8.7 Human Evolution

Like every other species, humans have evolved a combination of characteristics that enabled them to survive and flourish. In this section we examine what characteristics are responsible for human success and how and when humans evolved.

Figure 1 Even young children can manipulate objects.

Human Biological Characteristics

What makes humans unique as a species? Human success can be attributed in large part to our ability to perform complex reasoning, coupled with an exceptional ability to learn, to make and use sophisticated tools, and to communicate using complex language. These human abilities also required the evolution of at least three distinct physical characteristics. We have a very large brain relative to body size, our hands are capable of fine manipulation and coordination (**Figure 1**), and we walk upright (bipedal), freeing our hands to use tools.

But dolphins have large brains, many animals can communicate, and apes and some birds make and use tools. What is different in humans is the degree to which these and other biological characteristics have evolved.

Human Phylogeny

primate a group of relatively large-brained, mostly arboreal mammals that includes prosimians, monkeys, apes, and humans

Homo sapiens are primates. **Primates** are a relatively small group of mammals characterized by large brains relative to body size, forward-directed eyes, flexible hands and feet, and arms that can rotate fully. Many primates also have opposable thumbs that can touch their fingers and enable them to hold and manipulate objects. Most primates have tails (**Figure 2**).

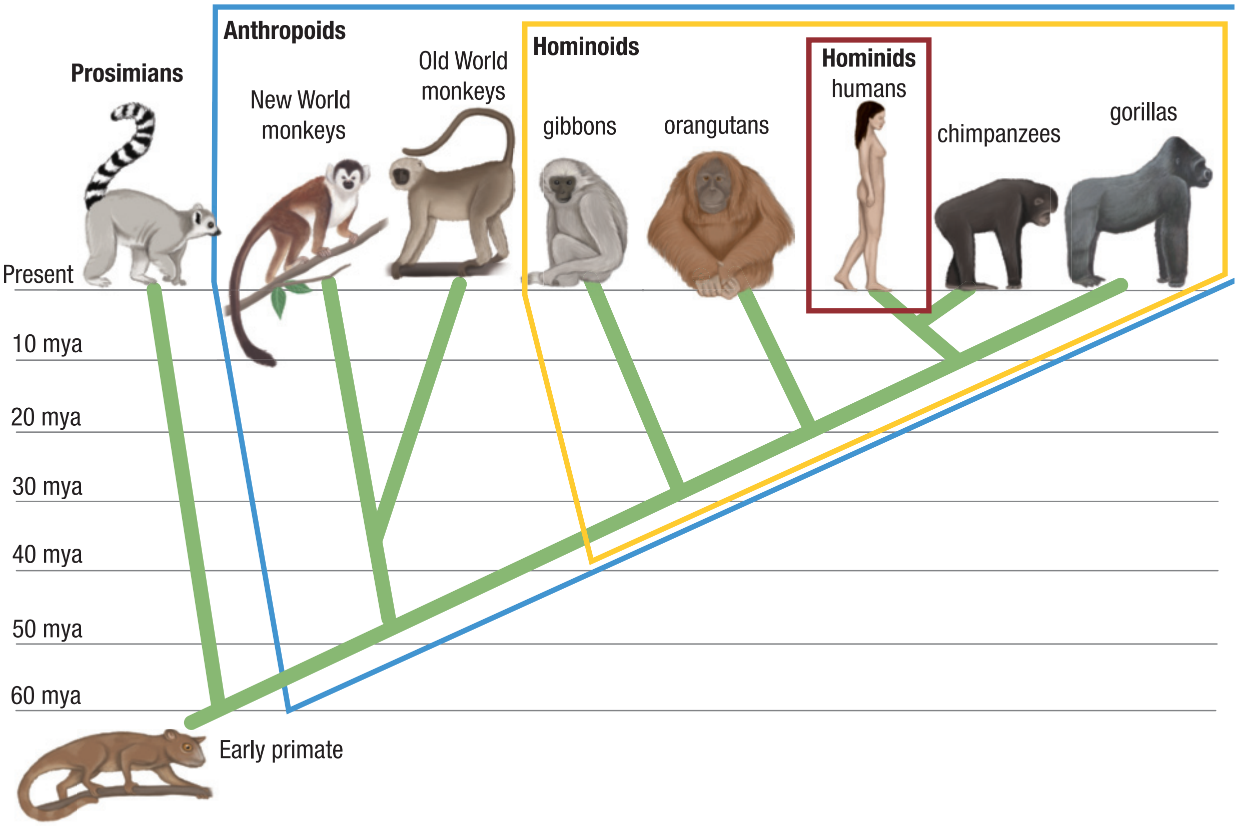

Figure 2 Cladogram showing the phylogeny of primates

prosimian the group of primates that includes lemurs, lorises, and tarsiers

anthropoid the group of primates that includes monkeys, apes, and humans

