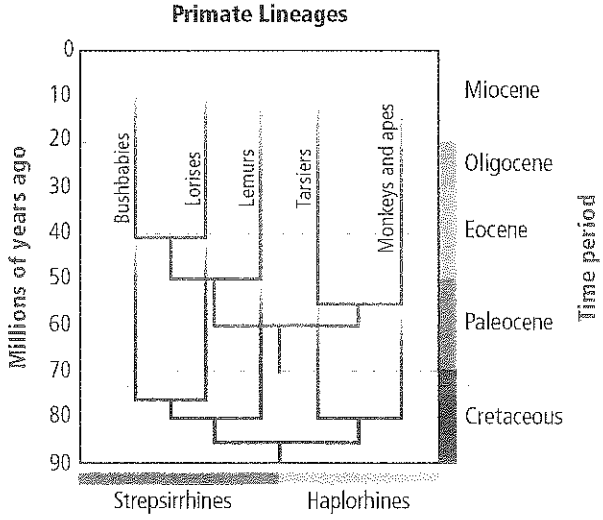
When did early primate lineages diverge?

The fossil record for primate evolution is sparse. In the simplified primate evolutionary tree at right, the green diagram shows the present divergence according to known fossils. The red diagram shows the time line with presumed fossils filling the gaps. Use the diagrams to answer the following questions.

Think Critically

1. **Summarize** why lemurs, lorises, and bushbabies are considered descendants of the earliest primates.
2. **Extrapolate** how far back the divergence of the lemurs might have occurred.
3. **Infer** whether tarsiers are more closely related to apes or to lemurs.

Data and Observations



*Data obtained from: Martin, Robert D. 2003. Paleontology: combing the primate record. *Nature* 422: 388–391.

Monkeys The end of the Eocene also saw the appearance of the monkeys. Early monkeys had larger brains than their anthropoid ancestors did, and their eyes were more forward-looking. Their snouts were less pointed and they relied less on smell. Scientists hypothesize that the New World monkeys diverged from the line that gave rise to the Old World monkeys sometime between 35 and 25 mya in Africa. While the Old World monkeys continued to evolve in Africa, the New World monkeys developed distinct characteristics in South America. By this time, Africa and South America had separated into two continents. How, then, did the New World monkeys arrive in South America?

Journey to South America Many scientists hypothesize that the New World monkeys evolved from an isolated group of ancestral anthropoids that somehow drifted to South America from Africa, perhaps on rafts of vegetation and soil, much like how the ancestors of lemurs might have drifted to Madagascar from the African mainland. Some scientists suggest that the New World monkeys might have diverged from the anthropoid lineage and made their journey millions of years earlier, when sea levels were lower and the continents were closer.

VOCABULARY

ACADEMIC VOCABULARY

Diverge
to become different in character or form
Their ideas diverged so much that they could not come to an agreement.

Aegyptopithecus In Africa and Asia, anthropoids continued to evolve. Many anthropoid fossils have been found at a site in present-day Egypt called the Fayum Basin. Now a desert, the Fayum was predominantly tropical when dozens of anthropoid species lived there 36-31 mya. The largest among them was Aegyptopithecus (ee gypt oh PIH thuh kus), often called the dawn ape. Some scientists hypothesize that this arboreal animal, which was about the size of a domestic cat, was ancestral to the apes. It might have been part of the anthropoid line that split from the Old World monkeys and might have given rise to orangutans, gorillas, chimpanzees, and humans.

Section 1 Assessment

Section Summary

- All primates share certain anatomical and behavioral characteristics.
- Primates include lemurs, New World monkeys, Old World monkeys, apes, and humans.
- Strepsirrhines are the most primitive living lineages of primates to evolve. They diverged from haplorhines before 55 mya.
- Anthropoids diverged from tarsiers by 50 mya.
- New World monkeys are the only nonhuman primates in the Americas.

Understand Main Ideas

1. THINK Identify **List** four characteristics that are representative of most primates that lead paleoanthropologists to conclude that primates share a common ancestry.
2. **Describe** how the characteristics of primates make them well-adapted for an arboreal lifestyle.
3. **Diagram** the evolutionary relationships of primates.
4. **Compare and contrast** major primate groups.

Think Critically

5. **Hypothesize** how the breakup of Pangaea might have contributed to the evolutionary history of primates.

MATH in Biology

6. Assume that life on Earth began 3.5 billion years ago. To the nearest percent, how much of this time have anthropoids been living?

Online Quiz

Reading Preview

Essential Questions

- What are the features of hominoids and hominins?
- How can hominoid evolution be traced from *Proconsul* to *Homo*?
- What are the similarities between the various australopithecine species?

Review Vocabulary

savanna: a flat grassland of tropical or subtropical regions

New Vocabulary

hominoid
bipedal
australopithecine

Multilingual eGlossary

Hominoids to Hominins

Main Idea **Hominins, a subgroup of the hominoids, likely evolved in response to climate changes of the Miocene epoch.**

Real-World Reading Link Have you ever tried to put together a puzzle that is missing some of its pieces? Human evolution is like that puzzle. Scientists who try to understand how humans evolved are slowed by the holes in the fossil record. Recent advances in genetics and molecular biology have helped, but the puzzle that is human evolution remains only partially assembled.

Hominoids

Hominoids (HAH mih noydz) include all nonmonkey anthropoids–the living and extinct gibbons, orangutans, chimpanzees, gorillas, and humans. The fossil transition from early anthropoid to ape is not clear; very few fossils from the late Oligocene epoch exist. The earliest hominoid fossils appear in the fossil record only about 25 mya, at the beginning of the Miocene epoch. These hominoids retained some ancestral primate features. For example, most had bodies adapted for brachiation. There is evidence that they had relatively large brains and had shoulders and hips that moved freely, and some might even have had the ability to stand on two legs.

Connection to Chemistry Scientists use fossils to help them determine when ancestral hominoids diverged into the hominoids that exist today. However, because the fossil record for hominoids is so sparse, scientists also turn to biochemical data to help them with this task. By comparing the DNA of living hominoid species, researchers conclude that gibbons likely diverged first from an ancestral anthropoid, followed by orangutans, gorillas, chimpanzees and bonobos, and finally, humans. **Figure 11** shows the potential divergence of these species. Chimpanzees and bonobos are the closest living relatives to humans. All three share at least 96 percent of their DNA sequences.

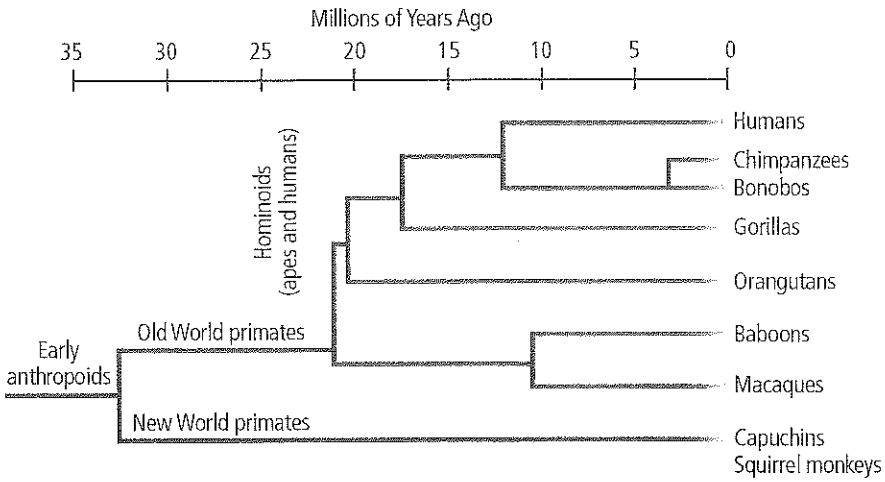


Figure 11 Orangutans, gorillas, bonobos, and chimpanzees all diverged from an ancestral anthropoid.

Figure 12 *Proconsul* was an early, small-brained hominoid that might have been a human ancestor.

Hominoid characteristics Hominoids are the largest of the primates, and they have the largest brain size in relation to their body size. They tend to have broad pelvises, long fingers, no tail, and flexible arm and shoulder joints. They also have semi-upright or upright posture, and, except for hominins, their arms are longer than their legs. Their teeth are less specialized than those of other animals, and their molars have a distinctive pattern that scientists use to distinguish hominoid fossils from other primate fossils.