All primates share a common ancestor dating from about 60 million to 70 million years ago. The evolutionary tree branches early on, giving rise to the **prosimians**, relatively small nocturnal species, and the anthropoids. The **anthropoid** group then splits into two distinct groups: the monkeys and the hominoids, or apes. During this time, continental drift was separating South America (the New World) from the land mass that would form Africa and Eurasia (the Old World). With the split, the early ancestors of monkeys divided into New World and Old World populations. The apes, easily distinguished by their lack of a tail, branched into the lesser apes, the gibbons, and what are referred to as the great apes and humans.

Genetic sequences of the entire human and chimpanzee genomes have now been completed. Detailed analysis of the genomes confirms that chimpanzees are our closest living relatives. Humans and chimpanzees share approximately 98.8 % of their DNA. Humans and chimpanzees both differ from gorillas by about 1.6 %. The most recent common ancestor we share with chimpanzees lived in Africa more than 6 million years ago. The branch ending with modern humans is a clade of many different species, including our direct ancestors. Members of this clade are called **hominids**.

Investigation **8.7.1**

Human and Chimpanzee Chromosome Comparison (page 368)
In this observational study you will have a chance to compare and analyze human and chimpanzee chromosomes.

hominid all species descended from the most recent common ancestor of chimpanzees and humans that are on the human side of the lineage

The Hominid Fossil Record

Hominid fossils record information about the sequence of steps in the evolution of humans. Fossils of hip bones, feet, leg bones, and footsteps provide information about whether or not a species walked upright. Fossils of the skull can be measured and used to track trends in brain size (**Figure 3**). Remains of stone tools and burial sites inform scientist about tool use and early human culture.

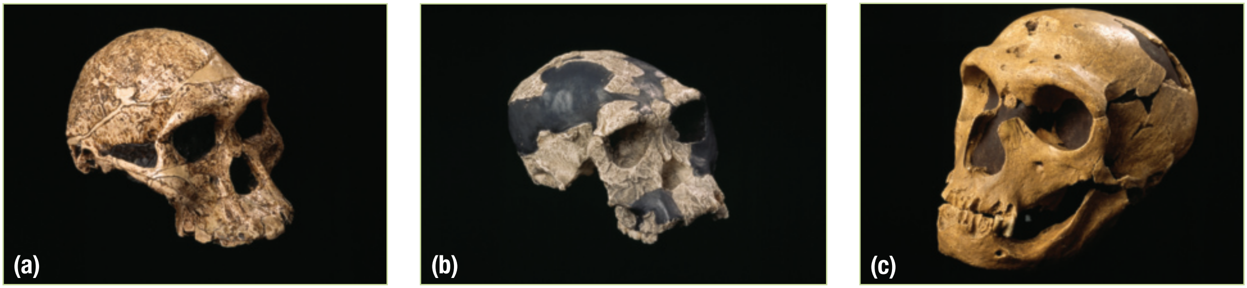

Figure 3 Fossil skulls of (a) *Australopithecus africanus*, (b) *Homo habilis*, and (c) *Homo neanderthalensis* show a progression in brain size. Note that bipedalism evolved in Australopithecus before the subsequent evolution of large brains.

Between 6 million and 7 million years ago, *Sahelanthropus* was beginning to occasionally walk upright (**Figure 4(a)**, next page). Recently discovered fossils, and the first evidence of stone tools used by *Australopithecus afarensis*, date to 3.4 million years ago. By 2 million years ago, the first members of our own genus, *Homo gautengensis*, and *Homo habilis* had evolved. *Homo habilis*, often called the handy man, was making stone axes and large cutting tools. Tools for hunting permitted hominids to dramatically increase the amount of meat in their diet, providing a rich source of protein and fats. By this time, hominid brains were significantly larger than the chimpanzee-sized brains of australopithecines.

The use of hearths for cooking dates to at least 790 000 years ago, and fire may have been used for cooking as early as 1.5 million years ago. Cooking food may have reduced disease and increased the variety of foods that could be consumed. Perhaps most notably, hominid brain size increased relatively rapidly from about 800 000 years ago to 200 000 years ago. During that time, *Homo heidelbergensis* evolved and may have given rise to both *Homo neanderthalensis* and *Homo sapiens*. The first modern humans had evolved by about 100 000 years ago in East Africa. **Figure 4(b)** (next page) illustrates a simplified version of a widely accepted but tentative cladogram of the *Homo* genus.

Today the hominid fossil record of more than 20 species consists of fossils ranging in size from small bone fragments to almost complete skeletons. They include the spectacular *Australopithecus afarensis* fossil finds at Laetoli, Tanzania, which include a set of 69 footprints dated to 3.6 million years ago. These footprints show that human ancestors evolved the ability to walk upright long before they had large brains (**Figure 5**, next page). Although the precise relationships among the many early hominid species remain unclear, an early branch probably gave rise to a number of robust *Paranthropus* species with heavy jaws and relatively small brains, while another ultimately gave rise to the genus *Homo*.

LEARNING **TIP**

Becoming Human
Hominid evolution happened gradually over millions of years. Over time, an *Australopithecus* species changed enough to be considered the first *Homo* species. Although the process is continuous, scientists must still decide on a specific point to switch naming from one genus to another. This is analogous to becoming an adult. Even though the process is gradual, you gain adult status “instantly” on your eighteenth birthday.