Hominoid biogeography During the Miocene epoch (24–5 mya), the world's climate became warmer and drier. As a result, tropical rain forests in Africa began to shrink. Many new animals, including new hominoids, evolved as they adapted to the changing environments. Between about 23 and 14 mya, perhaps as many as 100 hominoid species existed. Early hominoids were more diverse than the modern apes, and they migrated from Africa to Europe and Asia.

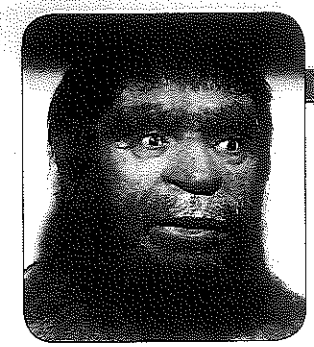
Proconsul The best-known hominoid fossils, and some of the oldest, are those from the genus *Proconsul*. **Figure 12** shows a fossil skull of one *Proconsul* species discovered by Mary Leakey in Kenya in 1948. This *Proconsul* species generally had the smallest brains of the hominoids. Most had freely moving arms and legs, and while they lived predominantly in trees, some might have had the ability to walk upright. Some scientists think that this *Proconsul* species is a human ancestor, but others suggest that one of the European hominoids–whose fossils are in some ways more humanlike than *Proconsul*–might have returned to Africa at the end of the Miocene and given rise to the human line.

Hominins

The lineage that most likely led to humans split off from the other African apes sometime between 8 and 5 mya. The hominins include humans and all their extinct relatives. These extinct relatives are more closely related to humans than to chimpanzees. The time line in **Figure 13** highlights some important hominin discoveries.

Figure 13
Hominin Evolution

Discoveries have shaped our understanding of how *Homo sapiens* evolved from hominoids.



1856 A partial skeleton of *Homo neanderthalensis* was discovered in a cave in Germany's Neander Valley.

1859 Charles Darwin's theory of evolution sparks a heated debate over whether humans and apes share a common ancestor.

1893 A fossil of "Java Man" is the first *Homo erectus* fossil discovered.

1926 Raymond Dart finds the first *Australopithecus* fossil. The "Taung Child" sparks debate about bipedalism.

1960–1962 Researchers find fossils of *Homo habilis*, the first large-brained hominin.

1860 1890 1955

(l)Pascal Goetgheluck/Photo Researchers; (b)Tom McHugh/Photo Researchers

Chimpanzee	Hominin
Skull attaches posteriorly	Skull attaches inferiorly
Spine slightly curved	S-shaped spine
Arms longer than legs and used for walking	Arms shorter than legs and not used for walking
Long, narrow pelvis	Bowl-shaped pelvis
Femur angled outward	Femur angled inward

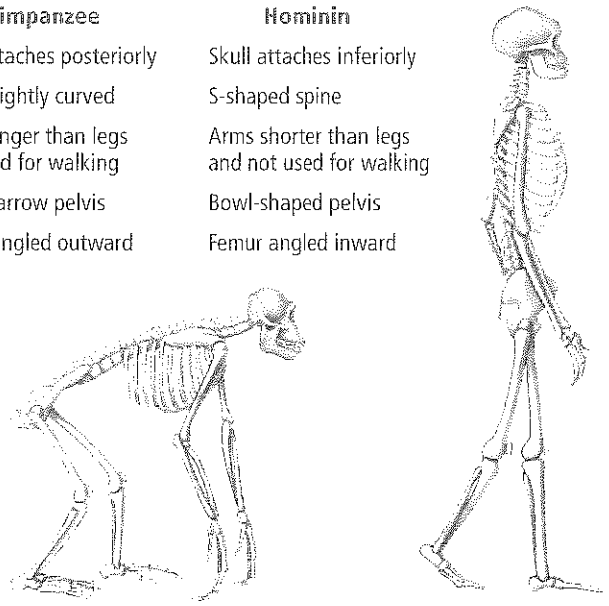


Figure 14 A comparison between chimpanzee and hominin skeletons illustrates evolutionary changes leading to bipedalism. **Observe and Infer** *What differences in the lengths of the arms and the legs do you detect?*

Hominin characteristics Hominins have bigger brains than other hominoids, with more complexity in parts of the brain where high-level thought occurs. The hominin face is thinner and flatter than those of other hominoids. Hominin teeth are also smaller. With lengthened thumbs and more flexible wrists, hominins have high manual dexterity. Hominins are also **bipedal,** which means that they can walk upright on two legs.

Examine **Figure 14,** which illustrates anatomical differences in a quadruped and a biped. When becoming bipedal, hominins developed a fully upright stance, shortened arms, restructured pelvic bones and foot bones, and a change in the position of the head on the spinal cord. In quadrupedal animals, or those that walk on all four limbs, the foramen magnum—the hole in the skull where the spine extends from the brain—is located at the back of the skull. In hominins, it is positioned at the base of the skull.

1974 The fossil remains of "Lucy" are discovered, providing convincing evidence that *Australopithecus* was bipedal.

1987 The theory of "Mitochondrial Eve" is proposed.

2000 A worldwide study of Y-chromosomes reveals that *Homo sapiens* emerged from Africa, supporting the Out-of-Africa hypothesis.

1970 — 1985 — 2000

1999 The discovery of a Neanderthal–Cro-Magnon hybrid child fossil supports the multiregional theory of human evolution.

2009 Scientists complete the sequence of mitochondrial DNA in the Neanderthal genome.

Joao Zilhao/Portuguese Institute of Archaeology

Disadvantages of bipedalism Bipedalism is not necessarily more efficient than quadrupedalism. Bipedal individuals are easier for predators to see, they might not run as fast, and bipedalism puts greater strain on the hips and back. Also, standing upright defies gravity and therefore requires more energy. Why, then, did hominins become bipedal when their ancestors were so well adapted to life in the trees?

Advantages of bipedalism There is no single answer to the question of why bipedalism developed. Bipedalism could have been selected for because it uses less energy than walking on all fours over long distances. Also, standing upright could have made it easier to see food sources. Walking upright for long distances might also have reduced the total area of the body exposed to sunlight and increased the area exposed to cooling winds.

One hypothesis explaining bipedalism is based on the idea that the African landscape was changing during the period when hominins evolved. Many scientists suggest that bipedalism was an adaptation to the new environment. The most successful hominins may have been those that evolved at the boundaries of the environments. Bipedalism would have allowed them to carry objects while walking through the forest, and to see above tall grasses to find food and avoid predators.

Another hypothesis, based on fossils of *Ardipithecus ramidus*, suggests that bipedalism evolved due to social structure. Fossils indicate that a social structure existed in which males cooperated with females to raise offspring. Males may have traveled through the forest to find food for their offspring. Bipedalism would have allowed *Ar. ramidus* to keep hands free while traveling with food or other objects.

Reading Check **Summarize** the advantages and disadvantages of bipedalism.

MiniLab 1

Observe the Functions of an Opposable Thumb

MiniLab

How do opposable thumbs aid in everyday tasks? Explore the advantages of performing everyday activities with and without the aid of opposable thumbs.

Procedure

1. Read and complete the lab safety form.
2. Create a data table to record your observations.
3. Have a partner tape your thumbs to the sides of your hands with **masking tape.**
4. Using your taped hands, perform the following tasks: pick up a **pen or pencil** and write your name on a **piece of paper,** tie your **shoelaces,** and open a **closed door.** Have your partner use a **stopwatch** to time each task.
5. Have your partner remove the tape from your hands, then repeat the activities in Step 4 with the use of your thumbs. Have your partner time each task.

Analysis:

1. **Compare and contrast** the time and effort required to complete each task with and without the aid of your thumbs.
2. **Infer** the advantages that ancestral primates with opposable thumbs would have had over competitors without opposable thumbs.

Hominin fossils Bipedalism evolved before many other hominin traits, and it is often used to identify hominin fossils. The earliest fossils of species that show some degree of bipedalism are 6–7 million years old. Evidence of true bipedalism has been suggested by the fossilized remains of *Ar. ramidus* and the australopithecines (aw stray loh PIH thuh seens).