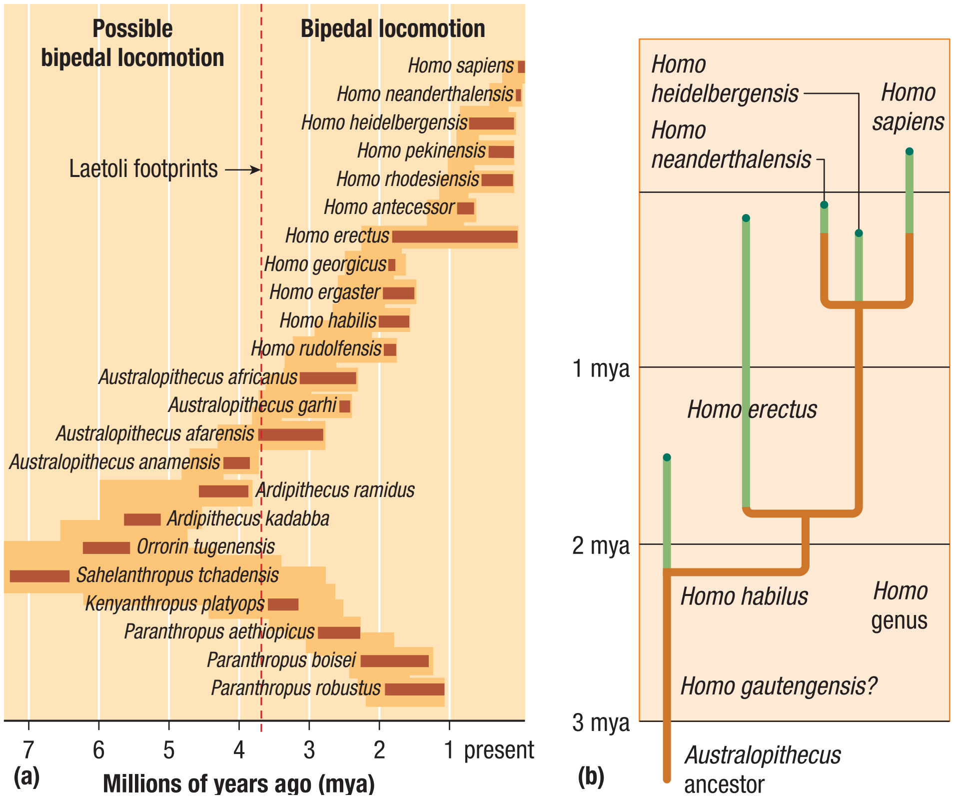

Figure 4 (a) Time frames during which early hominid species were living. Two very recently discovered hominid species, *Homo gautengensis* and *Australopithecus sediba*, are not included in this chart. (b) This simplified cladogram depicts the probable relationships within the *Homo* genus. Fossil evidence of the new species *Homo gautengenis* suggests it may have been an ancestor of *Homo habilis*.

Figure 5 The Laetoli footprint fossils are clear evidence of upright walking dating to about 3.6 million years ago.

Mini **Investigation**

Following Footsteps in Time

Skills: Researching, Predicting, Planning, Performing, Observing, Analyzing, Evaluating, Communicating

SKILLS HANDBOOK A2.1

In 1976, anthropologist Mary Leakey's team discovered a set of 69 hominid tracks in Laetoli, Tanzania. The 3.6-million-year-old fossils are the earliest evidence of bipedal motion in a hominid ancestor. In this investigation you will do a correlational study to predict the height of the individuals who made the Laetoli footprints.

Materials and Equipment: measuring tape

1. Make predictions about possible correlations between foot length, stride length, and height.
2. Measure the height and right foot length of at least 10 people. Ideally choose individuals with a wide range in height.
3. Have each individual walk at a normal leisurely pace; measure the distance they travel in 10 steps. Use this value to calculate their average stride length.
4. Plot two graphs—one of height versus foot length and one of height versus stride length. Draw a line of best fit through both sets of data.
5. Use the Internet and other sources to research the Laetoli and human footprints.

A. Did you find a correlation between foot length and/or stride length and height? Describe the correlation(s). T/I

B. Use your graphs to estimate the height of the two individuals in **Table 1**. T/I A

Table 1 Laetoli Footprint Data

Characteristic	Individual 1	Individual 2
foot length	18.5 cm	21.5 cm
stride length	28.7 cm	47.2 cm

C. Ask your teacher for the heights of the two individuals as calculated by paleontologists. How close were your height estimates to those of paleontologists? Suggest possible reasons for any differences. T/I

D. What role did volcanic eruptions and rainfall play in the formation of the fossilized tracks? T/I

E. Describe the comical events surrounding the discovery of the Laetoli fossils. T/I

F. How do the Laetoli and human footprints differ from those of chimpanzees when they walk on two feet? A

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Out of Africa

Fossils record the history of the distribution of species in both time and space. Fossil evidence tells the story of when and where our ancestors evolved and how they spread out across and around the world.

All early hominids evolved and lived in Africa (**Figure 6**). The first species to spread beyond Africa was *Homo erectus*, about 1.9 million years ago. The *H. erectus* population that left Africa spread out across much of Eurasia and survived until at least 100 000 years ago. The next species to spread beyond Africa, some 500 000 to 300 000 years ago, were the ancestors of the Neanderthals. *Homo neanderthalensis* populated parts of Europe. Relatively soon after the earliest modern humans evolved, they too began to spread out of Africa and into Europe and Asia, eventually reaching the Americas.