Australopithecines lived in the east-central and southern parts of Africa between 4.2 and 1 mya. They were small—the males were only about 1.5 m tall—and they had apelike brains and jaws. However, their teeth and limb joints were humanlike.

The Taung child Anthropologist Raymond Dart (1893–1988) identified the first australopithecine fossil, the "Taung child," in Africa in 1926. He called the species *Australopithecus africanus*, meaning "southern ape from Africa." *A. africanus* likely lived between 3.3 and 2.3 mya. The placement of the foramen magnum in the skull of the Taung child, shown in **Figure 15,** convinced Dart that *A. africanus* was bipedal. Not everyone agreed, because *A. africanus* had a small brain. Some scientists thought that larger brains evolved before bipedalism. The question continued to be debated for many years, even after the discovery of other African australopithecine fossils such as *A. bosei* and *A. robustus*, which indicated bipedalism and small brains.

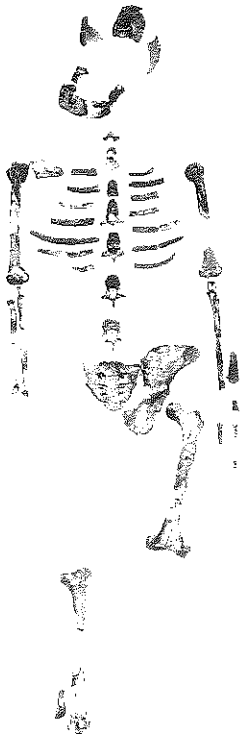
Lucy In 1974 in Kenya, anthropologist Donald Johanson discovered an australopithecine skeleton that helped resolve the debate. Lucy is one of the most complete australopithecine fossils ever found. She was a member of the species *A. afarensis*, which lived between 4 and 2.9 mya.

Lucy was about the size of a chimpanzee. She had the typical australopithecine skull and small brain, and her arms were still somewhat long in proportion to her legs. She also had finger bones that were more curved than those of modern humans, which indicates that she was capable of arboreal activity. However, her hip and knee joints were humanlike. It was clear that she walked upright. A few years later, Mary Leakey uncovered further evidence that australopithecines were bipedal when she discovered fossilized australopithecine footprints. Lucy's skeleton and the footprints of her relatives are illustrated in **Figure 16.**

Figure 15 The Taung child skull convinced Raymond Dart that *A. africanus* walked upright.

Figure 16 Fossilized footprints indicate that Lucy was bipedal. Though incomplete, this skeleton of Lucy indicates that *A. afarensis* had a small brain but also had the ability to walk upright.

Infer ***what bones scientists would examine to determine if Lucy walked upright.***



VOCABULARY

WORD ORIGIN

Australopithecine
from the Latin word *australis,* meaning *southern,* and the Greek word *pithekos,* meaning *ape*

Mosaic pattern Like other hominin fossils, Lucy and her relatives show a patchwork of human and apelike traits. In this way, they follow a mosaic pattern of evolution. Mosaic evolution occurs when different body parts or behaviors evolve at different rates. For example, hominins developed the ability to walk upright nearly two million years before they developed modern flat faces and larger brains.

Hominin evolution Within the last 30 years, scientists have discovered many more early hominin fossils. Some defy characterization and have led to new genus designations. Scientists have estimated that *Kenyanthropus platyops* (ken yan THROH pus • PLAT ee ops), for example, lived between 3.5 and 3.2 mya. Some scientists think that *K. platyops,* which means "flat-faced man," represents a completely new hominin genus.

Paranthropus There is also confusion about where *A. bosei* and *A. robustus* fit in the classification of hominins. Traditionally, these two species have been classified as robust forms of australopithecines, distinguished from the smaller, more slender forms by their size and muscular jaws. Today, many scientists prefer to put these primates in a separate genus called *Paranthropus.* Paranthropoids, which thrived between 2 and 1.2 mya, were an offshoot of the human line that lived alongside human ancestors but were not directly related.

Overlapping hominins However they are classified, these robust hominins appear to have lived alongside some of the slender australopithecines. They might have overlapped, for example, with *A. garhi,* an African australopithecine that was discovered in 1999. The illustration of the evolution of hominins is more like a bush than a tree. Many species lived successfully for years, often overlapping with earlier species and then–for unknown reasons–became extinct. By 1 mya, all australopithecines had disappeared from the fossil record. The only hominin fossils found after that time belong to the genus *Homo.*

Section 2 Assessment

Section Summary

- Hominoids are all of the apes, including gibbons, orangutans, gorillas, chimpanzees, and humans and their extinct relatives.
- Several species of hominins appear in the fossil record.
- Hominins include humans, australopithecines, and other extinct species more closely related to humans than to chimpanzees.
- Bipedalism was one of the earliest hominin traits to evolve.

Understand Main Ideas

1. **Summarize** how the climate of the Miocene epoch impacted the evolution of hominins.
2. **Describe** characteristics unique to hominoids.
3. **Describe** characteristics unique to hominins.
4. **Outline** hominoid evolution from *Proconsul* to *Homo.*
5. **Compare** australopithecine species.

Think Critically

6. **Discuss** Do you think hominins would have evolved if the climate had not changed during the Miocene epoch? Why?
7. **Classify** If you found a primate skeleton with arms shorter than legs, in what general category would you place it?

Online Quiz

Section 3

Reading Preview

Essential Questions

- How can the species in the genus *Homo* be described?
- What is the Out-of-Africa hypothesis?
- What are the similarities and differences between Neanderthals and modern humans?

Review Vocabulary

mitochondrion: an organelle found in eukaryotic cells containing genetic material and responsible for cellular energy

New Vocabulary

Homo
Neanderthal
Cro-Magnon

Multilingual eGlossary

Human Ancestry

MAIN Idea **Tracing the evolution of the genus *Homo* is important for understanding the ancestry of humans, the only living species of *Homo*.**

Real-World Reading Link Have you ever heard anyone use the term "cave man" in an insulting way? Unfortunately, this term is used sometimes to indicate brutish behavior. However, the people who lived in caves 40,000 years ago were very much like modern humans. Their art was beautiful, and their tools were sophisticated.

The Genus *Homo*

The African environment became considerably cooler between 3 and 2.5 mya. Forests became smaller in size, and the range of grasslands was extended. The genus ***Homo,*** which includes living and extinct humans, first appeared during these years. Although the fossil record is lacking fossils, many scientists infer that they evolved from an ancestor of the australopithecines.

Homo species had bigger brains, lighter skeletons, flatter faces, and smaller teeth than their australopithecine ancestors. They are also the first species known to control fire and to modify stones for tool use. As they evolved, they developed language and culture.

***Homo habilis* used stone tools** The earliest known species that is generally accepted as a member of the genus *Homo* is *Homo habilis,* called "handy man" because of its association with primitive stone tools. This species lived in Africa between about 2.4 and 1.4 mya. **Figure 17** shows a scientific illustrator's idea of what *H. habilis* might have looked like.

H. habilis possessed a brain averaging 650 cm^3, about 20 percent larger than that of the australopithecines. It also had other *Homo* species traits, including a smaller brow, reduced jaw, flatter face, and more humanlike teeth. Like australopithecines, it was small, long-armed, and seems to have retained the ability to climb trees. Other *Homo* species might have coexisted with *H. habilis,* among them a species called *Homo rudolfensis.* Because few fossils of *H. rudolfensis* have been found, its exact relationship to the rest of the *Homo* line is uncertain.

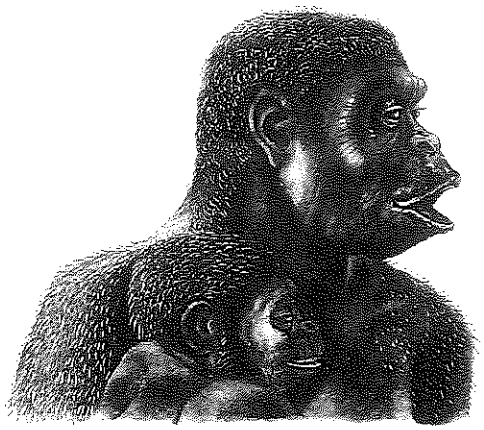


Figure 17 Scientific illustrators use fossils and their knowledge of anatomy to create drawings of what *H. habilis* might have looked like.

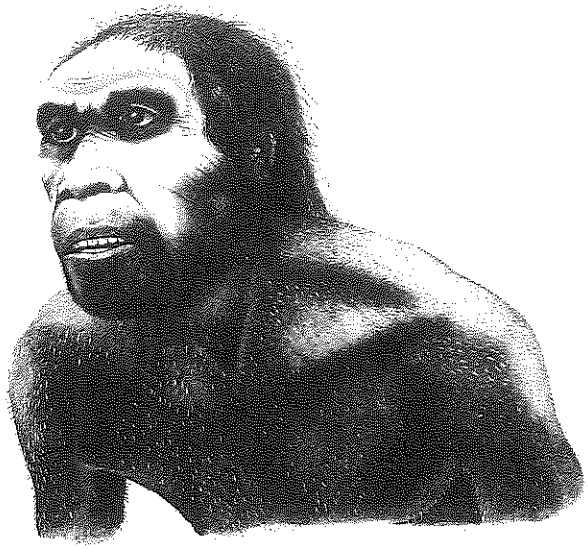


Figure 18 Models of nonliving species can be created from fossil remains. *H. ergaster* appeared in the fossil record about 1.8–1.3 mya.

***Homo ergaster* migrated** Within about 500,000 years of the appearance of *H. habilis*, another *Homo* species, *Homo ergaster*, emerged with an even larger brain. *H. ergaster*, illustrated in **Figure 18**, appeared only briefly in the fossil record, from about 1.8 to 1.3 mya. *H. ergaster* was taller and lighter than *H. habilis*, and had longer legs and shorter arms. Its brain averaged 1000 cm^3, and it had a rounded skull, reduced teeth, and what many scientists think was the first human nose (with the nostrils facing downward).

Tools Carefully made hand axes and other tools associated with *H. ergaster* fossils suggest to some scientists that *H. ergaster* was a hunter, but others think that *H. ergaster* was primarily a scavenger and used the tools to scrape the meat off scavenged bones.

MiniLab 2

MiniLab

Explore Hominin Migration

Where did early hominins live? Scientists carefully record the locations where fossils are found. The latitude and longitude coordinates represent the known geographic points of each *Homo* species' range.

Procedure

1. Read and complete the lab safety form.
2. Plot the following fossil sites on the map that your teacher gives you. Use a different color for each species. When you are finished, lightly shade in the approximate boundaries.

   H. habilis (2.4–1.4 million years ago): 37°E: 4°S, 36°E: 3°N, 36°E: 7°N, 43°E: 8°N

   H. erectus (2 million–400,000 years ago): 112°E: 38°N, 13°E: 47°N, 7°W: 34°N, 112°E: 8°S

   H. neanderthalensis (300,000–200,000 years ago): 8°E: 53°N, 66°E: 39°N, 5°W: 37°N, 36°E: 33°N

   H. sapiens (195,000 years ago–present): 70°E: 62°N, 24°E: 30°S, 138°E: 34°S, 112°E: 38°N, 99°W: 19°N, 102°W: 32°N

Analysis

1. **Hypothesize** when was the earliest that hominins could have migrated out of Africa. Where did they go? Use the map you made for reference.
2. **Determine** what sets of fossils overlapped in geographic ranges. What does this suggest?

Javier Trueba/MSF/Science Source

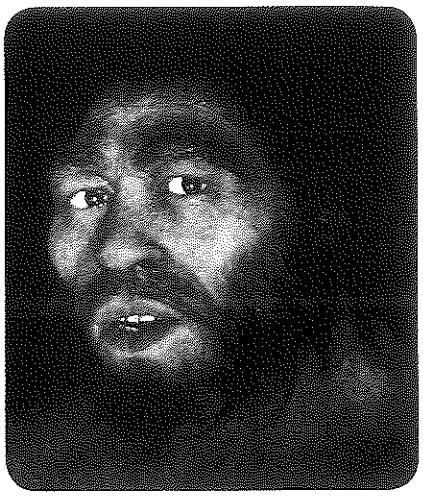


Figure 19 *H. erectus* might have lived in caves, made tools, and used fire.
Explain *some of the advantages* H. erectus *would have over* H. ergaster.

Migration Both scavenging and hunting are associated with a migratory lifestyle, and *H. ergaster* appears to have been the first African *Homo* species to migrate in large numbers to Asia and possibly Europe, perhaps following the trail of migrating animals. The later Eurasian forms of *H. ergaster* are called *Homo erectus*. Because *H. ergaster* shares features with modern humans, scientists hypothesize that *H. ergaster* is an ancestor of modern humans.

***Homo erectus* used fire** *H. erectus*, illustrated in **Figure 19,** lived between 1.8 million and 400,000 years ago and appears to have evolved from *H. ergaster* as it migrated out of Africa. While some scientists consider *H. ergaster* and *H. erectus* a single species, *H. erectus* appears to have evolved traits that the early African *H. ergaster* species did not have. Members of this species seem to have been more versatile than their predecessors, and they adapted successfully to a variety of environments. *H. erectus* includes "Java Man," discovered in Indonesia in the 1890s, and "Peking Man," discovered in China in the 1920s.

In general, *H. erectus* was larger than *H. habilis* and had a bigger brain. It also had teeth that were more humanlike. Brain capacity ranged from about 900 cm^3 in early specimens to about 1100 cm^3 in later ones. It was as tall as *H. sapiens*, but it had a longer skull, lower forehead, and thicker facial bones than either *H. ergaster* or *H. sapiens*. It also had a more prominent browridge. Evidence indicates that *H. erectus* made sophisticated tools, used fire, and sometimes lived in caves.

***Homo floresiensis*—"The Hobbit"** In 2003 a curious set of fossils were discovered on the Indonesian island of Flores. These fossils, which are about 18,000 years old, are heavily debated in the scientific community. Some scientists think they might represent a species called *Homo floresiensis* (flor eh see EN sus). Others think that the fossils belong to early human dwarfs and do not warrant classification as a separate species. *H. floresiensis*, nicknamed "The Hobbit," was only about 1 m tall when fully grown. While it had brain and body proportions like all the australopithecines, primitive stone tools were found with its fossils. In 2007 a study showed that *H. floresiensis* had apelike wrist bones—further support for its status as a separate species. You can compare *H. floresiensis* and *H. sapiens* skulls in **Figure 20.**

Reading Check What are the evolutionary relationships among *H. habilis*, *H. ergaster*, and *H. erectus*?

Figure 20 Scientists are debating whether *H. floresiensis* is a new species. The *H. floresiensis* skull on the left is smaller than the human skull on the right.
Infer *what this skull comparison might predict about the evolutionary relationship between* H. floresiensis *and* H. sapiens.

***Homo heidelbergensis*—traits** The transition from *H. ergaster* to modern humans appears to have occurred gradually. Numerous transitional fossils have been found that display a mixture of *H. ergaster* and *H. sapiens* traits. These fossils are often categorized as *Homo heidelbergensis,* but some scientists put them in the category *Homo sapiens.* These humans generally had larger brains and thinner bones than *H. ergaster* did, but they still had browridges and receding chins.

Reading Check **Relate** *H. heidelbergensis* to *H. sapiens.*

***Homo neanderthalensis* built shelter** A distinct human species called *Homo neanderthalensis,* or the **Neanderthals,** evolved exclusively in Europe and Asia about 200,000 years ago, likely from *H. erectus* or a *Homo* intermediary. Neanderthals were shorter but had more muscle mass than most modern humans do. Their brains were sometimes even larger than the brains of modern humans, though the brains might have been organized in different ways. Neanderthals had thick skulls, bony browridges, and large noses. They also had a heavily muscled, robust stature, as illustrated in **Figure 21.** Evidence of heavy musculature appears in the extremely large muscle attachments and the bowing of the long bones.

Neanderthals lived near the end of the Pleistocene ice age, a time of bitter cold. Their skeletons reflect lives of hardship; bone fractures and arthritis seem to have been common. There is evidence that they used fire and constructed complex shelters. They hunted and skinned animals, and it is possible that they had basic language. There is also some evidence that they cared for their sick and buried their dead.

Are Neanderthals our ancestors? In some areas of their range, particularly in the Middle East and southern Europe, Neanderthals and modern humans overlapped for as long as 10,000 years. Recent evidence suggests that modern humans and Neanderthals did interbreed. In fact, it is estimated that we share approximately two percent of our genome with Neanderthals. Scientists continue to research interactions between Neanderthals and modern humans. Neanderthals became extinct roughly 40,000 years ago.