CAREER LINK

Anthropologist
Anthropologists study the origins of humanity. To learn more about becoming an anthropologist,

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WEB LINK

To learn more about the migration patterns of *Homo* species,

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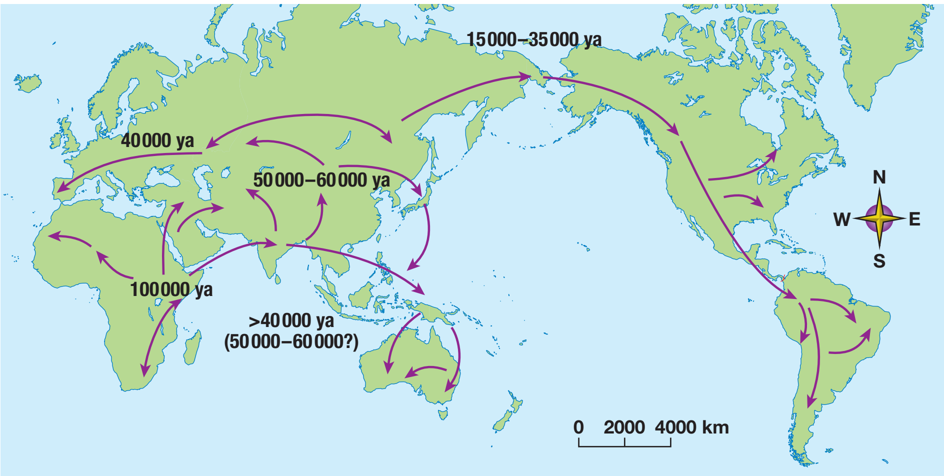

Figure 6 Migration routes of early hominids

Fossils and DNA

In what can only be described as a stunning technological achievement, scientists have been able to extract enough DNA from Neanderthal bones to sequence the entire Neanderthal genome. This has allowed geneticists to compare the DNA of Neanderthals with that of modern humans. The most striking discovery is that some small sequences of the Neanderthal genome are found in humans of Asian and European descent. These genetic remnants no longer have any function in humans, but they do suggest that some interbreeding may have occurred when early *Homo sapiens* made contact with Neanderthals.

Cultural Evolution

The first biologists to compare human and chimpanzee DNA were so struck by their similarity that they joked that perhaps the only differences between humans and chimpanzees were cultural. Their joke was not without some grain of truth. While our genetic differences are less than 2 %, our cultural differences are enormous.

Like humans, chimpanzees engage in some ritualized behaviours and use symbolic gestures to communicate (**Figure 7**). They also have a complex social organization. However, neither the chimpanzee nor any other animal has developed anything comparable to the extraordinary richness of human culture. More than 6000 human languages have been spoken, and human societies have engaged in countless artistic endeavours in music, dance, and the fine arts. Humans admire and cherish the talents of others. We have athletic heroes and movie stars. Human societies have different rituals, customs, and belief systems.

It is fascinating to consider how biological evolution might have influenced the development of culture and vice versa. Evidence suggests that from the time of our common ancestor with the chimpanzee, our ancestors lived as hunter–gatherers for more than 300 000 generations. In only the last 1000 generations or less have humans domesticated

Figure 7 Chimpanzees use both facial expressions and simple hand gestures to communicate.

plants and animals, developed agricultural systems, and begun to live in large population centres. Only during the last 10 generations has our population size skyrocketed.

There is evidence in the fossil record that our own species, *Homo sapiens*, and *Homo neanderthalensis* both performed burials and made body ornaments more than 50 000 years ago (**Figure 8**). While some believe that both species evolved these behaviours independently, others suggest that the Neanderthals began copying the activities of humans shortly after the two species came in contact.