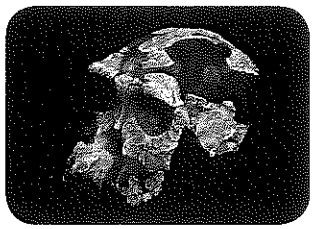
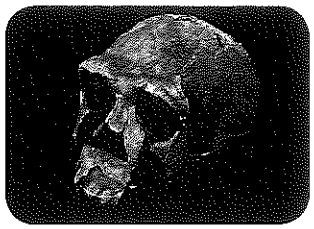
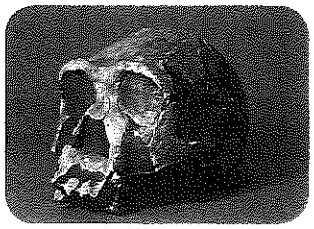
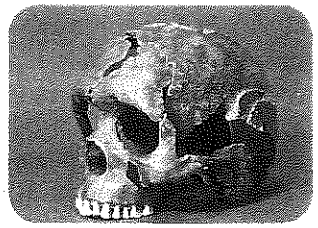
Figure 21 *H. neanderthalensis* had much thicker bones than modern humans and a pronounced browridge. Neanderthals were hunters who used fire and tools.

Emergence of Modern Humans

The species that displaced the Neanderthals, *Homo sapiens*, is characterized by a more slender appearance than all other *Homo* species. They have thinner skeletons, rounder skulls, and smaller faces with prominent chins. Their brain capacity averages 1350 cm^3. *H. sapiens* first appeared in the fossil record, in what is now Ethiopia, about 195,000 years ago. These early *H. sapiens* made chipped hand axes and other sophisticated stone tools. They appear to have had the ability to use a range of resources and environments, and at some point they began migrating out of Africa. **Table 2** compares modern humans with other *Homo* species.

Table 2 Characteristics of the *Homo* species

Interactive Table

Species	Skull	Time in fossil record	Characteristics
Homo habilis		2.4–1.4 million years ago	• Average brain had a capacity of 650 cm^3 • Used tools
Homo ergaster		1.8–1.2 million years ago	• Average brain had a capacity of 1000 cm^3 • Had thinner skull bones • Had humanlike nose
Homo erectus		1.8 million–400,000 years ago	• Average brain had a capacity of 1000 cm^3 • Had thinner skull bones • Used fire
Homo neanderthalensis		300,000–200,000 years ago	• Average brain had a capacity of 1500 cm^3 • Buried their dead • Possibly had a language
Homo sapiens		195,000 years ago to present	• Average brain has a capacity of 1350 cm^3 • Does not have browridge • Has a small chin • Has language and culture

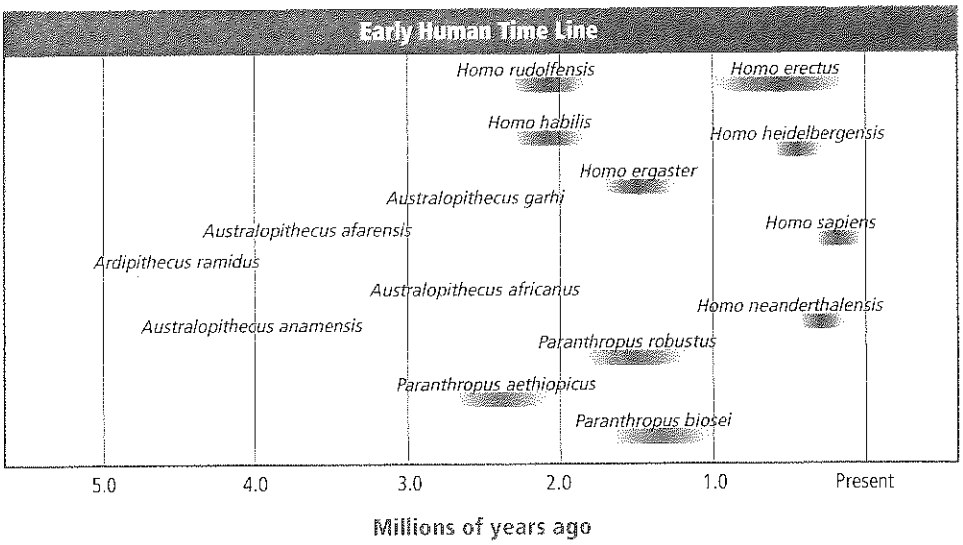


Figure 22 The period of existence of several early hominins overlapped until about 30,000 years ago.

Out-of-Africa hypothesis The world's population 200,000 years ago looked significantly different from how it does today. It was inhabited by a morphologically diverse genus of hominins, including primitive humans, Neanderthals, and modern humans, as illustrated in **Figure 22.** By 30,000 years ago, however, only modern humans remained. Some scientists propose that these modern humans evolved from several dispersed populations of early *Homo* species at the same time in different areas of the world. According to this multiregional evolution model, modern races of humans arose in isolated populations by convergent evolution.

Most scientists explain the global dominance of modern humans with the African Replacement model or, more commonly, the Out-of-Africa hypothesis. According to this hypothesis, which was first proposed by Christopher Stringer and Peter Andrews of the British Museum of Natural History in 1988, modern humans evolved only once, in Africa, and then migrated to all parts of the world, eventually displacing other hominins.

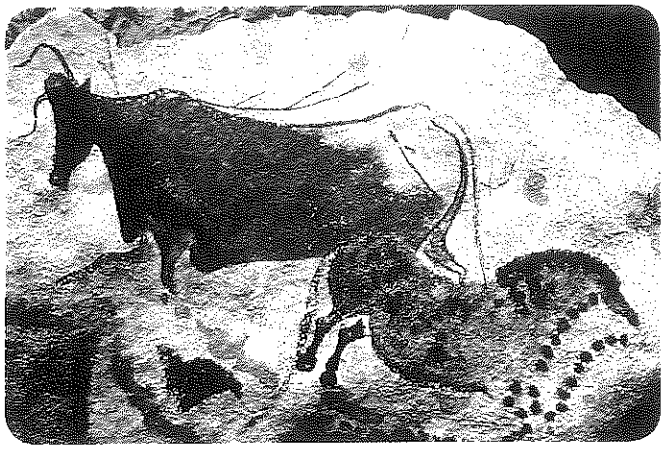
"Mitochondrial Eve" The Out-of-Africa hypothesis was supported by mitochondrial DNA analysis of contemporary humans in the early 1990s. Mitochondrial DNA changes very little over time, and humans living today have nearly identical mitochondrial DNA. Researchers Allan Wilson and Rebecca Cann of the University of California, Berkeley, reasoned that the population with the most variation should be the population that has had the longest time to accumulate diversity. This was exactly what they found in the mitochondrial DNA of Africans. Because mitochondrial DNA is inherited only from the mother, this analysis suggested that *H. sapiens* emerged in Africa about 200,000 years ago from a hypothetical "Mitochondrial Eve."

Later, work by other scientists studying DNA sequences in the male Y chromosome yielded similar results. While some scientists think that a single movement of only a few hundred modern humans ultimately gave rise to the world's current population, others think the process occurred in phases, with some interbreeding among the species that humans displaced.

Reading Check **Describe** evidence in support of the Out-of-Africa hypothesis.

Study Tip

Discussion Group Discuss with your classmates what you've learned about human evolution. What characteristics of early hominins have surprised you or your classmates?



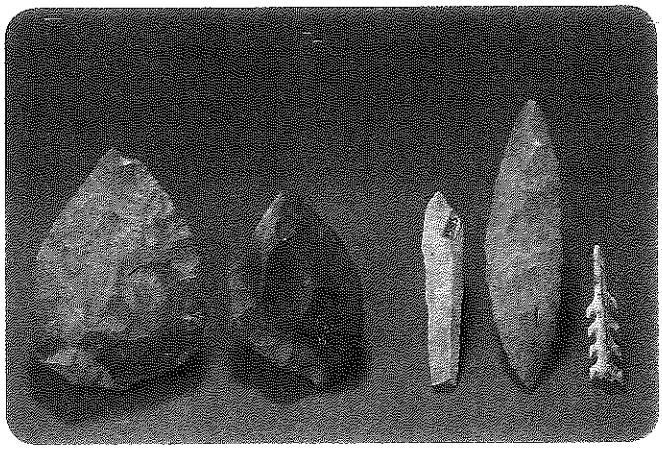


Figure 23 Cro-Magnons were known for their sophisticated cave paintings, tools, and weapons. The painting on the left was found in Lascaux Cave in France.

The beginning of culture The first evidence of complex human culture appeared in Europe only about 40,000 years ago, shortly before the Neanderthals disappeared. Unlike the Neanderthals, early modern humans expressed themselves symbolically and artistically in decorative artifacts and cave drawings, as illustrated in **Figure 23.** They developed sophisticated tools and weapons, including spears and bows and arrows. They were the first to fish, the first to tailor clothing, and the first to domesticate animals. These and many other cultural expressions marked the appearance of fully modern humans, the subspecies *Homo sapiens*. Some people call them **Cro-Magnons.** They represent the beginning of historic hunter-gatherer societies.

Connection to History Humans continued their migration throughout Europe and Asia. They probably reached Australia by boat and traveled to North America via a land bridge from Asia. From North America, they spread to South America. They adapted to new challenges along the way, leaving behind a trail of artifacts that we study today.

Section 3 Assessment

Section Summary

- The genus *Homo* is thought to have evolved from genus *Australopithecus*.
- Of the many species that have existed in the hominin group, only one species survives today.
- The first member of the genus *Homo* was *H. habilis*.
- The Out-of-Africa hypothesis suggests that humans evolved in Africa and migrated to Europe and Asia.
- *H. neanderthalensis* became extinct about 30,000 years ago, and *H. sapiens* moved into those areas inhabited by *H. neanderthalensis* at about the same time.

Understand Main Ideas

1. **Think Critically Hypothesize** why only one genus and species remains in the hominin group.
2. **Describe** how *H. habilis* might have lived.
3. **Apply** what you have learned about the Out-of-Africa hypothesis to what you know about the arrival of *H. sapiens* in North America.
4. **Compare and contrast** *H. neanderthalensis* and *H. sapiens*.

Think Critically

5. **Classify** how you would classify a fossil that was found in France and dated at about 150,000 years old if the skull had a thick browridge, but in most other ways appeared human.

Writing in Biology

6. **Hypothesize** the importance of language to the early modern humans and how it might have contributed to their success.

BioDiscoveries

A New Species... or Something Else?

In 2003, scientists found a partial skeleton and fragments of six or more other skeletons in a cave on the island of Flores, Indonesia. The "hobbits," as the scientists dubbed them, were humanlike beings a little over three feet tall, with heads the size of grapefruits and chimpanzee-sized brains. Tests revealed that the partial skeleton and fragments ranged between 13,000 and 95,000 years old.

These discovered remains have led to a big disagreement within the scientific community. Since their discovery, some scientists have claimed the "hobbits" are *Homo sapiens*, or modern humans, with a medical condition that caused their diminutive stature. Others insist that they are a new species, *Homo floresiensis.* Scientists on each side are using scientific methods to uncover the truth. Their different interpretations of the data are part of the collaborative scientific process.

Diseased modern humans? Scientists who doubt the "new species hypothesis" proposed several hypotheses to explain the tiny creatures' sizes and other characteristics. Some suggested that the "hobbits" were pygmies who suffered from microcephaly, a rare, sometimes genetic neurological disorder that results in a smaller-than-normal head. Other scientists have hypothesized that the miniature humans had hypothyroidism.

A new species? Most scientists who support the hypothesis that the "hobbits" are the new species *Homo floresiensis* think that they evolved from members of *Homo erectus*, a precursor to modern humans. Some, however, think that the "hobbits" evolved from an even earlier species of human called *Homo habilis*. Once on the island of Flores, scientists think that the organisms evolved to be dwarflike.

Scientists search for fossils at a cave site called Liang Bau on the island of Flores.

Structural differences Both groups of scientists are using the structural data provided by the bone fragments. These include the skull, wrist, foot, and shoulders. As more bone fragments are discovered and studied, more pieces are added to the puzzle.

WRITING in Biology

Peer Review Research the controversial fossils found on Flores. Write an article as though you are one of the researchers. Include your hypothesis, evidence, and conclusions. Submit your article to your classmates for peer review.

WebQuest

BIOLAB

WHAT CAN YOU LEARN ABOUT BIPEDALISM FROM COMPARING BONES?

Background: **Humans and chimpanzees have the same number of bones in the same places, but humans walk upright and chimpanzees do not. Can you identify the skeletal features that enable humans to walk upright on two legs? Assume that you are a paleontologist and have been given chimpanzee and human bones to identify and assemble. Then, you receive a third set. How is the mystery skeleton related to the human and chimpanzee skeletons?**

Question: *What unique skeletal features did humans evolve to become bipedal?*

Materials

envelopes containing paper bones and clues (2)
paper, pencil, and ruler

Safety Precautions

Procedure

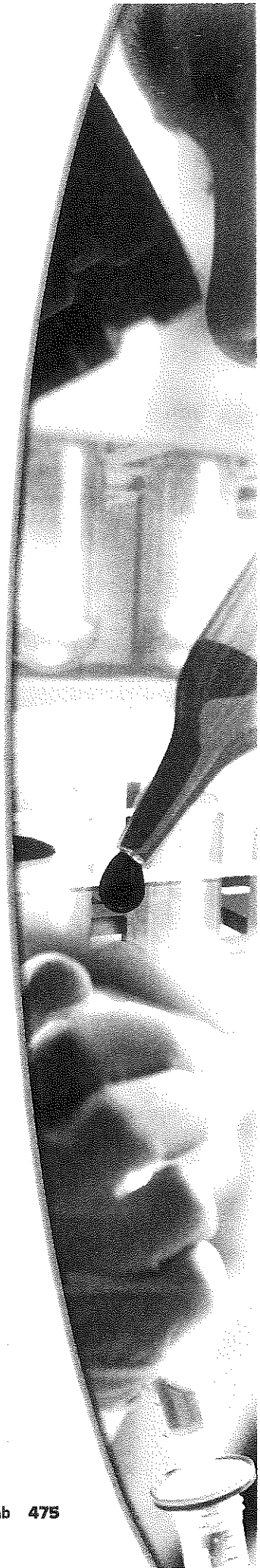
1. Read and complete the lab safety form.
2. Make a data table to help you compare the following characteristics of each of the three fossil sets you will examine: skull, rib cage, pelvis, arms, legs, and feet.
3. Make sure your teacher approves your table.
4. Open envelope #1.
5. Using the clues in your envelope, identify the bones, determine to which species they belong, and write down at least one distinguishing characteristic of each on your data table.
6. Open envelope #2.
7. Using the new set of clues, classify each new bone as chimpanzee, human, similar to both, similar to chimpanzee, or similar to human. Record the data in your table.

Analyze and Conclude

1. **List** features that a scientist might use to determine if a fossil organism was bipedal.
2. **Think Critically** Based on your knowledge, do you think the mystery fossil is bipedal? Why?
3. **Conclude** What organism do you think your mystery bones represent?
4. **Compare** your table with those of other students in the class. Did you arrive at the same conclusions? If not, discuss the differences.
5. **Experiment** Chimpanzees cannot completely straighten–or lock–their knees as humans can and must use more muscles when standing upright. Try standing for 10 s with your knees locked and for 10 s with your knees bent. Describe how your legs feel at the end.
6. **Reason,** from your mystery fossil bones, what it means to say that humans evolved in a mixed, or mosaic, pattern.

WRITING in Biology

Research and discuss why bipedalism is often thought of as an evolutionary compromise. List skeletal injuries that humans suffer as a result of walking upright.



Chapter 16 Study Guide

THEME FOCUS Stability and Change The changes that separated hominins from hominoids, such as larger brains and bipedalism, took place over 20–25 million years ago.

BIG Idea Evolutionary change in a group of small, tree-living mammals eventually led to a diversity of species that includes modern humans.

Section 1 Primates

opposable first digit (p. 452)
binocular vision (p. 452)
diurnal (p. 452)
nocturnal (p. 452)
arboreal (p. 455)
anthropoid (p. 455)
prehensile tail (p. 456)
hominin (p. 458)

MAIN Idea Primates share several behavioral and biological characteristics, which indicates that they evolved from a common ancestor.