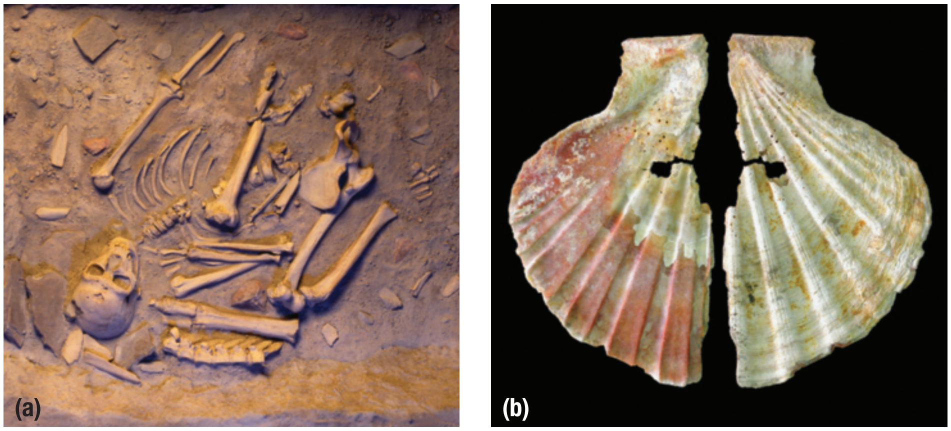

Figure 8 (a) Neanderthals performed burial rituals. (b) Perforated shells made into a neck pendant along with pigments that might have been used as cosmetics—from a Neanderthal site

UNIT TASK **BOOKMARK**

As you work on your Unit Task, consider how changes in our culture influence the evolution of other species.

A vital component of human culture is language and communication. Without the development of a rich spoken language, humans could not have realized our current success as a species. Evolutionary biologists are just beginning to understand the evolution of speech. We now know, for example, that a gene called FoxP2 codes for a protein that regulates a number of other genes and is vital for human speech. Individuals with even one defective copy of the gene have a severe speech and language disorder. The gene is found in all mammals and is highly conserved—meaning it varies little from species to species. The human and Neanderthal version of the FoxP2 gene differs from that of the chimpanzee in just two bases out of more than 2100. Genetic analysis also provides evidence that these two mutations have been strongly favoured by natural selection. It could be that one or both of these mutations provided our early ancestors with an enhanced ability to communicate.

Cultural Evolution Influences Biological Evolution

An interesting example of how cultural evolution influences biological evolution is evident in the recent evolution of lactose tolerance. Lactose tolerance evolved as human populations began to domesticate goats, cattle, and camels, and consume their milk. In these populations natural selection favoured those rare individuals who were more capable of digesting lactose. Mathematical modelling suggests that tolerant individuals had a 4 % to 10 % enhanced reproductive success in these populations. In this way, it was the cultural choice to domesticate livestock and consume their milk that created the new selective pressure for the evolution of lactose tolerance (**Figure 9**). In fact, the very rapid changes in human culture over the past 10 000 years have actually sped up human evolution. Researchers examining the human genome have uncovered evidence to suggest that the rate of human evolution has been greater over the past several thousand years than during the past few million years.

Figure 9 Lactose tolerance is a recently evolved trait.

Human culture has influenced the evolution of many other species but none more so than domesticated species. Indeed, the domestication of plants and animals by artificial selection and breeding is nothing less than directed evolution by humans. It is interesting to consider that after 300 000 generations of our own biological evolution, the human population numbered no more than a few million. It has been our ability to direct the evolution of other species that has allowed us to mass-produce foods and feed our own population that now numbers in the billions (**Figure 10**).

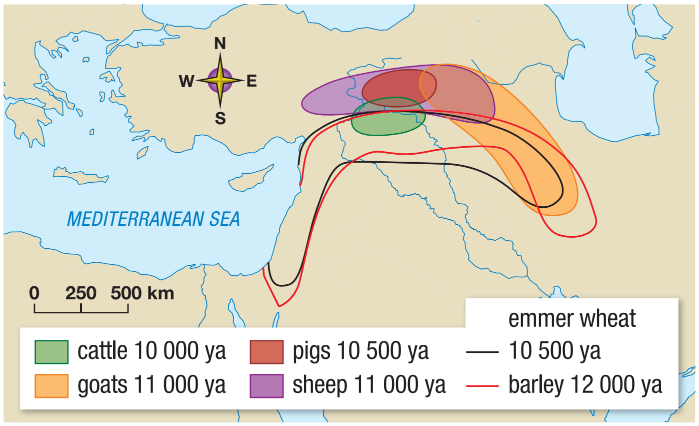

Figure 10 Humans have directly influenced the evolution of many species, including species we have domesticated through artificial selection. "ya" means years ago.

Human Races

Detailed comparisons of human populations from around the world have conclusively shown that, from a biological perspective, human "races" do not exist. Traits that we associate with races, most notably skin colour, are visually obvious but genetically minimal. There is far more diversity *within* so-called races than there is *between* races. The classification of humans by race is therefore a cultural choice on a par with classifying people based the language they speak, their blood type, or their religious beliefs (**Figure 11**).

Figure 11 Although humans have used skin colour as a way of categorizing people into races, the underlying genetic differences are very slight and there are no biologically distinct races of humans.

Are Humans Still Evolving?

Is our evolutionary path of any consequence today? Does it matter if we evolved from a common ancestor of apes? Are we still evolving today? Understanding our evolutionary past and how evolutionary processes work today has many benefits. For example, it can provide insights into healthcare problems. We know that in our past, rich food sources were scarce and natural selection favoured individuals who could detect sweet-tasting and fatty foods and could gain weight during times when food was readily available. Our sense of taste evolved to "let us know" that these were valuable foods. In our modern world, we still relish these foods but now it is easy for us to overindulge (**Figure 12**). This evolutionary preference for ice cream and similar foods is therefore partly responsible for the problems of obesity and heart disease.

Darwinian medicine, the use of evolutionary theory to understand medicine, is providing many important insights into the cause and spread of diseases. An evolutionary perspective can be very important. For example, humans often get a fever with a serious infection. The first question an evolutionary biologist might ask is whether or not a fever is an evolved response of the body to help fight off the infection. If this is the case, then taking a drug to lower your body temperature might be unwise. Similarly, is coughing an evolved mechanism to expel disease-causing organisms from your lungs? If so, would taking a medication that suppresses a cough be helpful?

In modern society, vitamin D deficiency is widespread. This is not at all surprising from an evolutionary perspective. For millions of years, ancestral and modern humans spent time outdoors every day and evolved the ability to synthesize vitamin D when exposed to sunlight. Today many people spend little or no time outside, and

Figure 12 Throughout much of our evolutionary past, natural selection favoured a fondness for rich foods.

WEB LINK

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when they do they are told to use sunscreen. Researchers are investigating the best way to balance the need to protect ourselves from damaging UV radiation and the risk of skin cancer with our evolved requirement to synthesize vitamin D.

In serious infectious diseases, biologists can track the evolution of the disease-causing agents as well as human evolutionary responses to these diseases. For example, a newly discovered allele called CCR5-D32 provides very strong protection against HIV/AIDS infections and may be under the influence of strong selective pressure in some populations.

Research This

Evolution on the Track

Skills: Researching, Analyzing

SKILLS HANDBOOK A2.1, A5.1.

Evolutionary biology is providing insights on the running track. Humans evolved as barefoot walkers and runners. Although humans are not fast compared to most other mammals, evidence suggests that humans did evolve to be efficient at running long distances. Barefoot running is rare in modern society. Instead, most of us wear specially designed sports shoes for running or other athletic activities. In this activity you will investigate the advantages and disadvantages of barefoot running.

1. Research the differences in how shoed runners and barefoot runners land on their feet as they run.
2. Investigate the current trend in barefoot running and the claim by Daniel Lieberman, a professor of human evolutionary biology at Harvard University, that it is possible to run barefoot on the hardest of surfaces.

A. Which running method produces more impact stress on the runner? T/I

B. How might natural selection have influenced the running mechanics of humans? Would you expect our natural running style to cause undue stress on our bodies? T/I A

C. Is it possible to just switch from running with shoes to running barefoot? Explain. A

D. Describe the key advantages and disadvantages of running barefoot. T/I

E. Abebe Bikila and Zola Budd were both champion athletes. In what events did they compete? K/U

F. Would you ever consider routine barefoot running? (**Figure 13**) Why or why not? A

Figure 13 Have you considered running in bare feet?

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A Human Legacy?

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> **Behavioural Psychologist**
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Evolution can inform us about where we have come from but not where we are going. We have evolved a brain and body capable of great achievements in the arts and in understanding the world around us. We have discovered our own biological origins and have the tools and freedom to direct our own future. Yet humans also behave in ways that threaten our own future and the future of other species.