- All primates share certain anatomical and behavioral characteristics.
- Primates include lemurs, New World monkeys, Old World monkeys, apes, and humans.
- Strepsirrhines are the most primitive living lineages of primates to evolve. They diverged from haplorhines before 55 mya.
- Anthropoids diverged from tarsiers by 50 mya.
- New World monkeys are the only nonhuman primates in the Americas.

Section 2 Hominoids to Hominins

hominoid (p. 461)
bipedal (p. 463)
australopithecine (p. 465)

MAIN Idea Hominins, a subgroup of the hominoids, likely evolved in response to climate changes of the Miocene epoch.

- Hominoids are all of the apes, including gibbons, orangutans, gorillas, chimpanzees, and humans and their extinct relatives.
- Several species of hominins appear in the fossil record.
- Hominins include humans, australopithecines, and other extinct species more closely related to humans than to chimpanzees.
- Bipedalism was one of the earliest hominin traits to evolve.

Section 3 Human Ancestry

Homo (p. 467)
Neanderthal (p. 470)
Cro-Magnon (p. 473)

MAIN Idea Tracing the evolution of the genus *Homo* is important for understanding the ancestry of humans, the only living species of *Homo*.

- The genus *Homo* is thought to have evolved from the genus *Australopithecus*.
- Of the many species that have existed in the hominin group, only one species survives today.
- The first member of the genus *Homo* was *H. habilis*.
- The Out-of-Africa hypothesis suggests that humans evolved in Africa and migrated to Europe and Asia.
- *H. neanderthalensis* went extinct about 30,000 years ago and *H. sapiens* moved into those areas inhabited by *H. neanderthalensis* about the same time.

Chapter 16 Assessment

Section 1

Vocabulary Review

Replace each underlined word or phrase with the correct vocabulary term from the Study Guide page.

1. A fifth limb might be used by a primate to grip a limb while engaged in reaching for and eating food.
2. Primates that are active at night are "wet-nosed" primates.
3. Depth perception evolved as the faces of primates became flattened.

Understand Main Ideas

Use the figure below to answer question 4.

4. Which is the term for the movement demonstrated by this gibbon?
   A. brachiation
   B. knuckle-walking
   C. quadruped movement
   D. upright locomotion
5. Which group was the first to evolve?
   A. African apes
   B. hominins
   C. New World monkeys
   D. Old World monkeys
6. Which adaptation results in a better gripping ability?
   A. complex brain
   B. flexible forelimbs
   C. opposable digits
   D. prehensile tail
7. The first primates most resembled which animal?
   A. gibbon
   B. gorilla
   C. tamarin
   D. lemur

Constructed Response

8. **Open Ended** Describe the usefulness of binocular and color vision.
9. **Short Answer** Which groups of primates make up the anthropoids?

Think Critically

10. **Hypothesize** Why do you think primate fossils have not been found on Antarctica?
11. THINK (Ideas) Suppose that while on a trip to Brazil, you found a fossil of a primate that closely resembles a squirrel monkey. Into which group of anthropoids would the specimen be placed?

Section 2

Vocabulary Review

Define the following vocabulary terms in complete sentences.

12. australopithecine
13. bipedal
14. hominoid

Understand Main Ideas

15. Which hominin species made the fossilized footprints shown in **Figure 16?**
   A. *A. afarensis*
   B. *A. africanus*
   C. *Paranthropus*
   D. *Proconsul*
16. Which hominoid might be ancestral to apes and humans?
   A. *A. afarensis*
   B. *A. africanus*
   C. *Paranthropus*
   D. *Proconsul*

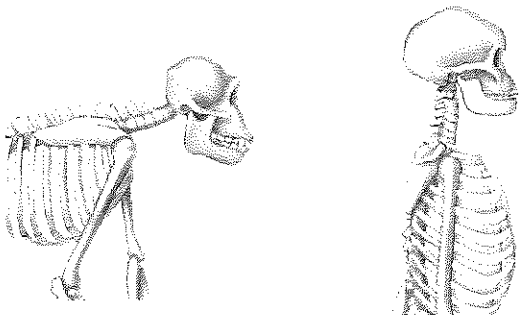
17. Which is the correct sequence of fossils as evidenced by the fossil record?
   A. *A. africanus, A. afarensis, Paranthropus, Proconsul*
   B. *Proconsul, A. afarensis, A. africanus, Paranthropus*
   C. *Proconsul, Paranthropus, A. afarensis, A. africanus*
   D. *Paranthropus, Proconsul, A. africanus, A. afarensis*

18. *A. afarensis* was bipedal but exhibited apelike traits. What type of evolutionary pattern might account for this?
   A. convergence
   B. mosaic
   C. divergence
   D. coevolution

Constructed Response

19. **Open Ended** Discuss the debate regarding the classification of *Paranthropus.*

Use the figure below to answer question 20.



20. **Short Answer** Describe the relevance of the foramen magnum's location to bipedalism.

Think Critically

21. THINK Explain how climate change might have contributed to the evolution of bipedalism.

22. THEME FOCUS Stability and Change Why is biochemical evidence important in helping scientists learn about the divergence of primate groups?

Section 3

Vocabulary Review

Each of the following sentences is false. Make each sentence true by replacing the underlined word with a vocabulary term from the Study Guide page.

23. The genus *Australopithecus* is thought to be ancestral to the genus *Proconsul.*

24. Cro-Magnons were adapted to cold climates. They eventually were replaced by modern humans.

25. *H. neanderthalensis* is the scientific name for modern humans.

Understand Main Ideas

Use the figure below to answer question 26.

26. The large brain and thickened browridges illustrated by the skull above are characteristic of which species?
   A. Cro-Magnons
   B. modern *H. sapiens*
   C. Neanderthals
   D. *Proconsul*

27. The first undisputed member of the hominin group was which of the following?
   A. *A. africanus*
   B. *H. antecessor*
   C. *H. ergaster*
   D. *H. habilis*

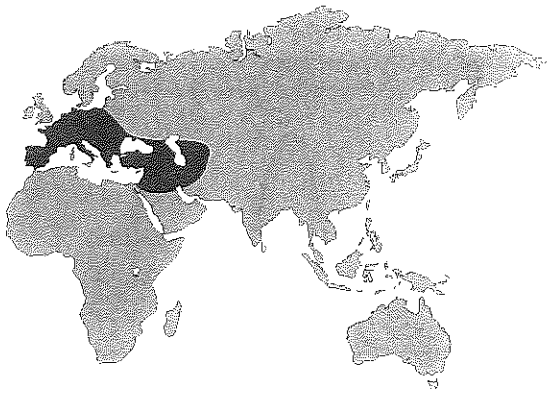
28. Which hominin was likely the first to migrate long distances?
   A. *H. ergaster*
   B. *H. antecessor*
   C. *H. neanderthalensis*
   D. *H. sapiens*

29. Which hominin likely first used fire, lived in caves, and made tools?
   A. *H. ergaster*
   B. *H. erectus*
   C. *H. neanderthalensis*
   D. *H. sapiens*

30. *H. heidelbergensis* is generally considered part of which group?
   A. Neanderthals
   B. *H. sapiens*
   C. Cro-Magnons
   D. australopithecines

Online Test Practice

Use the figure below to answer questions 31 and 32.



31. The map above represents the geographic range of which species?
   - **A.** *Homo erectus*
   - **B.** *Homo sapiens*
   - **C.** *Homo neanderthalensis*
   - **D.** *Homo heidelbergensis*

32. During what time did the species represented on the map live?
   - **A.** 300,000–200,000 years ago
   - **B.** 100,000–12,000 years ago
   - **C.** 2.4–1.4 million years ago
   - **D.** 1.8–1.2 million years ago

Constructed Response

33. MAIN IDEA Describe the importance of *H. habilis* in human evolution.

34. **Short Answer** Describe the importance of fire to the migration of early *Homo* species.

35. **Open Ended** From what you have learned about the evolution of primates, do you think *Homo sapiens*, our species, will continue to evolve? Why?

Think Critically

36. **Apply Concepts** Explain why mitochondrial DNA instead of nuclear DNA is used to study the evolution of modern humans.