There is no doubt that humans are biologically limited by our evolutionary history. We are not going to sprout wings and fly, but there is nothing in our genes that prevents us from making intelligent choices about our own future. We have certainly made much progress—legalized slavery and routine sacrifice were once widespread, accepted practices. Today, in most countries women and men have equal rights under the law, and forced child labour has been criminalized. We have evolved a brain capable of knowing which actions are needed to ensure a secure and sustainable future for ourselves and our descendants as well as for the biodiversity of life on Earth as a whole. How human society will decide to act in the future remains an unknown.

8.7 Summary

- Key evolutionary characteristics of humans include bipedalism, large brain size, and hands capable of fine manipulation.
- Chimpanzees are our most closely related living species.
- There is a rich fossil record of human ancestors consisting of more than 20 hominid species.
- *Homo sapiens* first evolved in Africa and began spreading out from Africa about 50 000 years ago.
- Biological and cultural evolution influence each other.
- An understanding of human evolution has many applications.

8.7 Questions

1. What selective advantage does each of the following traits provide to humans? K/U
   (a) a large brain
   (b) upright walking
   (c) complex finger movements
   (d) complex language
2. Most ground-dwelling mammals have eyes that look to the side, giving them a wide field of view to help them avoid predators. Many tree-dwelling mammals have eyes that are directed forward, giving them better 3-D vision. Suggest an evolutionary explanation for why ground-dwelling humans have forward-directed eyes. T/U
3. Look at your feet. What feature of the arrangement of your toes provides evidence of an evolutionary history that involved a tree-dwelling lifestyle? T/I A
4. What evidence suggests that human ancestors walked upright before they evolved large brains? T/I A
5. Humans have an innate ability to learn new behaviours. In contrast, most behaviours of most species are instinctive. This suggests that there are advantages and disadvantages of learned behaviour. For each of the following, decide how the learned behaviour is advantageous and/or disadvantageous: T/I
   (a) Young humans learn to walk at about one year old, while deer fawns walk when they are a few hours old.
   (b) Young humans learn their parents' language, while most frogs and birds sing their mating calls instinctively.
   (c) Humans learn to adapt to many different environmental conditions, while most species use instinctive behaviours suited to a specific type of environment.
6. In 2003, scientists discovered the fossil remains of a 1 m tall hominid with a small brain. They called the species *Homo floresiensis*, and it is affectionately known as "the hobbit." Use the Internet and other sources to learn more about this discovery. T/I
   (a) Are all scientists convinced these fossils represent a new species?
   (b) What alternative hypotheses have been presented to explain the small brain size of the individual?
   (c) What is the current status of *Homo floresiensis*? Which hypothesis is more widely accepted?
7. Compare modern humans and Neanderthals. What evidence suggests we are very closely related species? K/U T/I
8. Explain why biologists do not use characteristics such as skin colour or spoken language to classify humans. T/I A
9. Humans have lived as small groups of hunter–gatherers during most of the last 100 000 years. Our food consisted of some animals and many plants. Sweet foods, fatty foods, and salts were relatively rare. Today the favourite foods of most people fit into these same categories. T/I A
   (a) Make a list of 10 of your favourite foods. How many of them are sweet, high in fat, or salty?
   (b) Suggest a way that natural selection might have caused us to evolve love for these foods.
   (c) How has the evolutionary love of these foods influenced societal problems related to obesity and poor eating habits?
10. It is thought that the initial population of *Homo sapiens* that left Africa was relatively small, while the population that remained in Africa was quite large. Use this information to predict whether genetic variability will be higher among human populations in Africa or in other parts of the world. Use the Internet to check your prediction. T/I C
11. *Homo sapiens* have existed for only a few hundred thousand years. Most of the recent success of humans can be attributed to cultural and technological advances. T/I A
    (a) Do you think humans will continue to evolve as a species? Support your ideas.
    (b) What selective pressures do you think humans may be experiencing now and may experience in the future?
    (c) Hypothesize about potential human adaptations that could result.

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