37. **Predict** If modern humans had not arrived in Europe, do you think Neanderthals would have persisted?

38. **Hypothesize** How might *H. floresiensis* have coexisted with modern humans?

Summative Assessment

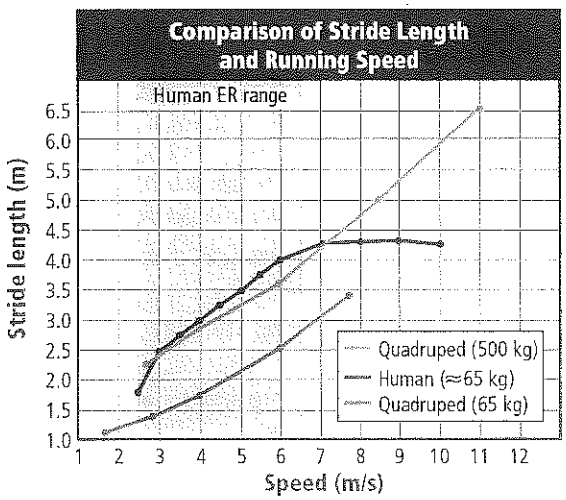
39. BIG IDEA Identify three characteristics that modern humans share with other primates, and three that separate them from other primates. Infer why the three that separate humans from other primates are important.

40. WRITING in Biology Write a paragraph to describe what you imagine a day in the life of *A. afarensis* to have been like.

DBQ Document-Based Questions

Scientists generally consider walking, but not running, to be a key trait in the evolution of humans. Like apes, humans are poor sprinters when compared to quadruped animals such as horses and dogs. Unlike apes, but like some quadrupeds, humans are capable of endurance running (ER), running long distances over extended time periods. The graph below compares speed during ER to length of an organism's stride (two steps for a human).

Data obtained from: Bramble, D. and Lieberman, D. 2004. Endurance running and the evolution of *Homo*. *Nature* 432: 345–352.



41. During ER, is the stride length of a human more like that of a 65-kg quadruped or a 500-kg quadruped?

42. Is a human more efficient at endurance running than a similar-sized quadruped, such as a cheetah or a leopard? Explain.

Online Test Practice

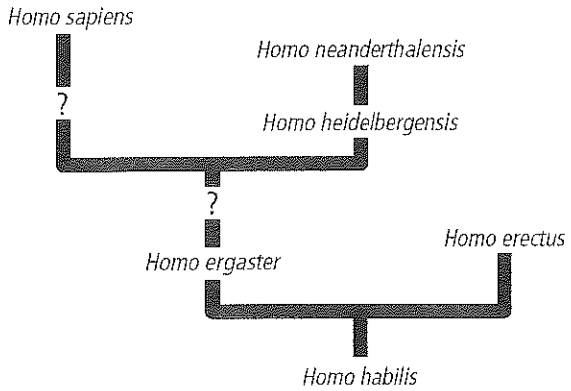
Standardized Test Practice

Cumulative

Multiple Choice

1. A scientific understanding of which natural process helped Darwin formulate the concept of natural selection?
   - A. artificial selection
   - B. continental drift
   - C. group selection
   - D. plant genetics

Use the diagram below to answer question 2.

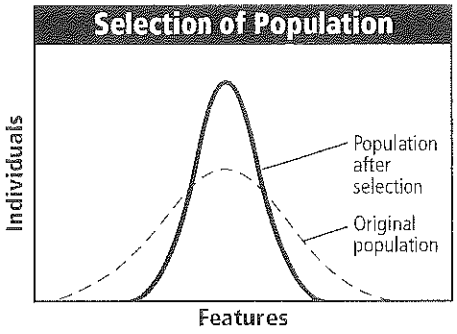


2. According to the diagram of the evolution of genus *Homo*, which is an ancestor of *Homo sapiens*?
   - A. *Homo erectus*
   - B. *Homo ergaster*
   - C. *Homo neanderthalensis*
   - D. *Homo rudolfensis*

3. Which is a physiological adaptation?
   - A. A beaver's teeth grow throughout its life.
   - B. A chameleon's skin changes color to blend in with its surroundings.
   - C. A human sleeps during the day in order to work at night.
   - D. An insect does not respond to a chemical used as an insecticide.

4. Which process can include the use of selective breeding?
   - A. curing a tree of a disease
   - B. finding the gene that makes a type of tree susceptible to disease
   - C. mapping the genome of a fungus that causes disease in trees
   - D. producing trees that resist certain diseases

Use the illustration below to answer question 5.



5. Which description fits the graph above?
   - A. Average-sized features are selected for in population X.
   - B. Larger features are selected for in population X.
   - C. Smaller features are selected for in population X.
   - D. Average-sized features are selected against in population X.

6. Which sequence correctly traces the order of hominin evolution?
   - A. *Australopithecus afarensis* → *Australopithecus africanus* → *Proconsul* → *Homo*
   - B. *Australopithecus africanus* → *Australopithecus afarensis* → *Proconsul* → *Homo*
   - C. *Homo* → *Australopithecus africanus* → *Australopithecus afarensis* → *Proconsul*
   - D. *Proconsul* → *Australopithecus afarensis* → *Australopithecus africanus* → *Homo*

7. Which of the following is NOT a reason why scientists support the endosymbiont theory?
   - A. Mitochondria and chloroplasts are found living outside eukaryotic cells.
   - B. Mitochondria and chloroplasts reproduce by fission.
   - C. The size and structure of mitochondria and chloroplasts is similar to prokaryotic cells.
   - D. The genetic material in mitochondria and chloroplasts is circular.

Short Answer

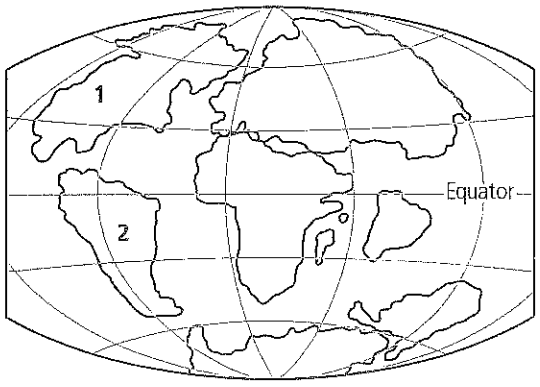
8. The gene that controls the fur color of guinea pigs codes for either dominant black fur (B) or recessive white fur (b). Suppose you want to find the genotype of a black guinea pig. Explain how you would do a test cross. Then use one or both Punnett squares below to show possible test-cross results.

9. A species of bird has a chemical in its tissue that is poisonous to many potential predators. Suppose you find another bird with a coloring pattern similar to the feathers of the first bird. What is this adaptation? Explain its importance.

10. Contrast the multiregional hypothesis and the Out-of-Africa hypothesis for human evolution.

11. Malathion is a pesticide used to control mosquitoes. Suppose a population of mosquitoes develops an ability to survive malathion spraying. How does this phenomenon fit with the ideas of variation and heritability in natural selection?

Use the figure below to answer question 12.



12. Discuss how land species and environments might change if the two numbered continents in the figure collided.

Extended Response

13. Suppose you are explaining human evolution to someone who is unfamiliar with the topic. Hypothesize why *Homo sapiens* is the only surviving member of the human family.

14. Some aggressive bacterial infections are treated with combinations of antibiotics. How would such a treatment affect drug resistance?

Essay Question

"If evolution almost always occurs by rapid speciation in small, peripheral isolates, then what should the fossil record look like? We are not likely to detect the event of speciation itself. It happens too fast, in too small a group, isolated too far from the ancestral range. Only after its successful origin will we first meet the new species as a fossil—when it reinvades the ancestral range and becomes a large central population in its own right. During its recorded history in the fossil record, we should expect no major change."

Gould, Stephen Jay. "Ladders, Bushes, and Human Evolution," *Natural History* 85 (April 1976): 30-31.

Using the information in the paragraph above, answer the following question in essay format.

15. Gould's research in evolution was devoted, in part, to explaining his theory of punctuated equilib-rium. In an essay, explain why the fossil record is incomplete.

NEED EXTRA HELP?

If You Missed Question . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Review Section . . .	15.1	16.3	15.2	13.1	15.3	16.2	14.2	13.1	15.3	16.3	15.1	14.1	16.3	15.2	15.3